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U.S. DEPARTMENT OF ENERGY

Outdoor Lighting Challenges and Solution Pathways

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Acronyms and Abbreviations

AMI	Advanced Metering Infrastructure
ANSI	American National Standards Institute
BG&E	Baltimore Gas & Electric
BUG	backlight, uplight, and glare
CIAC	Contribution in Aid of Construction
CALSLA	California Street Light Association
CCT	correlated color temperature
CEC	California Energy Commission
CFL	compact fluorescent lamp
CIE	International Commission on Illumination
CLC	Cape Light Compact
CRI	color rendering index
DLC	Design Lights Consortium
DOE	U.S. Department of Energy
DOER	Department of Energy Resources
ECRM	Energy Cost Reduction Measures
EECBG	Energy Efficiency and Conservation Block Grant Program
ESPC	Energy Savings Performance Contracting
fc	footcandle(s)
HID	high-intensity discharge
HPS	high-pressure sodium
IAMU	Iowa Association of Municipal Utilities
IES	Illuminating Engineering Society of North America
IOU	Investor-Owned Utility
IP	ingress protection
K	kelvin
kWh	kilowatt-hour
LBE	Lead by Example
LED	light-emitting diode
LLF	light loss factor
lm	lumen(s)
lm/W	lumens per watt
LPW	lumens per watt
MAPC	Metropolitan Area Planning Council
MARC	Mid-America Regional Council
MH	metal halide
MPSC	Michigan Public Service Commission
MSSLC	Municipal Solid State Lighting Consortium
MV	mercury vapor
NCLM	North Carolina League of Municipalities
NEEIP	Non-Building Energy Efficiency Investment Program
NEMA	National Electrical Manufacturers Association
PF	power factor
PG&E	Pacific Gas and Electric Company
PSNH	Public Service Company of New Hampshire
PUC	Public Utility Commission
RFQ	Request for Qualifications
RLF	Revolving Loan Fund
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric Company
SEMREO	Southeast Michigan Regional Energy Office
SFPUC	San Francisco Public Utilities Commission
SSL	solid-state lighting
tBTU	Trillion Btu
USDN	Urban Sustainability Directors
W	watts

Assessment of Market and Technical Barriers to High Performance Street Light Deployment

The advantages of using light-emitting diode (LED) street lighting continue to be documented with financial and energy savings. The environmental, service, safety, and cost benefits are drivers for the continued interest in LED retrofits and the pursuit of financial, regulatory, and technical solutions will help to accelerate LED street light improvement projects across more municipalities.

The accelerated market adoption of LED street lights is due in part to the dual trend of decreasing cost and increasing performance. The efficacy of LEDs, or measure of light output to power input, has steadily improved while simultaneously yielding a better quality and longer lasting light.

Introduction

Across the nation, outdoor lighting helps communities create a safe environment for residents and business owners to live, work, play, and travel. This is a vital public service supported by taxpayer dollars that municipalities and their utilities provide. However, this essential offering consumes a significant amount of energy, approximately 1.3 quadrillion Btu's, annually and is often tethered to substantial operational costs. Outdoor lighting can represent more than half of a municipal energy budget depending on the size of the municipality, the scope of the services offered, and efficiency of the public lighting. States and counties are also responsible for roadway lighting, often including freeway, interstate, bridge, and tunnel lighting.[1]

In the last five years, a number of municipalities have switched to new lighting technologies (e.g., induction and LED), that can reduce energy costs by approximately 50% over conventional technologies and provide additional savings through lower operations and maintenance due to longer lifetimes. While several options can be considered for converting outdoor lighting to more efficient technologies (see table 1), this paper largely refers to LED conversions as LEDs represent the majority of full scale conversions by local governments and states given the efficiency potential. This report primarily focuses on solutions that municipalities are adopting for LED conversions, however, most of the solutions discussed can apply to any level of government responsible for providing outdoor lighting.

Table 1: Overview of Exterior Lighting Source Technologies

Lamp Type	Demand (W)*	Source Efficacy (LPW)***	CCT (K)[2]	CRI[3]	Lifetime (Hours)	Price
High Pressure Sodium	70 - 400	80 - 120	1,900 - 2,200	22 - 70	15,000 - 40,000	$$
Low Pressure Sodium	50 - 180	130 - 170	1,700 - 1,800	---	16,000 - 18,000	$$
Ceramic Metal Halide	70 - 400	75 - 110	3,000 - 4,200	80 - 94	10,000 - 20,000	$$ - $$$
Metal Halide	70 - 400	40 - 70	3,000 - 4,200	60 - 80	10,000 - 20,000	$$
Compact Fluorescent	20 - 70	80 - 85	2,700 - 5,000	80 - 85	6,000 - 20,000	$
Induction	70 - 250	50 - 85	3,500 - 5,000	80 - 85	100,000	$$ - $$$
Light-Emitting Diode	9 - 1,300	up to 145**	2,700 - 7,000	42 - 97	70,000+***	$$ - $$$

NOTE: All numbers in this chart other than LED were compiled in 2010. Incumbent technology pricing has held steady since 2010. However, given changes in LED technology, the LED values were updated on 4/21/2015 per a search of the U.S. DOE Lighting Facts Database of Roadway and Parking Garage products that returned nearly 5,000 product listings. The LED wattage range reported includes products suitable for high-mast roadway and sports stadium lighting, applications that aren't reflected elsewhere in the table (and typically employ 1000-1500 W HID lamps).

* *Typical size of lamps used in exterior applications.*

** *Typical size of LED Luminaires used in exterior applications, luminaires contains multiple LEDs.*

*** *Based on initial lumens, system efficacy should determine and is dependent on the specific fixture style ballasts, and drivers employed.*

Market Potential for Energy and Cost Savings

Recent estimates suggest savings of approximately $6 billion per year if all outdoor lighting was switched to LED technology. Street lighting represents the single lighting application with the greatest potential for savings (Table 2). Beyond cost and energy savings, the higher efficacy of LED lights provides other benefits, including helping cities reach carbon reduction goals; reduced light pollution from less light being directed into the night sky due to optical control; and greater perceived public safety due to improved visibility through better color rendering, more uniform lighting distribution, and the elimination of many dark areas between poles. In addition, newer technologies with controls and sensors can contribute to additional savings of 20% to 40% based on a sliding scale of dimming and hours-use or operational time.

Table 2: Potential Energy Savings with LEDs based on 2012 Installed Stock*

Outdoor Lighting Application	Energy Consumption (Source tBtu/Site TWh)	U.S. Fixtures (Millions)	Penetration of LEDs (2012)	Potential Energy Savings (Source TBtstBtu/Dollars)
Street Lighting	452/43.5	44	2.3%	238/$2.3 Billion
Parking Lots	355/34.2	16	<1%	226/$2.1 Billion
Parking Structures	267/25.7	38	1%	144/$1.4 Billion
Building Exterior	135/12	62	<1%	54/$0.5 Billion
Other	4/3	19	80%	---
Total	**1,213/118**	**179**	**<1%**	**662/$6.3 Billion**

** 2010 U.S. Lighting Inventory; Adoption of Light-Emitting Diodes in Common Lighting Applications, Navigant, Revised May 2013*

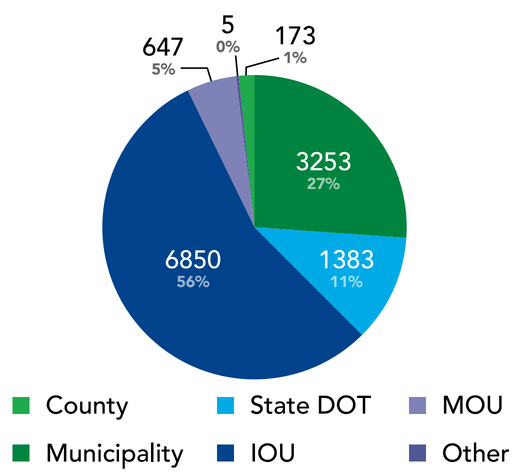
Given potential savings, and a growing body of documented performance and energy savings through demonstration projects, as well as full scale conversions completed in a number of cities across the nation, many states and municipalities are exploring making the conversion to high performance outdoor lighting. From 2012 to 2013 there was nearly a two-fold increase of LED use in outdoor lighting across the nation.[4] In addition, LED conversions provide an opportunity to utilities as they may help meet energy reduction goals. For example, as part of the State of Maryland's EmPOWER energy efficiency programs, utilities are authorized to include savings from more efficient street lighting to meet their energy goals.[5] As demonstrated by several examples discussed in this paper, LED conversions provide an opportunity for municipalities and utilities to work together for a common energy reduction goal.

Challenges

Outdoor lighting conversions frequently face obstacles ranging from technical to policy issues that may limit the pursuit of LEDs. This paper highlights three key challenges—financial, technical, and regulatory—and describes solution pathways that have been demonstrated by municipalities and states to overcome these challenges. When available, different solutions are discussed for different ownership categories as the ownership structure can impact potential opportunites. The two most frequent ownership categories are:

- Utility-owned and maintained
- Municipally-owned and maintained (this can apply to state or county ownership as well)[6]

Figure 1: Total Street and Area Lights Reported (1000s)



Street light ownership is a determining factor in calculating the long-term costs and benefits of conversions. A recent Municipal Solid-State Street Lighting Consortium (MSSLC) survery revealed that investor owned utilities (IOUs) own approximately 60% of the nation's street and area lights.[7] Data from this survey is representative of the survey respondents. A second phase of the MSSLC's inventory project will include a more robust estimate of the nation's total. In some areas, municipalities are looking to acquire ownership of outdoor lighting in order to proceed with conversion projects to achieve economic and energy savings benefits.

Table 3 summarizes three challenges and solution pathways expressed in this paper, along with municipal or utility owned lighting examples.

Table 3: Examples of Challenges and Solutions by City

Barrier / Challenge	Solution	Example Utility (U) or Municipally (M) Owned Lights; Transfer of Ownership from Utility to Municipally Owned Lights (U→M)
Financing	Debt	Infrastructure Bonds ▸ State of Massachusetts (M) ▸ San Diego, CA (M) ▸ Brookhaven, NY (M)
	Government Funded	Municipally Owned Utility ▸ Seattle City Light (M) ▸ Columbus, WI (M) ▸ Iowa Association of Municipal Utilities (M)
		State/Local Revolving Loan Fund ▸ Texas Loan Star Program (M) ▸ Urbandale, IA (M)
	Utility Programs	Rebate Programs ▸ Eversource Energy (M) ▸ Consumers Energy (M)
		On-Bill Financing ▸ Pacific Gas & Electric (California) (M) ▸ Southern California Edison (M)
	Third Party Financing	Energy Savings Performance Contracting ▸ Davis, CA (M) ▸ East Hartford, CT (M) ▸ Metropolitan Area Planning Council (M)
		Muncipal Loan ▸ Tarentum, PA (M)
		Regional Procurement Mechanisms ▸ Mid-America Regional Council, KS/MO (M) ▸ Southeast Michigan Regional Energy Office (U, M) ▸ Connecticut Conference of Municipalities (M) ▸ Cape Light Compact, MA (M)
LED Rate Tariff Structures	Engage Utilities on potential solutions to financing LED projects and rate changes	▸ West Palm Beach, FL (M, U) ▸ Asheville, NC (M, U) ▸ Georgia Power (U)
	Off-cycle updates due to rapid technology changes	▸ Southern California Edison (M, U)
	Engage the public utility commission (PUC)	▸ Ann Arbor, MI (M, U) ▸ North Carolina Utility Commission
	Engage state legislature	▸ State of Massachusetts ▸ State of Rhode Island ▸ State of Maine ▸ State of Maryland
	Rate Case Intervention	▸ Manchester, NH (M) ▸ Huntington Beach, CA (U)
Technology Changes	Third party advocacy	▸ Huntington Beach, CA (U → M) ▸ California Street Light Association
	Streetlight buyback/purchasing from IOU	▸ Richmond, CA (U → M)
	Pilot/demonstration projects documenting technical performance	▸ Las Vegas, NV (M) ▸ West Saint Paul, MN (U) ▸ San Francisco, CA (M)
	Model specifications	▸ Southern California Regional Energy Network (M, U) ▸ Portland, OR (M) ▸ Detroit, MI (M)

LED Street Light Costs and Pricing Trends

Cost Breakdown

The cost of LED street lighting systems has been on a steady decline over the past five years. While the initial capital costs are higher than conventional systems, the total cost of ownership for LED street lights is lower than convential lights. The total cost of ownership considers expenditures beyond the initial capital costs like equipment parts inventory, maintenance, and energy use. The total cost of ownership is important to support planning and procurement decisions. However, the focus of this section will be on the initial capitol costs which draw intense scrutiny when comparing the LED street lights to incumbent technologies. This section explains the key drivers behind the initial capital costs and provides actual examples of full estimates provided to cities in 2014 and 2015.

LED lighting systems have several components in the total cost of installation that are often rolled into a lump sum of the initial LED capital cost, including:

- **Material cost** – lamps, controls, fixture shields, and disposal fees
- **Labor needed for installation** – installation, project manager, project engineer, potentially others (finance, legal, etc.), depending on the nature of the project
- **Equipment needed for installation** – vehicles and traffic control devices

Break Even Costs

Municipalities must be careful to evaluate all elements of installation costs that are difficult to generalize and may impact the overall economic feasibility of a retrofit project. The "break even cost," or when total cost of upgrading to LEDs equals the cost of operating existing technology, varies from site to site. It depends on several factors: electricity costs, labor rates, what fixtures are being replaced and associated technology performance, and the redesign for the specific street and area lighting application.

It is also important to consider the projected decline in the cost of the technology. According to a recent 2015 U.S. DOE Solid State Lighting (SSL) report, LEDs are still more expensive than the incumbent competing technologies, however LED fixture prices have dropped by more than half since 2010 and are projected to continue to decline for at least the next few years.[8] As seen in the Table 4, between 2014 and 2017, the fixture price is estimated to drop by almost 60%. The fixture costs are then expected to flatten in the coming years. Further, lamp costs are expected to continue to decline or align with incumbent technologies, "LED lamp $/klm pricing is expected to decrease roughly 55% by 2017, relative to current pricing—a more modest decrease of 30% is projected for LED luminaires over this same period."[9]

Table 4: Summary of LED Package Price and Performance Projection (1/W/mm^2 and 25°C)

Metric	2014	2015	2017	2020	DOE Goal by 2020
Cool-White Efficacy (lm/W)	173	185	205	226	250
Cool-White Price ($/klm)	1.4	1.0	0.6	.35	.3
Warm-White Efficacy (lm/W)	146	162	190	220	250
Warm-White Price ($/klm)	1.7	1.2	0.7	.36	0.3

Pricing Trends

Based on the LED technology characteristics, LEDs are projected to cost less over their service life, and the experiences from cities with broad technology deployment supports these projections. For example, Los Angeles, California, completed a citywide street lighting replacement program and installed more than 150,000 LED streetlights, reducing energy usage by 63%, and saving $8 million in annual energy costs.[10]

Sample vendor price proposals provided to cities in 2014 have been captured in Table 5 for comparison by lamp type, manufacturer, geography, and quantity. 70w – 250w LED lamps are priced at less than $300 per fixture, and cities are selecting to install LED lights closer to the $150 per fixture range. The pricing variation found in these proposals can be attributed to a number of items including perceived quality, covered warranties, as well as installation costs. For example, there is a significant variation in the labor and equipment cost, which increases the all-in or installed cost per fixture from $300 to $600.

Table 5: Pricing Data from Sample RFP with Installation and Other Estimated Costs*

Source / Location	CA	CA	CA	NY	NY	NY	FL	MA	MA
Installation Included?	Yes	No	Yes	No	No	No	Yes	No	No
Manufacturer	A	B	C	D	E		F	G	H
Warranty (Yrs)	--	10	10	10	7	7	10	10	10
100W	$510	$181	$176	--	$201	$144	$439	$136	$204
Install Labor	--	$116	$72	--	--	--	--	$46	$70
Equip/Materials	--	$21	$10	--	--	--	--	--	--
Total Cost	$510	$318	$529	--	--	--	$439	$181	$274
Qty	647	529	237	--	60,500**	80,915**	142	8,406***	3,200
150W	$578	$213	$232	$240	$214	$144	--	--	--
Install Labor	--	$116	$72	--	--	--	--	--	--
Equip/Materials	--	$21	$10	--	--	--	--	--	--
Total Cost	$578	$350	$314	$240	$214	$144	--	--	--
Qty	607	1,826	124	18,000	60,500**	80,915**	--	--	--
250W	$453	$281	$259	--	--	--	--	--	$327
Install Labor	--	$116	$72	--	--	--	--	--	$70
Equip/Materials	--	$21	$10	--	--	--	--	--	--
Total Cost	$453	$418	$341	--	--	--	--	--	$397
Qty	1,346	627	69	--	--	--	--	--	1,225

NOTE: Blank space indicated that technology pricing was not requested or was not included in the RFP if not applicable to the city's application.
* *All price quotes are 2014 or later (include 100W, 150W, and 250W)*
** *Combined total of two sizes of luminaires in this location (further breakdown unknown).*
*** *Actual size breakdown unknown; average size of 100W nominal assumed.*

Challenges and Solution Pathways Discussion

States and cities across the nation are implementing full-scale outdoor lighting conversions, demonstrating they are a lucrative investment and that challenges to the conversion process can be overcome. This paper organizes the challenges some of these governments have faced into three main categories and provides real world examples of solutions:

- **Upfront Capital Costs:** If lighting is municipally owned, the city, county, or state is responsible for providing the upfront capital funding; even in some situations where street lighting is utility-owned, a municipality may be responsible for upfront capital costs.
- **Lighting Tariff Structures:** Many cities, counties, and states choose not to move forward with LED conversion or adaptive lighting because their utility does not offer an LED-related tariff for the fixture and controls, or the LED-related tariff is actually more costly than more conventional options given assumptions in the rate structure.
- **Performance and Reliability Requirements:** Concerns about expected performance, reliability, and the rapidly changing nature of the technology play a role in the decision making process around an LED conversion.

Challenges Associated with Financing Upfront Capital Cost of LED Fixtures

The main cost associated with the LED street light conversion is the upfront capital outlay, which can be significant. Although the technology cost rapidly decreased over the last five years, LED lights can still be two to four times more expensive than conventional high-intensity discharge (HID) "cobra-head" style lights until operations and maintance costs are taken into consideration. Recent product listings show some manufacturers are now providing bottom-line units that are nearly equal in pricing to a conventional cobrahead of equivalent quality.[11] Key considerations for determining financing are included in this section.

Who pays for the upfront capital cost?

The typical street light components include the pole, arm and brackets, and luminaire or fixture. These components may be partially or fully owned by either the utility or municipality. Organizations that own the street light poles are typically responsible for the cost of the actual fixture.

In the case where municipalities have made the decision to buy poles, they must identify a pathway to finance the initial cost of the fixture. In addition, it is important to note that many cities are contributing to some or all of the upfront costs for LED fixtures to enable utilities to proceed with timely retrofits. Utilities may require that a municipality provide upfront capital cost for any conversion before the fixture has fully depreciated, and include a Contribution in Aid of Construction (CIAC)[12] clause in their rate schedule for the installation of new fixtures or alterations of the existing system.

- In ***Southeast Michigan***, local utility DTE Energy requires the customer to cover most of the conversion cost through a CIAC; DTE contributes labor to the conversion, but the cities are asked to finance the majority of the project. This financial structure often makes it difficult to convince city boards or municipal leadership to agree to move forward with a conversion because debt is based on collateral, and in this situation the utility would still own the collateral.
- ***Dayton, Ohio***, provides an example of limited ownership with full capital cost responsibilities for any street light replacement, conventional or LED. The city owns 5,300 out of a total of 19,700 lights. The utility, Miami Valley Lighting, a division of Dayton Power & Light, is the majority owner of the street light assets and bills the city for all capital, energy, and maintenance costs. To help fund the cost of LED upgrades for city-owned street lights, the Dayton City Commission approved a city ordinance which allows for a six-year assessment (2014-2020) of all customer groups — residential, commercial, and industrial — to finance a $3 million LED upgrade and related lighting system expenditures.[13]

If utilities choose to make the capital investment required for an LED conversion, it is typically amortized through the rate structure. In order to spread out the cost associated with purchasing a large number of this asset, some utilities restrict the number of LED conversions they will complete per year across their territory.

- In a 2014 American Council for an Energy-Efficient Economy (ACEEE) report that highlights successes in outdoor lighting conversions funded by Vermont utilities, one strategy used to help with financial constraints of the utilities was to place limits on the number of LED street lights allocated in each service territory per year on a first-come-first-served basis, as included in the tariff language for the Central Vermont Public Service.

Are there additional costs beyond the new fixtures?

Stranded assets (light fixtures that will be replaced before they have reached their full lifecycle, typically 20 years-post installation) are usually factored into financial calculations. Although requirements will differ, utilities may require compensation for the stranded asset. Payments will range depending on when the street lights were installed, but can be as much as $200 per fixture. Depending on the stranded asset payment, this will add cost to the LED conversion and will impact the payback period.

If the city is also buying the poles from the utility, in addition to exchanging fixtures, then there may be additional infrastructure costs such as replacing poles, transformers, or power lines (wires) that are no longer structurally sound, as well as bringing any new acquisitions into line with municipal code.

Another cost that city governments are starting to explore is including advanced sensors on light fixtures that allow more energy savings features, and using the lighting pole as an integrated communication node for the city.

- ***San Jose, California***, maximized the energy and technology opportunity with available funding (American Recovery and Reinvestment Act funds and local utility, PG&E, rebates) and included a networked adaptive lighting control system with the LED conversion. This enables the city to remotely control the lighting system with real-time communication and monitoring and deploy adaptive lighting. It was projected that when the city implemented adaptive lighting (reducing the power level to 50% during periods of low vehicular activity) in conjunction with energy efficient luminaires, the street lighting cost would be reduced by 45%-64%.[14]

Financing Solution Pathways

Eight financing options ranging from traditional municipal bonding to municipally owned utility and investor owned utility programs are discussed below. Many organizations combine several of these options to develop the optimal financing package for their LED conversion.

Debt

Infrastructure bonds. Infrastructure bonds are government issued bonds that may include funding for a number of infrastructure related expenditures, including outdoor lighting retrofits. Outdoor lighting funds may be bundled in larger city-wide bonds or independently offered, in some situations; regions may also issue bonds that can be utilized by a number of municipalities.

- ***The Governor of Massachusetts*** announced in April 2015 a state-wide LED conversion project of 4,500 lights as part of the state's efforts to save energy and reduce greenhouse gas emissions. The Department of Energy Resources' (DOER) Leading by Example program (LBE) is collaborating with the Department of Conservation and Recreation (DCR) to implement a two-phase project that will upgrade DCR-owned lighting fixtures and infrastructure along the streets and parkways throughout the commonwealth. The first phase of the project, which includes the LED conversion of about 2,000 lights, is financed by multiple sources. The project will receive $1.2 million from DOER in "green" bonds through the Non-Building Energy Efficiency Investment Program (NEEIP). NEEIP provides low-cost financing for self-supporting clean energy projects that generate savings or revenue sufficient to cover the annual debt payments. The project will also leverage utility incentives from Eversource, National Grid, and Chicopee Electric Light. Incentives are provided as a rebate based on kilowatt-hour (kWh) saved through the commonwealth's energy efficiency program and will approximate $280,000. Lastly, DCR will provide $1 million from its capital budget.[15]

- ***San Diego, California*** provides an example of a city using bonds bundled with other funding sources. San Diego is currently enhancing the city's street lighting system by adding LED adaptive control lighting systems. The city was able to use $13.1 million of its Qualified Energy Conservation Bond (QECB) allocation to fund a portion of its city-wide lighting upgrades, which included a mix of induction and LED lighting. San Diego is also leveraging low interest California Energy Commission (CEC) loans, grants, bonds, and on-bill financing with the local utility (SDG&E) for funding projects. The process of coordinating and seeking the necessary approvals took more than one and a half years to align internal resources with external providers to implement the work. The city contributes its success to having a proven plan for each phase of the project cycle -- planning, design, implementation, and verification. For example, establishing a baseline inventory and energy use prior to construction in order to demonstrate post-construction benefits was critical.

- **Brookhaven, New York** is another example of bonds bundled with other funding sources. The town issued a $1.25 million bond resolution to finance an LED street light conversion project. The town expects to save at least $300,000 on energy costs annually, which will enable repayment of the bonds in 5 years.

Government Funded

Municipally Owned Utility. Municipally-owned utilities have access to low cost loans that can be repaid out of energy and maintenance savings.

- ***Seattle City Light***, a public utility which serves the City of Seattle and six suburban neighbors, has converted more than 50,000 of its 84,000-light system. The catalyst for the LED conversion was the desire to provide the highest level of customer service possible and increase the reliability of lighting fixtures. Seattle City Light rolled out a pilot program to perform engineering studies and gain customer feedback on aesthetics. The goal was to reduce the replacement turnaround time (peaking at three to four months) and reduce customer complaints.The $18 million project was funded by Seattle City Light: $17 million from the general fund and $1 million from the Energy Department's Energy Efficiency and Conservation Block Grant (EECBG). The estimated payback is 7.6 years.[16] The utility's LED conversion has proven to be highly successful with a reduction in outage complaints to less than 2%. Additional benefits of the LED conversion include reduced energy and maintenance costs; as a result of realized savings, customer rates dropped by as much as 30%.
- ***Columbus, Wisconsin's*** Department of Public Utilities pursued an LED upgrade after witnessing the success of pilot programs in other major cities like Los Angeles and Anchorage.[17] Following Los Angeles' 140,000 LED replacement project and with the help of an internal LED champion, the Columbus utility embarked on an LED retrofit project to convert nearly all of the city's inventory of 600 street lights. The utility benefited from an EECBG grant which covered 60% of the $260,000 total project with cost share from the city. Columbus expects about a 50% annual energy savings with a seven to eight year payback.[18]
- ***The Iowa Association of Municipal Utilities (IAMU)*** works with 136 municipally owned electric utilities in Iowa, with a customer base ranging from 100-25,000 customers. Even serving a small customer base, these utilities have found LEDs to significantly save energy and maintenance costs. As a result, they have self-funded retrofits out of their utility budgets, often in a phased approach to spread out the upfront cost and labor requirements. In addition, IAMU worked with the utilities to develop a Request for Proposal (RFP) that allowed for joint purchasing power, providing competitive fixture pricing for more than 20 municipal utilities.

State/Local Revolving Loan Fund (RLF). Revolving loan programs can often offer state and local governments access to loans at a lower rate than third-party loans for energy efficiency projects. The loans may not be large enough to cover a jurisdiction-wide conversion, but can be a good option for a bundled financing package. The savings from LED retrofits can also be used to create a RLF as demonstrated in the example below from Urbandale, IA.

- ***The Texas LoanSTAR Program*** administers a revolving loan fund for Energy Cost Reduction Measures (ECRM) including energy efficiency lighting systems. The City of San Antonio was able to use the LoanSTAR RLF to finance a $1.7 million conversion of LED traffic signals and pedestrian lights throughout the city. San Antonio benefitted from annual energy cost savings of $878,000 with a two-year payback. Similarly, the City of Austin borrowed $3.4 million to upgrade LED street lights and realized an annual energy cost savings of about $1.7 million and a two-year payback.
- ***Urbandale, Iowa*** partnered with MidAmerican Energy for a pilot project to use savings achieved from LED upgrades to fund a RLF program. EECBG funds were used to purchase and install 142 LED streetscape and pedestrian lights at an average cost of $1,685/light, which included fixtures and installation. The total cost of the project was approximately $240,000, with $95,000 from EECBG funds, $83,000 from the city's Capital Improvement Project budget and $61,000

from the State of Iowa's EECBG grant. The city expects an annual energy cost savings of $38,000, which includes electrical and maintenance savings. Twenty-five percent of the documented savings in energy costs was cycled into an RLF for continued funding of energy efficiency projects.

Utility Programs

Some utilities provide benefits such as rebates or low interest loans for outdoor lighting retrofits as part of the energy efficiency programs. In addition, on-bill financing from utilities may be an option.

Rebate Programs. Rate-payer funded utility rebate programs help to offset the initial cost of energy efficiency upgrades. As with other energy efficiency measures, street light incentives improve project economics, which will increase the likelihood for approval by a municipality's governing board and budget officials. With uptake in energy efficiency projects enabled by incentives, utilities are able to meet their own annual energy savings goals.

- ***Eversource Energy***, previously NSTAR, has provided assistance for conversions in Boston, helping to reduce the payback period. Forty percent of street lights in Boston were converted by the end of 2012, saving the city $2.8 million annually in electricity costs alone. Including reduced maintenance costs and other savings, Boston expects a payback period of only two to three years or sooner when factoring in rebates from Eversource. The Eversource replacement program offered rebates to municipalities that already owned their street lights. The incentive began at $0.20/kWh saved, but has more recently been adjusted downward. These incentives and an associated LED rate are only offered for customer-owned street lights; Eversource does not offer an LED rate to municipalities with utility-owned streetlights.
- ***Consumers Energy***, the public utility serving customers in all 68 of the Michigan's Lower Peninsula counties, has a Street lighting Replacement Plan and rebate program driven by customer interest. A voluntary Energy Efficiency Opt-in Program was created to allow formerly ineligible customers on Consumers Energy's street lighting rates an opportunity to receive incentives. The customer or municipality is responsible for a portion of the replacement cost and the incentives are based on fixture type and watts saved with the new fixture. Incentive amounts range from $0.40 to $0.60 per watt reduced. The rebate program is financed by the energy optimization surcharge as approved by the Michigan Public Service Commission. The surcharge is capped at approximately 2% of Consumers Energy's annual revenue. The opt-in program is limited to customer owned street lights; street lights owned by Consumers Energy are not eligible.[19]
- See also Cape Light Compact, page 16.

On-Bill Financing (OBF). This form of utility financing is not widely available, but some utilities provide loans for energy efficiency projects through OBF, allowing the municipality (borrower) to repay the cost through their utility bill. California utilities are most active with this funding mechanism.

- ***Pacific Gas and Electric (PG&E)***, serving Northern California, offers OBF, as well as rebates to off-set the capital cost of outdoor area and street lighting retrofit projects. PG&E's program is a zero percent interest loan where monthly re-payments for project costs are equivalent to the energy cost savings. Savings must be sufficient enough to repay the loan during the allowable payment term. The maximum loan amount for municipal customers is $1 million for all energy efficiency projects and of this maximum, street lights are capped at $250,000 (enough for 600-800 lights depending on the project scope). Rebates are applicable to municipally-owned and maintained street lights using PG&E approved, independently assessed products available through the DesignLights Consortium (DLC). PG&E will assist municipalities with analyzing energy cost savings based on its LS-2 Rate (Street Light Tariff) and the scope of the retrofit project. Rebates are issued after project completion to allow for reconciliation and compliance verification. To date, PG&E has supported a few hundred LED conversion projects exchanging approximately 180,000 lights of 567,000 municipally-owned lights in its service territory. The next phase of the LED program is to pursue conversion of utility-owned street lights.

- ***Southern California Edison (SCE)***, serving nearly 5 million customers in Southern and Central California, offers energy efficiency rebates and on-bill financing to municipalities to help fund LED retrofits of municipally-owned street lights. The rebates provide nearly 50% of the incremental cost of the LED fixtures. Remaining project costs can be financed through 0% interest, no-fee loans that are repaid in monthly installments as a line item on the municipal's monthly electric bill over a period of up to 10 years.

Third-Party Financing

Energy savings performance contracting (ESPC). ESPCs provide third-party financing with guaranteed savings in a complete turnkey installation program. Through ESPCs, energy service providers can finance the project (including stranded assets or buyback, if needed) as well as purchase and install the lights, and in some cases, provide maintenance. The city can pay for this package of services over many years out of the energy and maintenance savings as well as any potential energy rebates. Often times this activity is bundled into a broader city-wide ESPC contract across a number of energy savings services, or can be part of a broader statewide ESPC program.

- ***Davis, California*** is pursuing an ESPC with Siemens and Terra Verde to retrofit 3,166 city-owned street lights to jointly deliver a self-funded project through the energy savings. The city will replace 2,661 non-LED cobra head lights and 505 acorn style decorative street lights into new Ripley LED long-life photocells.

  The city has 447 poles with missing identification numbers and with this project Siemens will replace those pole numbers in accordance with PG&E and city standards. With these retrofits, the estimated first year savings include $200,000 in utility and light maintenance costs. The 15-year combined savings is projected to be $3,730,638. The first phase of the citywide Resource Efficiency Performance contract, will allow the city to modernize its infrastructure and reduce energy consumption and GHG emissions. The ESPC from Siemens includes a "no change" order, thus assuming all risk in terms of fixed price and payback within the performance guarantee established in the contract. Siemens will provide full-time project oversight and provide "as-built" GIS mapping of all street lights.

- ***East Hartford, Connecticut*** is partnering with Ameresco to plan and implement an LED street lighting improvement project throughout the town. City officials view the ESPC as an opportunity to increase energy efficiency and improve customer service, while reducing operating costs long-term. The project scope includes the installation of nearly 5,000 lights under a $2 million ESPC. The deal is structured to be budget-neutral for the town where operating and maintenance savings will be used to pay for the project. Ameresco will also provide ongoing maintenance to guarantee system performance.[20]

- ***The Metropolitan Area Planning Council (MAPC)*** is a regional planning agency that serves the 101 cities and towns of Metro Boston, MA. For its LED street light projects, MAPC provides extensive support and acts as an aggregator to receive bids for multi-town ESPC procurements. Cities must have ownership of poles before entering into the joint ESPC. MAPC manages all administrative aspects of the procurement, while a selection committee comprised of representatives from the participating municipalities selects the winning vendor. This vendor then signs a separate contract with each individual municipality. MAPC has worked with over 20 communities in this capacity. As of November 2015, MAPC reports completed installations of more than 14,900 LED street lights across the municipalities of Arlington, Chelsea, Natick, Woburn, Sharon, Somerville, and Winchester, with a combined savings of about $441,000 annually. An additional 14 communities have begun the ESPC process, which will include 33,000 additional LED retrofits.

  Participating municipalities experience several benefits through MAPC's joint procurement process. Based on input from municipalities, MAPC leverages its ESPC expertise to develop and draft the procurement document. This step saves each municipality significant staff time. MAPC also contributes technical assistance to the selection committee, supporting their efforts to review, analyze, and vet the vendor responses. Municipalities benefit from the economies of scale under a qualifications-based or price-based approach to selection, attracting more ESCO competition and better pricing than an individual community. In sum, MAPC's model offers cities and towns the support and flexibility to meet street lighting system needs individually, while improving costs and benefits collectively.

- See also Cape Light Compact, page 16.

Municipal loan. Given bond caps and other financing restrictions that can be in place at the municipal level, municipalities may also consider direct bank loans to finance an LED conversion.

- ***Tarentum Borough, Pennsylvania*** was able to transition from high pressure sodium street light fixtures to LEDs with a third-party financing option. Tarentum worked with GE Capital, Corporate Finance to secure a loan with a competitive interest rate. The cost to finance the project, which converted 100% of the borough's 400 street lights to programmable GE LED fixtures, was less than the savings gained from the reduced energy usage and maintenance costs – equating to zero dollars out of pocket and an instant annual cash flow of $8,000. The project was completed in 4 months, including securing financing.

Regional procurement mechanisms. Regional or state-level organizations can work across municipalities to negotiate lower rates when bundling the needs of several municipalities. In addition, regional networks can help negotiate ESPC contracts, or even the buyback option, helping provide assistance across financing, procurement and legal issues.

- ***The Mid-America Regional Council (MARC)*** is a metropolitan planning organization serving the Kansas City area that has regional authority to manage nearly 130 municipalities. Twenty-five of these cities and towns coalesced to pilot a small-scale outdoor high efficiency lighting retrofit program, "Smart Lights for Smart Cities." MARC coordinated the Smart Lights initiative to help communities install high-efficiency street lighting technologies with more than $4 million in funding through an Energy Efficiency and Conservation Block Grant. The primary objective of the initiative was to transform the street light market in the region to adopt high-efficiency streetlights.

  MARC was able to provide participating municipalities the benefits of technical expertise, operational efficiencies, and collective buying power when engaging multiple utilities and the public service commission to negotiate pilot LED tariffs. Member communities worked to overcome barriers and misperceptions about high performance lighting technology and were able to install 5,753 streetlights with 30 percent more high-efficiency streetlights, LED and induction, than initially anticipated. The total energy savings was well documented through evaluative processes, showing on average, a 55–61% reduction in energy usage. When compared to conventional streetlights, the high-efficiency streetlights made up only 55% of the total amount of emissions created from HPS lighting. The new streetlights are expected to save a combined $25 million in energy costs. MARC continues to encourage streetlight ownership and support the creation of a permanent tariff for energy-efficient streetlights by serving as a resource for useful information about available financing mechanisms, including QECBs, available through state and/or local governments.[21]

- ***The Southeast Michigan Regional Energy Office*** is a regional coalition of more than 20 non-profits and local governments in the Detroit metro area organized to develop tools and resources that enable greater energy efficiency in the region. SEMREO worked with the Urban Sustainability Directors Network (USDN) to draft an assessment of financial mechanisms available to fund regional procurement for LED street light projects with member municipalities. The assessment, *Bright Lights, Bright Futures: Project Financing Options*[22], identifies sources of funding, upfront capital requirements, recommendations, and other considerations. The list of funding sources include government (federal, state, and local), utility, and public-private partnerships. SEMREO is a resource for member communities to factor political will and readiness of capital in their decision-making for regional procurement strategies for LED street lights. SEMREO is currently involved in a DTE Energy rate case filed with the Michigan Public Service Commission and working to ensure that LED conversions are financially feasible for member communities. SEMREO, with the support of the USDN, published a guidance document for leveraging the consortium approach when negotiating with public utilities commissions and utilities, *Bright Lights, Bright Futures: LED Street Lights for Southeast Michigan, A Framework with Tools for a Regional Approach to Energy Efficient Street Lights.*[23]

- ***The Connecticut Conference of Municipalities (CCM)*** issued a Request for Qualifications (RFQ) in 2014 to solicit bids for LED retrofit, management, and maintenance services in support of Connecticut municipalities. The CCM project will help towns engage in negotiations for buyback from the utility, if desired. In 2015, the CCM selected three vendors to serve more than 150 member communities with LED retrofits. In this situation, economies of scale helped the cities to procure services and equipment at a lower price point. This approach demonstrates the advantages of channeling the interests of several cities across the region into a united discussion with the utility. In addition, the cities will benefit from technical expertise they may not currently be able to access.
- ***Cape Light Compact (CLC)***, is a municipal aggregator and energy efficiency program administrator serving all the towns on Cape Cod and Martha's Vineyard, Massachusetts. In its energy efficiency role, the organization used a ten year guaranteed ESPC with Siemens as an approach to convert municipally owned-street lights to LEDs for its 23 participating communities in a multi-year, phased project. Through increased economies of scale, localities have received better purchasing options, competitive electric rates, and improved operations and maintenance services. The CLC approached the influencers in each member community to listen to and educate the community about the LED street light technology and benefits, working with diverse towns ranging in size from eight street lights in Barnstable Village up to 2,573 in Falmouth. The project was support in part by $5.9 million in CLC incentive funds, available because it was a cost-effective initiative according to the Massachusetts Department of Public Utilities'-approved three-year Energy Efficiency Plan. In aggregate, approximately 15,700 street lights were converted with an estimated annual savings of 3,310,00 kWh (approximately 70% reduction), $657,000 in utility bill savings, and $212,000 in maintenance cost reductions.
- See also The Metropolitan Area Planning Council (MAPC), page 14.

Challenges Experienced with Outdoor Lighting Tariff Structures

An early step that many governments face when considering street light energy efficiency is understanding the utility rate structure for outdoor lighting options to determine if an LED conversion is feasible. Considerations are included below:

Does the utility (or utilities) in the municipality's service territory provide an LED rate in the outdoor lighting tariff?

A number of utilities already support achieving the benefits of LED lights and are considering adding LED rates, however, some utilities still do not offer an LED rate for unmetered street lights. For instance, in a 2015 study of Northeast utilities[24], only 13 of 45 investor-owned utilities (IOUs) offered LED rates. In this situation, the support of a state Public Utility Commission (PUC) or state legislation may be able to help municipalities move forward with LED conversions. Several examples are provided below where PUCs or states have passed enabling legislation to make it easier for cities to move forward with a conversion if a LED rate does not exist. Although PUCs and state legislative bodies can provide support, engaging directly with the utility to discuss a LED rate and financing of the upfront cost has proven to be very important, and in many cases most effective.

If an LED rate is included in the tariff, how does it compare to other outdoor lighting options? What assumptions are included in the rate?

The LED rate is composed of three primary drivers: the upfront capital cost of the actual fixture, ongoing maintenance costs, and the associated energy cost of operating the fixture. Although LED lighting results in savings in both maintenance and energy costs, the largest portion of the LED rate is the capital cost, so the LED rate may actually be higher than conventional lighting options.

Therefore, the assumptions used by the utility and regulator on the three components of the rate are essential to understand. For example, if the maintenance and energy savings are undervalued, or if price assumptions do not reflect the reduced rate of newer LED fixtures, the proposed LED rate may not properly reflect the true cost and opportunity associated with a potential conversion. In situations where a new outdoor lighting rate is filed, some municipalities have had success intervening to better understand—and in some cases negotiate—the assumptions used to develop the LED rate. If a rate has recently been approved, utilities may be open to considering off-cycle updates given the rapid technology changes that impact capital costs estimates (see Background section for recent customer data).

If there is no LED rate or the rate is unfavorable,another pathway to consider is municipal street light buyback or purchasing options and negotiating a different rate with the utility under municipal ownership.

LED Tariff Solution Pathways

Below are examples of successful approaches to overcome outdoor lighting tarrif challenges of some municipalities working with utilities to establish or amend LED rates. Another option is to seek rate changes via the PUC or state enabling legislation along with intervening in rate cases directly or with the assistance of regional third parties. A last consideration is buying back poles and negotiating a new rate at time of purchase.

Engage with the utility on potential solutions to financing a LED project and rate changes

If municipalities have decided that LED outdoor lighting is an avenue that they want to pursue to reduce costs and achieve energy savings, working directly with the utility can result in solutions that work for both parties.

- ***West Palm Beach, FL***, pursued an LED street light retrofit project on a system with multiple owners. The initial implementation of the conversion focused on city-owned and Florida Power & Light (FPL) utility-owned lights. For FPL owned lights, the city paid for the cost of the fixture/luminarie and the installation. For metered city-owned lights, the city purchased its street lights from FPL and paid FPL for the fixture and installation and FPL offered a reduced tariff specific to energy charges only (in addition to the purchase price, West Palm Beach incurred the cost to remove the old fixtures and install the new ones) and the utility agreed to a lower LED tariff rate; the city's FPL rate decreased from $9.96 to $2.71 per light per month, a savings of more than 70% per month. The city budgeted approximately $800,000 for the project and paid FPL the costs upfront. The negotiations and agreement process took three to four months and project installation took approximately six months to complete 1,451 retrofits. The ROI is about five years for this phase of the FPL project. The city is now pursuing the second phase to complete area-wide upgrades even with FPL's increased costs, which were adjusted after reassessing actual costs for the first project with West Palm Beach.

- ***Asheville, NC*** was successful in negotiations with local utility Progress Energy, which has since merged with Duke Energy. City staff partnered with a technical liaison at Progress Energy to develop a rate proposal based on equipment selection and performance. Due to the technical leadership and engagement with the rates department at Progress Energy, the resulting proposal offered the city a reduced LED rate, which was further reduced by the city taking ownership of the lights. Asheville secured low-cost financing via bond to purchase the street light poles and LED fixtures, which were installed by Progress Energy. The city paid a stranded asset cost of approximately $50 per light less than 20 years old taken out of service. The utility was amendable to this solution because of the need to replace older infrastructure and the city's ability to finance it at a lower rate. Under the new structure, the city pays Duke a 50% lower operating fee. While the city was not directly involved at the regulatory level, the special rate proposed by Progress Energy was approved by the North Carolina Utilities Commission. Asheville's project scope included 7,400 lights with a total savings of $450,000 annually.[25]

- ***Georgia Power***, serving all but four of Georgia's 159 counties, owns and operates approximately 850,000 outdoor lights, with 450,000 on government-maintained roadways and 400,000 outdoor area lights. In 2015, based on requests from customers and the maturation of LED technology, Georgia Power started to provide a rate for government roadway LED lights that is equal to or slightly lower than the high pressure sodium rate government customers currently pay. Municipalities in the Georgia Power service territory do not have to pay for LED upgrades because the upfront capital cost of the fixture is included in the LED rate. Georgia Power is engaged in working with their government customers to convert all of the 450,000 roadway lights to LED and is working with more than 30 municipalities who have signed agreements for the conversion to occur. In 2018-2019, Georgia Power will install networked lighting controls in all LED roadway and area lighting fixtures to enable municipalities to operate different levels of lighting depending on their need. Municipal energy bills will reflect the adjusted use of the lighting.

Off-cycle updates due to rapid technology changes

In this scenario, utilities submit new LED rates to the public utility commission (PUC) more frequently than typical rate change requests to accurately reflect the current status of LED technology. The rates reflect the lower cost of new capital which helps to lower costs of the LED rate overall as part ofthe rate calculation.

- ***Southern California Edison (SCE)***, serving nearly 5 million customers in Southern and Central California, has altered their LED lighting tariff rate updates for both municipally and utility-owned street lights more frequently than the 36-month rate setting proceeding cycle set by the California PUC. These off-cycle updates have been made to more accurately reflect the capital costs associated with LED lights given the decreasing cost of LED technology as it continues to mature. SCE first introduced LED pricing options for municipally-owned street lights in August 2009 and followed in May 2011 with LED options for utility-owned lights.

Engage Public Utility Commission

In most states, PUCs approve changes in tariffs that are submitted by the utility and there are opportunities for stakeholders to engage in the approval process. If the rate is contested, changes can take multiple years to move through the approval and review process. PUCs can also put in place enabling regulations related to outdoor lighting, such as requiring utilities to include an LED rate or allowing for municipal buyback of lights in specific territories or across the state.

- ***Ann Arbor, Michigan***, was the first city to fully convert street lights in a downtown area to LEDs. The city owns about 2,200 street lights and DTE owns the remaining 5,300. Since 2006, when the city began putting up test fixtures, to full-scale adoption of the technology, Ann Arbor invested over $1.3 million in LED conversions of city-owned fixtures. The city's Downtown Development Authority provided $630,000 and DOE Energy Efficiency and Conservation Block Grant funds provided more than $600,000 for upfront capital costs. DTE covered most of the cost for the first 100 DTE-owned street light conversions. Ann Arbor paid around $100,000 for the utility-owned LED conversions of about 400 fixtures and DTE covered the installation costs. The city estimated a 30% energy reduction and 41% reduction in maintenance time due to the conversion, yet the utility costs increased by 15%. Ann Arbor has since joined other Michigan cities in a rate filing intervention with the position that proposed DTE rates effectively halt LED conversions of their inventory and lengthen stated payback periods of recent projects they have undertaken to convert mercury vapor lights to LED. The anticipated payback for all LED conversions when including utility-owned, was estimated to be about six years.
- ***North Carolina Utility Commission:*** The North Carolina League of Municipalities (NCLM) intervened in Duke Energy Carolina's rate case (Docket No. E-7, Sub 1026) in pursuit of a lower rate for OL for municipalities, a customer-ownership option, and a mechanism for customers to take advantage of the declining cost of LED fixtures. In addition, NCLM argued that Duke be required to provide an LED street lighting schedule. The Commission included this requirement, that Duke file a new LED-based lighting tariff by December 31, 2013. Duke complied with revised outdoor lighting tariffs which added LED luminaires for new installations, LED luminaires for default replacement of mercury vapor luminaires, and transition options for customers who choose to install LEDs. Additional proposals to support the transition to LEDs were discussed at a joint August 2015 meeting held by Duke Energy and NCLM.[26]

Engage State Legislature

Given the energy savings associated with more efficient forms of outdoor lighting, some state legislatures have passed legislation making it easier for municipalities to pursue LED retrofits. States that passed enabling legislation have experienced the most municipal buybacks of street lights in the nation. Including a buyback calculation in the legislation plays a critical role in actual implementation of realizing such legislation. For instance, the state of Maryland has code provisions allowing for the purchase of street poles from electric utilities, but municipalities have largely been unsuccessful in pursuing purchases because of the definition around the buyback pricing is unclear.

- ***The Commonwealth of Massachusetts*** passed legislation in 1997 that required municipalities to have the right to purchase and own street lights. This legislation included a buy-back calculation that specified the price of new fixture-depreciation. As a result, more than 75 municipalities purchased their street lights and more than half of those have converted to LEDs, resulting in nearly 28,000 MWh of savings over a period of three years. Utilities Eversource and National Grid both offer rates that do not include maintenance costs for municipalities who own their street lights.[27]
- ***The State of Rhode Island*** enacted the Municipal Streetlights Investment Act in 2013, establishing formal procedures for municipalities to purchase their utility-owned outdoor lighting systems and directing electric distribution companies to file a tariff incorporating rates for customer-owned dimmable lighting. The subsequent Municipal Streetlight Tariff Program, giving municipalities the ability to purchase and maintain their street lights, was approved by the Rhode Island Public Utilities Commission in 2014 as a requirement of the Municipal Streetlight Investment Act.

  Currently, operations and maintenance costs are estimated to be $48 per year per fixture. Furthermore, the Partnership for Rhode Island Streetlight Maintenance (PRISM) has emerged and is offering municipalities who want to purchase their lights the opportunity to pool their maintenance service contracts for added buying power. A few municipalities have signed on and others are planning to contract for maintenance on their own.

The 2013 Act also required the utility to explore the idea of installing meters on utility-owned lights to more accurately measure consumption. A pilot program to test the meters' accuracy, functionality, and related processes is being negotiated between National Grid, stakeholders, and the PUC. The PUC must approve the final pilot proposal. In early 2015 the state has already recieved requests from 20 municipalities, representing about 65% of the 100,000 municipal lights in the state, asking for an inventory and purchase price. Energy savings for these conversions is expected to be at least 60% of current expenses. The money saved by each municipality depends on the number of conversions, but the City of Pawtucket, for example, who has 6,000 lights, expects to save about $500,000 in energy costs, along with significant maintenance costs.

- ***The State of Maine*** has a law that establishes a pathway for municipal buybacks. "An Act to Reduce Energy Costs, Increase Energy Efficiency, Promote Electric System Reliability and Protect the Environment" was enacted in 2013.[28] With regard to street lighting, Sec. E-1. 35-A MRSA §2523 speaks to ownership and maintenance, in addition to the transfer of ownership. Related dockets with Emera Maine and Central Maine Power are ongoing. Discussions continue between utilities and municipal advocacy groups, like the Municipal Street Lighting Group, around the valuation of assets—how to determine the cost of a sales price for street lights. Municipalities have the opportunity weigh in and monitor the Maine PUC's calendar of events and agendas.
- ***The State of Maryland*** introduced legislation in 2014 that would require utilities to offer options for local governments to transition to high efficiency street lights, including buy-back at a price equal to their cost minus depreciation. This legislation did not pass. However, there is Maryland legislative code that allows municipalities the ability to purchase street lights from the utility at a fair market value (Code of Maryland §1–1309, Local Government). Although this code allows for purchase of light poles by the municipality from electric companies, few municipalities have pursued this course of action.

Interventions

When new rates are introduced by a utility in a rate case before a PUC, municipalities may choose to intervene in the proceeding to better understand the rate assumptions. When a new tariff is approved, the rate can stay fixed for many years. Therefore, in situations where the LED rate appears to be disadvantageous compared to other outdoor lighting rates, it is important for the impacted municipalities to understand the assumptions involved in calculating the rate and determine if involvement in the proceedings could alter those assumptions.

- ***The Public Service Company of New Hampshire (PSNH)*** proposed an LED rate tariff that the City of Manchester found to be unfavorable. The city filed a request and was granted an intervention by the PUC to consider a redesign of the proposed tariff. The PSNH engaged the city and later changed the LED rate design by way of an amendment. In less than a year, PSNH reached a settlement with the city, its largest customer, with a decrease in the fixed monthly distribution charge from $8.50 to $3.30 per fixture and an increase in the distribution rate of $0.0139 to $0.0500 per watt. PSNH unbundled maintenance costs and the city assumed responsibility for city-owned street light maintenance in order to evaluate the true cost of service for LEDs. The net effect of the City of Manchester's intervention was a rate redesign resulting in a lower LED rate tariff for all customers. The city contracted with Siemens to implement a multi-phased LED conversion project for approximately 9,000 fixtures over the course of four months.[29]
- ***Huntington Beach, California*** is pursuing a city-wide transition to LED street lighting, including decorative lighting fixtures. The city's annual expenses are $1.8 million per year for energy and maintenance costs and rates are due to increase by 3.5% in July 2015. Huntington Beach is currently involved in a process to contest the Southern California Edison (SCE) proposed rate increase, as well as determine its basis for street lights valuation because the city would like to purchase 11,000 lights but questions the price. During the early project phases, Huntington Beach searched for a partner to assist them with addressing the service rate and asset valuation concerns with SCE. The city executed a letter of agreement with the City of Moreno Valley to intervene in the SCE rate design case. Additional cities joined

Huntington Beach and Moreno Valley to form an ad hoc group of local governments served by the SCE known as the Coalition for Affordable Streetlights (CASL). CASL members wanted SCE to offer "street light rates in line with actual costs, to improve its maintenance of street lights, and bring transparency to the street light ratemaking process." CASL was a co-intervener with the California City-County Street Light Association (CALSLA) which represents members across all of the state's IOUs.[30]

Third Party Advocacy

Advocacy groups and third party organizations working with multiple jurisdictions are providing insightful analysis and legal and regulatory support to municipalities on tariff issues. By forming an association or collaborative, municipalities benefit from having a central advocate to vocalize issues and pursue reform.

- ***The California Street Light Association (CALSLA)*** represents member municipalities before the California Public Utilities Commission (CPUC) in street light and traffic signal matters related to the public utility commission and the three major investor-owned utilities (IOU) in the state. CALSLA's members receive street light and traffic signal electric service from Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E). CALSLA provides rigorous analysis of technical, regulatory, and financial barriers in relevant proceedings. For example, CALSLA was engaged in reviewing and supporting PG&E's LED Street Light Program, in which there is no up-front cost to the customer, and only a small fee on the monthly bill to repay capital costs, resulting in a lower monthly utility bill for municipalities. CALSLA compared SCE's offerings to PG&E noting that SCE's main revenue source is the fixed charges (facilities or equipment costs), not energy costs, which gives municipalities much less incentive to transition to LED street lights. CALSLA is assisting the City of San Diego with its pursuit in a controls tariff to amend the SDG&E LED tariff. CALSLA has also been very involved with implementation strategies for AB719 which, required the CPUC to direct all IOUs in the state to offer an energy efficient street light program.[31] CALSLA continues to work on the issue of buybacks and other mechanisms that will enable cost-effective options for the transition to LED street lights, including efforts focused on SCE's buyback policy.

Street light buyback or purchasing options from the utility

A municipality's ownership of street lights can make the business case for LED exchanges more obvious because the required upfront capital costs will be associated with an asset owned by the municipality. Municipalities may also make different decisions from utilities on the types of fixtures needed, which can limit capital costs. Some cities are working with an energy service provider to broker a turnkey solution, including the buyback of the lighting fixtures, while others have purchased their systems independently. In any case, buybacks can be a lengthy process; for instance, in Massachusetts, buybacks have averaged six months, with a range of 90 days to two years.[32]

- ***Richmond, California*** implemented a multi-phased strategy to upgrade the city's entire street lighting system. The LED conversion covered an inventory of 7,500 street lights, 50% city-owned and 50% utility-owned. The city secured two California Energy Commission low interest loans for phases one and two. In the first phase, the city completed an LED demonstration project; in the second phase, the city converted all city-owned street lights to LEDs. The third phase of implementation covered utility-owned lights where a utility-owned tariff was not available from the provider, PG&E. The city and PG&E negotiated a plan to transition ownership to Richmond with a new tariff for service connection, pole arm, and bracket. PUC approval was required for this special tariff. The city purchased about 3,200 lights from PG&E at a cost of $50 per unit. The city needed to secure its own financing to purchase the new LED luminaires for phase three, and did this through a capital lease using a city-owned building as collateral. For the balance of about 500 street lights owned by PG&E, conversions have been completed via rate payer-funded programs where the rate payers gain some cost savings due to LED rate tariffs for utility-owned lights. Another benefit of this project resulted from the city using a grant to fund RichmondBUILD, a workforce training program, where students were hired by a third-party contractor to install the new LED fixtures. The total cost of the city's LED street light upgrade with the additional 2,000 lights it bought back from the utility, was $4,500,000 with an estimated savings of $200,000 in energy and $400,000 in maintenance per year. The city also saw improved street lighting with better illumination, resulting in additonal benefits like community satisfaction and sense of security.

Challenges Associated with Technology Changes and Options

LED street light performance has rapidly improved over the past few years and growing evidence indicates market acceptance and satisfaction with the current technology. Some university campus studies have confirmed what cities are experiencing, showing energy savings at 70% or more with lighting controls.[33] However, street light exchanges that are often considered "low-hanging fruit" are still difficult to achieve in some areas due to lack of confidence and experience with LED outdoor lighting technologies. Both utilities and government organizations have been hesitant to change to LED lighting due to lack of resources to investigate their reliability and performance concerns, as well as the rapidly changing technology. Key technology questions and strategies are discussed below.

Since LED is a newer technology, and has only been adopted at citywide scale during the past decade, could there be issues with reliability and performance?

Municipalities may lack the staff expertise or capacity to assess reliability and performance and will often take a conservative approach to ensure continued operations for this vital public service. In addition to ensuring public safety, cities are responsible to taxpayers for investing in technologies that perform as expected. If municipal staff does not have the necessary expertise to meet reliability concerns, the municipality can contract to a third party to handle the RFP luminaire specifications for appropriate lighting applications and confirm the RFP responds to the city's needs.

For a utility, if a new technology does not perform as expected, the utility is responsible for the costs associated with fixing the issue, and could be subject to fines from regulators or disallowed cost recovery. These considerations underscore the importance of investing in products that will perform reliably, which many utilities want to explore through pilots before expanding to a wider offering.

Is there a disadvantage to adopting LED technology now, given continued improvements in the technology, as well as future improvements in integrating sensors?

LED technology has improved dramatically over the past ten years, with enhanced manufacturing processes, materials delivering consistently high-quality light output by way of smaller components, and greater interoperability with other digital platforms, all of which significantly lowered the cost. Because LED retrofits require significant upfront cost and are estimated to have at least a ten-year lifespan, some organizations are hesitant to move forward with retrofits until the technology has reached market maturity. To overcome this concern, some cities have used a phased approach to their retrofits, and have been able to incorporate fixtures at a lower cost point in later phases. As noted in a January 2015 Northeast Energy Efficiency Partnership (NEEP) report, "LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic", both Seattle and Los Angeles have followed this approach and have experienced annual price drops in their associated fixtures (see Table 6).

Table 6: Example of LED Street Light Cost Reduction Over a 4-Year Period

	2009	2010	2011	2010	2013
Seattle (Purchases of 2,000+ Units)	$369	$288	$239	$204	$179
Los Angeles	$432	$298	$285	$245	$141

Although LED lighting will continue to experience innovations, the technology is now at a stage where it is cost competitive with other lighting options, and larger costs savings can be found in the potential for energy savings. The Energy Department expects that price reductions, which have followed a logarithmic curve, have begun to slow substantially and will be less significant than they have been in the past.

Technology Change Solution Pathways

The demonstration of LED technologies in pilot programs and use of model lighting specifications can mollify municipal and utility concerns regarding the adoption of LED street lights. Below are some examples of each approach.

Pilot and demonstration projects documenting technical performance

Through pilot demonstrations, utilities and cities are able to evaluate the performance of LED fixtures, often testing different wattages and fixtures, as well as survey customers on their perceptions of the changes. Furthermore, demonstration projects can uncover issues that may occur with weather conditions or unique features of the surrounding landscape. For example, an ongoing demonstration in Yuma, AZ, is finding some accelerated lumen depreciation effects that are likely to be ambient temperature related, though this is still under study.[34]

Cities and utilities will often test products from different vendors during a pilot process. Cities are also including wireless monitoring and controls systems in pilot projects, coupled with LED street light demonstrations or added on to previously installed lighting. This stems from their interest in maximizing savings, and the role of street lights as a broader integration node for wireless communications services.

- ***Las Vegas, Nevada*** conducted a pilot LED street light program using ARRA funds, testing 6,600 fixtures across all political wards for performance and public feedback. Projected savings expected to reduce the city's yearly electricity use by eight million kilowatt hours and save $400,000 per year in energy costs. After realizing better than expected savings, Las Vegas proceeded with full-scale replacements of over 42,000 fixtures at a replacement cost of $16.5 million and achieved $2 million in cost savings annually. The city is still testing and researching appropriate LED replacements for decorative and athletic field lighting.
- ***West St. Paul, Minnesota***, in partnership with Xcel Energy, is testing 500 lights of three different wattages in the residential and business districts of the city -measuring their electricity usage, light output, and brightness. West St. Paul's demonstration project has been highly successful, with documented energy savings and reduced service calls. Xcel Energy reported a range of 45-55% energy reduction with the use of LED lights compared to high pressure sodium (dependent on fixture installed). Given the successful outcome of the West St. Paul pilot, Xcel Energy filed an application with the Minnesota Public Service Commission in March 2015 to replace potentially up to 100,000 lights through out the state over the next five years.
- ***San Francisco Public Utilities Commission (SFPUC)*** completed a pilot project to evaluate three different proprietor LED street light wireless monitoring and controls systems in April 2014. SFPUC focused on studying the ability of these advanced controls systems to effectively manage and control street lights installed at three locations in San Francisco for a period of five months. The pilot project evaluated each suppliers' systems in terms of the installation process, central management system functionality and ease of use, and field performance. The project also looked at different approaches to using advanced street light controls for implementing adaptive lighting, which is the practice of varying the brightness of street lights to meet changing ambient conditions and activity levels. Finally, SFPUC conducted a public survey to evaluate resident response to LED street lights fitted with advanced wireless controls systems. The pilot evalution report identified the benefits of energy savings, enhanced maintenance through real-time status updates, and failure detection. As a result of the pilot project success and public acceptance, plans for citywide deployment include nearly 19,000 lights featuring wireless controls. The expected start date is September 2016.[35]

Model specifications

Model specifications can be customized to meet the needs of the organization seeking an LED retrofit. Using a model specification is critical to ensure that a municipality obtains the characteristics they need in a luminaire, helping address reliability and performance concerns. These include physical and durability aspects of the luminaire, such as the required level of ingress protection, corrosion resistance, and electrical immunity, as well as desired performance aspects like efficacy (lumens per watt), light distribution (e.g., backlight, uplight, and glare characteristics), and desired color temperature. Such specifications also need to be periodically updated to keep pace with relevant standards that are updated (e.g., ANSI C136.41-2014, Dimming Control Between an External Locking Type Photocontrol and Ballast or Driver,; or, ANSI C136.42 – SSL Cobra Head Retrofit Mechanical and Electrical Interchangeability). In addition, specifications should reflect any new recommendations issued for items such as dimming performance or dark skies compliance that a typical site may want to consider.

- ***Southern California Regional Network (SoCalREN)*** is an energy service collective authorized by the California Public Utility Commission (CPUC) to offer customized and energy project turnkey solutions in counties and cities in the SCE/SCG ("IOU") service territories. Available services include project management, energy use analysis, energy audits, technical review, utility on-bill-financing and incentive support, scope of work, expedited turnkey procurement, RFP bid support, financial advisory services, and construction management support. Their services, as an unbiased third-party, are customized for each project and agency. Lighting fixtures used in projects must be approved by a third party assessment body (Design Light Consortium) and the local investor-owned utility (Southern California Edison). For street lights specifically, SoCalREN uses the MSSLC's model specifications as a reference but leverages research and testing done by the City of Los Angeles and defaults to the city's approved fixtures.
- ***Portland, Oregon*** has roughly 55,100 street lights, approximately 49,000 of which are standard cobra head fixtures and 5,500 are post-top lights, the latter including a mix of historic ornamental and more modern versions that are primarily located downtown. Conversion is underway, with the cobra heads more than two-thirds completed and the post-tops next in the queue. Portland used the MSSLC Model Luminaire Specification for both sets of street lights. As is the case in many cities, post-top and decorative luminaires often involve older designs with historical significance. The MSSLC recently updated its Model Luminaire Specification (pending March 2016) to cover decorative lighting in order to help cities like Portland, OR, to address a niche application. According to the MSSLC, decorative lighting applications often call for use of a retrofit LED product that fits inside the existing fixture, rather than an integrated unit that replaces the entire assembly. Specifying appropriate retrofit products across sometimes multiple globe/fixture styles can present a number of challenges, such as achieving adequate thermal management and lumen distribution.
- ***Detroit, Michigan*** plans to complete a city-wide overhaul of its street lighting system of nearly current 88,000 lights, which have been redesigned and reduced to needing only approximately 65,000 lights by the end 2016. The Public Lighting Authority, created in 2013 by the State of Michigan to manage the operations and maintenance of all street and area lighting, relied on performance and photometric data before selecting a manufacturer and product. MSSLC specifications were modified to respond to criteria for different lighting illumination requirements and design guidelines, which include optics, controls, thermal conditions, and other design factor scenarios. The MSSLC specification includes scenarios that are used to represent the typical physical characteristics and performance requirements of a given luminaire's installation, and enable a respondent to an RFP to select the proper model(s) to include in their bid. The benefit to using a vetted specification framework like MSSLC is that it helps ensure that all essential product and performance elements are listed, making it easier for a municipality to specify requirements for its unique application(s).

Emerging Technology

As LED technology continues to evolve there are four major areas poised for growth and the potential to change the market further. These include: advanced metering infrastructure, networked outdoor lighting control systems, networked adaptive lighting, and sensor integration. A brief synopsis of each follows.

Advanced Metering Infrastructure (AMI)

As utilities begin to upgrade transmission and distribution systems, AMI meters or "smart meters" are being installed to provide more load management capabilities for electric service. Smart meters can also be installed on street and lighting systems to better monitor and accurately bill for service. To expand the smart metering concept, LED controls are being considered as a future addition to the luminaire. A control module will be on a chip that is located inside the luminaire, as that option will offer the cheapest first cost. Smart LED lighting technologies can "remotely control the LED lights to different modes for on, off, and dimming. The control module can also support color temperature mixing that enables LED lights to vary in color from warm light to cool light at different levels (will be commercially available as the market demands this functionality). In addition, the module supports mobile apps and cloud computing for remote control and monitoring of lighting over mobile devices."[36] Smart LED technology will also offer capabilities for monitoring various other sensors and cameras, that the municipality wants to attach to the pole. Smart LED lighting technologies afford municipalities the ability to install networked lighting systems with enhanced controls and the potential for additional energy cost savings.

Networked Outdoor Lighting Control Systems

In 2014, the U.S. DOE MSSCL released model specifications for Networked Outdoor Lighting Control Systems (formerly known as the Model Specification for Adaptive Control and Remote Monitoring of LED Roadway Luminaires) to assist municipalities with accelerating the adoption of systems that can further reduce the energy and maintenance costs of operating their streetlights. Best practices and verified energy and maintenance savings data are being gathered from multiple sources to increase confidence and provide "universally proven" information that many local governments rely on. The MSSLC's model specifications provides both a suggested set of high-level requirements and a template for translating unique user needs into clear and consistent specification language. The market for networked outdoor lighting technology and its commercial offerings are still in their infancy, however, and likely to evolve over time. The model specification is therefore likely to evolve to accommodate changes in the market.

Networked adaptive lighting

Large investor-owned utilities (IOUs) are considering incorporating networked lighting systems with smart grid projects. For a utility, network technology and software management programs create a platform for improved data exchange, including remote control and monitoring of light levels, fixture outages, and collaborative data services. For example, one company operating across Europe has recently expanded to at least four major utilities in the US: Florida Power & Light, ComEd, Baltimore Gas & Electric (BG&E), and Pepco.

Currently, there are not many examples of networked adaptive lighting in the U.S. market due to a number of barriers, such as a lack of guidance from the Illuminating Engineering Society (IES) which has its own review cycle for revising standards to minimize liability concerns. Municipalities typically adopt IES standards and technical recommendations.

- ***Cambridge, Massachusetts***, is one of a few U.S. cities that has piloted the use of adaptively controlled street lighting. The city is using dimming to compensate for lumen depreciation, and will also reduce illumination levels by 50% between specified hours. This reduction is predicated on a change of road classification due to decreased vehicle and pedestrian traffic, detailed in section 5.4 of the IES RP-8-14. Considering an average 12-hour light cycle, with illumination levels at 4 hours full and 8 hours at 50%, an additional 53% energy savings can be expected. A typical LED retrofit without adaptive controls would net about 33% energy savings. Therefore, the use of adaptive controls nets approximately a 75% reduction in energy over an LED system without controls. This is added to the 25-40% savings from the conversion of HPS to LED. Cambridge has reported a 75% initial energy savings over the previous HPS installation. This shows that adaptive controls and dimming will usually more than double energy savings by using existing recommended lighting practices.[37]

Sensors and integration to a broader node for cities

Sensors and controls integration into communication systems is a growing area of interest across municipalities. Cities and providers are still articulating the value proposition as the industry develops a global standard for information exchange between central management systems and outdoor lighting networks. These benefits will likely include financial and environmental benefits along with economic benefits from access to a broader communications network.

While recent market developments indicate future opportunities from added communications services like Wi-Fi hot spots; lighting and traffic signal controls; sensors monitoring air quality, transit flow, seismic activity; and EV charging stations, there are barriers in this emerging space (e.g., interoperability among components) that need to be addressed. Municipalities are cautious of current risks associated with investing in proprietary systems and components: these risks should decrease as ongoing industry consortia continue to migrate towards interoperability of components and software. In the meantime, testing and demonstration programs of smart cities are increasing and as cities begin to share research and results to support claims, other municipalities will follow with a degree of confidence in feasible energy and cost savings.

Endnotes

1. Industrial partners typically make a 25% commitment.1 2010 U.S. Lighting Market Characterization, Table 5.1 (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2010-lmc-final-jan-2012.pdf).
2. Correlated color temperature (CCT) indicates the warmth or coolness of a light's appearance . Light sources with a low CCT emit a warmer light that is more yellow or amber in appearance. Higher CCT values provide light with a cool white, or more bluish, appearance. Outdoor luminaires and lamps are available with CCTs ranging from about 2500 K to 6000 K.
3. Efficacy refers to the ratio of luminous output produced by a light source to power consumed by that source (lm / W). Color rendering index (CRI) is the current industry standard for measuring how accurately a light source renders the colors of the objects it illuminates when compared to a reference light source. The maximum CRI value is 100.
4. Adoption of Light-Emitting Diodes in Common Lighting Applications, revised May 2013. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led-adoption-report_2013.pdf and Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, August 2014. http://energy.gov/sites/prod/files/2015/05/f22/energysavingsforecast14.pdf
5. The EmPOWER Maryland Energy Efficiency Act Standard Report of 2014.
6. In some situations municipally owned is maintained by a contracted provider or the utility.
7. MSSLC conducted a voluntary, web-based inventory survey of 240 organizations, including 14 counties, 34 state departments of transportation (DOTs), 17 investor-owned utilities (IOUs), and 32 municipally-owned utilities (MOUs).
8. U.S. DOE SSL Program, Solid-State Lighting R&D Plan, May 2015. http://www.energy.gov/sites/prod/files/2015/06/f22/ssl_rd-plan_may2015_0.pdf
9. SSL Pricing and Efficacy Trend Analysis for Utility Program Planning. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_trend-analysis_2013.pdf
10. City of Los Angeles Department of Public Works Bureau of Street Lighting: http://bsl.lacity.org/downloads/led/LED_Energy_Savings_010215.pdf
11. A Municipal Guide for Converting to LED Street Lighting, http://www.leotek.com/education/documents/Leotek.LED.Streetlight.Guide.V7-101613.pdf
12. 26 CFR 1.118-2 - Contribution in aid of construction [Applicable to utility street light service in some states/utility service areas], https://www.law.cornell.edu/cfr/text/26/1.118-2
13. City of Dayton Street Light Special Assessment: http://www.cityofdayton.org/streetlights
14. City of San Jose streetlighting summary report. http://www.sanjoseca.gov/documentcenter/view/18941
15. 15 "Baker-Polito Administration Announces LED Conversion Project" http://www.mass.gov/governor/press-office/press-releases/fy2015/administration-announces-led-conversion-project.html
16. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/msslc_enews_jan2013.pdf and interview with Edward Smalley, Manager, Conservation Resources Division, 4/16/2015.
17. "Clinton Climate Initiative, LED Case Study, City of Los Angeles, March 2009." http://www.dvrpc.org/energyclimate/eetrafficstreetlighting/pdf/CCI_Los_Angeles_LED_Streetlighting_Retrofit_Program_Report.pdf
18. http://aceee.org/files/proceedings/2012/data/papers/0193-000190.pdf
19. http://www.consumersenergy.com/content.aspx?id=3768
20. http://www.ameresco.com/press/town-east-hartford-partners-ameresco-led-street-lights-and-exterior-lighting-espc-project
21. http://marc.org/Environment/Energy/pdf/Smart-Lights-Final-Report.aspx
22. Southeast Michigan Regional Energy Office report, Bright Lights, Bright Futures: Project Financing Options – in Draft
23. http://usdn.org/uploads/cms/documents/mi-led-streetlight-convening-report_final-01-27-14.pdf
24. Northeast Energy Efficiency Partnership's LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic report.
25. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/msslc-case-studies_webcast_05-08-2013.pdf; interviews with Maggie Ullman, former Sustainability Director in the City of Asheville, NC, and Kerby Smithson, Interim Sustainability Officer with the City of Asheville, NC, 4/16/2015.
26. Outdoor Lighting Discussion, Duke Energy & North Carolina League of Municipalities, August 11, 2015.
27. Enabling Legislation, Part I Administration of the Government/TitleXXII-Corporations, Chapter 164-Manufacturing and Sale of Gas and Electricity, Section 34, A-Municipal Street Lighting Service; https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXXII/Chapter164/Section34A
28. An Act To Reduce Energy Costs, Increase Energy Efficiency, Promote Electric System Reliability and Protect the Environment [PART E, Sec. E-1. 35-A MRSA §2523]. http://www.mainelegislature.org/legis/bills/bills_126th/billtexts/HP112801.asp
29. http://puc.nh.gov/Regulatory/Docketbk/2013/13-248/LETTERS-MEMOS-TARIFFS/13-248 2014-07-01 PSNH SETTLEMENT AGREEMENT.PDF
30. http://www.huntingtonbeachca.gov/files/users/city_clerk/Council-Minutes-Minutes-February-4-2013.pdf and interview with Antonia Castro-Graham, Energy & Sustainability Projects Manager, 3/18/201.
31. http://www.huntingtonbeachca.gov/files/users/city_clerk/Council-Minutes-Minutes-February-4-2013.pdf
32. http://www.mapc.org/system/files/bids/Buy%20Back%20Streetlights%20from%20Utility.pdf
33. SPEED Business Case: Adaptive Street and Area Lighting, June 2014. http://cltc.ucdavis.edu/sites/default/files/files/publication/FINAL_DRAFT_BC_Adaptive_Area_Lighting_140613.pdf
34. Yuma Border Patrol Area Lighting Retrofit Trial Demonstration, Final Report prepared in support of the U.S. DOE Solid-State Lighting Technology GATEWAY Program, December 2014 http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23724.pdf
35. Evaluation Report Wireless Control and Communication of LED Streetlights and Other Devices http://www.sfwater.org/modules/showdocument.aspx?documentid=5972
36. http://www.businesswire.com/news/home/20141119005048/en/Hodi-Technologies-Selects-Greenvity%E2%80%99s-Turnkey-IoT-Solution#.VR1htNLF-So
37. Interview with Bob Parks, 3/18/2015 and 4/16/2015. Cambridge Lighting Study Report, April 2010. http://www.cambridgema.gov/~/media/Files/CDD/Climate/lightingstudy/lighting_study_2010.ashx

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