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NEEA Study: Technology and Market Assessment of Networked Outdoor Lighting Controls

Prepared by:
Energy Solutions
1610 Harrison Street
Oakland, CA 94612

Northwest Energy Efficiency Alliance
PHONE
503-688-5400
FAX
503-688-5447
EMAIL
info@neea.org

Table of Contents

List of Tables

List of Figures

Executive Summary

OUTDOOR LIGHTING AND CONTROLS BACKGROUND

Outdoor lighting applications, including roadway lighting and parking lot and garage lighting provide crucial services for human safety, productivity and comfort in the modern urban and suburban landscape. The installed base of roadway lighting in the United States uses an estimated 52.8 TWh of electric energy annually, while parking lot and garage lighting uses an estimated 51.1 TWh. Combined, this is the equivalent of 166.6 million barrels of oil or over 71.6 million metric tons of CO_2-equivalent emissions, and also equivalent to the annual electricity use of almost 8.7 million homes. Energy Solutions estimates that the Northwest region of the U.S. uses 5.17% of national roadway and parking lighting energy, or 5.37 TWh of electricity usage and over 3.7 million metric tons of CO_2-equivalent emissions annually.

This study focuses on controls systems designed for street and parking lot lighting applications. Typical lighting controls for streetlights are simple relays activated by a photocell to turn fixtures on at dusk and off at dawn. Networked controls systems available today rely on wireless radio frequency (RF) and/or power line carrier (PLC) communications technologies to network individual lighting fixtures for smarter control strategies. These systems provide tools to manage and monitor city-wide streetlight assets remotely, including the potential to meter actual street lighting energy use. Networked controls that offer dimming capability can also provide energy savings through adaptive street lighting management, the practice of reducing lighting power and output as conditions change over time.

MARKET TRENDS

The market for advanced streetlight controls is relatively new and has been constantly evolving over the past several years. In 2009, the California utility Pacific Gas & Electric (PG&E) commissioned a study to evaluate the advanced streetlight controls market, focusing on five products considered leading technologies at the time. Since the January 2010 release of the PG&E study, the number of companies in the advanced controls market has increased dramatically, although some leading actors studied in the previous report, including TYCO and Streetlight Intelligence, have since closed streetlight controls operations. Installations of new networked streetlight controls continue to be mostly at the pilot scale rather than full commercial deployments.

Nonetheless, local jurisdictions are beginning to develop specifications and guidelines for streetlight management that include advanced controls strategies like scheduled dimming after-hours or during periods of low activity, a practice known as adaptive lighting. Streetlight operators are also lobbying for utility billing options that take advantage of network controls' energy monitoring capabilities. In the last year, proponents have increasingly emphasized "controls-ready" outdoor lighting products such as dimmable light emitting diode (LED) streetlights, so that lighting managers making investments in new technologies do not lose out on future savings opportunities from advanced controls.

Recently the U.S. Department of Energy's Municipal Solid-State Street Lighting Consortium (MSSLC) organized a Monitoring and Adaptive Controls Task Force, which has assembled street lighting stakeholders and experts to share lessons learned by members evaluating and demonstrating advanced streetlight controls products. The Task Force surveyed a broad range of the MSSLC's member cities and utilities in February 2011 and noted the following trends:

- Maintenance benefits, such as the ability to identify and address streetlight failures, constituted the most important factor driving interest in controls systems, followed by dimming functionality, and then metering and billing capabilities.
- Respondents clearly preferred managing their network systems and data independently. Streetlight managers prefer to own the system and data and to be independent of ongoing hosting and communication charges.
- Other key features of interest were GIS mapping, display, and management of assets, as well as security protocols for multiple levels of system access and operation.
- Users clearly favored RF over PLC-based communications.
- Cost remains the biggest obstacle to adoption.

EVALUATION ACTIVITIES

Because of the changes in this evolving market, NEEA organized this study to characterize the networked outdoor lighting controls market and its leading products. This project examined the market for new and updated solutions and identified the key product features desired by user groups and offered by available controls options. Energy Solutions has surveyed both manufacturers of the leading controls products and project managers for various demonstration or larger-scale installations to identify best-in-class solutions based on product features and in-field performance.

In total, eight lighting controls demonstration project managers and 12 controls manufacturers provided survey responses:

Surveyed Manufacturers		**Surveyed Demonstrations**
Acuity	Strategic Telemetry	Glendale, Arizona
Airinet	Streetlight Intelligence	Hamilton, Ontario
CIMCON	Venture	Kansas City, Missouri
Eagle WMAC	Virticus	Los Angeles, California
Echelon		Portland, Oregon
Lumewave		San Francisco, California
Owlet		San José, California
Ripley		U.S. Virgin Islands

Others were reviewed using secondary research. The 12 controls products ranged from relatively mature systems introduced several years ago to young systems still under development by early-stage startup companies. Of the 12 companies surveyed, two have yet to sell individual systems of over 100 units, and six launched their advanced outdoor controls products in the U.S. within only the past two years. On the other hand, some very significant lighting companies are either currently active in the market (Acuity - ROAM) or have announced plans for major product launches soon (Philips).

PRODUCT FEATURES AND COST

While the various controls systems rely on different networking protocols and topologies, each system has a similar set of basic components: a "node" to monitor and control individual fixtures and a "gateway" to facilitate communications between nodes and a central control server and management system.

Market-viable networked controls products all offer a similar set of standard features. Energy Solutions has identified a list of basic features that any competitive product must include:

- Basic on/off operation and sunrise/sunset trimming
- Failure detection and reporting
- Luminaire grouping
- Dimming and adaptive lighting capabilities
- GPS-based mapping of managed fixtures
- Power metering
- Web-based monitoring and control

In addition to the listed basic features, many products offer advanced features that may be desirable in certain installations, such as lumen depreciation adjustment, customer-hosted network and data (as opposed to vendor-hosted), and National Transportation Communications for ITS Protocol (NTCIP) compatibility. Some of these "additional features" will be of secondary importance to most users, although the MSSLC survey clearly indicated that the option for the customer to host and own the network with no ongoing costs remains key.

Interestingly, at least two of the features now in the basic feature set, dimming / adaptive capabilities and on-board power metering circuitry, were advanced or optional features at the time of the previous study only a year ago. This shows that the expectations for advanced lighting controls are still evolving along with the companies competing in the marketplace.

Only half of the companies surveyed provided hard costs for their controls systems; most preferred to quote costs on a case-by-case basis, depending on installation specifics. Reported per-fixture costs ranged widely, from less than $100 to $250. All manufacturers charge an up-front fee for the controls hardware, and some charge additional annual fees for software maintenance and support and server hosting. Surveyed manufacturers were reluctant to quote concrete figures but many stated they generally prefer to negotiate individual rates for each installation based on project size and desired functionality. Costs have not improved since the last study; they will likely decrease as manufacturers realize greater economies of scale and as competition among the growing number of market actors leads to greater efficiencies.

Survey responses from the project managers for the networked streetlight controls installations provided context for evaluating the effectiveness of different controls systems' features. The majority of project managers prioritized operations and maintenance (O&M) functionality, such as fixture grouping and failure detection and reporting. In general, project managers were satisfied with the ability of networked controls to detect faults and to significantly reduce the number of system outages. For the projects surveyed, managers were less involved or interested in dimming and adaptive lighting strategies offered by networked controls systems.

PRODUCT INSTALLATIONS AND MARKET MATURITY

While controls companies continue to market and develop their products, only two large-scale deployments (over 5,000 units) of these systems are installed in the U.S. (Glendale, AZ and Los Angeles, CA). As the MSSLC survey showed, cost remains the biggest obstacle to wide-scale adoption of networked streetlight controls. Non-energy benefits alone may not be sufficient to justify the cost of a new advanced networked controls system. Since streetlights in the U.S. generally operate as un-metered load and utilities charge based on assumed wattage and operating hours, dimming and adaptive lighting techniques may not result in financial benefits for the operating entity. For adaptive controls to be economically viable, streetlight operators will need to be able to monetize energy savings through new utility tariff models for customer-metered streetlights.

The research also showed that the majority of controls installations are deployed in conjunction with LED retrofits. Streetlight operators have shown less interest in installing controls systems on existing high-intensity discharge (HID) inventories that are not compatible with dimming controls, although as Glendale, AZ demonstrates, these systems do work well with traditional streetlights for outage detection and streamlined maintenance. As adaptive lighting guidelines become better defined and users are able to achieve lower energy costs due to improved streetlight energy management and new utility billing structures, advanced networked controls systems are likely to become increasingly common, especially with new LED installations. Based on the availability of advanced controls systems that offer dimming features, at a minimum, any street and parking lighting investments should include controls-ready, dimmable lighting products if not advanced networked controls themselves.

The various market-ready controls products available today are well positioned to meet the immediate needs of street lighting system administrators who desire fault detection and report generation to improve operations and maintenance. Dimming and adaptive lighting capabilities, as well as energy metering features, have also become standard for advanced controls systems, although guidance, standards, and metering structures to take advantage of these features need further development. While new companies are rapidly entering the market and existing companies continue to improve upon their product offerings, the majority of products are still relatively untested in the field, at least in terms of large-scale commercial installations. Cost competition among market players would also improve market penetration.

With so many technology options available, customers must rely on a combination of each product's feature set, customizability, level of maturity, and price to decide on the best option for a given installation. Organizations such as MSSLC and NEEA should continue to investigate these technologies over time to maintain up-to-date information for public stakeholders considering advanced networked controls for outdoor lighting. At a minimum, all street and parking lighting investments ought to include controls-ready, dimmable lighting products if not advanced networked controls themselves.

Introduction

Outdoor Lighting Background

Outdoor lighting applications such as roadway lighting and lighting for parking lots and garages provide crucial services for human safety, productivity, and comfort in the modern urban and suburban landscape. Lighting designed for outdoor applications must address multiple issues such as proper light distribution, glare, light pollution, energy usage, and lifetime.[1]

A recent Department of Energy report estimates that there are 52.6 million roadway fixtures installed in the United States, including 26.5 million streetlights and 26.1 million highway fixtures. Parking fixture estimates vary more widely, but the same report lists 505 million parking lot and garage fixtures in the U.S. For a sense of the magnitude of energy impact from these light sources, the installed base of roadway lighting uses an estimated 52.8 TWh of electric energy annually, while parking lot and garage lighting uses an estimated 51.1 TWh. Combined, that is the equivalent of almost 167 million barrels of oil or 71.6 million metric tons of CO_2-equivalent emissions, and equivalent to the annual electricity use of 8.7 million homes.[2]

Based on U.S. government data on developed land for the Northwest region (the states of Washington, Oregon, Idaho, and Montana for the purposes of this study) compared to developed land for the entire U.S., 5.17% of national roadway and parking lighting energy is attributable to the Northwest region.[3] Assuming the same mix of outdoor fixture wattages and operating hours as that of the nation, the Northwest region would represent 2.72 million roadway fixtures and 26.1 million parking fixtures, together responsible for 5.37 TWh of electricity and over 3.7 million metric tons of CO_2-equivalent emissions annually.

Outdoor Lighting Controls

This study focuses on advanced networked controls designed for street and parking lot lighting applications. Traditional lighting controls for streetlights are simple relays activated by a photocell to turn fixtures on at dusk and off at dawn. Basic photocells also often control parking lot lights. Parking garages may operate 24 hours per day with no real control options, although time clocks or lighting panel controls often control garage and lot lighting circuits associated with buildings with programmed schedules of nightly operation.

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[1] Navigant Consulting Inc. "Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications." Prepared for the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Building Technologies Program (2011).

[2] U.S. Environmental Protection Agency. "Greenhouse Gas Equivalencies Calculator," http://www.epa.gov/cleanenergy/energy-resources/calculator.html#results

[3] U.S. Department of Agriculture. "Acreage and Percentage of Non-Federal Land Developed," National Resources Conservation Service Data (1997).
For the purposes of this report, developed land is considered a better proxy for outdoor lighting energy usage than population; population may be rural (less street and parking lighting), urban (more street and parking lighting) or somewhere in between.

Compared to these traditional controls technologies, the wireless networked controls products explored in this study provide much more advanced features to better manage outdoor lighting operations and minimize energy impacts. Networked controls systems available today use wireless radio frequency (RF) signals and/or power line carrier (PLC) communications technology to network individual lighting fixtures for smarter controls strategies. These systems provide tools to remotely manage and monitor city-wide streetlight assets, including the potential to meter actual street lighting energy use. Networked controls that offer dimming capability can also provide energy savings through adaptive street lighting control: the practice of reducing lighting power and output as conditions change over time (i.e. lower traffic or pedestrian volume in late evenings).

A previous study by the large California utility Pacific Gas and Electric (PG&E) investigated advanced networked controls products for street lighting in 2009/2010, focusing on five products considered leading technologies at that time in this emerging market.[4] The PG&E Street Lighting Network Controls Market Assessment Report characterized some of the main benefits of the features offered by these advanced controls systems, including:

- Detection of outages
- Metering lighting energy usage, ideally for billing purposes (although some of the systems did not include power measurement circuitry and relied on fixture wattage assumptions)
- Trimming nightly operating hours to better match sunrise and sunset or simply to reduce overall run-time
- Dimming lights in areas typically over-lit due to lighting design constraints
- Mapping street lighting assets and grouping fixtures for more proactive management
- Overall enhanced flexibility in designing and operating streetlight systems

To evaluate energy savings potential, the previous PG&E assessment presented a scenario using networked controls to perform several functions described later in this report: nightly adaptive dimming to reduce power during low-activity periods, dimming to targeted light levels over the life of a lamp to compensate for typical over-lighting (due to expected lumen depreciation), and a reduction in operating hours by one hour per night (from 11.2 average hours to 10.2 average hours) to “trim” run-time during dusk and dawn periods.

The study estimated that this combination of controls strategies could save 29% of street lighting energy annually compared to standard photocell-only streetlight controls. New estimates of annual roadway lighting energy show a total savings of 15.3 TWh of electricity for the entire installed base of roadway lights (street and highway) in the U.S., or a reduction of around 10.6 million metric tons of CO_2-equivalent per year. In the Northwest region, the annual streetlight energy savings would be around 790 GWh of electricity and almost 545,000 metric tons of CO_2-equivalent emissions.

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[4] Shackelford, Jordan, et al. *Street Lighting Network Controls Market Assessment Report*. Pacific Gas and Electric Company Emerging Technologies Program (2010).

Advanced Controls Market

Due to the rapidly changing nature of the wireless networked controls market, within a year of publication of the PG&E study NEEA realized that an updated look at advanced streetlight controls would be beneficial. The marketplace has seen several new entrants offering advanced controls products for street and parking lights. New companies have released new products; pre-existing companies have added features to their existing products; and some formerly active companies have curtailed or eliminated their streetlight controls offerings. Many installations of viable networked controls products have taken place in recent months as well, mostly at the demonstration scale, providing the opportunity to see these controls perform in real-world conditions.

Changes in this evolving market prompted NEEA to organize this study to refresh the characterization of networked outdoor lighting controls products. This project has scanned the market for new and updated solutions and identified the key product features desired by user groups and offered by available controls options.

Energy Solutions surveyed both manufacturers of leading controls products – 12 companies completed surveys – and project managers for various demonstration or larger-scale installations of these products – eight project managers completed surveys – in order to identify best-in-class solutions based on product features and in-field performance.

Drawing from the product and demonstration research, this report characterizes the outdoor networked controls market in general, as well as specific controls technologies in terms of desired and available features, product maturity and cost, user satisfaction, and other criteria. Two comparative matrices describe all of the products surveyed in detail and the surveyed demonstration projects, respectively. This study intends to provide a snapshot of the current state of the advanced streetlight controls market and to provide guidance to potential consumers regarding the features and specifications offered by commercially available products. This report also examines some of the necessary next steps towards increasing adoption of energy-saving controls products and adaptive lighting practices.

Evaluation Activities

This report consists of findings from two principal evaluation activities: a) a survey of currently available networked controls manufacturers to characterize system feature sets and specifications and b) a survey of project managers of networked controls installations to determine user satisfaction with real-world performance of various controls products.

Manufacturer Survey

Manufacturer outreach focused primarily on companies with established, market-ready products, but also included a few smaller startup companies with demonstrated North American installations. Energy Solutions based this initial list of 20 controls manufacturers on previous and current research efforts, participation in bi-weekly calls with the MSSLC Controls Task Force, and discussions with NEEA:

Airinet	Owlet	Sun Tec

CIMCON	Relume Technologies	Tyco Electronics
Eagle WMAC	Ripley	Vasona Labs
Echelon	ROAM Acuity	Virticus
Lightronics	SWARCO	Venture Lighting
Lumewave	Strategic Telemetry	Wattstopper
Jennic	Streetlight Intelligence	

Energy Solutions initially contacted these organizations to request participation in a manufacturer survey developed from discussions with MSSLC, NEEA and other stakeholders. Based on the outcomes of initial research and manufacturer outreach to determine the level of market readiness of each technology, 14 companies received surveys and 12 completed and returned them.[5] Respondents' answers and other publicly available product information aided in development of product briefs for each company (included in Appendix B). Each product brief reports the following details for each technology:

- Company Background
- System Overview
- Hardware and Controls Features
- Network Characteristics
- System Deployment and Cost Considerations (for products with available cost data)

The manufacturers' responses led to creation of a product matrix, which condenses information from the 12 product briefs into a single table for ease of access and comparison.

Demonstration Project Manager Survey

Energy Solutions also developed a project manager survey to understand motivations for installing a controls system; identify specific product or feature preferences; and to gauge overall satisfaction with a given product.[6] Discussions with the MSSLC's Controls Task Force and NEEA informed the survey questions, along with information from the MSSLC's Controls Task Force Streetlight Manager survey. Discussions with stakeholders identified 17 demonstration sites, prioritized according to size, maturity and controls product used. Of 10 project managers asked to participate, eight completed and returned surveys.[7] Controls demonstration briefs based on their responses (and found in Appendix C) each include details on the following:

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[5] In addition to the 12 completed manufacturer surveys, research took place on nine additional companies. A brief description of these companies and their controls products can be found in the "Additional Networked Controls Manufacturers (Not Surveyed)" section of Appendix B.

[6] For copies of the blank manufacturer and project manager survey instruments, please see Appendices D and E.

[7] Additional sites are listed in the "Additional Controls Demonstrations (Not Surveyed)" section of Appendix C.

- Project Background
- Controls Product Selection Process
- System Operation and Functionality
- Energy and Maintenance Considerations

Information from all demonstration briefs is presented in a single table for quick comparison and analysis across a number of controls system installations.

Market Characterization

The market for advanced streetlight controls has been evolving over the past several years, with many changes even since the PG&E study released in early 2010. Since that time, the number of companies offering advanced controls for outdoor lighting has increased and the types of controls products and features have changed. Issues such as adaptive lighting standards and advanced controls-ready lighting products have become more prominent. Public stakeholders interested in advanced networked controls and adaptive lighting strategies have also become more organized in investigating controls opportunities and sharing experiences with pilot installations. For all of the interest and activity in the market, however, some major hurdles still remain before advanced controls gain major penetration in the outdoor lighting market; thus far, large commercial installations are still very limited.

Company Developments

Pinning down the number of advanced controls products available in the market is difficult, as young start-up companies and long-standing lighting controls manufacturers frequently announce new products. Philips has recently announced entry into the advanced streetlight controls market in the U.S., and another large European company, SWARCO (traffic products and solutions), is announcing similar intentions. Acuity's ROAM brand continues to lead in terms of overall market penetration in the U.S. while at the same time, some companies formerly viewed as market leaders are bowing out. Streetlight Intelligence, one of the larger presences in the Canadian market, ceased operations in 2011. Large electronics manufacturer Tyco, whose LumaWise product was evaluated in the 2010 PG&E study, has also indicated it is no longer focusing on streetlight controls.

The volume of new and young companies as well as established firms entering the market, and the exit of some larger brands, speak to a marketplace not yet consolidated and still in the process of maturing. The 12 controls products evaluated in detail for this report range from systems introduced several years ago to young systems just launched and still under development. Of the 12 companies, two have yet to sell individual systems of over 100 units. Almost all (10) of the companies' advanced outdoor controls products were introduced within the past four years; six launched within the past two years. Four companies interviewed had 10 or fewer employees.

Installation Progress

Installations of new networked streetlight controls continue to be mostly at the pilot scale rather than full commercial deployments. Large installations have been rare; Glendale, AZ and Los Angeles, CA (underway), both ROAM projects, are the largest U.S. deployments identified. Despite the importance to prospective customers of product specifications and feature sets, product maturity, as demonstrated by real-world installations, is equally as important in a new and evolving market. Roughly, half the products evaluated in this study completed installation of their first systems of 100 or more fixtures in 2009 or later. ROAM remains the current market leader in terms of large-scale deployments. To a lesser extent, Ripley and Venture can claim to offer more field-tested products.

This market study highlights several factors (discussed in greater detail later) that still need to be addressed for advanced networked controls to take off in terms of number and size of installations. Overall, up-front costs for the systems remain high while the energy savings guaranteed by the systems are less clear. For the manufacturers whose survey responses included reported costs, estimates ranged from $100 to $250 per fixture for network hardware, and in many cases included ongoing costs for network hosting and services. Importantly, when compared to cost information from the PG&E report of over a year ago, costs in this report appear to have remained stable even as the number of products increases. Competition and consolidation among vendors will likely eventually lead to decreases in costs, which may be necessary for these products to succeed.

Features such as outage detection and reporting are touted as major benefits by the manufacturers and most of the project managers interviewed agreed, although the cost savings attributable to these features are not always quantifiable. Energy savings from the systems, e.g. reduced operating hours or lighting wattage, are also currently difficult to monetize. Utilities generally bill streetlight energy at flat monthly rates (un-metered) based on assumed wattage and operating hours. New utility metering structures that accept streetlight energy data from customers' networked controls systems would incentivize the use of advanced controls to save energy and would help advanced controls to become more economically-viable investments. In California, the cities of San José and Oakland and an organization called the California City-County Street Light Association (CAL-SLA) are lobbying the California Public Utilities Commission (CPUC) to develop a customer-owned, customer-metered streetlight tariff in which the meter is essentially the streetlight networked controls system. CAL-SLA proposes that networked controls energy data be specified to meet CPUC accuracy requirements and that it be transmitted electronically to the utility in an agreed-upon format. In prepared testimony to the CPUC for PG&E's current application for revised rate design, an advocate of networked streetlight metering rates explained:

> "… [T]he introduction of network control systems changes [the] equation. These systems can cost-effectively and accurately measure and transmit the energy consumption of every streetlight via a metering chip or a calculation based on amperage

and voltage readings. The control systems can measure and report variations in energy consumption, such as a dimmed light, one that is failing or erroneously on or off."[8]

According to a May 31, 2011 status update a settlement has been reached on a rate design for a new network controlled streetlight pilot program in PG&E territory.[9]

New and "Controls-Ready" Lighting Products

In step with the growth in advanced controls options, new lighting technologies such as light emitting diode (LED) and induction streetlights are gaining major momentum. The parallel growth of advanced lighting and advanced controls markets is not coincidental; the higher controllability of products like direct current (DC)-driven LED streetlights relative to traditional high-intensity discharge (HID) technologies means advanced controls are often better suited to LED installations. Most LED streetlight vendors now offer dimmable versions of their fixtures and some are even partnering with advanced controls manufacturers on some products. New, fully dimmable HID products are now available as well.

Michael Siminovitch, the director of the California Lighting Technology Center (CLTC) at UC Davis, has been leading the charge in the last year for new outdoor lighting investments to include advanced controls-readiness. In an article in the July 2010 edition of Lighting Design and Application (LD+A), the magazine of the Illuminating Engineering Society of North America (IESNA), Siminovitch warns that significant energy savings opportunities are trapped by investments in LED streetlights lacking controls-readiness for adaptive lighting.[10] For LED streetlights, controls-readiness would be a matter of specifying inclusion in new installations of dimmable LED drivers that can accept commands more sophisticated than simple on/off. Siminovitch explained that due to inherent features of LEDs that make them more compatible with dynamic dimming practices, LED installations can achieve energy savings well above the typical static on/off controls if coupled with advanced controls.

The project manager interviews for this study also pointed to a link between LED retrofit projects and advanced networked controls. Only a few of the controls installations examined were on existing HID lighting systems – most were part of LED installation projects.

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[8] Report on Street Light Rate Design Pacific Gas and Electric Company Application NO. 10-03-014. Prepared by Laura Stuchinsky for the California City-County Street Light Association. San José, California. October 6, 2010 https://www.pge.com/regulation/GRC2011-Ph-II/Testimony/Cal-SLA/2010/GRC2011-Ph-II_Test_Cal-SLA_20101006-02.pdf

[9] Application 10-03-014 Before the Public Utilities Commission of the State of California of Pacific Gas and Electric Company To Revise Its Electric Marginal Costs, Revenue Allocation, and Rate Design, including Real Time Pricing, to Revise its Customer Energy Statements, and to Seek Recovery of Incremental Expenditures. (U 39 M). https://www.pge.com/regulation/GRC2011-Ph-II/Pleadings/PGE/2011/GRC2011-Ph-II_Plea_PGE_20110531_211461.pdf

[10] Siminovitch, Michael. *Taking the long view on LED street lighting*. (RESEARCH MATTERS). LD+A Magazine. July 1, 2010.

Public Stakeholder Coordination and Priorities

MSSLC CONTROLS TASK FORCE ACTIVITIES

In light of all of the new outdoor lighting and controls technologies, utilities and municipalities responsible for streetlight inventories throughout the U.S. and Canada, as well as other stakeholders such as energy efficiency organizations, have become increasingly coordinated in their efforts to evaluate products. One particularly significant development since the 2010 controls market assessment is the U.S. Department of Energy's Municipal Solid-State Street Lighting Consortium (MSSLC), launched in 2009 to bring together cities, utilities, and other stakeholders promoting quality lighting and power efficiency.[11] Membership currently stands at over 270 organizations.

The MSSLC has been primarily focused on lighting technologies, including drafting a Model Specification for LED Roadway Lighting, but in the fall of 2010 the MSSLC also organized a Monitoring and Adaptive Controls Task Force. This Task Force has assembled street lighting stakeholders and experts from utilities, cities, and energy efficiency organizations to share lessons learned by members evaluating and demonstrating advanced streetlight controls products. The Controls Task Force has held twice-monthly meetings since November 2010 and is working on a draft Performance Specification for Remote Monitoring and Control of Roadway Lighting for streetlight managers' eventual use in specifying advanced controls for their managed assets.

To scope the controls specification, the Task Force surveyed a broad range of the MSSLC's member cities and utilities in February 2011 to ask them what they want in advanced controls systems. Respondents included 64 cities and 33 utilities, most commonly managing 50,000 to 100,000 streetlights, but with some respondents responsible for over one million lights. Based on the ranges of numbers of streetlights reportedly managed by the surveyed agencies, the survey represented somewhere between 5 million to over 13 million streetlights in North America, including 1 million to over 3.7 million city-managed lights and 3.9 million to over 8.5 million utility-managed lights. Survey responses revealed some important trends:

DESIRED BENEFITS

- Maintenance benefits, such as the ability to identify and address streetlight failures, constituted the most important factor driving interest in controls systems. Respondents rated "alerts for malfunctioning equipment" as the most important operational function.
- Saving energy and money by dimming or turning off streetlights and monitoring lighting energy was the next-most important factor.

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[11] Department of Energy. "DOE Municipal Solid-State Street Lighting Consortium," http://www1.eere.energy.gov/buildings/ssl/consortium.html, accessed June 2011. See also: Smalley, Edward. "2011 LightFair – U.S. DOE Booth," Presentation. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/smalley_consortium_lightfair2011.pdf, accessed June 2011.

- Other important features included billing and metering in real time, controlling network data in-house, and emergency alerts.

SYSTEM MANAGEMENT AND OPERATIONS PREFERENCES

- Respondents clearly preferred managing their networked systems and data independently as opposed to having the vendor host the networked systems and data. Streetlight managers prefer to own the system and data and to be independent of ongoing hosting and communications charges. Sixty-one percent said they would not purchase a system if they had to pay an ongoing communication and hosting fee.
- Other key features of interest were GIS mapping, display, and management of assets, as well as security protocols for multiple levels of system access and operation.
- Users clearly favored wireless communication-based solutions over PLC-based communications.

ADVANCED CONTROLS DRAWBACKS

- Cost, including concerns over ongoing communication and hosting fees, remains the biggest obstacle to adoption.
- Organizations currently lack structure for management of controls systems and guidelines for adaptive lighting management.
- Respondents expressed concern over data and network security, noting a preference for in-house data and network hosting.
- Respondents expressed concern over system scalability.
- The general lack of information on and familiarity with controls products presents a significant barrier.

Adaptive Lighting Trends

Roadway lighting guidelines and criteria require local jurisdictions to maintain certain lighting levels based on the type or classification of a roadway. Dimensions, traffic volume, pedestrian volume and other factors determine the light levels jurisdictions will require for different roadway classes. Localities have historically designed street lighting systems for the most onerous conditions a roadway will experience over the course of a night; in other words, at peak traffic and/or pedestrian volumes. Also, HID lighting equipment is normally available only in fixed rated wattages and outputs. If lower wattage equipment cannot meet the light levels required by a standard, higher-wattage and -output equipment must be selected from the next available wattage bin, resulting in over-lit conditions.

With the advent of dimming outdoor lighting products and controls, operators can modify light output to match the local standard more closely, or alter light levels as environmental conditions change. This practice is known as adaptive lighting. As the PG&E study discussed, adaptive lighting practices are becoming increasingly interesting to street lighting managers as a way to reduce energy costs and extend the lifetime of lighting equipment. Siminovitch of the CLTC argued in a recent The Atlantic magazine article that the greatest potential for savings from new light sources is in their compatibility with adaptive controls.[12] His previously mentioned LD+A article also makes this point: "Dynamic controlled street lighting is perhaps one of the largest opportunities that exists in the U.S for energy savings."[13]

Due to increasing interest in adaptive lighting opportunities, Bonneville Power Administration, a large nonprofit utility in the Pacific Northwest, held several Adaptive Lighting Symposia in 2010 and 2011 with assistance from Washington State University and the CLTC. These symposia brought together utility, military, academic and private stakeholders to discuss opportunities to couple new light sources and controls to maximize energy benefits. [14] The CLTC also recently released a Guide for Implementing Adaptive, Energy-Efficient Exterior Lighting.[15] The guide indicated that new adaptive exterior lighting and controls products can provide 30% to 75% energy savings over traditional systems by coupling efficient dimmable light sources with schedules or sensors.

Entities responsible for street lighting operations and corresponding utility bills are taking notice of the energy savings achievable through advanced networked controls and adaptive controls practices. The city of San José released an "Adaptive Street Lighting Design Guide" in 2011 that establishes guidelines for dimming the city's streetlights "when reduced pedestrian and vehicular traffic justify lower light levels."[16] This guide relies on the roadway classification system outlined in IESNA RP-8-00, the North American roadway lighting standard, to determine when, where, and by how much it is acceptable for the city to dim its lights.[17]

San José's guide represents a major innovation in local lighting standards, moving away from the traditional model of static requirements and towards adaptive practices enabled by advanced controls. IESNA currently does not offer guidance on the use of RP-8-00 for adaptive lighting, although the newest European standard for roadway lighting, CIE 115:2010, includes a comprehensive discussion on how to apply the European standard in adaptive lighting scenarios.[18] As RP-8-00 is the prevailing North American standard, better guidance on applying for adaptive lighting would greatly facilitate cities' adoption of adaptive lighting practices.

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[12] Espen, Hal. *The Light Fantastic*. Technology Section of The Atlantic Magazine. July/August 2011. http://www.theatlantic.com/magazine/archive/2011/07/the-light-fantastic/8545/

[13] Siminovitch, Michael. *Taking the long view on LED street lighting*. (RESEARCH MATTERS). LD+A Magazine. July 1, 2010.

[14] Adaptive Lighting Symposia Final Report. March 11, 2011. BPA Energy Efficiency: http://www.bpa.gov/energy/n/emerging_technology/pdf/Adaptive_Lighting_Final_Report1-28-11.pdf

[15] Adaptive Exterior Lighting: Guide for Implementing Adaptive, Energy-Efficient Exterior Lighting. California Lighting Technology Center. University of California, Davis. 2011: http://www.pierpartnershipdemonstrations.com/documents/cltc_adaptive_exterior_lighting.pdf

[16] City of San José. "Public Streetlight Design Guide," (2011).

[17] Illumination Engineering Society of North America (IESNA). "RP-8-00 Roadway Lighting: American National Standard Practice for Roadway Lighting," Standard Practice Subcommittee of the IESNA Roadway Lighting Committee (2005).

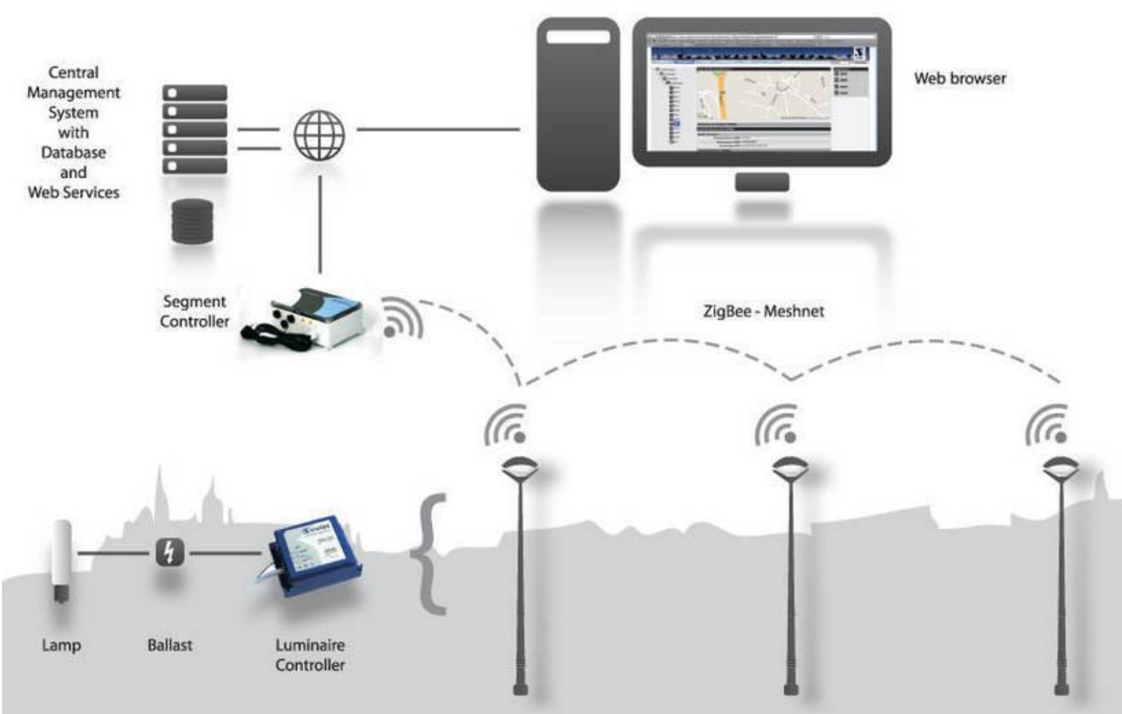
[18] International Commission on Illumination (CIE). "115:2010: Lighting of Roads for Motor and Pedestrian Traffic," Technical Guide. (2010).

Technology Characterization

Components and Compatibility

Networked controls systems for outdoor lighting typically consist of at least three main components: a fixture level “node” controller, a gateway, and a central management server, as shown in Figure 1 below. Node controllers are typically connected directly to the fixtures they control. Many controls products, such as ROAM, Airinet, CIMCON and others, offer a standard National Electrical Manufacturers Association (NEMA) twist lock installation option for attaching the node controller, which can be easily installed on new fixtures or swapped in on existing fixtures.[19] For some products, nodes can also be installed inside the fixture itself or inside the pole. This allows for greater flexibility in fitting a variety of fixture types. Surveyed manufacturers reported node controller power demands from .5W to 4W in normal operation (see product matrix for comparisons). Reported node-to-node or node-to-gateway ranges vary from 100 feet to two miles among the products surveyed, depending on the installation environment.

Gateways wirelessly connect the nodes to the central management server. The different controls systems offer a variety of installation locations and mounting options for gateways. These devices typically demand <1.5W to 20W of power during normal operation.



[19] A standard NEMA twist lock installation is not sufficient to allow for dimming. Separate leads must be connected to the ballast to provide the 0-10V or PWM dimming signal.

Figure 1: Illustration of Typical Networked Streetlight Controls System[20]

The central management server allows system administrators to communicate with individual fixtures, fixture groups, and the entire system. Vendors generally provide web-based access to the central management server; the software can be installed on-site with the customer or remotely on the vendor's servers. Due to data security issues, users typically prefer to host the central management servers locally.

With respect to light source compatibility, aside from Venture's Leafnut system, which is specifically for metal halide fixtures, all technologies surveyed claimed to be compatible with all common outdoor light sources (HID, LED, induction). However, some features of the controls system may not be compatible in retrofit applications. For example, light output dimming requires a compatible driver or ballast, which would normally not exist in most current HID streetlight systems.

Network and Communications

Networked controls systems rely on two forms of communication to deliver information between nodes and gateways: power line carrier (PLC) signaling or radio frequency (RF). PLC communication uses transceivers that send information on the power line itself, rather than broadcast over the air. The American National Standards Institute (ANSI) 709.2 (LonWorks) standard for PLC is an open, extensible architecture that allows control devices from multiple manufacturers to communicate with each other. This underlying protocol has been used in thousands of control applications throughout the world.[21]

Multiple radio frequency (RF) communications protocols, both open and proprietary, are available. Many of the controls products in the study use the ZigBee standard for RF communications. The ZigBee Alliance is an open, non-profit association dedicated to establishing a set of standards to define RF communications in low-power wireless control networks. Zigbee was designed for networks requiring secure, low data rate transmission at low power.[22] Communication frequency is typically in the 900MHz or 2.4GHz band; some controls products offer both frequency options to suit the customer's needs.

Several types of wireless RF networks exist for various applications. All controls products in this study used one of the following three basic network topologies, illustrated in Figure 2 below: point-to-point, star, or mesh.

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[20] Owlet controls diagram. Source: Owlet. "Owlet Nightshift," http://www.owlet-streetlight.de/english/owlet/, accessed June 2011.

[21] Shackelford, Jordan, et al. *Street Lighting Network Controls Market Assessment Report*. Pacific Gas and Electric Company Emerging Technologies Program (2010).

[22] Illumination Engineering Society of North America (IESNA). "TM-23-11 Lighting Controls Protocols." IES Controls Protocol Committee (2011).

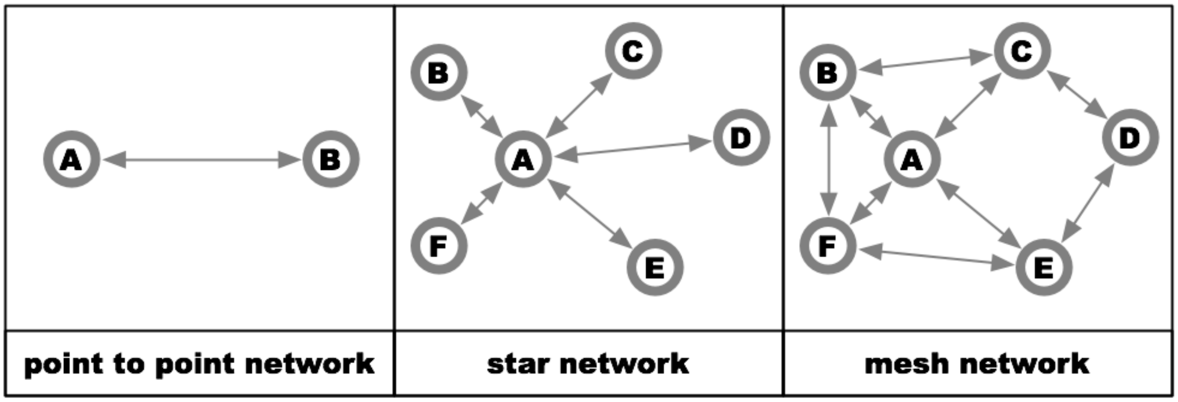

Figure 2: Typical Network Topologies[23]

> *Point-to-point* - In point-to-point networks, each node communicates with a single other node. This represents the simplest, most basic type of network topology. In a switched point-to-point network, point-to-point connections are dynamically set up and dropped as needed. Conventional telephony is based on this communications model.
>
> *Star* - Star networks are based on point-to-multipoint topology. In star networks, a single node serves as the central communications hub for all nodes. While star networks are simple to set up, the central communications hub represents a single point of failure for the entire system.
>
> *Mesh* - In mesh network topology, each node is connected with one or more nearby nodes in the network. Since each node has more than one connection point, mesh networks are typically more robust and better equipped to guard against communications breakdowns. Accordingly, however, mesh networks are usually more complicated to implement. The majority of systems in this study rely on mesh networking topology.

Backhaul communication between gateways and the central management system typically relies on Ethernet, cellular, or Wi-Fi connectivity. Many products offer a range of communication types to best suit the characteristics of each installation location; some systems can also use proprietary peer-to-peer communications.

Standard Product Features

As the market for advanced lighting controls rapidly changes, manufacturers are continuing to improve and add functionality to their products' feature sets. The study of 12 leading networked outdoor lighting controls products showed that the majority of products offered many similar capabilities, while some products were able to provide unique, more technologically advanced options.

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[23] NBT Ventures. "Of points, stars, and meshes," http://nbtventures.wordpress.com/2008/06/09/of-points-stars-and-meshes/, accessed June 2011.

Energy Solutions' research and analysis revealed that a successful controls product should offer, at a minimum, the following basic set of features. While the exact specifications of these features vary, almost all of the products surveyed offered these features at some level, and each competitive technology in the networked streetlight controls market should provide them.

BASIC ON/OFF OPERATION AND SUNRISE/SUNSET TRIMMING

Traditional lighting systems use photocells to determine when a light needs to be turned on or off. Controls systems can instead use a highly accurate astronomical clock to schedule the exact time a luminaire should turn on or off. The network interface can also be used to remotely program on/off schedules per the operator's commands.

The astronomical clock can be used in conjunction with location data for sunrise/sunset trimming functionality, allowing networked controls systems to capture additional energy savings by shortening a streetlight's nightly and annual runtime based on astronomical dusk/dawn calendars. This more precise scheduling would switch lights on later and off earlier than would otherwise be expected with traditional photocell control. Typically, the system relies on each controller's precise GPS location to program offsets to optimize each fixture's on/off schedule.

FAILURE DETECTION AND REPORTING

Without the benefit of a networked controls system, street lighting system administrators have difficulty discovering faults and failures in their lighting systems. For example, day burners – streetlights that remain lit unnecessarily in daylight hours – are typically the result of photocell failure, as traditional streetlight design requires failure to "on" for public safety. Day burners can continue to remain lit, wasting energy, for many days before a technician discovers the problem. In many cases, street lighting system administrators must rely on costly maintenance checks or citizen reports to identify faults and failures.

A streetlight controls system with luminaire monitoring functionality can automatically identify both communication and luminaire performance issues within the network, and generate a fault report to inform the relevant parties of the specific action required. This feature can potentially lead to significant operations and maintenance improvements, and was highly prioritized across the board among surveyed networked streetlight controls project managers. While each controls technology in this study offers different options for reporting failures, all technologies are able to generate daily system reports, and many can automatically send these reports to specified users.

LUMINAIRE GROUPING

Fixtures fitted with networked controls can be placed into administrator-defined groups in the management software for ease of scheduling and monitoring.

DIMMING AND ADAPTIVE LIGHTING CAPABILITIES

Networked controls products can achieve energy savings by dimming fixtures when lower levels of light are acceptable. This was an advanced or optional feature only a year ago, at the time of the PG&E study, but has become a baseline requirement for competitive systems today.

Dimming functionality requires a compatible electronic ballast or LED driver in addition to the control module. Typically, the control module sends a 0-10 volt or pulse width modulation (PWM) signal to the ballast, which adjusts the light output to the specified level. DALI (digital addressable lighting interface) is another method by which a controller can provide dimming instructions to the lamp. DALI is a digital interface that allows for 254 discrete levels of dimming intensity, commonly used with fluorescent fixtures.[24] Once the ballast receives the dimming instruction, it then uses either constant current reduction (CCR) or PWM on power supplied to the light source to reduce luminous output. PWM is generally the preferred dimming method for LEDs, since it prevents color shifting that may occur with changes in drive current.[25]

Outdoor light fixtures are often over-specified in terms of output during lighting design to ensure that light levels meet lighting criteria requirements. Networked controls with dimming functionality can help correct the over-lighting by customizing the light level from each fixture, resulting in potentially substantial energy savings.

Adaptive lighting, as discussed in the market characterization above, is another key feature that can provide significant energy savings, although lighting project managers for the demonstrations surveyed generally have not prioritized adaptive lighting control. Power metering features of advanced controls, described in detail below, could allow utilities to bill streetlights based on actual, rather than assumed, energy usage, which in turn incentivizes adaptive lighting practices.

The current lack of clear guidelines in North American outdoor lighting criteria like RP-8-00, combined with a lack of streetlight billing structures and utility protocols that allow for controls-system metered lighting energy, create conditions that may not incentivize the use of adaptive practices and dimming. As these issues are resolved, streetlight project managers will likely place greater emphasis on using adaptive lighting management practices to achieve greater energy savings.

GPS-BASED MAPPING OF MANAGED FIXTURES

The ability to identify each fixture in a lighting system by its geographic location is a key feature for streetlight management. Many systems use barcode scanners to tag individual fixtures with their GPS coordinates during installation, while some systems include onboard GPS receivers in each controller. The central management software will typically provide a graphical overlay (commonly via Google or BING maps) to

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[24] Illumination Engineering Society of North America (IESNA). “TM-23-11 Lighting Controls Protocols.” IES Controls Protocol Committee (2011).

[25] *Ibid*.

display each fixture according to geographic location. Some systems also offer support for full GIS integration.

POWER METERING

Energy usage data is of particular interest to street lighting project managers as well as to utilities. While most streetlights currently operate as un-metered load, accurate “revenue grade” energy usage data from advanced controls systems could be used to bill streetlights on actual, rather than assumed, energy use; this would allow users to quantify and monetize energy savings from adaptive lighting management.

All technologies in this study provided some form of power metering, albeit to different degrees of accuracy. In the 2010 PG&E study, at least one company used programming logic to merely assign wattages to controlled fixtures rather than actually measuring power. Based on the evolution of the technology, this method of power metering would no longer be acceptable for networked controls.

It should be noted that companies typically provided only a single number to represent measurement accuracy; however, accuracy may vary according to the wattage being controlled on the fixture. For example, it is unlikely that a meter could obtain the same measurement accuracy for a full powered LED fixture versus one that has been dimmed to 20% power, as power meters are typically rated for specific current/voltage ranges.

Before power metering can be used for billing purposes for streetlights, there will need to be some standardization in terms of the acceptable frequency and accuracy of power measurements recorded by lighting controls systems. Utilities maintain specific but not necessarily uniform requirements for revenue grade metering, often referencing the ANSI C12.1 American National Standard for Electric Meters.

WEB-BASED MONITORING AND CONTROL

The underlying software for a networked controls system is typically hosted either on-site or in another location on vendor or third-party servers. In any hosting scenario, a user has full access to the controls system via an Internet connection. Web-based software typically allows the user to monitor and control all of the fixtures in the system from any location through a standard web browser, with any Internet-enabled device.

Advanced Product Features

In addition to the basic features described above, many of the products surveyed offered several advanced features with varying specifications. In some cases, these features were characterized as “optional” and require additional cost.

LUMEN DEPRECIATION ADJUSTMENT

Some systems offer support for lumen depreciation adjustment, which prevents over-lighting in the initial stages of fixture or lamp operation, since light sources typically depreciate in light output over time. Lumen depreciation adjustment can typically be accomplished in one of two ways: algorithmic or sensor-based. An algorithmic adjustment relies on an assumed lumen depreciation curve for a given luminaire; it automatically schedules the luminaire to dim initially, and gradually increases power over time to compensate for lumen depreciation.[26] All systems that offer dimming and scheduling capabilities should technically be able to provide some level of algorithmic lumen depreciation adjustment.

A sensor-based adjustment requires the use of a light output meter (see below) to sense light being generated by the luminaire. The system then uses this information to dim the luminaire to the desired level, as measured by the light output meter. Lumen depreciation adjustment is a potential source of significant energy savings for street lighting systems.

LIGHT OUTPUT METERING

Only one product, Streetlight Intelligence (operations halted in 2011), offered standard light output metering. This meter was internal to the fixture and was able to measure light from the source. This data could be used in conjunction with power metering data to evaluate luminaire performance and augment the system's fault detection capabilities. Additionally, a controls system could use light output metering to inform lumen depreciation adjustments in real time[27].

CUSTOMER HOSTING OF NETWORK

Each controls technology requires the use of a central server to store the data and software that allows the controls system to function. Many vendors prefer to host this software on their own systems to allow for smoother integration of their feature sets. However, most streetlight system administrators prefer for a number of reasons to host the software on-site at each installation. Many prefer to pay an up-front cost and not be subject to recurring payments for software and data hosting services. Additionally, for vendor-hosted options, streetlight system administrators expressed concern about data security and long-distance communications reliability. For example, when the U.S. Virgin Islands decided to install networked controls on its streetlight system, it prioritized local hosting capabilities due to the relatively remote location of the installation.

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[26] Some manufacturers noted that this would be different for any lamp-ballast/driver combination, so would need to be customized for each installation.

[27] While Streetlight Intelligence had been offering this as a standard feature, other manufacturers question the usefulness and feasibility of this feature altogether, citing concerns over the achievable accuracy and measurement reliability of light output metering devices.

NTCIP COMPATIBILITY

The U.S. Department of Transportation's NTCIP family of standards provides protocols and object definitions to allow electronic traffic control equipment from different manufacturers to communicate and inter-operate. NTCIP is a product of collaboration between the National Electronics Manufacturers Association (NEMA), the American Association of State Highway Transportation Officials (AASHTO), and the Institute of Transportation Engineers (ITE), meant to increase compatibility of devices and software from different vendors used in the transportation community.[28]

Currently, the main NTCIP standard of interest for networked outdoor lighting controls is NTCIP 1213 (v02.20): National Transportation Communications for ITS Protocol: Object Definitions for Electrical and Lighting Management Systems (ELMS). This protocol provides object definitions for communication between a "Traffic Management Center" (TMC) and devices such as roadside luminaires and sensors to "control or monitor various functions, including dimming; light-activated, scheduled or manual operation; or power meter measurement."[29] Among the surveyed manufacturers, only Strategic Telemetry, Streetlight Intelligence, and Airinet currently offer NTCIP 1213 compliance. Though standardization and inter-operability are very important to some customers, other customers and vendors indicate that it is too early for an optimal protocol because the networked lighting controls market is still maturing and the features and objects that will eventually be consistent enough across manufacturers to create a viable open protocol are still evolving.

TRAFFIC/PEDESTRIAN SENSORS

A networked controller could theoretically use traffic and pedestrian sensors to greatly enhance adaptive lighting management. Similar to occupancy sensors in indoor applications and to some small-scale outdoor applications, traffic and pedestrian sensors may be applied to improve streetlight systems. Most systems claim to be compatible with motion-based sensors and would be able to set controllers to function as directed by movement in the area. However, currently no controls products offer this as a standard feature. Some manufacturers have expressed concern over the reliability of these sensors at the greater heights required for streetlight application. As with all energy-saving features, system administrators will likely only prioritize this feature if streetlight billing is based on actual metered energy consumption.

Controls Manufacturer Comparison Matrix

This report focuses on 12 networked streetlight controls technologies. Each manufacturer received a questionnaire to provide specific technical information on each technology. The

[28] NTCIP. "NTCIP Background: Information," http://www.ntcip.org/info/, accessed June 2011.
[29] AASHTO, et al. "NTCIP 1213 v02.20 National Transportation Communications for ITS Protocol: Object Definitions for Electrical and Lighting Management Systems (ELMS)," (2011).

comparison matrix (Tables 1 & 2) represents a synthesis of the survey information collected with extensive desk-based web research. This data is meant to inform general comparisons of feature sets offered by different technologies; Energy Solutions has not independently verified any figures or specifications presented in the table through third party testing or analysis. The information provided is drawn directly from publicly available web resources and communications with manufacturers.

Virtually all of the controls technologies offer many of the same basic features: luminaire grouping, remote on/off switching, sunrise/sunset trimming, backup astronomical clock, failure detection and web-based access. However, different technologies rely on different communication frequencies and protocols, and in some cases, different network topologies. As a result, node-to-node and node-to-gateway ranges vary greatly between technologies. Ripley's Aladdin system claims to offer the greatest range, at three to six miles with direct line of sight. Some products, such as CIMCON, Echelon, Strategic Telemetry, and Virticus allow for both RF and PLC communications within the same network.

Products also offer varying degrees of power metering accuracy, from 10% down to 0.5%, as reported by Airinet. Some controls products, such as those offered by Airinet and Streetlight Intelligence, offer feature-rich devices that include advanced options such as light output metering and lumen depreciation adjustment; other products focus on simpler designs that provide only the most basic functionality. Each controls product also offers slightly different reporting options, but most note that their systems can be customized to suit individual customers.

Table 1: Controls Manufacturer Product Matrix I

Overview						
Company	CIMCON	Lumewave	Virticus	Acuity	Eagle WMAC	Strategic Telemetry
Product	LightingGale	Lumestar	Rialto, Ventura, Malibu	ROAM	Eagle BULIT	SmartLights
Year of first install of over 100 lamps	2009	N/A	2010	2004	2011	2009
Pilot and commercial installations	US Virgin Islands; Haverhill, MA	Davis, CA	Portland, OR; Chula Vista, CA; Irvine, CA	Los Angeles, CA; Glendale, AZ	Memphis, TN; New Orleans, LA	Minneapolis, MN; Kansas City, MO
Components and Compatibility						
Node to gateway ratio	1,000:1	Unlimited	500:1	2,000:1	200:1	2,000:1
Node installation options	NEMA twistlock, inside fixture, inside pole	NEMA twistlock, ½" threaded nipple	Inside fixture, inside pole	NEMA twistlock	NEMA twistlock, hard-wired	Varies
Lamp type compatibility (LED, HID, etc.)	All	All	All	All	All	All
Component certifications	FCC	UL 773, UL 916	UL 916	FCC Part 15	UL	NR
Network and Communications						
Communication type	RF mesh/PLC	RF	RF mesh/PLC	RF mesh	RF mesh	RF mesh/PLC
Frequency/Protocol	2.4 GHz, IEEE802.15.4, Zigbee pro	902-928 MHz	915 MHz	2.4 GHz, IEEE 802.15.4	2.4 GHz	Zigbee/LonWorks
Range	3,000 ft* with obstructions, 2 miles LOS	1.5-3 miles LOS	100-200 ft with obstructions, 200-400 ft LOS	1,000 ft LOS	1/4 mile with obstructions	Application Dependent
Backhaul communications	Ethernet, cellular	Ethernet, cellular	Ethernet, cellular, Wi-Fi	Ethernet, cellular	Ethernet, cellular, Wi-Fi	Ethernet, cellular, proprietary
NTCIP 1213 compliant	No	No	No	No	No	Yes
Network security	AES 128	AES 128	AES 256	AES	AES 128	AES 128
Load from Network Control Components						
Node	2.5W	0.5W	1W	1.6W	<4W	Varies
Gateway	1.5W	<1.5W	20W	5.5W	<4W	Varies
Other	N/A	N/A	N/A	Dimming Module - 1.6W	N/A	N/A
Additional load per streetlight	N/A	N/A	N/A	N/A	N/A	N/A
Features						
Luminaire grouping	Yes	Yes	Yes	Yes	Yes	Yes
Power metering % accuracy	1%	1%	1%	10%	5%	2%
Dimming support	0-10V	0-10V	0-10V or PWM	0-10V	0-10V	0-10V
Photocontrol	Yes	Yes	Optional	Yes	Optional	Yes
Remote on/off scheduling	Yes	Yes	Yes	Yes	Yes	Yes
Backup astronomical clock	Yes	Yes	Yes	Yes	Yes	Yes
Sunrise/sunset trimming	Yes	Yes	Yes	Yes	Yes	Yes
Failure detection	Yes	Yes	Yes	Yes	Yes	Yes
Light output metering	Optional	No	Optional	No	Optional	No
Option for lumen depreciation adjustment	Yes	No	Yes	Yes	Yes	Yes
Option for traffic volume sensor	Yes	Yes	Yes	No	Yes	Yes
Web based access and control	Yes	Yes	Yes	Yes	Yes	Yes
Mapping	Google maps overlay; fixtures tagged with GPS	None at present	BING maps overlay; fixtures tagged with GPS	DeCarta mapping; fixtures tagged with GPS	Mapping available but unspecified	Google maps overlay
Reporting options	Crystal report, XLS, CSV	SQL	Customizable for each customer	PDF, XLS, XML	Access, CSV, XLS, customizable to more	CSV, XLS, customizable to more

Table 2: Controls Manufacturer Product Matrix II

Overview						
Company	Streetlight Intelligence	Echelon	Owlet	Airinet	Ripley Lighting Controls	Venture
Product	Lumen IQ	Edge Control Node; PL/RF; LED Driver	Nightshift	Lumitrol	Aladdin	Leafnut
Year of first install of over 100 lamps	NR	2010	2009	N/A	2008	2007
Pilot and commercial installations	Hamilton, Ontario; Calgary, Alberta	China; France; Norway	South Africa; Hayward, CA	Pueblo, CO; Kansas City, MO; Colorado City, CO	Sumter, SC; United Kingdom; San Jose, CA	Pensacola, FL; United Kingdom
Components and Compatibility						
Node to gateway ratio	250:1	NR	150:1	500:1	10,000:1	256:1
Node installation options	Inside Fixture or external mounting	Inside Fixture or External Mounting	Inside Fixture	NEMA twistlock	NEMA twistlock, inside fixture, inside pole	External mounting
Lamp type compatibility (LED, HID, etc.)	All	All	All	All	All	Metal halide
Component certifications	NR	N/A	ETL	NR	CE	UL, CSA
Network and Communications						
Communication type	RF mesh	PLC/RF mesh	RF mesh	RF mesh	RF star	RF point to point
Frequency/Protocol	900 MHz	2.4 GHz; LonWorks	2.4 GHz, Zigbee Pro	2.4 GHz; 900 MHz	900MHz, Plextek UNB	915 MHz, WiMAC
Range	3,500 ft	N/A	400 ft	2 miles	1-2 miles with obstructions, 3-6 miles LOS	3,000 ft* with obstructions, 5.5* miles LOS
Backhaul communications	Ethernet, cellular, Wi-Fi	Any IP-based technology	ADSL, cellular	Wireless P2P, Wi-Fi, Ethernet, cellular	Ethernet, cellular, Wi-Fi	Cellular
NTCIP 1213 compliant	Yes	No	No	Yes	No	No
Network security	AES 128	AES 128	AES 128	AES 128	AES	AES 128
Load from Network Control Components						
Node	1W	< 2W	2.1W	< 1W	.5W	1.22W
Gateway	20W	< 10W	8W	<4W	10W	2.13W
Other	N/A	NR	NR	N/A	N/A	N/A
Additional load per streetlight	N/A	NR	NR	N/A	.5W	N/A
Features						
Luminaire grouping	Yes	Yes	Yes	Yes	Yes	Yes
Power metering % accuracy	1%	2%	2%	0.5%	2%	NR
Dimming support	0-10V, Proprietary	0-10V, PWM	0-10V, DALI	0-10V, DALI, Multi-Level relay	0-10V, DALI	50% bi-level
Photocontrol	Yes	No	Yes	Yes	Yes	Yes
Remote on/off scheduling	Yes	Yes	Yes	Yes	Yes	Yes
Backup astronomical clock	Yes	Yes	Yes	Yes	Yes	No
Sunrise/sunset trimming	Yes	Yes	Yes	Yes	Yes	Yes
Failure detection	Yes	Yes	Yes	Yes	Yes	Yes
Light output metering	Yes	Optional	No	No	No	No
Option for lumen depreciation adjustment	Yes	Optional	Yes	Yes	Yes	Yes
Option for traffic volume sensor	No	Optional	Optional	Yes	Yes	No
Web based access and control	Yes	Yes	Yes	Yes	Yes	Yes
Mapping	BING maps overlay	Google maps overlay	Google maps overlay	XML/KML compatible; fixtures tagged with GPS	GIS compatible; fixtures tagged with GPS	Google maps overlay; fixtures tagged with GPS
Reporting options	CSV, XLS	Customizable for each customer	CSV, HTML, PDF, EDI 867, customizable to more	Access, CSV, XLS customizable to more	XML	CSV, XLS

Product Cost Considerations

The manufacturer survey also requested information on system deployment costs and annual fees for each technology based on a hypothetical 5,000-fixture installation. Many manufacturers were reluctant to quote concrete numbers (though some did), instead stating that they prefer to work individually with each client to negotiate an appropriate fee for each project.

The total system and operating costs varied widely among those manufacturers that did provide information on cost. All systems require an upfront payment to cover the cost of the controls hardware. Typical fixture-level controller costs ranged from less than $100 to $250, while reported gateway costs ranged up to $10,000. Gateway costs can also depend on the backhaul communications type; cellular-based gateway devices are generally more expensive than Ethernet or Wi-Fi based devices. Additionally, some manufacturers charge software licensing and support fees and/or server hosting fees. These annual fees also varied greatly, with some manufacturers charging up to $20 per fixture, depending on project variables.

This information is meant to provide a very general snapshot of the range of costs that would be required for a 5,000-fixture installation, but must be analyzed with careful consideration of the many factors that affect the figures quoted above. For example, fully featured products are more expensive, but also provide greater utility to meet certain needs. Furthermore, ongoing product support and server hosting fees for each technology will likely vary substantially, depending on individual customers' specific requirements for each project.

As the market matures, total costs for wireless networked controls systems will likely decrease. However, it appears that costs have not decreased compared to cost information from the PG&E report of early 2010, even as the number of products has continued to increase. This may be indicative of a market still in the process of maturing. Competition and consolidation among vendors will likely lead to eventual decreases in costs, which may be necessary for these products to succeed.

Controls Demonstrations Comparison Matrix

In order to gain an understanding of consumers' levels of satisfaction with the real-world performance of the controls products studied in this report, eight project managers of networked streetlight controls installations in the U.S. and Canada filled out surveys to describe their experiences with the controls technologies in their installations. Their responses are summarized in Tables 3 and 4. Each project manager may have interpreted slightly differently the 1-to-5 scale the survey used for their responses; while responses by a single project manager show his or her relative satisfaction with a given functionality or usefulness of a specific product feature, responses across projects may be difficult to compare.

In general, project managers for these demonstration products were most interested in non-energy benefits such as streamlined operations and management. They therefore highly valued controls products' abilities to detect faults and to generate notices and reports. Additionally, many projects also sought to evaluate the controls products' energy metering capabilities. Most demonstrations did not prioritize energy-saving features, such as dimming or adaptive lighting control; this may in large part be due to the current un-metered billing structure for most streetlights, which results in managers being unable to reap financial benefits for adaptively reducing street lighting energy.

Project managers expressed general satisfaction with wireless networked controls' abilities to improve streetlight operations and maintenance through accurate fault detection and power metering; many stated that they would highly recommend to any municipality or streetlight operator installation of such controls on all streetlight systems.

Table 3: Controls Demonstration Matrix I

Overview					
Pilot Location	Glendale, AZ	Hamilton, Ontario	San Jose, CA	SFPUC	Portland, OR
Entity; Territory Size	City of Glendale; 19,554 total fixtures	City of Hamilton; 45,000 total fixtures	City of San Jose; 62,000 fixtures	San Francisco Public Utilities Commission; 18,500 fixtures	City of Portland; 54,500
Technology	ROAM	Streetlight Intelligence	ROAM	ROAM	Virticus
Date of Install	Jan-08	May-10	Jan-10	Jan-10; Nov-10	Early 2011
Number of Fixtures Controlled	19,554	10	140	50 non-dimming; 22 dimming	2 (+28 scheduled in May)
Primary Features Demonstrated or Investigated	Operations and maintenance	Operations	Operations and Maintenance; Data Collection	Operations and Maintenance	Operations and maintenance; Energy savings
High Priority Product specifications	RF Mesh network, frequency (avoid cell tower interference), network security	N/A	Remote management system, failure notification, map driven applications, dimming, laptop-accessible control and monitoring	Wireless network, cost, maturity	RF mesh network with Ethernet backhaul; self-hosting capability; component certifications; network security
Most useful features	Failure detection, maintenance tickets, data reports	Luminaire Grouping, Remote Scheduling	Dimming, Remote Scheduling, Failure detection	Failure detection, maintenance tickets, data reports	Luminaire grouping, power metering, dimming, scheduling, astronomical clock, failure detection, maintenance reports, data reports
Least useful features	Did not specify	Power Metering, Dimming, Failure detection, data reports	Luminaire Grouping, Data Reports	Did not specify	Traffic volume sensor
System Operation and Functionality	Most Difficult ← → Easiest 1 2 3 4 5				
Installation: How would you characterize the installation process for the network controls?	5	3 Router failures delayed installation	5	4	4
System Compatibility: How would you characterize the network controls system's compatibility with existing lighting circuits and wiring?	5 Not tested with induction or LED	1 Additional time and money to retrofit	4	5	5
Training Requirements: How would you characterize the level of training required to prepare staff for installation?	3 Not overly difficult but training is required	2	5	5	4 Installation is simple and intuitive
Programming Process: How would you characterize the commissioning process for the controls network?	5 Some issues with approximated street addressing of lights	1	5 Took 24 hours to configure lamp's location on the web page	4	3 Initial communication issues solved with switch to Windows 7
Energy and Maintenance Considerations	Very Low ← → Very High 1 2 3 4 5				
Ease of Use: How would you characterize the network controls system's ability to improve streetlight operations and management practices?	5	NR	4	5	4 Still in early stages of the project
Data and Reporting: How would you characterize the usefulness of the data and reporting capabilities of the controls network?	5	1	4	4	4 Data will improve management and decision making
Energy Savings: How would you characterize the energy benefits attributed to the control system?	1 Did not test energy benefits	2 40% when fully dimmed, but flat-rate billing structure is a barrier.	5	1 City does not plan to dim streetlights at this time	4 Hope to initially dim by 30% to account for lumen depreciation
Non-Energy Benefits: How would you characterize the non-energy benefits attributed to the control system?	1 No *monetary* benefits; high operations and maintenance benefits	1 Never quantified any other benefits	5	4	4
Customer Support: How satisfied are you with the customer support from the streetlight network controls manufacturer / vendor?	5	3 Helpful	5 E-mail or phone response within 24 hours	5	5

Table 4: Controls Demonstration Matrix II

Overview					
Pilot Location	Los Angeles, CA	US Virgin Islands	Kansas City, MO	Kansas City, MO	Kansas City, MO
Entity; Territory Size	City of Los Angeles; 210,000 total fixtures	US Virgin Islands Water & Power Authority; 16,271 total fixtures	City of Kansas City; 92,000 total fixtures		
Technology	ROAM	CIMCON	Sun-Tech	Strategic Telemetry	Airinet
Date of Install	2009	Feb-11	Feb-11		
Number of Fixtures Controlled	40,000	600	15	15	15
Primary Features Demonstrated or Investigated	Operations and maintenance; Metering; Dimming	Operations and maintenance; Billing	Operations and Remote Controls, luminaire lifetime		
High Priority Product specifications	RF mesh network w/ 2-way communication; self-hosting; GIS compatible	Self hosting, open system architecture	Open protocols; Zigbee/AMI compatibility; power monitoring, commissioning, owner hosting, no ongoing fees		
Most useful features	Luminaire grouping, dimming, scheduling, astronomical clock, failure detection, maintenance reports, data reports	Power metering, astronomical clock, sunrise/sunset trimming, failure detection	Luminaire grouping, power metering, scheduling, failure detection, maintenance reports, data reports	Luminaire grouping, power metering, scheduling, failure detection, maintenance reports, data reports	Luminaire grouping, power metering, scheduling, failure detection, maintenance reports, data reports
Least useful features	Sunset/sunrise trimming	Dimming, light output metering, lumen depreciation adjustment	Backup astronomical clock, Sunrise/Sunset trimming	Backup astronomical clock	Did not specify
System Operation and Functionality	Most Difficult ← → Easiest 1 2 3 4 5				
Installation: How would you characterize the installation process for the network controls?	5	5	4	4	5 Plug and Play
System Compatibility: How would you characterize the network controls system's compatibility with existing lighting circuits and wiring?	5	5	4	5	5
Training Requirements: How would you characterize the level of training required to prepare staff for installation?	2	5	4	4	5
Programming Process: How would you characterize the commissioning process for the controls network?	3	2 Vendor did this part	3	5	5 Self-commissions using GPS
Energy and Maintenance Considerations	Very Low ← → Very High 1 2 3 4 5				
Ease of Use: How would you characterize the network controls system's ability to improve streetlight operations and management practices?	5	3 Should improve maintenance and scheduling	4	4	5 Highly recommended
Data and Reporting: How would you characterize the usefulness of the data and reporting capabilities of the controls network?	5	3 Useful for comparing energy consumption of different fixtures	5	5	5
Energy Savings: How would you characterize the energy benefits attributed to the control system?	5	2 Will likely be larger once installation is fully complete	5 Dimming would provide roughly 20% additional energy savings	5 Dimming would provide roughly 20% additional energy savings	5 Dimming would provide roughly 20% additional energy savings
Non-Energy Benefits: How would you characterize the non-energy benefits attributed to the control system?	5	5 Ability to know which lights are malfunctioning is a benefit	5	5	5
Customer Support: How satisfied are you with the customer support from the streetlight network controls manufacturer / vendor?	4	3	5	4	5

Conclusions

THE CONTROLS MARKET IS STILL EVOLVING

The advanced outdoor lighting controls market has progressed rapidly over the last several years. Since the PG&E study of early 2010, a number of new manufacturers have entered the field, although some companies previously active in this market have also ceased operations. Other established lighting companies have also recently announced plans to enter the market. The range of available products has grown significantly, but the number of large controls installations remains relatively small. Overall, the market is still maturing and many factors need to fall into place for substantial growth to occur.

Project managers for controls demonstrations and larger scale installations expressed overall satisfaction that wireless networked controls were able to improve streetlight operations and maintenance through features such as accurate fault detection and power metering. Many stated that they would highly recommend that other municipalities or streetlight operators install controls on their systems. This general satisfaction suggests that controls products are capable of meeting customer expectations in these areas.

A clearer set of standard features for all controls products now exists:

- Basic on/off operation and sunrise/sunset trimming
- Failure detection and reporting
- Luminaire grouping
- Dimming and adaptive lighting capabilities
- GPS-based mapping of managed fixtures
- Power metering
- Web-based monitoring and control

Dimming and on-board power metering, previously considered optional or advanced features, are now offered standard for almost all products. In addition to the basic feature set, many products also provide advanced capabilities with additional functionality, improved system integration and increased energy savings.

- Lumen Depreciation Adjustment
- Light Output Metering
- Customer Hosting of Network
- NTCIP Compatibility
- Traffic/Pedestrian Sensors

While these additional features will be attractive to some users, most of them may be of secondary importance in the system purchase decision. The customer-hosted network option, however, is very important to a majority of users (based on user feedback). In the MSSLC survey, users stated a preference for hosting data internally and purchasing the controls system for a one-time, upfront cost. A one-time fee structure is easier to integrate into municipal budgets than ongoing fees that represent a continued drain on operations budgets. The trend toward self-hosting is likely to continue, although most controls companies offer – and some currently require – a vendor-hosted solution.

Survey results showed that most end-users also prefer systems that use RF communications over PLC, due to greater versatility and compatibility with existing lighting infrastructure. Product specifications such as communication type, and feature sets such as those described above, are important for prospective users, but equally important is demonstrated product maturity. Although smaller manufacturers may be able to offer broader feature sets and greater customizability, established leaders like ROAM can claim to offer a more polished, field-tested product.

MAINTENANCE AND OPERATIONS BENEFITS ARE CLEAR

This research indicates that streetlight managers install networked controls primarily to streamline maintenance and operations practices. While virtually all products also provide a number of energy savings features, end-users consistently rated maintenance-related features such as fault detection and reporting, and basic operations such as on/off scheduling, as the most useful or important product features.

Product information and user feedback indicate that the maintenance/operations features of existing advanced networked controls are already satisfactory to most users. In other words, the controls companies have gotten it right when it comes to these features and significant additional development of such features appears unnecessary.

ENERGY SAVINGS AND METERING BENEFITS ARE LESS CLEAR

In contrast to maintenance and operations, energy savings from adaptive lighting features and the benefits of streetlight energy metering have been less influential in the decision-making process to-date. Focusing growth and development on this area will be necessary to propel these technologies, both from the standpoint of product development and market acceptance of adaptive lighting and controls-based energy metering. Users' collective focus on maintenance savings rather than energy savings so far is in part due to the current un-metered billing structure for most streetlights, which results in managers being unable to reap financial benefits from adaptive lighting. A number of surveyed project managers noted that they did not use the dimming function specifically because there was no utility cost benefit. Likewise, guidelines for adaptive lighting practices are only beginning to emerge. Until controls-enabled energy savings can be monetized and appropriate adaptive lighting guidelines are developed, market adoption will remain relatively low.

This report does note some encouraging recent developments in these areas. Several organizations, including the city of San José, the International Commission on Illumination (CIE), and the CLTC have recently published documents providing guidance on design and implementation of adaptive lighting. California cities are also lobbying their state's utilities commission to introduce rate schedules that accept and define customer-provided streetlight metering data from networked controls. Estimates from the previous streetlight controls market assessment suggested that adaptive lighting features could reduce energy use by up to twenty-nine percent. Changing billing structures from flat rate to customer-metered for advanced networked streetlights, and using the controls data for billing purposes, could provide a strong financial incentive for streetlight managers to adopt controls.

COSTS REMAIN A HURDLE

Costs will continue to be a major barrier to widespread adoption of networked controls. Managers adopting networked controls for their streetlights may pay can currently expect to pay from $100 to $250 per fixture for system deployment and in some cases may pay significant ongoing fees as well. Although costs have not decreased since the last study, they are likely to eventually come down as manufacturers realize greater economies of scale, and as competition among the growing number of market actors leads to greater efficiencies. Accounting for energy savings from the controls systems, as mentioned above, should also increase product cost-effectiveness, in turn increasing market adoption and further driving down costs.

RECOMMENDATIONS

Based on these findings, recommended strategies for increasing market adoption of networked controls are:

1. Continued information consolidation and sharing among public stakeholders.

   Given the wide variety of available controls options, groups such as the MSSLC Controls Task Force and NEEA should continue to provide information and discussion forums on controls products and relevant policy issues. The MSSLC should continue its schedule of presentations and conferences, which improve the general knowledge base among stakeholders. Periodic updated market studies will also help to further characterize this still-maturing and evolving market.

2. Coordinated development of guidelines and policies on networked controls energy metering, utility billing and adaptive lighting.

   Stakeholders should jointly work on developing and lobbying for metering structures appropriate for customer-provided controls-based lighting energy data, as well as providing product manufacturers with clear guidance on accuracy and reporting requirements for energy data. Utility input will be important as well. More extensive adaptive lighting guidance from IESNA and/or other national standards bodies will also be instrumental for this market.

3. Controls cost reductions.

   Cost reductions will largely be up to competitive forces in the market, but customer demands will likely decrease overall system costs, especially those relating to ongoing costs.

4. Controls-readiness in outdoor lighting investments.

   Significant current and future potential for energy savings with advanced controls dictate that street and parking lights should be purchased with dimming controls-readiness, if not outright advanced networked controls. This will better prepare such equipment for later retrofitting with advanced controls and will help prevent lost savings opportunities in the future.

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Appendix B: Controls Product Briefs

Airinet

COMPANY BACKGROUND

Airinet is a small and relatively young company founded in 2005 and based in Pueblo, Colorado. Airinet provides an array of network services, including citywide wireless networks, street lighting management, electrical management, irrigation management and surveillance networks. The company currently consists of nine employees.

Airinet's largest installation to-date is an exterior lighting system installed for Black Hills Energy in Pueblo, Colorado, in 2009. Airinet's controls system has also been demonstrated in Kansas City, Missouri and Colorado City, Colorado.

Figure 3: Airinet's Fixture-Level Lumitrol Controller

SYSTEM OVERVIEW

The Airinet controls system, released in 2009, consists of three major components (see Table 5): Lumitrol™ (fixture-level controller shown in Figure 3), system management user interface (LMS shown in Figure 4) and its AirNode™ (network gateway shown in Figure 5). This controls system uses mesh RF communications to control and monitor lights. The customer can access the network and send commands to the controlled fixtures via the Internet from any location.

Table 5: Overview of the Airinet Controls System

System Components	
Component names	Fixture-level Node: Lumitrol Network Gateway: AirNode Management System: Web Interface: user-hosted
Node to gateway ratio	Recommended: 500:1
Node installation	On top of fixture in place of photocell

Lamp/fixture type compatibility	All

In a typical installation, a single AirNode gateway can typically control up to 500 Lumitrol nodes.[30] Monitoring for each node is performed based on a scheduled interval. Real-time monitoring (up to every second) for each node is also available. Each Lumitrol device has a power draw of less than 1W. The AirNode gateway has a continuous power draw of 4W. The electronic components in the Lumitrol and AirNode have a 10-year rated lifetime. Airinet offers a 10-year warranty for all components in its systems, which includes troubleshooting and technical support. Airinet reports that all of its controls products are manufactured and assembled in the United States.

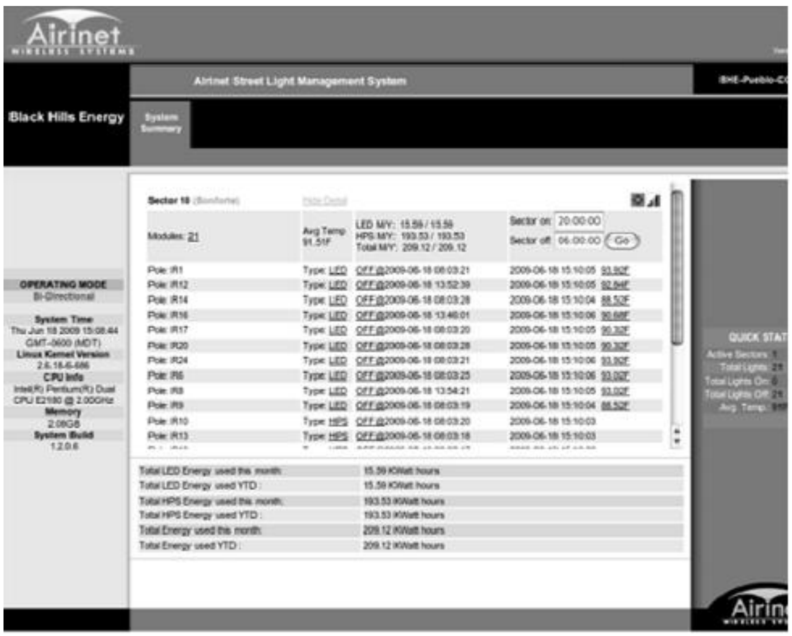

Figure 4: Screen Capture of Airinet's Software Interface

Reporting from the system is customized according to the customer's preference, but can include details such as volts, amps, watts, cumulative watt hours, power factor, VAR, phase angle, and cost. These measurements can be configured to record up to once per second. Airinet provides real-time alerts, measurements, charting and visualizations on any standard Internet browser, and all features are available on mobile devices as well. These alerts are instant and are self-clearing based on condition corrections in real-time.

[30] The AirNode gateway has a maximum of 2,000 nodes per gateway, but a 500:1 ratio is recommended due to RF bandwidth constraints.

Figure 5: Airinet's AirNode Network Gateway

HARDWARE AND CONTROLS DETAILS

Airinet offers a range of standard features in its controls system, including the following:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

In addition to this basic functionality, Airinet provides many additional features (see Table 6). The system has an integrated GPS receiver and uses GPS coordinates to perform sunrise/sunset trimming. Airinet supports 0-10V, DALI, and Multi-level relay dimming and PWM dimming from 0% to 100% at 0.4% intervals, with compatible ballasts. The Airinet system also includes an ambient light sensor; it can also save lighting energy by adjusting luminaire power over time using sensor-based lumen depreciation calculations to maintain consistent lumen output.

Each Lumitrol controller also monitors current, voltage and power to an accuracy of < 0.5%. Airinet can track and report additional usage data and statistics as requested by the customer. In the event of communications failure, the Lumitrol nodes operate off stored parameters. Modules perform self-diagnostics and recovery operations, if possible. The node has built-in flash storage for offline loggings and a battery backup for continuous operation during power outages of up to one month. Once a connection is re-established, the gap information is synced to the server.

The Airinet system also includes Utility Grade metering (exceeds IEC 62053 / ANSI C 12.20 standards) and user configurable cost reporting.

Table 6: Overview of Airinet's Features

Features	Details
Power metering	Measures I, V, P, PF, to < 0.5% accuracy
Dimming support	0-100% at 0.4% levels. Requires ballast that supports 0-10V, DALI, or Multi-level relay dimming
Photocontrol	Yes, software adjustable sensitivity
Mapping/GIS compatibility	Can interoperate with other GIS systems that use XML/KML data.
Sunrise/sunset trimming	Yes
Reporting options	.xls, .csv, Access, flat files, and user configurable visualizations (charts)

NETWORK

Airinet uses two RF frequencies (2.4 GHz and 900 MHz) to communicate between Lumitrol controllers and the AirNode network gateways (see Table 7); the hosts can choose the frequency they prefer. Typical RF range between nodes and gateways is two miles. The AirNode gateway communicates with the central management system via an Ethernet, 3G, 4G, Wi-Fi or wireless peer-to-peer connection. Gateways can communicate in a wireless peer-to-peer configuration at a range of up to 20 km. Airinet's user interface is web-based, with icons indicating status and providing control options.

Table 7: Airinet Communications Specifications

Communications	
Communication Type (Node to Gateway)	Mesh RF
Frequency/Protocol	2.4 GHz and 900 MHz
Range (Node to Node, Node to Gateway)	Node to Node: 2 miles Node to Gateway: 2 miles
Backhaul Communications	Ethernet, 3G, 4G, Wi-Fi, Wireless PtP
NTCIP 1213 compliant?	Yes
Security	AES 128 encryption

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

The Lumitrol installation and commissioning process is plug-and-play: The node is installed into the fixture in the same manner as a twist-lock photocell, and has complete over-the-air activation. Each module self-registers its GPS location information and is regularly updated. Zones are automatically created and modules automatically join zones based upon the GPS location.

The standard upfront system costs are for nodes, gateways, and software, typically sold as a one-time charge in which the owner owns and operates the system from its server with no recurring charges. Airinet also provides an optional Software as a Service (SAAS) package, in which it hosts the system software.

CIMCON LightingGale

COMPANY BACKGROUND

CIMCON Software Inc. is a medium-sized company based in Westford, MA, specializing in industrial automation systems. CIMCON has been in business since 1988, and currently has 180 employees. CIMCON's primary areas of expertise include oil and gas operations, water resource management, and power transmission and distribution.

CIMCON has pilot and commercial installations in Massachusetts and Asia, including a 5,000 light installation in central India. In addition, the U.S. Virgin Islands Water and Power Authority is in the process of installing 14,000 streetlights controlled by the CIMCON system. This project began in February 2011 and as of May 2011, 600 fixtures have been successfully fitted with CIMCON controls.

Figure 6: CIMCON's Fixture-Level Controller

SYSTEM OVERVIEW

The CIMCON controls system, released in 2007, consists of an iSLC controller (see Figure 6), a wireless gateway, and the LightingGale (LG) central management system (see Figure 7). CIMCON offers three levels of iSLC controllers depending on need (see Table 8): the iSLC10 is the most basic wireless controller, which allows simple on/off switching; the iSLC3000 offers additional features, such as dimming and power metering. The iSLC4000 offers a similar feature set to the iSLC3000 but is based on PLC communications technology. These latter two communication technologies can be utilized within the same network, although separate gateways are generally required to manage each of these sub-networks. The communications system is scalable to hundreds of thousands of nodes per installation (1,000 nodes per gateway, several hundred gateways per installation).

Table 8: Overview of CIMCON's Controls System

System Components	
Components	Fixture-level node: iSLC10/3000/4000 Network gateway device: Wireless Gateway Management system: LightingGale
Node to gateway ratio	500 to 1000:1
Node installation	NEMA twist lock, or inside fixture or pole
Lamp/fixture type compatibility	All

The CIMCON system is compatible with any fixture type, from HIDs to LEDs. CIMCON's iSLC controllers and wireless gateways can be installed on the lamp in place of existing photo sensors or mounted either inside the lamp or at the pole. CIMCON's controllers are therefore compatible with many different types of fixtures. The iSLC controllers draw 2 W of power, while the gateways draw an average of 1.5 W. CIMCON reports that both iSLCs and wireless gateways have a rated lifetime of 10 years. RF transceivers are FCC certified in the U.S. CIMCON's standard warranty is one year (an extended warranty is available at additional cost) and also covers troubleshooting and remote support.

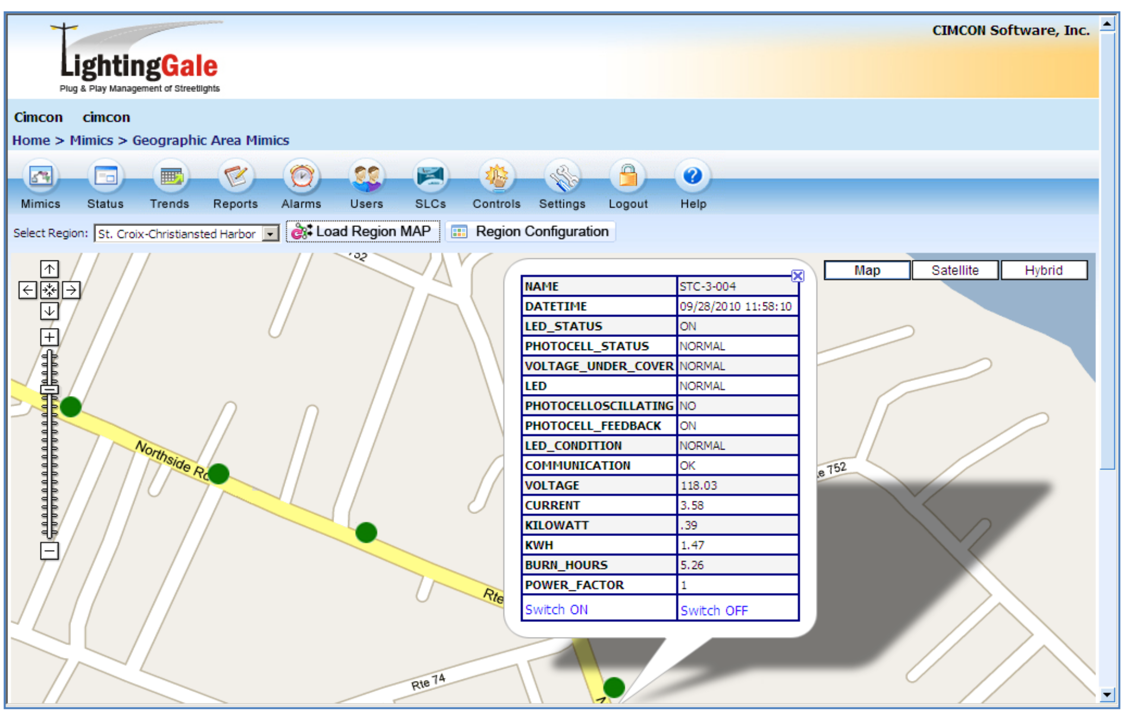

Figure 7: Screen capture of CIMCON's LightingGale Software

LightingGale (LG), a web-based central management software program, allows users to monitor and manage individual or grouped iSLC controllers from any location. LG is compatible with operating systems from Windows 2003 server onwards. In the LightingGale interface, shown above in Figure 7, controlled fixtures are identified in the Google maps overlay as green circles. Users can remotely configure streetlight operating schedules, dimming schedules, and alarm and event settings and notifications. LG identifies each controller by its pole ID and GPS coordinates; it can then specify different modes of operation (manual, astronomical timer, photocell, etc.) for each pole or group of poles. Each controller also has data storage memory (32kb) to log events and energy data in case of communication failure. In the event of fixture or communications failure, LG generates alarms for immediate delivery via text message (SMS) or email to the appropriate parties.

HARDWARE AND CONTROLS DETAILS

CIMCON's full line of iSLC controllers offers the following features:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

All iSLCs can also track lamp burn hours, which can then be used for predictive maintenance, allowing lamp replacement to be planned in advance. In addition to these features, CIMCON's iSLC 3000 and iSLC4000 controllers allow for dimming (0-10V or PWM) over the full range supported by the ballast (see Table 9). The iSLC 3000 and iSLC4000 controllers can track 13 parameters including current, voltage, power, and power factor to one percent accuracy. Fault monitoring is used to report lamp burning, lamp cycling, and ballast failure, over/under voltage, abnormal power consumption, low power factor, network communication failure, as well as other potential failure events. All faults are sent to the central management software which generates alarms to relevant parties. Additionally, alarms are recorded and stored at the central server. LightingGale generates monitoring reports in Crystal Report, Excel, or Word formats. Customers have the ability to design and customize these reports to suit their needs.

Table 9: Overview of CIMCON's Features

Features	Details
Power metering	I, V, P, PF; Accurate to 1%.
Dimming support	0-100%; Requires ballast that supports 0-10V or PWM dimming
Photocontrol	Yes
Sunrise/sunset trimming	Location based
Mapping/GIS compatibility	Google maps overlay
Reporting options	Crystal Reports, PDF, Word and Excel

NETWORK

As previously noted, CIMCON can use both PLC and RF in a single installation (see Table 10); however, this typically requires separate gateways for the different sub-networks. For RF communication between iSLC nodes, CIMCON relies on Zigbee Pro. It operates at 2.4GHz and has a transmission range of up to two miles between nodes with no obstructions. In a typical city installation, its transmission range is around one kilometer. CIMCON also offers other frequency options for RF range, based on the customer's requirements. Backhaul communication with the wireless gateways occurs through an Ethernet or cellular (GPRS) connection. CIMCON relies on a standard Advanced Encryption Standard (AES) 128-bit security encryption for protecting network communications.

Table 10: CIMCON's Communications Specifications

Communications	
Communication Type	Mesh RF and PLC
Frequency/Protocol	2.4GHz IEEE 802.15.4 Zigbee Pro
Range	1 km
Backhaul Communications	Ethernet or cellular (GPRS)
NTCIP 1213 compliant	No
Security	AES 128

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

CIMCON's installation process is comprised of three steps. First, gateways are installed in locations that allow for Ethernet or GPRS connectivity. Next, controllers are fit to each lamp, and then LG central management software is installed on the customer's own server. Each lamp is identified by a unique controller ID linked to the pole ID. The pole location is defined by the GPS coordinates and can be configured from the central management software. CIMCON offers two software licensing models; the customer can choose to either host the central monitoring software on-site, incurring a one-time charge, or to pay an initial setup fee plus an annual service fee for CIMCON to host the software remotely. For the customer-hosted option, CIMCON charges based on the cost of the server and the number of users required. For the CIMCON-hosted option, the cost structure depends on the total number of controllers in the system.

Eagle WMAC

COMPANY BACKGROUND

Eagle WMAC is a small company founded in 2009 and based in Memphis, Tennessee. Eagle WMAC is experienced in industrial control applications, as well as both municipal and utility lighting. Recently, Eagle WMAC has begun to provide monitoring services for a range of commercial and industrial equipment. The company currently has less than 10 employees.

Eagle WMAC's controls system is currently installed in pilot projects in Memphis, Tennessee and Wheaton, Illinois. Eagle WMAC also has a commercial installation in New Orleans, Louisiana.

Figure 8: Eagle WMAC's BULIT Controller

Figure 9: Eagle WMAC's EAGLE-200-AX JACE gateway

SYSTEM OVERVIEW

Eagle WMAC released the EAGLE BULIT system in January of 2010. The BULIT system consists of a fixture-level BULIT controller (see Figure 8), an EAGLE-200-AX JACE gateway (see Figure 9), and a central management server (see Table 11). BULIT is compatible with any lamp type; depending on the lamp and fixture type, it can be installed via a standard universal NEMA three terminal connection point, or through direct wire to the lighting product.

Table 11: Overview of the Eagle WMAC Controls System

System Components	
Component names	Fixture-level Node: BULIT Network Gateway: EAGLE-200-AX JACE Management System: Eagle Interface
Node to gateway ratio	200:1
Node installation	NEMA twist lock or hard-wired
Lamp/fixture type compatibility	All

A single EAGLE-200-AX JACE can control up to 200 BULIT controllers, and power draw is typically less than 4W for both the BULIT controllers and the EAGLE-200-AX JACE gateways. Eagle WMAC reports an expected lifetime of 15 years for its products. Components are FCC-compliant and appropriately Underwriters Laboratories (UL)-listed.

Eagle WMAC's controls system relies on a mesh RF network to communicate between nodes and gateways, and either Ethernet, cellular or Wi-Fi for backhaul communications between gateways and the central management server.

HARDWARE AND CONTROLS DETAILS

Eagle WMAC offers a range of standard features in its controls system, including the following:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

Additionally, Eagle WMAC supports 0-10V dimming with compatible ballasts and drivers, and can measure power based on voltage and current calculations to five percent accuracy (see Table 12). Eagle WMAC also offers a "storm tracker" photocell override feature to control for unexpected changes to ambient light conditions. In the event of communications failure or other fault detection, the system immediately generates custom alerts via email, text, and on-screen display.

Table 12: Overview of Eagle WMAC's Features

Features	Details
Power metering	Optional; Measures I, V, P to 5% accuracy
Dimming support	0-10V
Photocontrol	Optional
Mapping/GIS compatibility	Supports geospatial software integration
Sunrise/sunset trimming	Location based
Reporting options	Csv, xls, Access, customizable

NETWORK

Eagle WMAC uses a mesh RF (2.4GHz) network to communicate between gateways and nodes (see Table 13). Eagle WMAC reports node-to-node and node-to-gateway ranges of a quarter-mile; Eagle WMAC also offers an optional "High Gain Antenna" to increase range. The EAGLE-200-AX JACE gateways communicate with the central management server via an Ethernet, cellular or Wi-Fi connection. Eagle WMAC reports that the network is 100% scalable, allowing for infinite upgrades and additions.

Table 13: Eagle WMAC Communications Specifications

Communications	
Communication Type (Node to Gateway)	Mesh RF
Frequency/Protocol	2.4 GHz
Range (Node to Node, Node to Gateway)	¼ mile (typical w/ obstructions)
Backhaul Communications	Ethernet, cellular, Wi-Fi
NTCIP 1213 compliant?	No
Security	AES 128

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

Installation and commissioning of Eagle WMAC require a qualified technician. Once hardware has been properly installed, devices are powered on one at a time, beginning with devices nearest the JACE controller. Each device is discovered and programmed through the software system. Last, physical I/O point validation is required to complete the system installation. Eagle WMAC offers a two-year warranty for all components; installation and troubleshooting support is also available at additional cost. Eagle WMAC charges an upfront one-time payment, with no annual fees for the use of its controls product.

Echelon

COMPANY BACKGROUND

Echelon Corporation is a leading open-standard energy control networking company headquartered in San José, California. Echelon's LonWorks communication platform was introduced in the 1990s, and is today a well-established technology, providing a wide range of solutions to commercial and electric utility customers. Echelon technologies connect more than 35 million homes, 300,000 buildings and 100 million devices to the smart grid. Echelon's Edge Control Node system is part of the LonWorks family of products within the commercial business sector; it is used for a variety of applications in low-voltage distribution management, including street lighting.

Figure 10: Echelon's Smart Server Gateway

Echelon's Power Line Carrier (PLC) transceivers have been installed in a number of streetlight applications throughout the world, including Norway, France, the United States and China. Echelon installed over 16,000 fixtures with LonWorks chipsets in China in 2010, and expects to install 500,000 fixtures by 2014.[31]

SYSTEM OVERVIEW

The Edge Control Node (ECN), released in 2010, aggregates a number of applications (including street lighting) and provides distributed intelligence at the transformer level. Either the ECN or its predecessor, the SmartServer (see Figure 10), can be used in street lighting applications. Within the context of street lighting controls, the SmartServer and ECN perform similar functions; the SmartServer is typically used in streetlight-only applications, while the ECN is employed when street lighting is one of multiple system applications.

Echelon's Street Lighting solution has three components: Echelon's Street Lighting Controller (SLC), Street Light Bridge (a PL to RF bridge) and the Edge Control Node (ECN) or SmartServer gateway[32] (see Table 14). The Street Lighting Controller is available with two possible configurations: 1) A PL chip integrated inside the ballast and/or driver or 2) an externally-mounted PL controller along with ballast/driver. On each fixture, the Street Lighting Controller communicates with compatible HID ballasts or LED drivers supplied by a third

[31] Echelon. "Echelon Control Network Solutions Save Energy with Smart Street Lighting in China," http://www.echelon.com/company/press/2011/pressPDFs/china_streetlight.pdf, accessed June 2011.

[32] Note that within the context of this report, Echelon's Edge Control Node is considered a gateway. Echelon refers to it as a node because the ECN controls a number of different applications in addition to street lighting, including advanced metering infrastructure, alternative energy sources, and electric vehicle charging).

party.[33] These SLC nodes communicate over power lines to the gateway, which is either a SmartServer or ECN. The SmartServer or ECN acts as a connection point between the smart ballasts/drivers in the fixtures and a central management system such as Streetlight.vision. Each SLC consumes 1-2W, while each ECN consumes less than 10W. Figure 11 illustrates a typical configuration of the Echelon system.

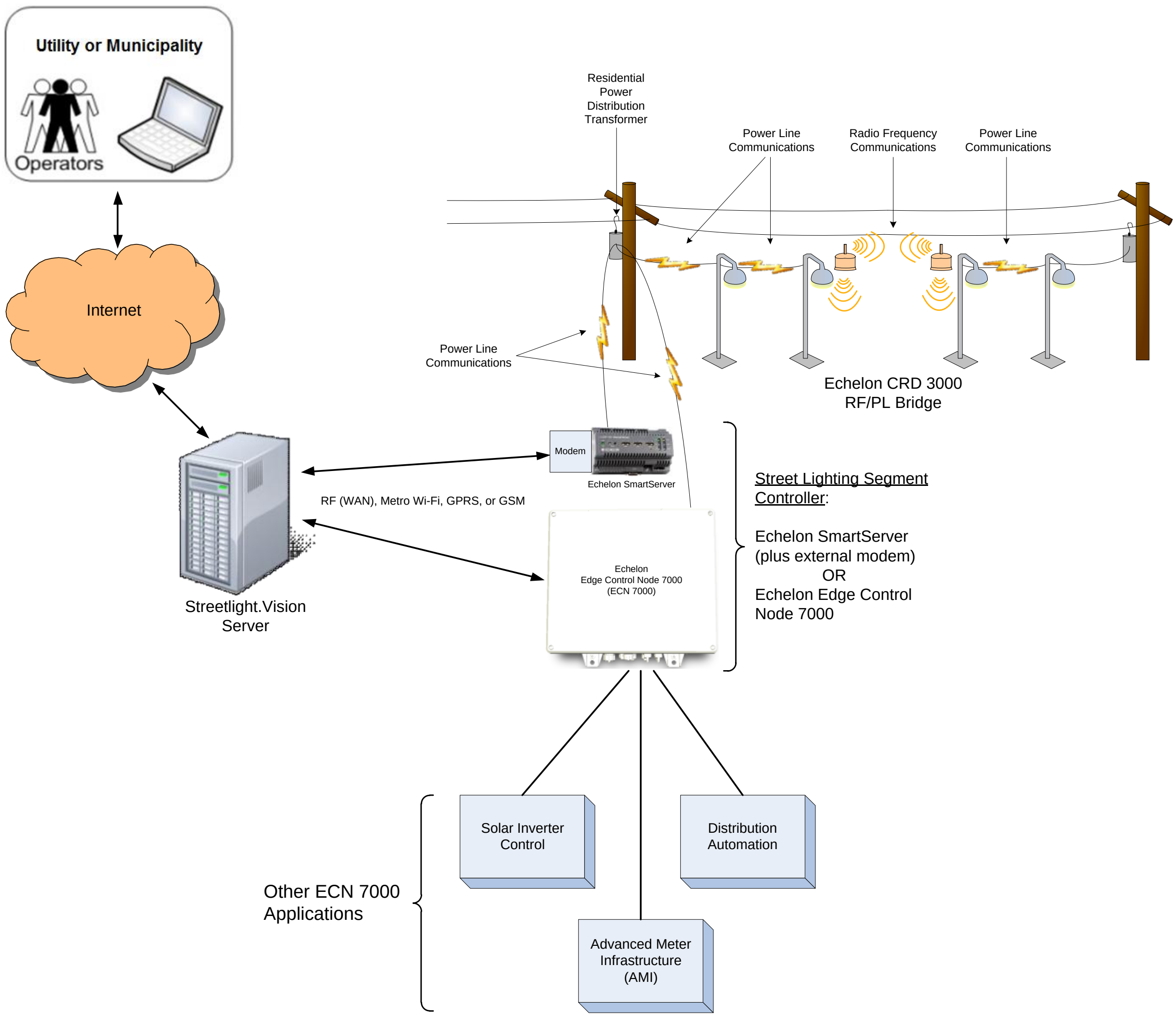

Figure 11: Diagram of Basic System Architecture of the Echelon System

Table 14: Overview of the Echelon Controls System

[33] Echelon specifies that to be compatible with the system, ballasts/drivers must be: 1) dimmable; 2) capable of out-detecting lamp and electrical failures; 3) able to measure and set data such as lamp status, lamp level, accumulated energy use of the streetlight, voltage, current and power factor, and to send data over low voltage line networks using LonWorks protocol; and 4) able to receive switch and dimming commands from a streetlight segment controller over power lines using LonWorks protocol. Echelon (2007). *Monitored Outdoor Lighting: Market, Challenges, Solutions, and Next Steps.* September 2007. www.echelon.com/solutions/streetlight/documents/Echelon_StreetlightWhitepaper_FINAL.pdf

System Components	
Component names	Fixture-level Node: Street Lighting Controller or Street Light Bridge Network Gateway: Edge Control Node or SmartServer Management System: SmartServer; Streetlight.vision
Node to gateway ratio	200:1
Node installation	Inside fixture or externally mounted
Lamp/fixture type compatibility	All

HARDWARE AND CONTROLS DETAILS

Echelon's system offers a range of standard features in its controls system, including the following:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

Echelon provides many other features in addition to this basic functionality (see Table 15). The system supports dimming in increments of one percent and monitors current, voltage and power. Echelon uses a 0-10V or PWM signal to send dimming signals to the ballast. It also provides sunrise and sunset trimming based on GPS coordinates. In the event of a communications failure, lights will continue to operate based on an astronomical clock and an e-mail or text message will be sent to the system administrator. On/off times, burn hours, and power consumption can be programmed to be logged locally for the duration of the failure. The fixtures are also capable of remotely downloading and integrating new features and upgrades.

Streetlight managers access the system using centralized streetlight monitoring software and a web interface. They can use either the Echelon SmartServer interface or a third party interface, such as the Streetlight.vision central management system. The SmartServer interface is geared toward the initial setup and monitoring of smaller installations such as small parking lots, which do not require intensive management. The Streetlight.vision management system is used for larger installations requiring more control and intensive management. Lamp burn hours and total energy consumption are recorded in the system for each fixture. Echelon's Street Lighting Controller has power metering to an accuracy of two percent. System-wide power and energy reporting is also available. Echelon's controls are manufactured in China and the U.S.

Table 15: Overview of Echelon's Features

Features	Details
Power metering	Measures I, V, P to 1% accuracy
Dimming support	0-10V, PWM and PL integrated drivers. Requires ballast that supports respective dimming method.
Photocontrol	No
Mapping/GIS compatibility	Compatible with Google Maps overlay
Sunrise/sunset trimming	Based on astronomical clock
Reporting options	MySQL database that can be used in any browser.

NETWORK

Echelon uses PLC between fixtures on a power line, which are transmitted to the SmartServer or ECN gateway (see Table 16). The PL / RF bridges communicate with other bridges using a 2.4 GHz RF signal. The backhaul communications from the gateway to the central management system can be accomplished using a variety of standard wide area network wired and wireless IP-based communication technologies, including cellular, Wi-Fi, or broadband.

Table 16: Echelon's Communications Specifications

Communications	
Communication Type (Node to Gateway)	RF and PLC
Frequency/Protocol	2.4 GHz (RF) and ISO/IEC 14908.1 and 14908.3 (LonWorks Protocol and power line signaling)
Range (Node to Node, Node to Gateway)	No Response
Backhaul Communications	Cellular, Wi-Fi, Broadband, other
NTCIP 1213 compliant?	No
Security	AES 128 encryption

SYSTEM DEPLOYMENT CONSIDERATIONS

Echelon provides a standard warranty of one year on system components, although extended warranty options are also available. The Street Lighting Controllers are pre-installed into the fixture at the factory. Once the luminaire is installed on site, the SmartServer/ECN automatically discovers all the nodes on the PLC segment and commissions them. The Streetlight.vision system interface can accommodate multiple users with different groups, such as administrator or read-only. Echelon provides one or two days of system training, depending on the respective needs of administrators, installers and field engineers. Echelon provides all hardware for a one-time cost. The Streetlight.vision management system is also sold either for a one-time cost or as a Software-As-A-Service (SAAS) package.

Lumewave

COMPANY BACKGROUND

Lumewave is a small and relatively young venture-backed company based in Sacramento, California. Lumewave provides standards-based wireless solutions for control and monitoring of existing and emerging lighting technologies. Lumewave was founded in 2009, and has four employees directly involved in engineering and sales.

Currently, Lumewave's largest installation is a 30-fixture pilot project at the University of California at Davis, installed in 2010. This installation is part of a larger 2,000-fixture project which will be completed in summer 2011. Lumewave has a number of other small pilot installations, including an illuminated pathway at a Wisconsin resort and a parking lot in Pennsylvania.

Figure 12: Lumewave's Fixture-Level Top900 Controller

SYSTEM OVERVIEW

The Lumewave control system was released in 2010 and consists of three major components – the TOP900 (fixture-level controller shown in Figure 13), a Gateway (network gateway), and a central management system (see Table 17). This controls system relies on RF communication (902-928 MHz) to control and monitor lights. The TOP900 node can replace a standard photocell on top of fixture. This controls device comes in two versions, one with a photocell-type twist lock plug and one with a ½" threaded nipple for more versatile mounting for shoebox fixtures and multi-head poles.

Table 17: Overview of the Lumewave Controls System

System Components	
Component names	Fixture-level Node: TOP 900 Network Gateway: Gateway Management System: Central
Node to gateway ratio	Unlimited
Node installation	Replaces photocell or threaded nipple for other mounting
Lamp/fixture type compatibility	All

The power draw for each TOP 900 device is less than 0.5W, and for each gateway, less than 1.5W. The TOP900 uses standard RF communications typically employed in communications across college campuses. The manufacturer reports the devices will last roughly 20 years. The components are designed to meet UL 916 (a UL standard for energy management equipment) and UL 773 (a UL standard for Plug-In Locking Type Photocontrols for Use with Area Lighting), but have not yet received official UL listing. Product components are manufactured in Taiwan, but for a small additional fee Lumewave can supply products meeting the Buy America Act.

HARDWARE AND CONTROLS DETAILS

Lumewave offers a range of standard features in its controls system, including the following:

- Luminaire Grouping
- Remote on/off scheduling
- Web-based access and control
- Backup astronomical clock
- Failure detection

In addition to this basic functionality, Lumewave provides a number of other useful features (see Table 18). Lumewave's TOP900 controllers have user-adjustable photocell set points, as well as an astronomical clock with up to nine programmable nighttime events. Its grouping system allows for unlimited customer sites: each site can have up to 255 networks, with up to 255 groups in each network. The number of nodes per group is unlimited. Lumewave's power metering uses a Smart Meter IC chip set which measures and stores information at 15-minute intervals, with one percent accuracy. Lumewave's TOP 900 also provides algorithmic sunset/sunrise trimming. The controller supports bi-level controls and 0-10V dimming from 0-100% at five percent intervals with compatible ballasts.

Each TOP900 controller also monitors current, voltage and power to an accuracy of one percent. Lumewave can track and report additional usage data and statistics as requested by the customer. In the event of communications failure, lights will continue to operate as previously programmed and tracked data will continue to be logged. The user receives a message when the malfunction occurs, and the device continues communication attempts while alerting users of the failure. The TOP900 controller also has a patent pending direction of travel feature which takes a motion detector input, determines the direction of travel and uses peer-to-peer communications to turn on lights in the direction of travel or to illuminate a specific group of fixtures. The controller can also accept multiple inputs from other sources, such as traffic volume sensors and call buttons.

Table 18: Overview of Lumewave's Features

Features	Details
Power metering	Measures I, V, P to 1% accuracy
Dimming support	0-100% at 5% levels. Requires ballast/driver that supports 0-10V
Photocontrol	Yes
Mapping/GIS compatibility	GIS compatibility not presently available, will be in near future.
Sunrise/sunset trimming	Yes, based on an algorithm
Reporting options	Available in SQL database, exported in .csv format

NETWORK

Lumewave uses RF (902-928 MHz) to communicate between TOP900 controllers (see Table 19). Typical RF range between nodes is 1.5 to 3 miles, with a 3-10 mile line of sight (LOS) between gateways and nodes. Any TOP900 node can be turned into a repeater if necessary to extend network range. The gateway communicates with the central management system via an Ethernet or cellular connection.

The central management system operates on Windows Server 2008, Windows XP and Windows 7. The controller infrastructure is shown through a tree-based pull-down system. This interface provides fault detection and reporting of any network/hardware issues, as well as tracking of control and maintenance statistics. All events are time-stamped, logged and available for display with data measured in 15-minute increments. Data retrieval and display can occur in real-time and in next-day reporting.

Table 19: Lumewave Communications Specifications

Communications	
Communication Type (Node to Gateway)	RF
Frequency/Protocol	902-928MHz (RF)
Range (Node to Node, Node to Gateway)	1.5-3 miles LOS
Backhaul Communications	Ethernet, cellular
NTCIP 1213 compliant?	No
Security	AES 128 encryption

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

System commissioning uses a bar code scanner and a fixture/pole locator chart. For existing fixtures, the installer installs the TOP900-TL on top of the fixture using a specially-"slotted" twist lock receptacle. A low-voltage wire package is dropped through the slot and the appropriate wires are connected to accomplish the dimming operation. The installation process takes roughly 5-10 minutes. After the installation process is complete and the system is energized, the node finds its network, group and ID and completes the commissioning process. Lumewave provides a five-year warranty for its products, and lifetime phone-based troubleshooting and support. The standard upfront system costs cover nodes, gateways and software. At present, the system requires no software licensing fee.

Ripley Aladdin

COMPANY BACKGROUND

Ripley is an established leader in the lighting photocontrol industry. In 1999, the company was acquired by SouthConn Technologies, Inc. Ripley has partnered with an experienced European firm on the Aladdin system, its wireless streetlight controls product offering.

Ripley released the Aladdin controls system in 2007, and has been actively distributing it in the North American market since 2008. It is currently demonstrating the Aladdin controls system in multiple installations in Northern California. Ripley's largest North American installation is at Shaw Air Force Base, in Sumter, South Carolina (3,000 lights). Ripley is in the process of installing Aladdin on relatively large-scale street-lighting systems in the United Kingdom in the cities of Birmingham (100,000 lights) and Coventry (38,000 lights).

Figure 13: Ripley’s Telecell Controller

SYSTEM OVERVIEW

The Aladdin controls system consists of Telecells (see Figure 14) at the fixture level, Base Station gateways, and a Central Station System Server (see Table 20). Ripley uses a star (non-mesh) topology RF network, where each Telecell is in direct radio communication with an assigned Base Station. Backhaul communication from the Base Station to the central server can be accomplished via Ethernet, cellular communication, or Wi-Fi. Each individual Ripley Base Station can control up to 10,000 Telecells; a complete system is scalable up to 15 Base Stations, or 150,000 fixtures. Ripley offers the option of owner-hosted central management software and can alternatively provide a Ripley-hosted server. The server can be accessed through a standard web browser, allowing the user to monitor and control the system from any location.

Table 20: Overview of the Aladdin Controls System

System Components	
Component names	Fixture-level Node: Telecell Network Gateway: Base Station Management System: Central System
Node to gateway ratio	10,000:1
Node installation	NEMA twist lock receptacle, or inside the fixture or pole
Lamp/fixture type compatibility	All

Telecells are typically installed in place of a twist-lock photocell, but can also be installed inside or outside the fixture or pole. The flexibility of having different installation options allows Telecells to control a variety of fixture types. Telecells typically draw less than 0.5W; Base Stations typically draw 10W. Telecells are “Conformité Européene" (CE) certified and have a rated lifetime of 15 years. Ripley offers a standard five-year warranty on components with a range of support options. Ripley reports that components are made in Malaysia and assembled in both Europe and the U.S.

HARDWARE AND CONTROLS DETAILS

Ripley offers standard capabilities and features in its controls system, such as:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

Additionally, Ripley's Aladdin system offers full utility-grade metering of current, voltage, power, and power factor at two percent accuracy (see Table 21); Ripley is currently in the process of testing this feature with the large California utility, Pacific Gas and Electric (PG&E), in the city of Oakland. The Aladdin system can also dim compatible ballasts and drivers in one percent increments. These features can potentially be combined to make lumen depreciation adjustments. Ripley also measures temperature, a potential indicator of lamp and fixture health. Ripley offers sunrise and sunset trimming based on the location of each fixture. Although its system is capable of using network time protocol (NTP) for synchronizing component clocks, for security reasons Ripley prefers to use time synchronization from GPS satellites.

In the event of communications failure, lights will continue to operate as previously programmed. Each fixture will also continue to log data, including utility metering data, until communications are reestablished. Failure notifications are immediately reported to the central server and displayed on the graphical interface. Additionally, the user can set alarms to be sent directly via email or SMS text messages. The system can also report lamp cycling and day burners, and will alert the user in the event that lights are operating outside of normal parameters.

Table 21: Overview of Aladdin's Features

Features	Details
Power metering	Measures I, V, P, PF to 2% accuracy
Dimming support	0-100% at 1% increments. Requires ballast that supports 0-10V or Dali dimming
Photocontrol	Yes
Mapping/GIS compatibility	Assigned GPS coordinates per Telecell; Interfaces with GIS systems
Sunrise/sunset trimming	Yes
Reporting options	Xml

NETWORK

As stated earlier, Ripley uses an RF star network to communicate directly between Telecells and Base Stations (see Table 22); Telecells do not communicate with other Telecells in the network as in a mesh topology. Specifically, Ripley uses Plextec's Ultra Narrow Band (UNB) networking technology, which was designed for long-range, low-power, and low-data-rate applications. Plextec UNB has been used in military applications and utilizes frequency hopping for added communications security. Range between Telecells and Base Stations is typically one to two miles in urban environments and three to six miles in rural environments. Base Stations communicate with the central server using Ethernet, cellular or Wi-Fi. Aladdin's central server can be accessed using a standard web browser from any location.

Table 22: Aladdin's Communications Specifications

Communications	
Communication Type	RF star
Frequency/Protocol	900MHz Plextec UNB
Range	1-2 miles urban and 3-6 miles rural
Backhaul Communications	Ethernet, cellular, Wi-Fi
NTCIP 1213 compliant	No
Security	AES

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

During the installation process, the technician uses a handheld GPS device to scan in each Telecell's unique barcode and identify its GPS location; the data from the device is later uploaded to the central server to complete the commissioning process. The central server is typically installed on an on-site, customer-owned server; however, Ripley also offers other hosting options. It can set up three levels of system access: User, Manager, and Administrator, with a range of standard accessibility options. In addition to the cost of the hardware, Ripley charges an annual fee for full technical support and software updates.

ROAM

COMPANY BACKGROUND

ROAM is a subsidiary of Acuity Brand Controls, wholly owned and operated by Acuity Brands, Inc., headquartered in Atlanta, Georgia. Acuity Brands, Inc., together with its subsidiaries, is one of the world's leading providers of lighting fixture equipment and services and employs 6,000 associates. The ROAM division, established in 2004, employs 11 associates and is headquartered outside Atlanta in Convers, Georgia.

ROAM is a market leader in lighting controls and has been featured in a number of medium- to large-scale installations. The city of Glendale, Arizona currently uses the ROAM system to monitor over 19,000 street lights, while the city of Austin, Texas is in the process of installing the ROAM system on 70,000 lights. ROAM's largest existing installation is in Los Angeles, California, where the municipality is currently controlling roughly 32,000 street lights. In total, ROAM has over 80,000 devices currently installed in the U.S.

Figure 14: ROAM's Fixture-Level Controller

Figure 15: ROAM's Wireless Gateway

SYSTEM OVERVIEW

ROAM stands for Remote Operation Asset Management. The ROAM system consists of 1) ROAM communicating photocontrols (see Figure 15), compatible with any NEMA twist lock receptacle, which serve as the communications node; 2) one or more ROAM gateways (see Figure 16) – each gateway manages up to 2,000 nodes through a wireless mesh network; 3) a remote Network Operation Center (NOC) (see Figure 17) which manages communications, safeguards and communicates data, and conducts high-level diagnostics; and 4) a secure ROAM Internet portal, which provides the ability for full work order management and allows users to schedule and control lighting operations (see Table 23). If dimming is desired, a separate dimming control module must be installed inside the fixture.

ROAM is compatible with any fixture that has a locking-type receptacle. The ROAM photocontrol, with diagnostic and wireless technology, locks on top of the fixture and replaces a traditional on/off photocontrol. ROAM can be used with any light source from 45 to 1,000 watts.

Table 23: Overview of the ROAM Controls System

System Components	
Component names	Fixture-level Node:

	Node Network Gateway: Gateway Management System: NOC
Node to gateway ratio	2000:1
Node installation	NEMA twist lock
Lamp/fixture type compatibility	All

System owners and operators are able to command and schedule the streetlights to turn on/off from the web portal. Operators can also capture historical data on repairs, maintenance and equipment replacements through an integrated work order module, and can generate reports on malfunctions repair and repair data, also through a work order management module. The average latency is two to four minutes, and depends on the number of streetlights being commanded or scheduled, the distance, and lamp type. The load from each ROAM photocontrol is on average 1.6 W, with a maximum of 2.2 W. The ROAM-enabled gateway has an average power draw of 5.5 W, with a maximum of 12 W. A dimming control module (required if the customer desires dimming) consumes an additional average 1.6 W, with a maximum of 2.2 W.

ROAM system components currently come with a three-year product warranty, extendable to five years, and have a reported eight-year design life. ROAM's analysis projects a 0.76% annual failure rate for photocontrols and field experience to date (> two years, 25,000 devices), suggests an approximate one percent annual failure rate.

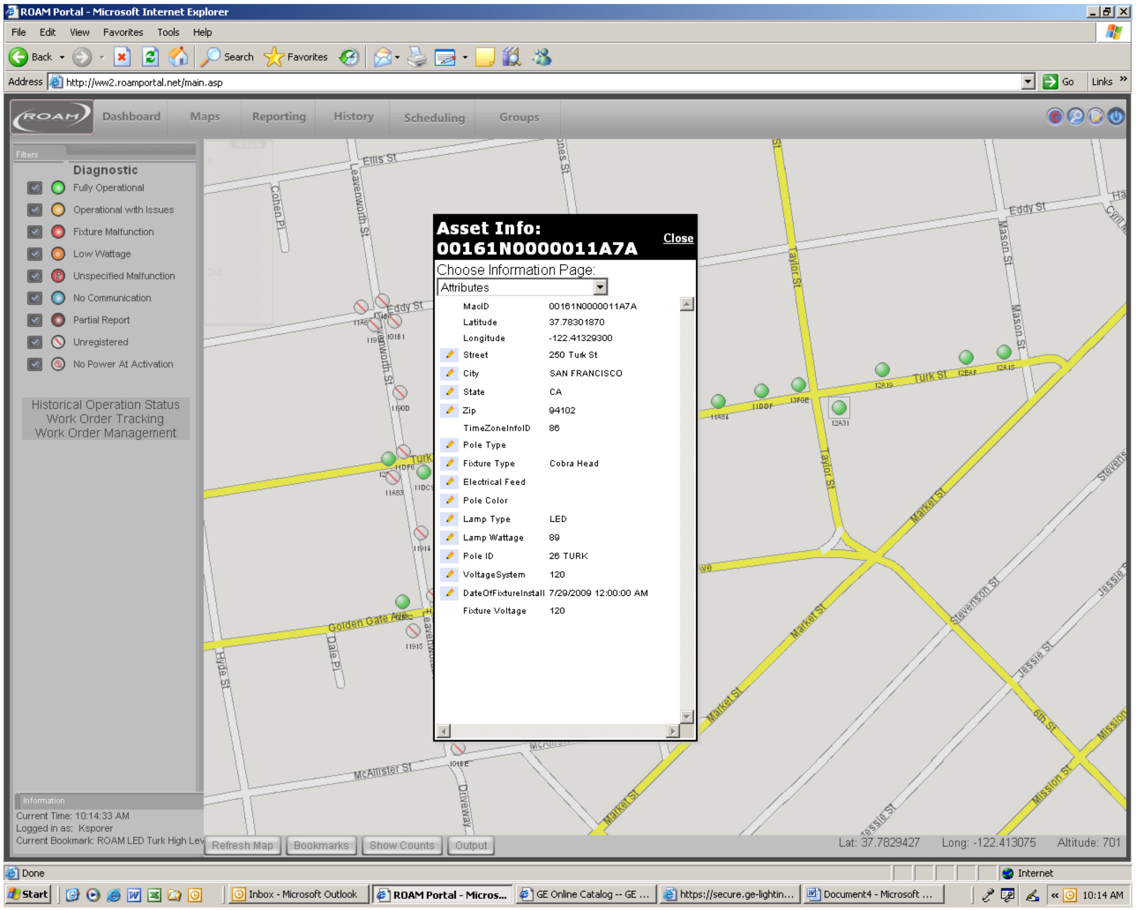

Figure 16: Screen capture of ROAM's NOC Software

Figure 17 shows a screen capture of ROAM's Network Operations Center (NOC) software, as accessed in Microsoft Internet Explorer. Mapping for the ROAM NOC is licensed from deCarta. Fixtures are represented by icons, which can be clicked to issue immediate commands. The user can also choose to opt out of the deCarta mapping feature in cases where map visualization is not necessary (for example, in small parking lots) to lower the cost of installation. ROAM provides multiple reporting options to help the user track system and luminaire performance. Graphs and reports can be generated in Excel, PDF or XML.

HARDWARE AND CONTROLS DETAILS

ROAM offers a standard set of features in its controllers:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

ROAM controllers also collect operational information from the fixture and transmit the information wirelessly back to the gateway. The ROAM controller can detect and report on a variety of operating conditions, such as day burning and cycling. ROAM also monitors and collects data on average power draw each hour, as well as average, maximum and minimum line voltage every hour, accurate to 5 to 10 percent (see Table 24). Once the NOC detects a fault, alarms are sent in near-real-time to users via email, xml alerts or pagers.

In the event of communications failure, fixtures will continue to log data for up to four days (although the customer could upgrade this feature at an incremental cost). Fixtures operating on a set schedule will continue to operate as previously programmed. In the event of a system-wide outage, fixtures will default to photocell control.

ROAM controllers require a separate dimming control module to allow for light level dimming in low traffic situations. With a dimming control module, ROAM controllers can provide 0-to-100% dimming with 256 increments, when paired with a dimmable ballast or driver.

Table 24: Overview of ROAM's Features

Features	Details
Power metering	Measures I, V, P to 10% accuracy
Dimming support	0-100% with 256 increments; Requires Dimming Control Module; Requires ballast that supports 0-10V dimming.
Photocontrol	Yes
Mapping/GIS compatibility	DeCarta maps overlay (optional)
Sunrise/sunset trimming	User scheduled
Reporting options	Excel, pdf, xml

NETWORK

The gateway serves as the central collection point for multiple ROAM photocontrols in the vicinity. ROAM nodes communicate at 2.4 GHz using IEEE 802.15.4 standard protocols, and have a range of 1,000 feet with a clear line of sight (see Table 25). The nodes and gateway form a WAN; each node communicates with other nodes in order to deliver data to the gateway. Routing decisions within the mesh network are made at the node level, which improves the robustness of the network.

The gateway communicates with the NOC either by cellular uplink, Ethernet, or Wi-Fi. Communications between the gateway and ROAM NOC are encrypted using the AES algorithm. The user can access the ROAM NOC with a standard web browser from any location. ROAM provides unique user IDs and passwords to set different permission levels.

Table 25: ROAM's Communications Specifications

Communications

Communication Type	Mesh RF
Frequency/Protocol	2.4 GHz, IEEE 802.15.4
Range	1000 ft LOS
Backhaul Communications	Ethernet, cellular
NTCIP 1213 compliant	×
Security	AES

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

The installer uses a barcode-enabled handheld personal digital assistant (PDA) along with a GPS device to collect location data to match with each unique ROAM node. The pre-commissioned ROAM node replaces the existing photocell and immediately initiates the monitoring process and begins to link with other ROAM nodes to join the network. The data from the PDA is uploaded to the ROAM-hosted NOC to complete the installation process. ROAM believes that hosting the NOC on its own servers allows it to better address customer support issues, such as providing software updates, bug fixes, and troubleshooting; however, the customer pays only an upfront charge for the duration of the contract.

Schreder Owlet

COMPANY BACKGROUND

Owlet is an independent company within the Schreder Lighting Group, an outdoor lighting services company which provides lighting fixtures and design services for architectural, roadway, floodlighting, tunnel and transit applications. While Schreder has a wide range of outdoor lighting expertise and services, Owlet focuses exclusively on the remote management and control of outdoor lighting systems. As part of the larger Schreder lighting family, Owlet provides an array of turnkey services from system design to installation and setup.

Schreder and Owlet are both based in Europe, but have sales representatives and manufacturing plants located in the United Sates.

Owlet’s Nightshift controls system for streetlights and area lighting was released in 2009, and its largest commercial installation to date is a 1,200-fixture project in South Africa. The largest North American installation is a 1,000-fixture project in Hayward, California, installed in 2011.

Figure 17: Owlet's Column Controller (CoCo)

SYSTEM OVERVIEW

Owlet's Nightshift controls system consists of two types of nodes, LuCo and CoCo (see Figure 18); a gateway system, SeCo (see Figure 19); and a central management system (Web Interface) (See Table 26). Each node type is designed for a different fixture application, and can be mixed throughout an installation. The LuCo (luminaire controller) is installed directly into a luminaire, and comes in two[34] versions: LuCo-DALI, to control IEC 62386 DALI compliant drivers or ballasts; and LuCo-M, with a built-in Class 1 energy meter. The CoCo (Column Controller) is designed for in-pole mounting, and is shipped with up to two independent, individually-metered power switches. This application is ideal if more than one load is attached to a pole or if the node is attached to a non-standard fixture.

Each node communicates with the SeCo (Segment Controller), Owlet's gateway device, using a self-healing, mesh RF network. The SeCo collects this data and transmits it to a secure Webserver interface (see Figure 20) which can be accessed using a standard web browser. A key feature of the Nightshift system is its use of open-source software.

[34] A third version, LuCo-U, is available in the European market. The LuCo-U controller does not have a metering device, and is used for applications where a common energy meter is mounted in the feeder pillar.

Table 26: Overview of the Owlet Nightshift Controls System

System Components	
Component names	Fixture-level Node: LuCo, CoCo Network Gateway: SeCo Management System: WebServer
Node to gateway ratio	150:1
Node installation	Inside fixture or inside pole
Lamp/fixture type compatibility	All

In a typical installation, a single SeCo gateway can control up to 150 LuCos or CoCos. Power draw for each LuCo or CoCo is 2.1 W, and 8W for the SeCo Gateway. Each component has a reported MTBF of 14-15 years[35], and is also ETL certified[36]. Owlet's controller hardware is manufactured in Slovakia, but core components are made in the U.S. and meet American Recovery and Reinvestment Act of 2009 (ARRA) purchasing requirements. The SeCo can communicate with the Nightshift Webserver User Interface (UI) using ADSL, GPRS or 3G. The Webserver (shown below) is browser-independent and is a MySQL database compatible with any web browser.

Figure 18: Owlet's Segment Controller (SeCo)

HARDWARE AND CONTROLS DETAILS

Owlet's Nightshift system offers a range of standard features in its controls system, including the following:

- Luminaire grouping (up to 11 groups)

[35] Different MTBF methods result in different values. Owlet uses the 'part count method' for MTBF calculations, and has approximately eight years until one percent failure rate.

[36] ETL certified the control devices following UL 916 (a measurement standard for Energy Management Equipment) and CSA 22.2.

- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

In addition to this basic functionality, Owlet provides many additional features. It supports a variety of dimming methods, including DALI, 0-10V. Each Owlet controller monitors current, voltage, power and power factor to an accuracy of two percent. The Segment Controller receives monitoring data from one node every four seconds, moving on in a loop pattern, repeating the process after all nodes have communicated with the SeCo. For a gateway with 150 nodes, each node has a 10-minute (600-second) interval between monitoring data points.

Figure 19: Screen capture of the Nightshift User Interface

Owlet also provides sunrise and sunset trimming, which is performed using an astronomical clock and a photocell (see Table 27). To prevent accidental day-burn events, the astronomical clock locks the photocell until it is nearing dusk, and then the clock releases the photocell to operate as usual. This prevents the light from being turned on by human interference (such as covering the photocell) during the day. In the event of a communications failure, lamps will continue to operate based on an astronomical clock. Burn hours and accumulated energy are continuously measured and are stored in non-volatile memory, and will continue to be logged for the duration of the failure.

Owlet also offers algorithmic lumen depreciation adjustments based on a light source depreciation algorithm. At this time, the Owlet system does not support a traffic volume sensor, and traffic-related dimming is algorithmic based on user inputs.

Owlet can also provide billing based on a metered structure.

Table 27: Overview of Owlet Nightshift's Features

Features	Details
Power metering	Measures I, V, P, PF to 2% accuracy
Dimming support	0-10V, DALI. Requires ballast that supports respective dimming method.
Photocontrol	Yes
Mapping/GIS compatibility	Compatible with Google Maps overlay
Sunrise/sunset trimming	Based on astronomical clock + photocell
Reporting options	MySQL database that can be used in any browser.

NETWORK

Owlet's mesh RF network uses the Zigbee Pro protocol (2.4 GHz) to communicate between its controllers and gateways (see Table 28). The Owlet Nightshift system uses entirely open-source software.

Table 28: Owlet's Communications Specifications

Communications	
Communication Type (Node to Gateway)	Mesh
Frequency/Protocol	2.4 GHz (RF)
Range (Node to Node, Node to Gateway)	400'; can be configured to reach up to 4000'
Backhaul Communications	ADSL, GPRS, or 3G
NTCIP 1213 compliant?	No
Security	AES 128 encryption

SYSTEM DEPLOYMENT CONSIDERATIONS

System setup uses a Zigbee bar code scanner record to identify the locations of the fixture controllers. The system does not record GPS location during component deployment; instead it offers "drag-and-drop" functionality in the user interface. GIS information is typically used for larger installations. The system can accommodate multiple users from different groups such as administrator or read-only. Owlet provides a comprehensive training manual and a one-day training session for administrators and two- to three-day training sessions for field engineers. Owlet offers a five-year warranty for all components in its system. Monitoring data can be exported in a range of formats including MySQL, .csv, html, .pdf, and EDI 867. All software costs are built into the sales price of the Owlet system with no additional software license fees.

Strategic Telemetry

COMPANY BACKGROUND

Strategic Telemetry is a small and relatively young company founded in 2005 and based in Reading, Pennsylvania. Strategic Telemetry develops software solutions for management of publicly-owned infrastructure such as roadway and area lighting, signage, and traffic signals. Its SmartLights software system, released in 2009, uses open protocols to integrate its products with current existing management systems such as the NTCIP 1213 standard. Currently, the largest installation of Strategic Telemetry's controls product is in the city of Minneapolis, a 400-fixture project installed in 2009 and covering a 26-block section of downtown Minneapolis.

SYSTEM OVERVIEW

The SmartLights Controls system consists of three major components (see Table 29): Streetlight Controller (fixture-level controller), Data Logger (network gateway), and a Central Management System (software/central management system). This controls system relies on a mix of RF and PLC communications to control and monitor lights, depending on the suitability of each for a given location, as described below. The SmartLights system uses an open protocol, user-hosted system, in which the system administrator can access the network and send commands to the controlled fixtures via the Internet from any location.

Table 29: Overview of the SmartLights Controls System

System Components	
Component names	Fixture-level Node: Streetlight Controller Network Gateway: Data Logger Management System: Central Management system
Node to gateway ratio	Up to 2000:1
Node installation	Inside fixture or inside pole
Lamp/fixture type compatibility	All

Both RF and PLC communications systems can function simultaneously within a single network, so the system is able to utilize the benefits of both technologies. For instance, projects with Homeland Security requirements or heavy engineering applications can use the more secure PLC systems, while utility applications can use a mesh RF network. SmartLights uses the Zigbee and LonWorks protocols for RF and PLC communications, respectively. The SmartLights system also complies with the NTCIP 1213 standard.

A single Data Logger gateway can typically control up to 2,000 Controllers, although this is application-dependent. If it is circuit-based, it can control up to 50 streetlights per gateway; if it is not circuit-based, it can accommodate up to 100 power lines per data logger. Strategic Telemetry offers a number of component safety certifications, and reports that all of its controls products are manufactured and assembled in the United States.

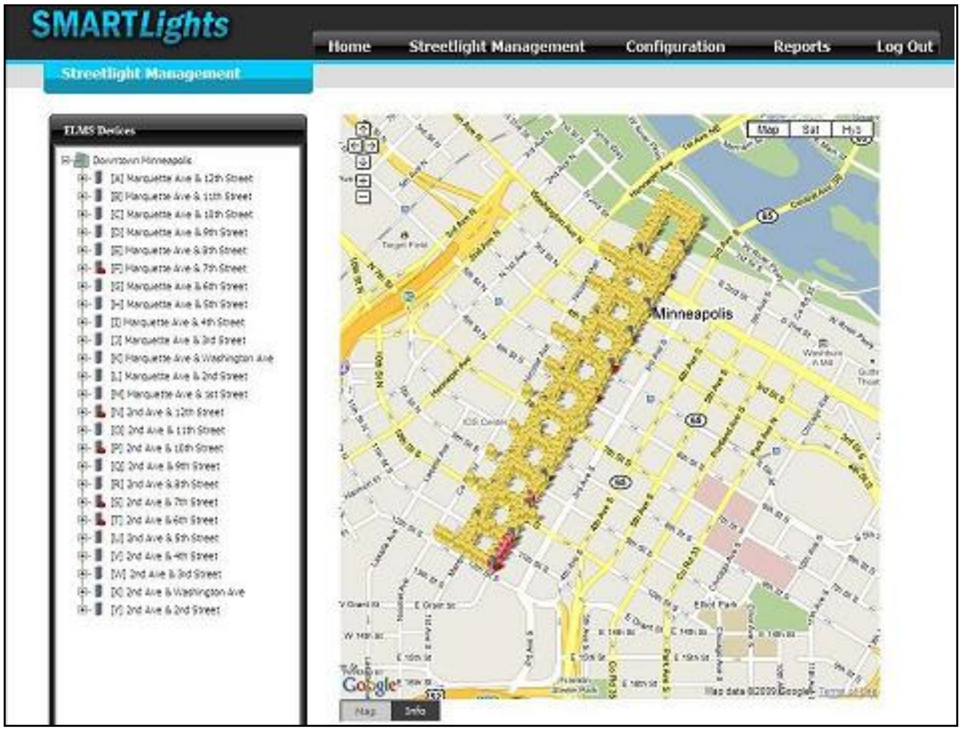

Figure 20: Screen Capture of Strategic Telemetry's SmartLights Interface

The web interface (shown above in Figure 21) has an interactive tree view using a Google Maps overlay, and includes both high-level representation and individual drilldowns that provide added granularity for fixture display. Reporting options from the SmartLights system can be customized according to the customer's preference.

HARDWARE AND CONTROLS DETAILS

Strategic Telemetry offers a range of standard features in its controls system, including the following:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

In addition to this basic functionality, SmartLights provides many other features including sunrise/sunset trimming and lumen depreciation adjustments (see Table 30). SmartLights supports 0-10V dimming from 0-100% in 256 steps. The SmartLights system includes optional features such as circuit-based controls and a ground fault monitoring sensor, which can detect electrical leakage or pole knockdowns and cut off power to the individual light. Optional radio-enabled bar code scanners allow for mobile asset tracking.

Each Controller also monitors current, voltage and power to an accuracy of two percent; SmartLights can track and report additional usage data and statistics as requested by the customer. In the event of communications failure, lights will continue to operate as previously programmed and tracked data will continue to be logged. The system also includes a circuit-based revenue grade meter and a circuit-based photocell interface.

Table 30: Overview of SmartLights' Features

Features	Details
Power metering	Measures I, V, P to 2% accuracy
Dimming support	0-100% across 256 increments (<0.5%). Requires ballast that supports 0-10V dimming
Photocontrol	Yes
Mapping/GIS compatibility	Assigned GPS coordinates per node, Google Maps overlay
Sunrise/sunset trimming	Yes
Reporting options	SQL Server back-end; can be exported as .csv, .xls, etc. Bill report generation included

NETWORK

The SmartLights system uses both mesh RF and PLC to communicate between its nodes and network gateways (see Table 31), and can accommodate both communications technologies in the same network. The RF frequency is typically 902.3 MHz but can vary by application. The Data Logger gateway communicates with the central management system via an Ethernet, GSM, or proprietary connection. The software interface is web-based, with icons indicating status and providing control options. The customer can access the central management system through any standard web browser.

Table 31: SmartLights' Communications Specifications

Communications	
Communication Type (Node to Gateway)	Mesh RF and PLC
Frequency/Protocol	Zigbee (902.3 MHz, application dependent), LonWorks
Range (Node to Node, Node to Gateway)	Application Dependent
Backhaul Communications	Ethernet, GSM, Proprietary
NTCIP 1213 compliant?	Yes
Security	AES 128 or 256

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

Strategic Telemetry offers a range of installation and commissioning services, from a pre-packaged "system in a box" to a sophisticated system that integrates and interfaces with additional loads such as traffic signals, dynamic message signs and other Intelligent Transportation Systems. The central management system can be configured to include a wide variety of user-defined types and system permissions, including read-only and page restrictions. Strategic Telemetry also provides a comprehensive training manual to the system owner. Strategic Telemetry charges a one-time fee for its SmartLights system; the central management server is owner-hosted and based on fully open source architecture, with no additional upkeep or maintenance costs. Strategic Telemetry offers a five-year warranty for all components in its system.

Streetlight Intelligence Lumen IQ

COMPANY BACKGROUND

Streetlight Intelligence, Inc. is a small Canadian company based in Victoria, British Columbia. The company was founded in 2003 and has 16 employees. Streetlight Intelligence provides products for both networked and standalone street lighting controls;[37] its networked streetlight controls system is called Lumen IQ.

[37] According to an April 19, 2011 press release, Streetlight Intelligence announced on the company webpage the temporary layoff of all employees and the suspension of operations. While it is uncertain whether the company will resume business it was included in this report given the advanced product maturity and presence of testing sites throughout Canada.

Streetlight Intelligence has 27 pilot sites in Canada, including a 500-light installation in Calgary installed in 2008, and a 10-fixture installation in Hamilton, Ontario. Streetlight Intelligence's first installation of over 100 lamps occurred in 2008.

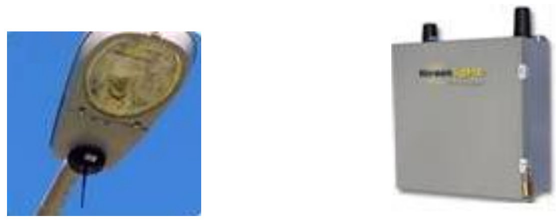

Figure 21: Streetlight Intelligence's Fixture Controller and Station Gateway

SYSTEM OVERVIEW

The Streetlight Intelligence system, Lumen IQ, released in 2003, consists of three major components (see Table 32): Lumen IQ C200 Controller (node), Lumen IQ Station (gateway) (both shown in Figure 22), and Lumen IQ Central (software/central management system shown in Figure 23). In addition to these core components, Streetlight Intelligence also offers the Lumen IQ Commander, a Wi-Fi enabled portable programmer that serves as an in-field commissioning and servicing device. This proprietary system relies on a mesh RF network for node to gateway communications. The Controller can be retrofitted onto an existing fixture or ordered as part of fully-integrated new fixtures.

The Lumen IQ Controller nodes rely on a mesh RF (900 MHz) network to communicate with the Station gateway. The Station gateway relays information to the Central management system via cellular, Ethernet, or Wi-Fi communications. A single Station gateway can control up to 250 Controllers in a typical installation. Power draw for each Controller is 1W on average, while the gateway uses an average of 20W. Lumen IQ Controllers have relevant Canadian Standards Association (CSA) and UL listings, with a reported MTBF of 23 years.

Table 32: Overview of the Lumen IQ Controls System

System Components	
Component names	Fixture-level Node: Controller Network Gateway: Station Management System: Central
Node to gateway ratio	250:1
Node installation	Can be mounted internally or externally
Lamp/fixture type compatibility	All

The figure below shows a screen capture of Streetlight Intelligence's Central software. Lights are tracked using GPS coordinates (captured during installation) and are viewable through a BING Maps overlay. Each luminaire's asset record includes pole ID, GPS location, luminaire descriptors, and a compass heading of the fixture. The web-based interface can be accessed using an Internet Explorer browser and displays geographical locations of all devices and their current operating states. Scheduling and reporting preferences can be managed from the Central system as well.

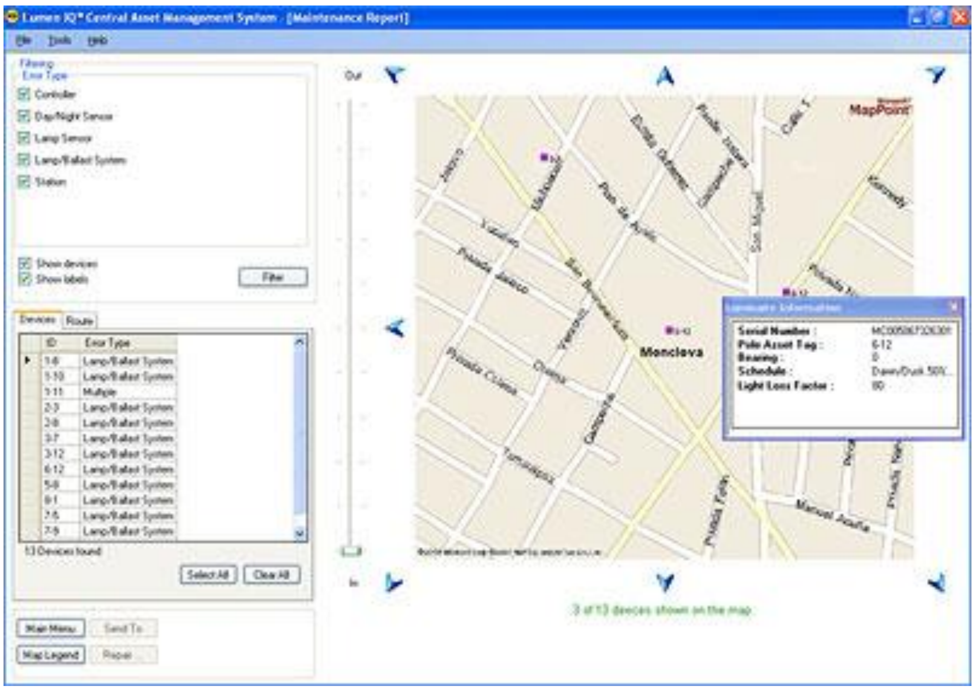

Figure 22: Screen capture of Streetlight Intelligence's Central Software

HARDWARE AND CONTROLS DETAILS

The Lumen IQ system offers a range of standard features in its controls system, including the following:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

In addition to this basic functionality, the Lumen IQ system provides many other features such as sunrise/sunset trimming (see Table 33), which helps to reduce unnecessary burn hours. It supports 0-10 V dimming for electronic ballasts, as well as its own proprietary and patented system for HID ballast dimming. Lumen IQ's LED dimming range is from 0-100% in one percent increments, while the HID dimming range is 0-60% (100% to 40% light output) in one percent increments. Each Controller also monitors current, voltage and power to an accuracy of one percent. In the event of communications failure, lights will continue to operate as previously programmed; tracked data will continue to be logged off-line; and relevant personnel will be notified via text and e-mail. Additionally, each Controller offers relative light output metering and monitoring, including sensor-based lumen depreciation adjustment. The Lumen IQ system can produce a number of proprietary software reports that are exportable to .csv or .xls formats. Lumen IQ states that the accuracy of its billing reports has been verified and accepted by a number of utility customers.

Table 33: Overview of Lumen IQ's Features

Features	Details
Power metering	Measures I, V, P to 1% accuracy.
Dimming support	LED: 0-100% at 1% increments. HID: 0-60% at 1% increments.
Photocontrol	Yes
Sunrise/sunset trimming	Photocell based
Mapping/GIS compatibility	BING Maps overlay.
Reporting options	.csv, .xls

NETWORK

As stated earlier, the Lumen IQ system uses mesh RF (900MHz) to communicate between Controller nodes and Station gateways (see Table 34). Typical RF range between fixtures is one kilometer with direct line of sight. The Station gateway communicates with the Central management system via an Ethernet, cellular, or Wi-Fi connection. The Central management system includes a web-based user interface with a variety of reporting and control options, and is accessible via an Internet Explorer web browser.

Table 34: Lumen IQ's Communications Specifications

Communications	
Communication Type (Node to Gateway)	Mesh RF
Frequency/Protocol	900MHz
Range (Node to Node, Node to Gateway)	1 kilometer – line of sight
Backhaul Communications	Ethernet, cellular, Wi-Fi
NTCIP 1213 compliant?	✓
Security	AES 128 encryption

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

Installation takes roughly 15 minutes per node; each node is then commissioned in the field with the Lumen IQ Commander. Commissioning takes roughly one minute, and the system is automatically 'live' once the luminaires have completed this process. Streetlight Intelligence provides a comprehensive system training manual.

The standard upfront system costs are for nodes, gateways, and software. An annual fee, based on the number of streetlights controlled, includes software licensing fees, data hosting and communications. In the event of a product failure or malfunction, Streetlight Intelligence offers a five-year warranty for all components in its system. For billing purposes, the Lumen IQ system can interface with the client's own asset management systems. It is also possible for clients to host the central management system themselves with a compatible server and MS SQL.

Venture Lighting Leafnut

COMPANY BACKGROUND

Venture Lighting, a part of Advanced Lighting Technologies Inc., was founded in 1983. Based in Solon, Ohio, Venture focuses exclusively on advancing metal halide technology. As such, Venture's Leafnut controls system is designed for use solely with metal halide lamp fixtures and is sold exclusively with Venture's constant-wattage autotransformer (CWA) magnetic HID ballast kit.

Venture has teamed with European-based Harvard Engineering PLC on the Leafnut product, which was first released in Europe in 2006. Venture and Harvard Engineering have installed Leafnut in many locations in the United Kingdom. The largest worldwide installation is in South England, where Leafnut is controlling about 16,000 fixtures in Surrey County. This installation is expected to grow to 89,000 fixtures. Venture brought Leafnut to North America in 2010, where its largest installation is at an auto auction parking lot in Pensacola, Florida.

Figure 23: Venture's Branchnode Gateway

SYSTEM OVERVIEW

Venture's Leafnut system consists of three main components (see Table 35): Leafnode (node controller), Branchnode (gateway shown in Figure 24), and the Trunknode (software/central management system shown in Figure 25). Each Branchnode can control up to 256 Leafnodes, which are externally mounted to individual fixtures. The system uses point-to-point RF network topology on a proprietary 915MHz WiMAC communications protocol. The figure below is a screen capture of Venture's Trunknode central management system, which uses Google Maps overlays to graphically represent the location of each fixture in the system.

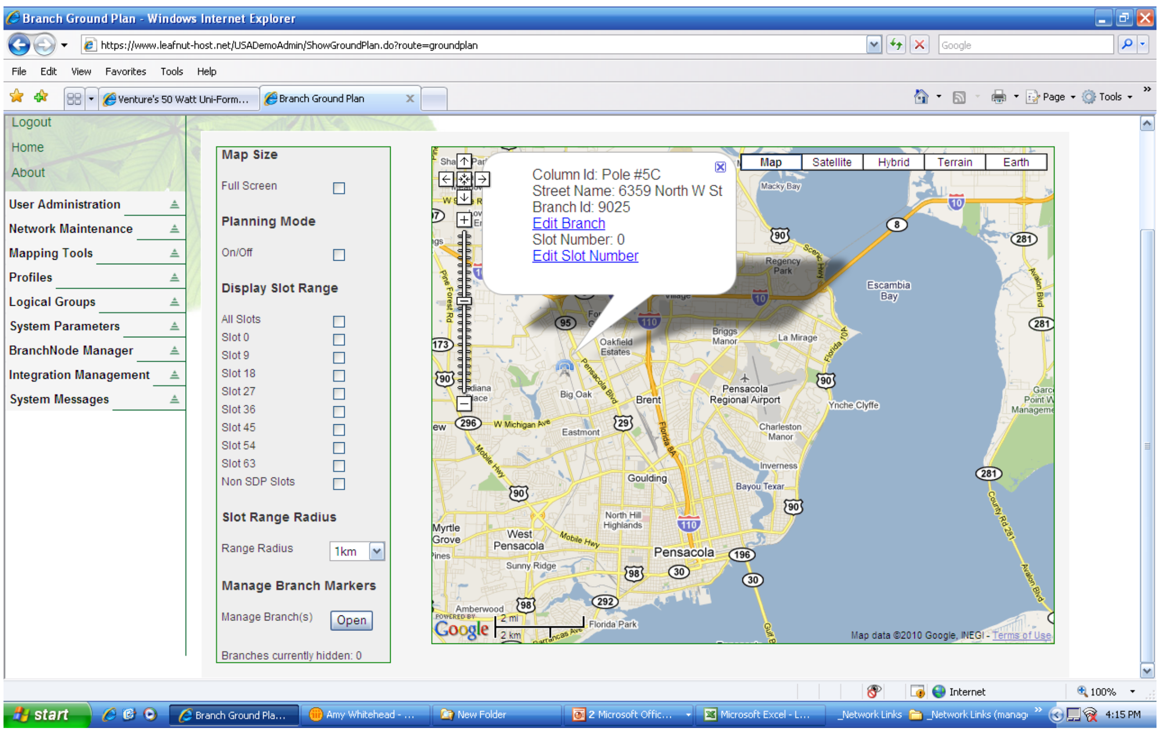

Figure 24: Screen Capture of the Leafnut Trunknode Interface

Venture allows the customer to host the Trunknode software on its own servers, which can then be accessed from any location through a standard web browser. Leafnut components are made in the United Kingdom and are UL-certified. At this time, Venture's primary target market is exterior parking lots.

Table 35: Overview of Venture's Controls System

System Components	
Component names	Fixture-level Node: Leafnode DRA Network Gateway: Branchnode DRA Management System: Trunknode
Node to gateway ratio	256:1
Node installation	Externally Mounted
Lamp/fixture type compatibility	320W-875W metal halide

Leafnodes draw 1.2W on average, while Branchnodes draw 2.1W. Leafnut offers a five-year warranty when the system is purchased with a Venture Lighting lamp and ballast combination.

HARDWARE AND CONTROLS DETAILS

Leafnut offers a standard set of features for its controls system, including:

- Luminaire grouping
- Remote on/off scheduling
- Failure detection
- Web-based access and control

Leafnut is also able to bi-level dim CWA-ballasted lamps down to 50% power (see Table 36). It also monitors power consumption and generates UK-approved metering reports.

Table 36: Overview of Leafnut's Features

Features	Details
Power metering	I, V, P (% accuracy unpublished)
Dimming support	50% for CWA
Photocontrol	Yes
Mapping/GIS compatibility	Latitude/longitude coordinates by GPS; Google Maps overlay
Sunrise/sunset trimming	Location based
Reporting options	.csv, .xls

NETWORK

As stated earlier, Leafnodes communicate using a point-to-point WiMAC network RF 915MHz frequency (see Table 37). RF range between features can be up to eight kilometers with direct line of sight, but drops to one kilometer or less with obstructions in a typical urban setting. The Branchnodes communicate with the Trunknode via a GSM/3G cellular signal. The customer can access the Trunknode on a secure connection through a standard web browser from any location with an Internet connection.

Table 37: Leafnut's Communications Specifications

Communications	
Communication Type	Point-to-point RF
Frequency/Protocol	915MHz/WiMAC
Range	8km line of sight, typically 1km w/ obstructions
Backhaul Communications	Cellular
NTCIP 1213 compliant	No
Security	AES 128 encryption

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

After all the nodes and fixtures have been installed, Leafnode IDs are individually recorded and added to the central management system. Over the next 24 hours, the system will sync communications between gateways and nodes. Once sync is complete and communications have been established, Venture can run checks to determine which nodes need further commissioning. In addition to the cost of the hardware, Venture charges an annual fee for the customer to operate its Trunknode software.

Virticus

COMPANY BACKGROUND

Virticus is a small and relatively early stage venture-backed company founded in 2008 and based in Portland, Oregon. Virticus focuses exclusively on wireless and PLC networked lighting controls, both outdoor and indoor, and offers support for dimming LED arrays and other light source options, integrated software and services and communication of certified power metering information. The company currently has more than 10 employees.

Although its focus is exterior lighting, Virticus' largest installation to-date is an interior system of 1,500 lights for a Boston Scientific warehouse. In total, Virticus currently manages over 2,000 indoor lights in various locations. Virticus' largest outdoor installation is in Irvine, California, where the Virticus system controls roughly 100 parking lot fixtures. Virticus also has installations in Portland, Oregon and Chula Vista, California, as well as in Brazil and

China. Virticus expects to be controlling 500 streetlights in Portland by fall 2011, along with close to 1,000 lights in the city of Philadelphia.

Figure 25: Virticus Fixture-Level Rialto Controller

Figure 26: Virticus Ventura Network Gateway

SYSTEM OVERVIEW

The Virticus controls system, released in 2010, consists of three major components (see Table 38): Rialto (fixture-level controller shown in Figure 26), Ventura (network gateway shown in Figure 27), and Malibu (software/central management system shown in Figure 28). This controls system relies on a mix of RF and PLC communications to control and monitor lights, depending on the suitability of each for a particular location, as described below. The Rialto can be installed inside of either the fixture or the pole, allowing for installation with a variety of fixture types. Virticus prefers to host the Malibu system and network data on its servers so that it may sync with Virticus' GIS databases and other tools, although customer hosting of the network is also an option. The customer can access the network and send commands to the controlled fixtures via the Internet from any location.

Table 38: Overview of the Virticus Controls System

System Components	
Component names	Fixture-level Node: Rialto Network Gateway: Ventura Management System: Malibu
Node to gateway ratio	*500:1
Node installation	Inside fixture or inside pole
Lamp/fixture type compatibility	All

*Virticus notes that a 6,000:1 ratio is “technically possible,” but a 600:1 ratio is recommended

The Virticus system relies on RF as well as PLC to communicate with Rialto nodes from a central control point, depending on which is most applicable. Both communication systems can function simultaneously within a single network, so the system is able to utilize the benefits of both technologies. For instance, fixtures inside a parking structure with concrete walls can be connected via PLC while fixtures outside of the structure can be connected via RF. Additionally, the Virticus system can be installed directly into fixture poles. This allows Virticus to control non-standard-shaped fixtures in addition to more common cobra-head fixtures.

In a typical installation, a single Ventura gateway will typically be able to control up to 500 Rialtos. The system is designed to scale to over 10 million fixtures in a single network. Power draw for each Rialto device is less than 1W average, while the Ventura gateway has an average power draw of 20W. The electronic components in Virticus’ Rialto and Ventura units are rated to 100,000 hours lifetime. The reported MTBF for the assembled units is 10 years for the Rialto controller and seven years for the Ventura gateway. Virticus offers a five-year warranty for all components in its system, and is certified under UL916, a UL standard for energy management equipment. Virticus reports that all of its controls products are manufactured and assembled in the United States.

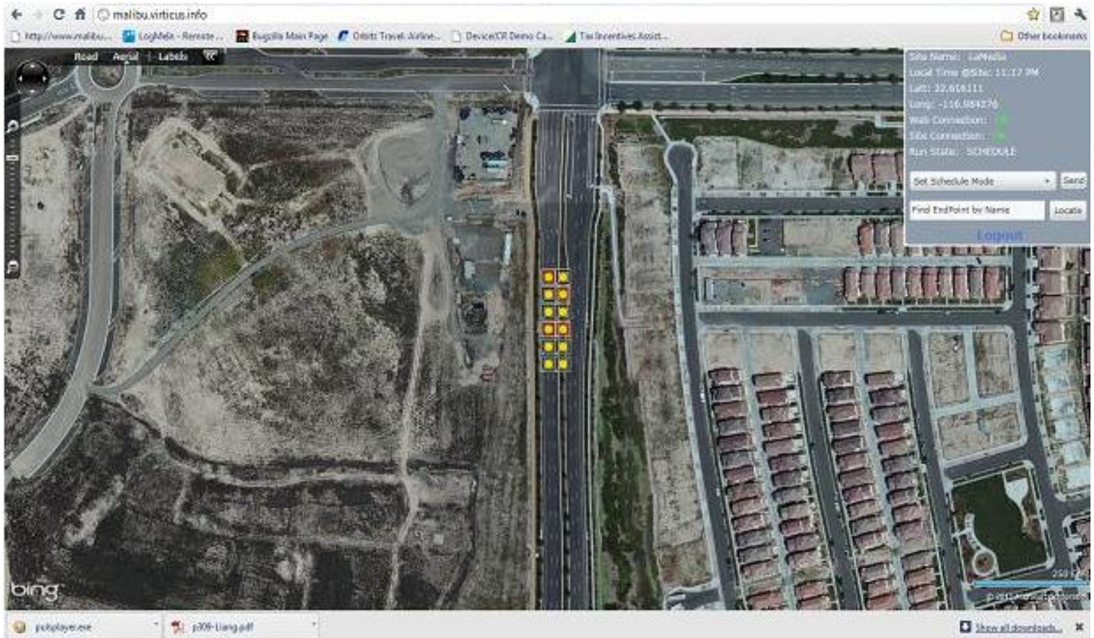

Figure 27: Screen Capture of Virticus' Malibu Software Interface

The location of each light is assigned in the system using GPS. Coordinates are pre-commissioned into each Rialto at Virticus' factory and viewable through a BING Maps overlay. The icons in the graphic represent individual lights, which can be controlled through any web browser from any Internet-connected device. Reporting from the Malibu system is customized according to the customer's preferences and can include details such as power, current and voltage, measured up to 30 times per second. Virticus typically sets up system reporting for hourly results, which the company considers "real time" for practical purposes, noting that more frequent reporting intervals are possible but require more power and may congest communications.

HARDWARE AND CONTROLS DETAILS

Virticus offers a range of standard features in its controls system, including the following:

- Luminaire grouping
- Remote on/off scheduling
- Backup astronomical clock
- Failure detection
- Web-based access and control

In addition to this basic functionality, Virticus provides many additional features (see Table 39). Virticus uses GPS coordinates to perform sunrise/sunset trimming. Virticus supports both 0-10V and PWM dimming from 0% to 100% at 0.5% intervals, with compatible ballasts. Virticus also uses "slew rate dimming," which is meant to prevent adverse reactions to the human eye by sudden changes in light levels. The Virticus system can also save lighting energy by adjusting luminaire power over time to maintain consistent lumen output, using either sensor- or algorithm-based lumen depreciation; Virticus refers to this as lifetime harvesting.

Each Rialto controller also monitors current, voltage and power to an accuracy of one percent. Virticus can track and report additional usage data and statistics as requested by the customer. In the event of communications failure, lights will continue to operate as previously programmed and tracked data will continue to be logged. Virticus also offers optional features such as a light output meter, which can be used to inform lumen depreciation adjustments for each fixture.

Table 39: Overview of Virticus' Features

Features	Details
Power metering	Measures I, V, P to 1% accuracy
Dimming support	0-100% at 0.5% levels. Requires ballast that supports 0-10V or PWM dimming
Photocontrol	Optional
Mapping/GIS compatibility	Assigned GPS coordinates per Rialto, BING Maps overlay
Sunrise/sunset trimming	Based off GPS coordinates
Reporting options	Multiple formats; customized for each client

NETWORK

As stated earlier, Virticus uses both mesh RF (915MHz) and PLC to communicate between Rialto controllers and the network gateways (see Table 40), and can accommodate both communication technologies in the same network. Virticus notes that its system's RF communication frequency of 915MHz does not conflict with Wi-Fi traffic at 2.4GHz, the other standard Zigbee frequency. Typical RF range between features is 200 to 400 feet with direct line of sight, and about half that when obstructions are present. The Ventura gateway communicates with the Malibu central management system via an Ethernet, cellular, or Wi-Fi connection. The Malibu interface is web-based, with icons indicating status and providing control options. The customer can access Malibu through any standard web browser.

Table 40: Virticus Communications Specifications

Communications	
Communication Type (Node to Gateway)	Mesh RF and PLC
Frequency/Protocol	915MHz (RF)
Range (Node to Node, Node to Gateway)	200’ – 400’ line of sight; 100’– 200’ with obstructions
Backhaul Communications	Ethernet, cellular, Wi-Fi
NTCIP 1213 compliant?	No
Security	AES 256 encryption

SYSTEM DEPLOYMENT AND COST CONSIDERATIONS

The system is designed to be installed by an electrician; Virticus ships the network components pre-commissioned so that the customer can install them and then log in to the management interface to begin controlling and monitoring. Virticus can set up a variety of accounts for a single system with different levels of access and control (observability and controllability) per the customer’s request.

The standard upfront system costs are for nodes, gateways and software. Virticus prefers to host the Malibu network and data on its own servers, as this allows the company to link with its own GIS data and other licensed software. This model requires the customer to pay an ongoing fee per fixture, depending on the size of the project and wattages of the lamps. However, Virticus is willing to work with the customer to install the Malibu software to host the network locally for a negotiable one-time up-front charge.

Additional Networked Controls Manufacturers (Not Surveyed)

Additional advanced outdoor lighting controls manufacturers emerged during the course of this study, with varying levels of available details on their products and companies. Time and resource limitations prohibited investigation of every manufacturer and product. This section of additional technologies covers those products that did not receive thorough review for this study. Most appear to be either established companies with new products in this market space or start-up companies with products at the earliest stages of market readiness. The information presented here comes largely from company marketing materials, product brochures and websites.

PHILIPS AMPLIGHT

http://www.amplex.dk/solutions/amplight/overview/

Philips AmpLight is an automated lighting management system that can reportedly deliver up to 35% streetlight energy savings. Danish parent company Amplex announced in July 2010 that Philips had acquired its AmpLight streetlight management activities; Philips is beginning to introduce the product in the U.S.

AmpLight is a lighting cabinet-based system that relies on dedicated streetlight circuit infrastructure (see Figure 29). A Philips representative states that over half of the cities in the U.S. can make use of this type of system, but experience has indicated that dedicated, uninterrupted cabinet-based streetlight circuits are not present in many cities.

The AmpLight system is designed to put intelligent monitoring and control in streetlight cabinets and network cabinets together in a centralized streetlight management system. Hardware must be installed in the control cabinets to enable communication from the central server location to the control cabinets via wired and wireless carriers such as:

- GPRS/GSM
- SMS
- Wi-Fi
- WiMAX
- Fiber optics
- Ethernet
- PLC

Control room GIS and mapping features are designed to make it easy to dispatch resources. The solution features:

- Central control
- Complete monitoring
- Dimming
- Remote metering
- Power quality metering
- Voltage stabilization
- Control room installation
- Dimming at off-peak traffic hours

Listed clients include Copenhagen, Gothenburg, Beijing and Istanbul and the national road authorities of Sweden and Norway.

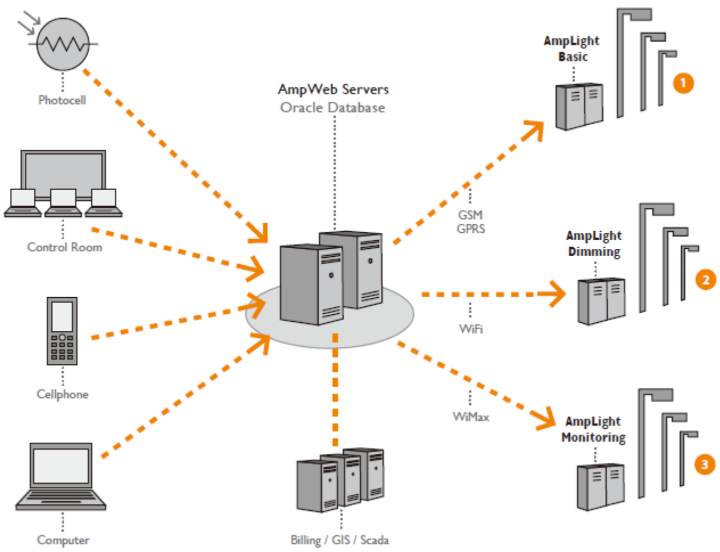

Figure 28: Philips AmpLight Schematic

PHILIPS STARSENSE

www.philips.com/starsense

The new Starsense system from Philips is a fixture-based (as opposed to cabinet-based) lighting management system designed for monitoring, controlling, metering and diagnosing outdoor lighting. Starsense enables individual fixture switching and dimming. Fixtures can be grouped in the system, and the age and condition of each lamp can be monitored and failures reported at the exact location. System hardware consists of the Outdoor Luminaire Controller, which detects failures and switches and dims the fixture using a 0-10 V dimming signal and an on/off relay, and the Segment Controller (SC) which communicates with the Luminaire Controller via PLC. The Segment Controller controls a number of OLCs connected to the same power lines and gathers information and backhauls to remote PC via the Internet, typically through GPRS. Features include:

- Constant Light Output function. Using a locally-stored algorithm to dim lights at the beginning of the service period and increasing power over the service period to compensate for the depreciation factor of the lamp. This avoids over-illumination and can save up to eight percent on total energy consumption over the lifetime of a lamp.
- Low-traffic dimming: Starsense can be used to dim down the lights depending on traffic volume and in accordance with regulations.
- Data collected by Starsense that tracks the hours of illumination for each lamp can be used to claim warranty replacement, and to validate energy bills for the system.

Starsense communication is based on the LonWorks PLC protocol. This open protocol has been widely adopted in the European market. The Starsense system provides options for interfacing with other asset management systems, giving customers more front-end choices on their systems. The standard system features web-based configuration software for commissioning and Starsense Supervisor Software (see Figure 30) for monitoring and managing the data from the SCs, collecting and aggregating data in a central database.

Figure 29: Philips Starsense Supervisor Screenshot

SENSUS LIGHTING CONTROL

http://sensus.com

Sensus is a utility system services and products company that specializes in meters, regulators, fire service assemblies, transmitters, leak detection equipment, monitors and Automatic Meter Reading (AMR), Advanced Metering Infrastructure (AMI), distribution automation and smart grid solutions. Sensus is a privately-held company with almost 4,000 employees on five continents.

Sensus Lighting Control is an advanced lighting controls solution coupled exclusively with a Sensus induction lighting fixture designed to reduce municipal lighting energy. The system uses the Sensus FlexNet AMI system for long-range radio control of each fixture via primary-use licensed spectrum to guarantee an uncluttered path for transmissions.

System design and features include:

- Point-to-multipoint network
- Programmable remote control and scheduling
- Alarm notification and outage reporting
- Data reporting for energy usage
- Lighting on/off controlled by monthly solar tables, optional photocell
- Demand response capable
- Timer dimming function available

WI-OLC SYSTEM (WIRELESS OUTDOOR LIGHTING CONTROL SYSTEM)

http://www.fpolc.com/WiOLC_System.htm

The Sunrise Technologies, Inc. brands include FP Outdoor Lighting Controls (acquired in 2003), Sun-Tech, and BrownBetty Communications. Sunrise is a wholly-owned unit of Electro Switch Corp. The FP Outdoor Lighting Control (FP-OLC) brand name covers a range of twist-lock photocells for outdoor lighting fixtures for the commercial and industrial distributor markets. Other products include auxiliary power devices for pole-mounted equipment such as Wi-Fi radios and security cameras.

The Wireless Outdoor Lighting Control System from Sunrise, referred to as Wi-OLC, consists of twist-lock photocell-based Preprogrammed Lighting Control Communications Modules (LCCM) (see Figure 31) and a communications base station to connect the network to a PC-based management platform. The LCCMs are pre-programmed with Sky Control Network Software and automatically form a self-healing multi-hop 802.15.4 mesh network. The Wi-OLC solution does not appear to offer dimming but can be used to turn off a percentage of lights when full lighting is not required.

Figure 30: Wi-OLC LLCM Controls

DIMONOFF STREETLIGT MONITORING AND CONTROL SYSTEM

http://www.dimonoff.com/secteurs/view/Streetlight

DimOnOff is a Canadian company that manufactures wireless distributed lighting control and automation products for indoor and outdoor environments. The DimOnOff Streetlight Monitoring and Control System uses PLC and/or radio frequency communications to network addressable streetlight control points. The wireless option is a self-healing, auto-discover network that uses 2.4GHz 802.15.4 ISM, with a range up to 1,000 feet line of sight.

Streetlight control and monitoring features include on/off control, lamp and ballast status, usage timers, cycling detection, electrical measurements (current, voltage, power, power factor), temperature logging and a bi-level dimming module option. The network can also use Substation (SS) Remote Terminal Units (RTU) for cabinet-based control, logging and reporting. The system Master Control Center (MCC) (see Figure 32) uses a SCADA server software license with free updates for one year, and allows web-based remote control and monitoring for multiple clients.

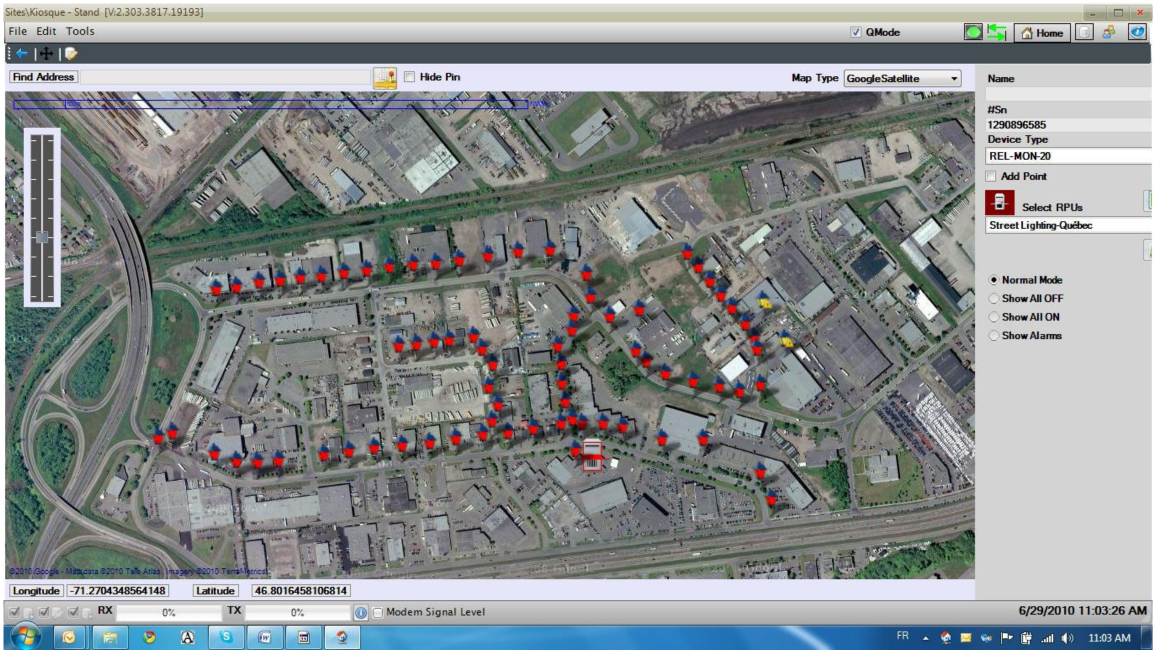

Figure 31: DimOnOff Streetlight Monitoring Interface

SWARCO

http://www.swarco.com/en/News/News/Archive/LIGHT-MANAGEMENT-BY-SWARCO-V.S.M

SWARCO is a world leader in traffic systems and roadway materials, offering a range of road marking, signaling and traffic management products and services. The company was founded in 1969 in Austria and now employs over 2,700 people in 20 countries. SWARCO is the world's largest traffic signal maker and a market leader in traffic management in Europe.

The SWARCO Traffic Management Division includes energy-saving LED traffic lights and adaptive controls for traffic flows, highway and tunnel guidance systems, and state-of-the-art traffic telematic software. In the first quarter of 2011, the company announced entry into the "lighting management business" with Light Management by SWARCO, beginning first in Germany and then marketing later in other countries.

The controls product offering will incorporate SWARCO's Futurlux LED streetlights. It is unclear at this time what type(s) of communication infrastructure, networking strategies, and controls and monitoring features are or will be included in the SWARCO Light Management system.

RELUME TECHNOLOGIES

http://www.relume.com/htm/products_sentinel.htm

Relume Technologies, Inc., incorporated in 1994, is an LED fixture manufacturer headquartered in Michigan. Relume Sentinel is the company's streetlight monitoring and control system. This system was characterized in the previous PG&E market assessment and no new information was available at the time of this study.

Relume Sentinel is a streetlight monitoring and control system that relies on a city's existing public safety communication infrastructure, using high-powered RF transmissions to and from fixtures across secure, FCC-licensed communication channels in dedicated public safety bands.

Sentinel provides on-off, dimming, and flashing control of individual streetlights or any zone/group of streetlights. Sentinel is comprised of three main hardware components: the fixture-level Wireless Lighting Control Module; a Master Network Interface Module at the municipal communication point; and existing municipal ultra-high-frequency (UHF) radio repeaters. The system uses a point- to multi-point network topology that operates in the 450 to 470 MHz UHF band.

LUMINET, BY VASONA LABS

http://www.vasonalabs.com/Vasona_Labs/LumiNet.html

Vasona Labs is a small California-based company offering the LumiNet Intelligent Networked Outdoor Lighting Controls product. Limited information was available about this product at the time of this study.

The LumiNet system consists of a Lamp Controller either mounted on the fixture at the twist-lock photocell interface or within the fixture housing. The Lamp Controllers form a self-healing wireless network and communicate with LumiNet Gateways (up to 250 fixtures per Gateway) that collect and store sensor data for thousands of streetlights. The Gateways' backhaul connection to the Internet is via GSM/GPRS.

The LumiNet Operations Center is the web-based interface used to intelligently manage the lighting system. Status and maintenance reports are available on demand. The Operations Center allows individual lights to be grouped into virtual zones that can be independently controlled. Total energy usage can be reported per fixture, on a zone basis, or for an entire lighting network.

Controls features include:

- On/Off
- Dimming
- Monitor lamp failure
- Monitor energy usage
- Lamp Interfaces
- On/Off line voltage relay
- 0-10V dimming
- Bi-level dimming
- PWM dimming
- DALI dimming

TYCO ELECTRONICS LUMAWISE

Tyco Electronics, Ltd. is a public company based in Switzerland that provides engineered electronic components, network solutions, telecommunication systems and specialty products. Tyco has been active in the advanced streetlight controls market from 2006 on with the Lumawise product for wireless monitoring and management of streetlight assets via a self-configuring network. However, at the time of this study Tyco stated it is no longer actively marketing Lumawise as a key product.

Appendix C: Controls Demonstration Briefs

City of Glendale, Arizona: ROAM

PROJECT BACKGROUND

The city of Glendale, AZ operates 19,554 streetlights over an area of 55 square miles. The city operates primarily 100W, 150W, 250W, and 400W high-pressure sodium (HPS) fixtures, but also operates 200 250W metal halide fixtures in an entertainment district.

The city decided to install the ROAM wireless networked controls system in January 2008 due to the large volume of customer complaints of streetlight outages. In addition, customers repeatedly called back to inform the city that repairs had not been made. The city relied on internal capital improvement funds to finance this installation.

CONTROLS PRODUCT SELECTION PROCESS

The city of Glendale prioritized the following features in the product selection process:

- Communications type – mesh RF has been effective
- Frequency – concerned about issues with cell tower signal interference

The city was primarily concerned with ensuring that the networked controls would be reliably connected through a robust communications system and network. Two-way communication is available but is not heavily used by the city since its primary focus is monitoring and tracking data for each fixture in its system.

SYSTEM OPERATION AND FUNCTIONALITY

Overall, the city of Glendale has been very satisfied with the ROAM controls system. Installation was simple, and HPS compatibility was no problem. The project manager noted that while training was definitely needed, the process was fairly easy. The project manager also noted that the commissioning process was very straightforward and that combining GPS coordinates with a map overlay to track streetlights was an especially interesting feature.

System Operation and Functionality Overview	Low ←→ High 1 2 3 4 5
Ease of installation	5
Compatibility with existing circuits and wiring	5
Ease of staff training	3
Ease of programming and commissioning process	5

ENERGY AND MAINTENANCE CONSIDERATIONS

Glendale installed the ROAM system primarily for improving streetlight management and operations. The project manager said the data tracking and reporting features were most useful to the city. The city reported a reduction of its system-wide outages and malfunctions from an estimated twenty percent of fixtures to less than four percent. The ROAM system also greatly reduced the volume of citizen calls regarding malfunctioning streetlights from twenty percent to about three percent.[38] Since energy savings were not prioritized, the city did not actually use the ROAM system for dimming or on/off scheduling. Glendale has been very satisfied with the customer support it has received.

While the project manager expressed a high degree of satisfaction with the ROAM controls product, the city has not observed measurable direct financial savings from maintenance and operations improvements. While the system did eliminate the need to manually check for outages, this was already a very low cost. The reduction in outages constituted the greatest benefit of the controls system; it could result in a reduction in liability claims since the city can be confident that all lights in the system are functioning properly.

Energy and Maintenance Considerations Overview	Low ← → High 1 2 3 4 5
System's ability to improve operations and management practices	5
Usefulness of data and reporting capabilities	5
Energy benefits attributed to the control system	1
Non-energy benefits	1*
Vendor / Manufacturer customer support	5

*The project manager interpreted this as only economic benefits. The system did help to realize other, non-economic benefits.

City of Hamilton, Ontario, Canada: Streetlight Intelligence

PROJECT BACKGROUND

The city of Hamilton, Ontario currently operates 45,000 streetlights, comprised of 150W HPS lamps overseen by two management staff. Hamilton began a two-month pilot project in May 2010 via installation of networked controls on 10 HPS lamps. The project was implemented as part of a senior staff directive to pilot energy savings technologies, and has since been disassembled. Natural Resources Canada provided the control systems for free, while the city paid for the cost of installation and take-down of the controls system.

[38] Shackelford, Jordan, et al. *Street Lighting Network Controls Market Assessment Report*. Pacific Gas and Electric Company Emerging Technologies Program (2010).

CONTROLS PRODUCT SELECTION PROCESS

Natural Resources Canada provided Hamilton with Streetlight Intelligence's Lumen IQ controls system; therefore the city did not have a formal product selection process.

SYSTEM OPERATION AND FUNCTIONALITY

Some difficulties emerged during the installation and commissioning process. The software initially failed to work during installation due to a network-based router failure; however, Streetlight Intelligence's support team was able to resolve this issue.

The city noted that although the controls could be retrofitted onto existing luminaires, doing so would require additional work and budget. The city also noted that the commissioning process was not easy, and that training staff to appropriately install and manage the system would take time.

System Operation and Functionality Overview	Low ←→ High 1 2 3 4 5
Ease of installation	3
Compatibility with existing circuits and wiring	1
Ease of staff training	2
Ease of programming and commissioning process	1

ENERGY AND MAINTENANCE CONSIDERATIONS

The flat billing rate for unmetered power limited the potential energy savings opportunity, so the economic savings on the energy bill did not match the energy savings from reporting. The host reported 40% energy savings when the luminaires were dimmed to 50%, although this level of dimming required a sufficient drop in pedestrian activity. While the lights were also dimmed to other percentages, the energy reduction was not linear, and 50% dimming provided the most consistent energy savings.

Energy and Maintenance Considerations Overview	Low ←→ High 1 2 3 4 5
System's ability to improve operations and management practices	N/A
Usefulness of data and reporting capabilities	1
Energy benefits attributed to the control system	2
Non-energy benefits	1
Vendor / Manufacturer customer support	3

City of Kansas City, Missouri: Airinet, Sun-Tech, and Strategic Telemetry

PROJECT BACKGROUND

The city of Kansas City, Missouri, operates 92,000 streetlights comprised of 100W, 150W, 250W, and 400W HPS lamps maintained by 10 service technicians. Kansas City began an LED pilot program in February 2011 as part of a DOE Gateway Demonstration Pilot Project, replacing 45 HPS lamps with network-controlled LED fixtures ranging from 63-300W. The project did not use the controls' dimming capabilities to evaluate the long-term performance of the LED luminaires. The city currently has a negotiated streetlight rate with Kansas City Power & Light, but it plans to switch to a tariff structure upon completion of this pilot project.

CONTROLS PRODUCT SELECTION PROCESS

Kansas City decided to install networked controls so it could monitor power consumption and temperature of each LED fixture, as well as evaluate the remote monitoring and controls systems. The city's high-priority features in the product selection process were:

- A wireless network operating at either 2.4 GHz or 915 MHz
- Strong network security
- Open system architecture
- Self-hosting capabilities[39]
- Relevant safety certifications (desired but not required)
- NTCIP compliance (desired but not required)

Kansas City selected Airinet, Sun-Tech, and Strategic Telemetry to each install 15 units at nine different sites. The products were selected for their open communications protocols, Zigbee and AMI compatibility, power monitoring capabilities and self-commissioning process. A number of other products considered failed to meet these specific requirements.

SYSTEM OPERATION AND FUNCTIONALITY: SUN-TECH

Kansas City has been satisfied overall with Sun-Tech's controls system. The installation and commissioning process was relatively straightforward, although each node must be manually barcode-scanned or logged into the system by pole location. The distance between the nodes and gateways was sometimes too great to get an adequate signal. Kansas City resolved this by placing intermediate nodes to relay the signal to the gateway.

System Operation and Functionality Overview: Sun-Tech	Low ←→ High

[39] Kansas City manages its lighting controls internally, and therefore self-hosting capability was an important feature.

	1 2 3 4 5
Ease of installation	4
Compatibility with existing circuits and wiring	4
Ease of staff training	4
Ease of programming and commissioning process	3

ENERGY AND MAINTENANCE CONSIDERATIONS: SUN-TECH

Although Kansas City did not use Sun-Tech's dimming features for this pilot project, it noted that dimming would have increased energy savings by an additional 20 percent.

Enhanced monitoring of system operations and reduced maintenance costs constituted key non-energy benefits.

Energy and Maintenance Considerations Overview: Sun-Tech	Low ⟷ High 1 2 3 4 5
System's ability to improve operations and management practices	4
Usefulness of data and reporting capabilities	5
Energy benefits attributed to the control system	5
Non-energy benefits	5
Vendor / Manufacturer customer support	5

SYSTEM OPERATION AND FUNCTIONALITY: STRATEGIC TELEMETRY

Kansas City has been very satisfied overall with Strategic Telemetry's controls system. No issues arose during the installation and commissioning process; however, the nodes should be positioned within 0.25 miles of each other to maintain proper communication.

System Operation and Functionality Overview: Strategic Telemetry	Low ⟷ High 1 2 3 4 5
Ease of installation	4
Compatibility with existing circuits and wiring	5
Ease of staff training	5
Ease of programming and commissioning process	5

ENERGY AND MAINTENANCE CONSIDERATIONS: STRATEGIC TELEMETRY

Although Kansas City did not use Strategic Telemetry's dimming features for this pilot project, it noted that dimming would have increased energy savings by an additional 20 percent.

Enhanced monitoring of system operations and reduced maintenance costs constituted key non-energy benefits.

Energy and Maintenance Considerations Overview: Strategic Telemetry	Low ⟷ High 1 2 3 4 5
System's ability to improve operations and management practices	4
Usefulness of data and reporting capabilities	5
Energy benefits attributed to the control system	5
Non-energy benefits	5
Vendor / Manufacturer customer support	4

SYSTEM OPERATION AND FUNCTIONALITY: AIRINET

Kansas City has been very satisfied overall with the Airinet's controls system. The project manager noted that the installation was a very simple, plug-and-play process. Once energized, the control used GPS to commission itself. The project manager was very impressed with the overall performance of this product, and highly recommended the system as a "Cadillac" compared to most similar controls systems.

System Operation and Functionality Overview: Airinet	Low ⟷ High 1 2 3 4 5
Ease of installation	5
Compatibility with existing circuits and wiring	5
Ease of staff training	5
Ease of programming and commissioning process	5

ENERGY AND MAINTENANCE CONSIDERATIONS: AIRINET

Although Kansas City did not use Airinet's dimming features for this pilot project, it noted that dimming would have increased energy savings by an additional 20 percent.

Enhanced monitoring of system operations and reduced maintenance costs constituted key non-energy benefits.

Energy and Maintenance Considerations Overview: Airinet	Low ⟷ High 1 2 3 4 5
System's ability to improve operations and management practices	5
Usefulness of data and reporting capabilities	5
Energy benefits attributed to the control system	5
Non-energy benefits	5

Vendor / Manufacturer customer support	5

City of Los Angeles, California: ROAM

PROJECT BACKGROUND

The city of Los Angeles, California's Bureau of Street Lighting operates 210,000 fixtures over 472 square miles. The Bureau operates HID, induction and LED fixtures between 35 and 1000W. As part of the LED Street Lighting Energy Efficiency Program, the Bureau is undergoing large-scale retrofits of HID lamps with LED fixtures. The city installed Beta LED streetlights in 2009 and expects to be replacing roughly 30,000 HID streetlights per year through 2013. In conjunction with the LED retrofits the Bureau is also conducting an evaluation of wireless controls products. In all, the Bureau expects the LED Street Lighting Energy Efficiency Program to save over 40,000 tons of carbon emissions per year and to reduce operations and maintenance costs.[40]

The Bureau decided to install networked controls primarily for maintenance and power metering purposes and was also interested in the dimming capabilities of controls systems. The Bureau's controls installation is currently around 40,000 fixtures. It chose the ROAM system due to its status as the current market leader for networked streetlight controls systems and relied on internal funds to pay for this project.

CONTROLS PRODUCT SELECTION PROCESS

The city of Los Angeles prioritized the following features in the product selection process:

- Communications type – RF mesh
- Self-hosting capabilities

The Bureau reported a desire for a wireless mesh network with two-way communications for power metering and scheduled dimming. It also noted a preference for a photocell-sized node-level controller. Additionally, the Bureau required that the installed controls system be compatible with the city's GIS system.

SYSTEM OPERATION AND FUNCTIONALITY

The project manager did not elaborate on the city of Los Angeles' experiences with the ROAM system, but expressed general satisfaction with the system's operation and functionality.

System Operation and Functionality Overview	Low ⟷ High

[40] City of Los Angeles. "Bureau of Street Lighting," http://bsl.lacity.org/, accessed June 2011.

	1 2 3 4 5
Ease of installation	5
Compatibility with existing circuits and wiring	5
Ease of staff training	2
Ease of programming and commissioning process	3

ENERGY AND MAINTENANCE CONSIDERATIONS

The Bureau is currently managing the ROAM system internally with some support from the vendor. While the Bureau did not specifically quantify energy and maintenance savings, it appears highly satisfied with ROAM's performance in these areas.

Energy and Maintenance Considerations Overview	Low ⟷ High 1 2 3 4 5
System's ability to improve operations and management practices	5
Usefulness of data and reporting capabilities	5
Energy benefits attributed to the control system	5
Non-energy benefits	5
Vendor / Manufacturer customer support	4

City of Portland, Oregon: Virticus

PROJECT BACKGROUND

The city of Portland, Oregon, operates 54,500 street lights over an area of 134 square miles. The majority of these streetlights are HPS cobra head fixtures between 100W and 250W. The Portland Bureau of Transportation is currently working on demonstration projects with solid-state lighting products and decided to install controls in conjunction with these projects to quantify potential energy and O&M savings. As of April 2011 only two fixtures were being controlled by the Virticus system; 28 more were to be fitted with Virticus controls by May and a total of 500 or more by the end of 2011. As this project is still in the very early stages of implementation, some of the following responses from the city of Portland are based on anticipated experiences, influenced partly by the manufacturer's claimed functionality.

PRODUCT SELECTION PROCESS

The Portland Bureau of Transportation valued the following features in its selection process:

- Communications type – mesh network with Ethernet backhaul
- Self-hosting – Software is being imported into the city's central server
- Component safety certifications – Virticus is UL-certified

- Network security – important to limit access from outside the city's firewall

The Portland Bureau of Transportation was impressed with the feature set offered by Virticus, as well as its cost and customer service. Virticus' Portland location offered the Bureau easy access to company officials. Virticus showed a willingness to customize its installation to best meet the city's needs.

SYSTEM OPERATION AND FUNCTIONALITY

The city of Portland has been satisfied thus far with the Virticus system's operation and functionality. City employees and contractors found installation to be intuitive and relatively simple. The city also appreciated that Virticus is compatible with all lamp types. The city noted that the commissioning process is probably best done by the manufacturer. Initial communication issues were resolved when Virticus switched to Windows 7 and Remote Desktop Connection.

System Operation and Functionality Overview	Low ⟷ High 1 2 3 4 5
Ease of installation	4
Compatibility with existing circuits and wiring	5
Ease of staff training	4
Ease of programming and commissioning process	3

ENERGY AND MAINTENANCE CONSIDERATIONS

Portland is very interested in the data monitoring and reporting capabilities of the system and believes these capabilities will lead to better management of resources and overall decision-making.

The city also hopes to achieve substantial savings by initially dimming lights by 30% to account for lumen depreciation. The city also noted that broad-spectrum lighting may require fewer overall lumens to achieve the same perceived luminance, leading to even greater savings.

Energy and Maintenance Considerations Overview	Low ⟵⟶ High 1 2 3 4 5
System's ability to improve operations and management practices	4
Usefulness of data and reporting capabilities	4
Energy benefits attributed to the control system	4
Non-energy benefits	4
Vendor / Manufacturer customer support	5

San Francisco Public Utilities Commission: ROAM

PROJECT BACKGROUND

The San Francisco Public Utilities Commission (SFPUC) operates over 18,500 streetlights, mostly HPS fixtures of various wattages. In 2009-2010 SFPUC conducted a pilot demonstration of new LED streetlight fixtures and incorporated non-dimming ROAM nodes on over 50 of the new streetlights. The advanced controls pilot was described in PG&E Application Assessment Report #0906 in January of 2010.[41] As an extension of the original controls pilot, in November 2010 SFPUC installed 22 dimming LED fixtures and ROAM controls, including ROAM dimming control modules within the fixtures, in a separate area of the city.

In late 2011 SFPUC will begin replacing all 18,500 HPS cobra-head style streetlight fixtures with LEDs; installation of the fixtures, including advanced wireless controls, will take approximately 14 months.

The original ROAM controls pilot demonstrated the simplicity and effectiveness of web-based control, monitoring and management of SFPUC's streetlights through the ROAM RF mesh networking. The ROAM system was easy to install and commission, as the controls were compatible with standard photocell receptacles and the nodes networked themselves after installation. SFPUC successfully grouped and controlled pilot luminaires and detected fixture outages through the user interface. SFPUC was able to easily contact ROAM's customer support during system testing.

CONTROLS PRODUCT SELECTION AND INSTALLATION PROCESS

SFPUC decided after installation of the original non-dimming ROAM system that an evaluation of the dimming system on LED fixtures would be useful. SFPUC was already familiar with the ROAM system and network operation and topology from the original demonstration.

[41] Shackelford, Jordan, and Terrance Pang. *LED Street Lighting and Network Controls San Francisco, CA*. Pacific Gas and Electric, Emerging Technologies Program Application Assessment Report #0906 (2010).

The new dimming system installation was also reportedly as easy as installing a new fixture and photocell, since the dimming controls modules were pre-installed in the fixture by the manufacturer. SFPUC found the ROAM system commissioning process to be relatively straightforward, although identifying each fixture in the network requires nodes be manually barcode-scanned during installation then logged into the system. However, ROAM's comprehensive activation manual simplified the entry of attribute information. In the original non-dimming ROAM installation, SFPUC noted that the hand-held GPS locator that uploads node location experienced satellite communication issues due to interference from tall buildings; this was not a significant problem, however, as the operator was able to later easily assign coordinates from a laptop.

SYSTEM OPERATION AND FUNCTIONALITY

SFPUC has been satisfied overall with the ROAM controls system. It is compatible with existing lighting circuitry and infrastructure. ROAM provided training on its system, but operating the new technology was almost intuitive and internal training of field staff was not a problem.

Installation of the dimming networked controls system presented a couple of issues. The ROAM dimming control modules installed within the fixture to interact with the dimmable LED drivers were improperly wired by the fixture manufacturer. The mis-wiring caused the ROAM node to lose communication with the dimming control module when the fixture is turned off, so the operator could not set dimming schedules until the fixtures were switched on.

In addition, nodes experienced some difficulty communicating with the gateway device approximately 150 yards from the nearest fixtures, due to a significant amount of interference from cellular antennas installed on a building at the demonstration location. To overcome this issue, the SFPUC moved the gateway device to a new location within 75 yards of the nearest nodes. ROAM is currently testing a new node at this location designed to address the interference problem.

System Operation and Functionality Overview	Low ⟷ High 1 2 3 4 5
Ease of installation	4
Compatibility with existing circuits and wiring	5
Ease of staff training	5
Ease of programming and commissioning process	4

ENERGY AND MAINTENANCE CONSIDERATIONS

SFPUC did not install dimming ROAM controls in the original pilot and experienced minimal energy benefits from the non-dimming controls. The new ROAM installation that includes dimming LED fixtures and control units allowed SFPUC to test the dimming functionality of the ROAM controls; however, current utility billing practice does not allow SFPUC to achieve cost savings from dimming to lower power because streetlights are billed as non-metered load at a flat rate based on rated wattage. San Francisco will achieve energy and cost savings from HID-to-LED retrofits, but at this time has no plans to actively dim streetlights.

SFPUC reported that the non-energy benefits of the system are significant and are the primary area of interest for the city of San Francisco, including enhanced monitoring of system operations, identification of defective lights and reduced maintenance costs.

Energy and Maintenance Considerations Overview	Low ↔ High 1 2 3 4 5
System's ability to improve operations and management practices	5
Usefulness of data and reporting capabilities	4
Energy benefits attributed to the control system*	1
Non-energy benefits	4
Vendor / Manufacturer customer support	5

* The city does not have plans to actively dim streetlights, although the pilot installation has demonstrated the controls' dimming capabilities.

City of San José, California: ROAM

PROJECT BACKGROUND

The city of San José, California operates 62,000 streetlights comprised of 230W LPS lamps on cobra head fixtures. San José began this lighting controls pilot in January 2010 as part of an internal project through the San José Redevelopment Agency, replacing 140W LPS fixtures with network-controlled 219W Beta LED fixtures. The city implemented a networked controls system to cost-effectively monitor individual and aggregate streetlight energy consumption and to measure and report variations in energy consumption that pinpoint performance and/or maintenance issues. The city previously conducted demonstration projects using PLC communications as discussed in a previous report (PG&E 2010).

CONTROLS PRODUCT SELECTION PROCESS

The city of San José selected products based on a competitive bidding process. The highest-priority specifications in its selection process were:

- Communications type
- Frequency NTCIP 1213 compliance
- Self-hosting capabilities
- Relevant safety certifications
- Secure remote management system
- Map-driven monitoring application
- Full range dimming support from 0-100%

- Data storage and information retrieval capabilities

In addition to these requirements, the city emphasized the importance of continued luminaire operation during communications failures as well as laptop-based monitoring at the project site. The city listed open system architecture as a low priority.

SYSTEM OPERATION AND FUNCTIONALITY

San José has been very satisfied overall with ROAM's controls system. The installation and commissioning process was relatively straightforward. The commissioning process required recording GPS coordinates using a hand-held device then downloading them at the end of the day. While communications came online directly after the installation of a luminaire, it took the host company 24 hours to configure the luminaire and its location onto the interface web page – a minor inconvenience.

System Operation and Functionality Overview	Low ⟵⟶ High 1 2 3 4 5
Ease of installation	5
Compatibility with existing circuits and wiring	4
Ease of staff training	5
Ease of programming and commissioning process	5

ENERGY AND MAINTENANCE CONSIDERATIONS

San José reported energy savings of approximately $8,500 per year and maintenance savings of approximately $3,200 per year. ROAM provided very helpful customer support and sent a representative to work with field crews during the initial installation. ROAM responded to all calls and e-mails within 24 hours.

Energy and Maintenance Considerations Overview	Low ⟵⟶ High 1 2 3 4 5
System's ability to improve operations and management practices	4
Usefulness of data and reporting capabilities	4
Energy benefits attributed to the control system	5
Non-energy benefits	5
Vendor / Manufacturer customer support	5

U.S. Virgin Islands: CIMCON LightingGale

PROJECT BACKGROUND

The U.S. Virgin Islands Water & Power Authority serves roughly 5,000 customers over 135 square miles. The utility currently operates 16,271 streetlights, primarily HPS (100, 200, 400W) and metal halide (175W) cobra head fixtures. These streetlights are in the process of being retrofitted with Cooper LED (200W equivalent) cobra head fixtures. The U.S. Virgin Islands Water & Power Authority began installing the CIMCON LightingGale controls system on its fixtures in February 2011 to reduce the number of day burners, reduce maintenance costs and increase billing accuracy. As of May 2011, 600 streetlights had been fitted with controls.

CONTROLS PRODUCT SELECTION PROCESS

The U.S. Virgin Islands Water & Power Authority listed the following features as especially high priority:

- Self-hosting capabilities
- Open system architecture

The project manager of the U.S. Virgin Islands Water & Power Authority noted that self-hosting was an absolute necessity due to concerns over potential communication breakdowns between the islands and the mainland. The project manager also noted a need for a system allowing communication with other current and future devices. After considering ROAM, Echelon, and Lumawise, the U.S. Virgin Islands Water & Power Authority eventually selected the CIMCON system.

SYSTEM OPERATION AND FUNCTIONALITY

The U.S. Virgin Islands Water & Power Authority has been very satisfied overall with the CIMCON controls system. The project manager noted that installation was very easy; even the 30-minute training session was ultimately not necessary. The project manager also reported no compatibility issues. While the U.S. Virgin Islands Water & Power Authority has yet to complete the full installation, commissioning has thus far been a non-issue handled by the vendor.

System Operation and Functionality Overview	Low ← → High 1 2 3 4 5
Ease of installation	5
Compatibility with existing circuits and wiring	5
Ease of staff training	5
Ease of programming and commissioning process	N/A

ENERGY AND MAINTENANCE CONSIDERATIONS

The project manager noted that the controls system will improve maintenance and scheduling, identifying which streetlights are malfunctioning and enabling replacement of those fixtures in a single trip. Additionally, collected data is useful for comparing energy consumption of different types of fixtures.

The U.S. Virgin Islands Water & Power Authority has not yet completed the full installation of CIMCON controllers, so the majority of the project's energy savings have not been realized. The project manager believes that the project will achieve greater energy savings after full implementation. The U.S. Virgin Islands Water & Power Authority expects to see a combined annual energy and maintenance savings of $250,000.

Energy and Maintenance Considerations Overview	Low ←→ High 1 2 3 4 5
System's ability to improve operations and management practices	3
Usefulness of data and reporting capabilities	3
Energy benefits attributed to the control system	2
Non-energy benefits	5
Vendor / Manufacturer customer support	3

Additional Controls Demonstrations (Not Surveyed)

During the course of this study, a number of ongoing and future pilot and demonstration projects came to light in addition to the eight described above. Some useful material on each project is listed below; the information draws largely from press releases and MSSLC discussion notes and is not based on project manager surveys. This list of current demonstrations and pilots is merely a sampling of the projects and installations identified during research.

PG&E: ALADDIN AND VIRTICUS

PG&E is currently testing the Aladdin controls system in San Francisco, California at its Beale Street headquarters. The project manager for this pilot noted that the installation maturity was not sufficient to provide useful data or inform substantive conclusions. PG&E also plans to test the Virticus system, as well, at the same location.

CALIFORNIA LIGHTING TECHNOLOGY CENTER: LUMEWAVE

California Lighting Technology Center (CLTC) is a University of California, Davis affiliated group focused on lighting energy efficiency and technology development. CLTC has received a grant from the California Energy Commission (CEC) to develop basic network adaptive control standards that cities could use as a template for purchasing such systems. CLTC is working with BETA and ROAM to develop this standard, which has not yet been finalized.

The Center is also partnering with Lumewave to test its streetlight controls system. CLTC has installed the Lumewave controls system on six 70W bi-level induction roadway fixtures on the UC Davis Campus. Each fixture is installed with an occupancy sensor which can determine the occupant's direction of travel. This pilot project was funded by the California Energy Commission's Public Interest Energy Research Program.[42]

THE CITY OF SEATTLE, WA: OWLET

The city of Seattle has been studying LED technology in streetlight applications since 2008. It installed 5,000 residential LED fixtures in 2010 and is also currently planning a small pilot project, potentially involving the Owlet controls system.

Seattle's concerns about data security drive its interest in a controls solution that offers self-hosting capabilities so that data can be stored behind city and utility firewalls. Additionally, the city wanted fixtures with controls pre-wired and commissioned prior to installation. The city also noted the importance of flexibility in a controls device's installation options to allow it to be fitted on varying pole and fixture types. As of May 2011, the city reported that implementation of this project had yet to begin.

THE CITY OF HAVERHILL, MA: CIMCON

The city of Haverhill, MA announced in February 2011 that CIMCON had been selected to implement a three-month wireless streetlight management pilot program using the LightingGale controls system. CIMCON controllers will replace photocell sensors on about 50 of the city's streetlights. The purpose of this project is to reduce energy and maintenance costs of its streetlight system while maintaining resident safety.[43]

THE CITY OF AUSTIN, TX: ROAM

In August 2010, the Austin City Council approved the installation of a comprehensive streetlight management system. The purpose of this installation was to precisely and proactively identify system outages, improve repair and response time and save energy. During the first phase of this project, 3,300 fixtures will be fitted with ROAM controls by the end of summer 2011.

In February 2011, Acuity Brands announced that the city of Austin will be controlling all 70,000 of its fixtures with the ROAM controls system. This system will be installed and

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[42] EVERLAST Lighting, CLTC (California Lighting Technology Center). "UC Davis Continues Efforts to Reduce Lighting Energy Usage with New SMART Controls System." EVERLAST Lighting press release, EVERLAST Lighting website, http://www.everlastlight.com/download/pdfs/everlast/UC_Davis_Lumewave_Demo.pdf.

[43] Briefing Wire. "CIMCON Software Pilots Wireless Streetlight Management System in Haverhill, MA," http://www.briefingwire.com/pr/cimcon-software-pilots-wireless-streetlight-management-system-in-haverhill-ma, accessed June 2011.

operated by Austin Energy, with an anticipated completion date of 2014. The ROAM system will save an estimated $1,000,000 annually in combined energy and maintenance costs.[44]

ONCOR: ROAM AND TYCO

Oncor is a regulated Texas electrical utility serving about one-third of the state and operating about 400,000 streetlights. Oncor started a project in December 2008, installing 548 luminaires with the TYCO Lumawise system. Due to the frequency of severe electrical storms in the area, Oncor replaced all nodes in July 2010 to increase their ability to withstand lightning strikes. Oncor installed three gateways (although only two were required) to provide redundancy to guard against communications failures.

Oncor reported that the TYCO system was extremely sensitive; faults indicated in the TYCO system would often clear without intervention after a day. Oncor therefore had little confidence in the reliability and accuracy of TYCO's fault monitoring capabilities. The utility also reported contractors and maintenance personnel unaware of the TYCO system physically removing the TYCO controllers when they did not recognize them. Oncor purchased the system for one year, specifying a single administrator able to grant access to 30 people. Oncor appreciated the ability to provide unique IDs and passwords, with individualized access and permissions.

In a separate LED pilot project beginning in September 2010, Oncor also tested the ROAM monitoring system on 506 lights in a variety of settings and applications. Oncor expressed satisfaction with ROAM's ability to diagnose problems within the network. Oncor has a two-year contract agreement with ROAM and pays on-going service fees. Oncor noted that the utility would have preferred to host and control its own data, rather than to have to rely on a third party for this service as is currently required.

THE CITY OF PUEBLO, CO AND BLACK HILLS ENERGY: AIRINET

Black Hills Energy, in partnership with the city of Pueblo, Colorado, is engaged in an LED Street Lighting Initiative[45] to evaluate LED technology for use in street lighting applications. Black Hills Energy installed 10 new 250W equivalent LED lights and 10 new 250W HPS lights in June 2010, which it will monitor for two years using the Airinet system. Airinet controllers are currently tracking temperature, energy consumption and burn hours.[46]

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[44] Mfrtech. "Acuity Brands' ROAM System Selected for Austin, TX Outdoor Lighting Upgrade," http://www.mfrtech.com/articles/10418.html, accessed June 2011.

[45] Black Hills Energy. "Black Hills Energy Lights-up Pueblo with LEDs," http://www.blackhillsenergy.com/community/initiatives/led, accessed June 2011.

[46] Gray, Charlie. "Energy Efficient Street Lighting Analysis," Presentation. http://www.eei.org/meetings/Meeting%20Documents/2010-05-18-Analysts-LED.pdf, accessed June 2011.

Appendix D: Controls Manufacturer Survey Instrument

Communications	Responses
Communication Type (Mesh RF, PLC, etc.). Security, data and communication encryption	

Background	Responses
Product Name	
Company Name	
Internet URL	
Company Background (Years in Business, # of Employees, etc.)	
Year product was released	
If not N. America based, number of years in N. American market, distribution method.	
Year of first install of over 100 lamps	
Largest installation (city/organization, date, contact information)	
Largest N. American installation (city/organization, date, contact information)	
Pilot Installations (list of cities/organization, dates)	
Commercial Installations (list of cities/organization, dates)	

Frequency/Protocol	
Range (node-to-node and gateway-to-node); topology	
Backhaul Communications (Ethernet, cellular, Wi-Fi, etc.)	
NTCIP 1213 compliant (y/n)	
Please describe any other important communication attributes.	

Controls and Components	**Responses**
Fixture-level component name, location on fixture, description, rated lifetime / MTBF (Mean-time before failure); please attach cut-sheet	
Gateway component name (and ratio to fixtures), installation location, description, rated lifetime / MTBF; please attach cut-sheet	
Other system components (and ratio), description, rated lifetime / MTBF; please attach cut-sheet(s)	
Component safety certifications (NEC, NRTL, CSA, ETL UL)	
Please provide catalog numbers for products.	
Controls and Components	**Responses**
Components made in (country of origin)?	
Network Time Protocol (NTP) for synchronizing component clocks?	

System and Fixture Compatibilities	Responses
Lamp and Fixture Type(s) Compatibility	
Ballast/Driver Min. Requirements	
Ballast/Driver dimming compatibility (multi-level relay, 0-10V dimming, DALI, other)	

Load from Network Control Components	Responses
Node (W)	
Gateway (W)	
Other (W)	
Additional load per streetlight (W), please describe	

Capabilities, Functions and Features	Responses
Photocontrol (y/n), remote on/off control, scheduling (y/n), backup astronomical clock per control device (y/n)	
Dimming (y/n). If yes, within what range and at what increments?	
Power metering (y/n, sampling rate, and % accuracy: current, voltage, power)	

Luminaire grouping (y/n, describe)	
Sunrise and sunset trimming (y/n)	
Scalability of hardware and comm. network (y/n, describe) Accommodation for future upgrades?	
Luminaire, photocell, ballast/drive failure detection (y/n) and response to component failure (operation during malfunction)	
Response to communication failure, between fixture and gateway, gateway and server	
Fixture light output metering (y/n)	
Lumen depreciation adjustment (y/n), algorithmic or sensor-based?	
Traffic volume sensor support (y/n also - does this feature come included?)	
Fixture-level programming and data storage(y/n, describe). Off-line logging of status, energy possible?	
Other features; please describe.	

Network Management, Monitoring and Reporting	**Responses**
Describe web / graphic interface, OS compatibility, display of network infrastructure, schedules and devices, operational status, etc.	
Fault detection and reporting for network/hardware/software issues (y/n), detection of communications failures (y/n)	
Dual control and maintenance statistics (y/n)	
Describe geospatial mapping features and management of network, GIS compatibility, luminaire information storage (pole identifier,	

location, mode of operation, grouping, etc.).	
Describe monitoring functions, including data recording interval, alert options (SMS, email, etc.), real-time data availability vs. next day reporting, etc.	
Reporting options (.csv, .xls, Microsoft Access Database, Proprietary Software, etc.). Billing report generation of utility-grade metering data (y/n, describe)	

System Deployment Considerations	**Responses**
Please describe system installation and commissioning process	
Warranty period for all components (including firmware). Does this include troubleshooting / support?	
Security options	
Owner-hosted central management server, data storage and control (y/n, please describe)	
System Deployment Considerations	**Responses**
Please list user access level settings: administrator, operations, read-only access, etc.	
Software licensing model (1-Time Charge, Annual Fee, etc.)	
Open/Proprietary system architecture?	
Comprehensive system training manual (y/n); if electronic file, please provide.	

Sample Costs for Fully Featured Network Control System: 5,000 Fixture Project	**Responses**
Node ($/node) Number of Nodes	
Gateway ($/fixture) Number of gateways	
Other hardware (Servers, PDAs, repeaters, etc.; please describe)	
Inventory all other hardware	
Software fees, licenses, server / hosting, etc. (please describe)	
Total up-front cost	
Total ongoing costs, if any (service, hosting, etc.)	

Appendix E: Demonstration Manager Survey Instrument

Background	Comments
Organization Name:	
Organization Background: - Location - Size of Service Area	
Street Lighting Background: - Number of streetlights in territory - Number of streetlight technicians	
Network Controls product used:	
Date / Size of Network Controls Installations:	
Baseline Lamp/Fixture Type; Rated Wattage *(e.g. Metal Halide on Cobrahead; 250 Watts)*	
Retrofit Lamp Type *(e.g. LED on Cobrahead; 125 Watts)*	
Decision Process: Why did your organization decide to install network controls?	

Product Selection	Comments
Product Selection: Why did you select this product?	
Additional Products Considered: What other network controls options were considered?	
Funding Source: What was the funding source for this project? (Internal, ARRA, State/Federal Grants, etc.)	

Product Specifications:	**Relative Importance:** Least Important ⟷ Most Important 1 2 3 4 5	**Comments:**
- Communications Type *(Mesh Network, PLC, etc.)*		
- Frequency		
- NTCIP 1213 Compliant		
- Self-Hosting		
- Component Safety Certifications *(NEC, NRTL, CSA, ETL UL)*		
- Network Security		
- Open System Architecture		
Features: What were the most important features/capabilities that were considered in the product selection process?		
Communication: How does the system communicate from fixture to fixture and from central control point to the fixtures? Is there two-way communication?		

Installation and Commissioning	**Comments**
Installation: How difficult was the installation of the network controls? Most Difficult ⟷ Easiest 1 2 3 4 5	
System Compatibility: How would you characterize the network controls system's compatibility with existing lighting circuits and wiring? Most Difficult ⟷ Easiest 1 2 3 4 5	
Training Requirements: How would you characterize the level of training required to prepare staff for installation? Most Difficult ⟷ Easiest 1 2 3 4 5	
Programming Process: How would you characterize the commissioning process for the controls network? (i.e., programming and populating the streetlight database, establishing communication and connectivity across the network, and network interface setups? Most Difficult ⟷ Easiest 1 2 3 4 5	
Installation and Commissioning Issues: Briefly describe the installation and commissioning process, any issues you faced and how they were resolved.	

System Operation and Functionality	Comments		
System Functions:	**Available (Y/N)?**	**Do you use this feature (Y/N?)**	**If so, rate your experience:** Least Useful ↔ Most Useful 1 2 3 4 5
- Luminaire Grouping			
- Power Metering			
- Dimming			
- Remote Scheduling			
- Backup Astronomical Clock			
- Sunrise/Sunset Trimming			
- Failure Detection			
- Light Output Metering			
- Lumen Depreciation Adjustment			
- Maintenance Tickets/Reports			
- Data Reports			
- Traffic Volume Sensor			
- Other features:			
Ease of Use: How would you characterize the network controls system's ability to improve streetlight operations and management practices? Least Useful ↔ Most Useful 1 2 3 4 5			
Data and Reporting: How would you characterize the usefulness of the data and reporting capabilities of the controls network? Least Useful ↔ Most Useful 1 2 3 4 5			

Energy Savings: How would you characterize the energy benefits attributed to the control system? Savings as a fraction of total load (%)? Very Low ◄——► Very High 1 2 3 4 5	
Non-Energy Benefits: How would you characterize the non-energy benefits attributed to the control system? Very Low ◄——► Very High 1 2 3 4 5	
Customer Support: How satisfied are you with the customer support from the streetlight network controls manufacturer / vendor? Very Dissatisfied ◄——► Very Satisfied 1 2 3 4 5	
Controls Management: Does your organization manage the streetlight controls internally? If not, describe the roles of any third party companies in your streetlight operations.	
Lessons Learned: What would you do differently? What barriers did you encounter and how did you resolve them?	
Costs: How much did network controls add to the cost of the system (total $ per fixture)? Are you paying a monthly/annual fee for additional services ($ per fixture)?	
Estimated Energy and Maintenance Cost Savings: What were the estimated energy and maintenance savings from installing network controls? (in $ / yr and % of budget)	
System data for billing purposes: Is system energy data used for billing purposes? If so, how is this information shared with the utility?	

Tariff structure: Was the tariff structure changed to provide for savings from controls?	
Other:	

Appendix F: Glossary of Acronyms

AASHTO: American Association of State Highway Transportation Officials. AASHTO is a nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. Its primary goal is to foster the development, operation and maintenance of an integrated national transportation system.

AMI: Advanced Metering Infrastructure (AMI) are systems that measure, collect and analyze energy usage, and communicate with metering devices such as electricity meters, gas meters, heat meters and water meters, either on request or on a schedule. These systems include hardware, software, communications, consumer energy displays and controllers, customer associated systems, Meter Data Management (MDM) software and supplier business systems. (Wikipedia).

ANSI: American National Standards Institute. ANSI facilitates the development of American National Standards (ANS) by accrediting the procedures of standards developing organizations (SDOs). These groups work cooperatively to develop voluntary national consensus standards.

CE: Conformité Européene. CE Marking on a product is a manufacturer's declaration that the product complies with the essential requirements of the relevant European health, safety and environmental protection legislation, in practice by many of its Product Directives.

CIE: International Commission on Illumination. CIE is an international organization devoted to worldwide cooperation and the exchange of information on all matters relating to the science and art of light and lighting, color and vision, photobiology and image technology.

CLTC: California Lighting Technology Center. The CLTC's stated mission is to stimulate, facilitate and accelerate the development and commercialization of energy-efficient lighting and daylighting technologies. CLTC accomplishes these goals through technology development, demonstrations and outreach and education activities in partnership with utilities, lighting manufacturers, end users, builders, designers, researchers, academics and government agencies.

CPUC: California Public Utilities Commission. The CPUC regulates privately-owned electric, natural gas, telecommunications, water, railroad, rail transit and passenger transportation companies.

CSA: Canadian Standards Association. CSA is a not-for-profit membership-based association serving business, industry, government and consumers in Canada and the global marketplace to develop standards that address issues such as enhancing public safety and health.

DALI: Digital Addressable Lighting Interface. DALI is a method by which a controller can provide dimming instructions to the lamp. DALI is a digital interface that allows for 254 discrete levels of dimming intensity, commonly used with fluorescent fixtures.

ELMS: Electrical and Lighting Management Systems.

GPRS: General Packet Radio Service.

GSM: Global System for Mobile Communications.

HID: High Intensity Discharge.

IESNA: Illuminating Engineering Society of North America. The IES seeks to improve the lighted environment by bringing together those with lighting knowledge and by translating that knowledge into actions that benefit the public.

LED: Light Emitting Diode.

MTBF: Mean Time Before Failure.

NEMA: National Electrical Manufacturers Association. NEMA is the trade association of choice for the electrical manufacturing industry. Founded in 1926 and headquartered near Washington, D.C., its approximately 450 member companies manufacture products used in the generation, transmission and distribution, control and end-use of electricity.

NTCIP: National Transportation Communications for ITS Protocol. The U.S. Department of Transportation's NTCIP family of standards provides protocols and object definitions to allow electronic traffic control equipment from different manufacturers to communicate and inter-operate.

PLC: Power Line Carrier.

PWM: Pulse Width Modulation. Pulse Width Modulation is a technique for controlling power to inertial electrical devices using electronic power switches. The average value of voltage and current fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The adjustment of the frequency and duration of on/off switching varies the power output supplied to the load.

RF: Radio Frequency

UL: Underwriters Laboratories. UL is a global independent safety science company offering expertise across five key strategic businesses: Product Safety, Environment, Life & Health, University and Verification Services.