Street Lighting Retrofit Projects:
Improving Performance, while Reducing Costs and Greenhouse Gas Emissions
Outdoor Lighting Program

EXECUTIVE SUMMARY

Street lighting can constitute a significant portion of a municipal government’s electricity costs and greenhouse gas emissions. The increasing concern about greenhouse gas emissions and the cost of energy is leading many municipalities to take measures to reduce emissions in cost-effective, practical ways. Retrofitting street lighting systems — replacing existing equipment with more efficient and functional new technology — presents a compelling opportunity for municipalities to reduce energy bills and maintenance costs, avoid greenhouse gas emissions, and enhance the overall performance and efficiency of their lighting systems.

Globally street lighting is believed to account for 159 TWh of electricity use per year, or more than the annual power produced by 36 power plants of 500 MW capacity. Reducing this consumption by 50 percent — an achievable goal — would eliminate almost 80 TWh of electricity consumption and over 40 M Tonnes of CO2 emissions annually.¹

New and emerging technologies have brought attention to retrofit projects, enabling municipalities to take action today and achieve the near-term benefits cited above.

This white paper examines the potential of energy-efficient street light retrofits in municipalities, and provides a blueprint for a successful retrofit program, using the experience of leading cities’ projects and the Clinton Climate Initiative’s (CCI) assessment of the market. While the white paper focuses primarily on municipalities, the opportunity to save money and reduce emissions can be realized by any owner of street lighting equipment. The cost savings and emissions avoided extend beyond street lighting as well: park lighting, pathway lighting, parking lot lighting and parking garage lighting can all be targeted using a similar strategy and technologies.

The following observations and project-planning recommendations are explored:

**Energy Use and Public Lighting**
Street lighting can represent from 5% to over 60% of a municipal government’s electric bill, depending on the municipality’s size, the services it offers, and the efficiency of its public lighting. By improving public lighting efficiency, many municipalities will be able to help meet their climate goals and cut their spending. Due to the typically centralized ownership structure of street lighting systems, many municipalities are able to act directly and swiftly.

**New Technologies Enable Retrofit Projects**
Emerging technologies such as light-emitting diodes (LEDs) and induction lighting, along with improved control and monitoring systems, have presented municipalities with an array of new options for high-quality cost-effective lighting. These technologies can offer superior efficiency and more appealing light than incumbent technologies such as mercury vapor and high-pressure sodium vapor (HPS). While these emerging technologies bear diverse benefits, it is critical that municipal governments take caution to select quality products given the market’s emerging state.

**The Retrofit Opportunity**
Intelligent planning and deployment of street lighting retrofit projects can enable municipalities and utilities to save money, reduce emissions, and improve the quality of street lighting today, even with the evolving product market and constrained municipal budgets. Projects can provide an attractive return on investment, with simple payback commonly achieved in seven to ten years and, in some cases, with a
positive project cash flow starting in Year 1. Recent and current projects in Anchorage, Alaska, and Los Angeles, California, demonstrate the efficacy of these projects. Yet adoption beyond these cities has been negligible.

**Barriers to Adoption**
The negligible adoption can be attributed to four key barriers:
- Concerns about the performance and reliability of new technologies
- Concerns about the performance and reliability of new equipment providers
- Product selection made difficult by rapid innovation
- Perceived scarcity of affordable and appropriate finance to cover projects with longer (6-10) year payback periods

Concerns about product and manufacturer performance and reliability can be mollified through reviewing best practices, stringent product evaluation, and comprehensive warranty terms. Rapid innovation can be addressed by continuously evaluating new products during a multi-year conversion project. Perceived scarcity of finance can be addressed through a variety of project finance options; these options are best explored in the context of a project cash flow analysis.

**Finance**
Project finance options that municipalities might consider include: government funds; utility company financing, rebates and incentives; internal municipal funds; debt arrangements; third party equity investments; and carbon financing.

**Retrofit Roadmap**
By following a series of recommended retrofit process steps, municipalities and utilities can mount successful retrofit projects that convert their street lighting systems to the new energy-efficient and cost-efficient technologies.

CCI is a program of the William J. Clinton Foundation, an international non-profit organization. Through the Outdoor Lighting Program, CCI aims to help cities around the world improve the energy efficiency of street light systems and reduce carbon emissions worldwide. CCI services available to municipalities and utilities include advising on project management, purchasing, financing, and technology. CCI works directly with cities to initiate new projects and to move existing projects forward more quickly and cost-effectively. Outdoor Lighting Program assistance to cities for street light projects will vary based on the city’s technical expertise, staffing and experience. (See Appendix A for additional information.)
INTRODUCTION

The confluence of rising energy prices and mounting concern over the adverse impacts of climate change has led municipal governments and utility companies to assess how they might reduce their greenhouse gas emissions in cost-effective and expedient ways. Indeed, many municipalities and utilities have pledged to markedly reduce their greenhouse gas emissions on aggressive time scales, necessitating significant measures to reduce emissions in order to meet those political and corporate commitments.

To date, these factors have motivated a few proactive municipalities and utilities to focus attention on their energy-intensive public lighting systems, where both new and existing technologies present opportunities to save energy. Through thoughtfully implemented retrofit projects, municipalities have found vastly enhanced performance, significant energy and other cost savings, and impressive greenhouse gas emission reductions. These municipalities and utilities have looked to broad-spectrum (white) light sources, including LED and induction, mated to novel control and monitoring systems.

Starting in September 2008, the first commercially viable LED lighting project for a roadway lighting application was deployed at scale by the City of Anchorage, Alaska. To date, 4,650 LED fixtures have been installed by the Anchorage Department of Public Works; energy use has dropped by 45% - 58%, according to measurements taken from metered circuits, surpassing the municipality’s initial projections. With uncommonly high electricity prices — 12 cents per kilowatt-hour — the municipality anticipates achieving a full payback in 6.5 years.

Shortly after Anchorage deployed its first fixtures, on February 16th, 2009, the City of Los Angeles, California, announced that over the next five years it would convert 140,000 of its residential street lights to LED. Through a deft act of foresight, the Los Angeles Mayor’s Office and the Bureau of Street Lighting — which manages the municipality’s 209,000-fixture public lighting system — avoided future budget shortfalls due to rising electricity prices by planning and implementing the retrofit project. Debt service today, they found, was less burdensome than energy costs tomorrow. The fixtures will reduce electricity use by greater than 50%; through energy savings, maintenance savings and a generous rebate provided by the Los Angeles Department of Water & Power — the municipally-owned utility company — the project is expected to achieve a simple payback in seven years.

Reduced energy bills and avoided greenhouse gas emissions are two incontestable benefits of these cities’ public lighting projects. But these are only two of the numerous benefits to municipalities when public lighting projects are well planned and use appropriate equipment. Other benefits include: reduced maintenance costs, decreased light pollution, decreased light trespass, and, most importantly, enhanced visibility and performance.

This white paper will review these benefits and explain how municipalities and utilities can achieve them. The paper first will consider the energy consumption and emissions of municipal public lighting. Next, it assesses the new fixture and controls technologies that make retrofit projects profitable today, while identifying obstacles to successful product selection such as concerns about product and manufacturer reliability, and rapid product innovation. It will then review various finance strategies that governments can utilize as potentially affordable sources of project finance. Finally, the white paper describes a process for retrofitting public lighting systems within current standards, in the near-term, to help municipalities and utilities seize a prodigious savings opportunity.

Energy Use of Public Lighting
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In a review of regional market assessments, CCI observes that public lighting consumes approximately 1.3% of E.U. and 0.9% of United States end-use electricity, accounting for 66,000,000 megawatt-hours of electricity use and 36,000,000 tons of CO₂e emissions. Extrapolating from these regional market assessments as well as UN data on public lighting energy use, CCI estimates that public lighting on a global scale consumes 159,000,000 megawatt-hours of electricity annually, generating 80,745,000 tons of CO₂e emissions.

Table 1.1: Street Lighting -- Annual Electricity Use and Emissions

<table>
<thead>
<tr>
<th>Region</th>
<th>Share of End-Use Electricity Consumed by Street Lighting</th>
<th>Magnitude of End-Use Electricity Consumed by Street Lighting</th>
<th>Estimated GHG Emissions from Street Lighting</th>
<th>Estimated Number of Street Lights Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe [EU-25]viii</td>
<td>1.3%</td>
<td>35 TWh</td>
<td>14 MT</td>
<td>56.2 million</td>
</tr>
<tr>
<td>United Statesix</td>
<td>0.9%</td>
<td>31 TWh</td>
<td>22 MT</td>
<td>37.9 million</td>
</tr>
<tr>
<td>Global</td>
<td>0.9%</td>
<td>159 TWh</td>
<td>81 MT</td>
<td>219.8 million</td>
</tr>
</tbody>
</table>

*1 TWh = 1,000,000 MWh; 1 MT = 1,000,000 tonnes

Taking 50% as a conservative present-day benchmark for energy savings potential, this suggests that in the United States and Europe alone, 33,000,000 megawatt-hours of electricity use and 18,000,000 tons of CO₂ emissions could be avoided annually through near-term intervention by street lighting equipment owners. Globally, 79,000,000 megawatt-hours of electricity use and 20,250,000 tons of CO₂ emissions could be avoided annually through near-term intervention.

Street lighting’s share of a municipal government’s electric bill ranges widely depending on the size of the municipality, the scope of services it offers, and the efficiency of its public lighting. For large municipalities with comprehensive municipal services including waste and wastewater treatment, public transit and more, street lighting can represent approximately 5% of the municipal government’s electric bill. For smaller municipalities with less comprehensive municipal services, street lighting can surpass 60% of the electric bill.

<table>
<thead>
<tr>
<th>City</th>
<th>Share of Municipal Government’s GHG Emissions from Street Lighting</th>
<th>Magnitude of Municipal Government’s GHG Emissions from Street Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York Cityxi</td>
<td>3.2%*</td>
<td>136,621 metric tons/year</td>
</tr>
<tr>
<td>Houstonxiii</td>
<td>4.5%</td>
<td>90,542 metric tons/year</td>
</tr>
<tr>
<td>Bostonxvii</td>
<td>17.8%</td>
<td>36,737 metric tons/year</td>
</tr>
<tr>
<td>Sydneyxv</td>
<td>37.0%</td>
<td>14,023 metric tons/year</td>
</tr>
<tr>
<td>Melbourne</td>
<td>53.1%</td>
<td>5,309 metric tons/year</td>
</tr>
</tbody>
</table>

*Includes Traffic Signals

Since many municipalities directly own and oversee operation of their public lighting systems, public lighting represents an asset with centralized ownership that can be strategically targeted by municipal governments to reduce municipal greenhouse gas emissions. Municipal governments can act directly and swiftly to reduce emissions and utility bills.

NEW TECHNOLOGIES ENABLE RETROFIT PROJECTS
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The recent, rapid development of solid-state lighting devices, chiefly light-emitting diodes (LEDs), for general illumination has substantially disrupted the traditional public lighting market, elevating the dialogue on whether new broad-spectrum light sources might be more effective, more aesthetically appealing, and safer alternatives to previous public lighting technologies. The emergence of LED street lighting has also renewed focus on another broad-spectrum light source — induction. Additionally, the arrival of better control and monitoring systems (CMS) allows municipalities to optimize their maintenance service and, in some scenarios, dim public lighting during late-night hours when vehicular and pedestrian traffic is low. Each of these technologies as well as the incumbent alternatives, principally mercury vapor and high-pressure sodium, will be considered below.

Before considering these new technologies, however, a review of the incumbent street lighting technologies is needed. The table below outlines various technologies currently used for street lighting. The data suggest that both lamp and fixture efficiency are critical drivers of potential energy savings, and new technologies can improve system efficiency. Under the heading Performance Profile, several parameters are considered. Typical Lamp Efficacy refers to the luminous efficacy — or lumens generated per watt of electricity — of various street light technologies. Typical Fixture Efficiency stipulates the efficiency with which street light fixtures direct lamp lumens toward the target surface, i.e. roadway or sidewalk. Typical Net Efficacy reflects the efficiency of the system, including lamp and fixture.

<table>
<thead>
<tr>
<th>% Market Share</th>
<th>Performance Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>United States</td>
</tr>
<tr>
<td>High-Pressure Sodium</td>
<td>59%</td>
</tr>
<tr>
<td>Low-Pressure Sodium</td>
<td>10%</td>
</tr>
<tr>
<td>Mercury Vapor</td>
<td>20%</td>
</tr>
<tr>
<td>Metal Halide**</td>
<td>5%</td>
</tr>
<tr>
<td>Compact Fluorescent</td>
<td>2%</td>
</tr>
<tr>
<td>Incandescent</td>
<td>4%</td>
</tr>
<tr>
<td>LED</td>
<td>0%</td>
</tr>
<tr>
<td>Induction</td>
<td>0%</td>
</tr>
</tbody>
</table>

*Dimmable ballasts or drivers are required for dimming functionality.

**Metal Halide excludes CosmoPolis system, which merits treatment separate from other Metal Halide products. See Appendix B for more information.

While the range of HPS lamp efficacy reaches up to 150 lumens per watt, most HPS lamps used for street lighting typically operate at a peak efficacy of 120 lumens per watt. When fixture efficiency is considered, this reduces the net efficacy for HPS street lighting to 54 lumens per watt — superior to mercury vapor lighting, but lower than LED or induction products with high fixture efficiencies. The wide range in LED net efficacy — from a poor 30 lumens per watt to an impressive 90 lumens per watt — reflects a lack of consistency in LED product quality across manufacturers. It is critical to identify reliable products by reviewing best practices from other cities.

Induction products with highly efficient fixture optics also can outperform incumbent technologies, as can CosmoPolis products with highly efficient fixtures. All products benefit incrementally from the utilization of electronic ballasts and CMS systems.

For additional analysis of incumbent and new technologies, refer to Appendix B.
RETROFIT OPPORTUNITIES AND CHALLENGES

Municipalities and utilities can save significant operating expenses and meaningfully reduce greenhouse gas emissions by implementing retrofit projects that enhance the quality of street lighting service. Such projects can be planned today, even with an evolving product market and a constrained project budget. When planned and deployed intelligently, street lighting retrofit projects can provide an attractive return on investment — simple payback is commonly achieved in seven to ten years. In some cases, such a project can be cash flow positive starting in Year 1.

Large, coordinated retrofit projects are far more economical than small-scale, piecemeal projects. Conversion through attrition leaves valuable energy savings on the table: 79% of a high-pressure sodium fixture’s life-cycle cost is electricity, with the remaining 21% being comprised of maintenance and installation costs.xxii

Example Projects

To demonstrate the efficacy of these projects, consider two examples of municipalities that have moved forward with large-scale retrofit projects in the past 18 months:

- **Anchorage, Alaska**, following a March 2008 pilot test comparing LED and induction fixtures with existing high-pressure sodium vapor fixtures, moved forward in September 2008 with a retrofit of 4,400 150W and 250W high-pressure sodium vapor fixtures on residential streets to 82W and 111W LED fixtures respectively. The project will achieve simple payback in seven years; the energy savings is 45% - 58%. Enabling its retrofit project, the City of Anchorage rewrote its municipal lighting ordinances to account for new luminaire classification system, BUG (Backlight, Uplight, Glare) ratings, per IESNA TM-15, and integrated a Lumen Effectiveness Multiplier (LEM) table to guide designers in the use of broad spectrum light sources. In the pilot test, Anchorage residents vastly preferred the broad spectrum LED and induction light to the narrow-spectrum high-pressure sodium light.xxii

- **Los Angeles, California**, after testing both LED and induction fixtures to replace high-pressure sodium vapor fixtures, began a retrofit of 140,000 residential street lights to LED technology during the next 5 years. The project will additionally equip every new fixture with a remote monitoring system, enabling two-way communication with fixtures to optimize maintenance delivery and verify energy savings. The project will, upon full implementation, reduce 68,640,000 kilowatt-hours per year of demand and avoid 40,500 tons of CO₂e emissions. The project will be financed through a rebate provided by the Los Angeles Department of Water and Power and a seven-year $40M loan at a rate of 5.25% — it will be repaid through energy and maintenance savings.xxiii

Finance

Overview

One of the most commonly cited obstacles to retrofit projects is finance: municipalities often have several projects competing for internal funds, may be restricted from increasing indebtedness or may not be aware of the range of external sources that may be available.
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No single silver bullet finance solution exists, yet there are a number of finance options that municipalities might consider. These options can, in some cases, stand alone or can also be blended together to create a financing plan for the project.

A broad outline of potential finance options is provided below; however, it is important to note that finance options may vary significantly by geography and according to project details.

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government</td>
<td>Stimulus funds, state/provincial programs, municipal programs</td>
</tr>
<tr>
<td>Utility Company</td>
<td>Utility-based rebates, incentives, and on-bill finance programs</td>
</tr>
<tr>
<td>Internal</td>
<td>Municipal government funds / budget allocations; could be structured as inter-city loan</td>
</tr>
<tr>
<td>Debt</td>
<td>Equipment Leases, including</td>
</tr>
<tr>
<td></td>
<td>• Capital Leases</td>
</tr>
<tr>
<td></td>
<td>• Operating Leases</td>
</tr>
<tr>
<td></td>
<td>• Tax-Exempt Lease Purchases (TELP)</td>
</tr>
<tr>
<td>Bonds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Tax-Exempt</td>
</tr>
<tr>
<td>Structured Finance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Medium-term structured loans from commercial banks or other third party financiers</td>
</tr>
<tr>
<td>Third Party Equity</td>
<td>Institutional Investors or Private Equity Funds looking for medium-term stable returns</td>
</tr>
<tr>
<td>Carbon Finance</td>
<td>Potential to fund a portion of the project with CERs or VERs via the technology provider or a Carbon Fund</td>
</tr>
</tbody>
</table>

Detailed information on each source of funding can be found in Appendix C.

Retrofit Roadmap

Anchorage and Los Angeles defined successful project plans on which other entities can build. By following several common retrofit process steps, municipalities and utilities can capitalize on significant energy and maintenance savings, while avoiding any missteps caused by a conversion to new technologies.

<table>
<thead>
<tr>
<th>Retrofit Roadmap</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>Activity</td>
</tr>
<tr>
<td>1</td>
<td>Define high-level project goals. Review these goals within the context of other municipal goals/priorities. Commit to timeline. Survey staff resources; if necessary, consider hiring a consultant who is experienced with street lighting improvement projects. Sample goals: reduce lighting-related costs, GHG emissions; improve visibility, safety; improve equity of municipal street lighting service.</td>
</tr>
<tr>
<td>2</td>
<td>Evaluate existing equipment, and define opportunities for system improvement.</td>
</tr>
<tr>
<td>3</td>
<td>Choose replacement fixture technologies to consider: LED, induction, etc. Choose control systems to consider: WiFi, PLC, etc. Review projects that have tested and deployed these technologies, and solicit their evaluation results, specifications, etc.</td>
</tr>
<tr>
<td>Timeline</td>
<td>2 weeks</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>4*</td>
<td>If no other municipalities’ test experiences can be leveraged, plan and deploy a small-scale pilot test to evaluate technologies selected in Step 3. Pilot tests should include objective and subjective evaluations. Utilize lighting engineers in objective evaluation; engage local residents in subjective evaluation. Develop streetlighting standards incorporating results of pilot tests.</td>
<td>3-6 months</td>
</tr>
<tr>
<td>5</td>
<td>Concurrent with Step 4, conduct detailed economic analysis to assess whether full-scale deployment is financially feasible. During economic analysis, conduct assessment of local finance options available to your municipality or utility.</td>
<td>3-6 months (concurrent)</td>
</tr>
<tr>
<td>6</td>
<td>With results from Steps 4 and 5, craft business case for full-scale implementation.</td>
<td>1 month</td>
</tr>
<tr>
<td>7</td>
<td>Navigate local approvals process; finalize finance plan.</td>
<td>1 month</td>
</tr>
</tbody>
</table>

*NOTE: if your municipality or utility has already begun or completed pilot testing, then you can proceed with drafting a detailed economic analysis and business case.*
APPENDIX A: The Clinton Climate Initiative

Climate change is a defining challenge of the 21st century. Unless we reduce greenhouse gas emissions drastically in the next 10 years, rising temperatures and changing weather patterns will have a devastating impact on our natural and economic systems. Our future depends on swift action with significant impact.

The William J. Clinton Foundation launched the Clinton Climate Initiative (CCI) to create and advance solutions to the core issues driving climate change. We take a holistic approach, addressing the major sources of greenhouse gas emissions and the people, policies, and practices that impact them. Working with governments and businesses around the world, CCI focuses on three strategic program areas: increasing energy efficiency in cities, catalyzing the large-scale supply of clean energy, and working to measure and value the carbon absorbed by forests.

CCI’s effectiveness draws from several core strengths.
- We operate at the nexus of business, politics, and environmental groups, where there is tremendous opportunity for bridging understanding.
- We take an analytical approach to complex problems and produce viable business solutions.
- We have global scale and reach, and the ability to convene leading experts from the private, public and academic sectors around ongoing partnerships or specific projects.

A large part of our work is aimed at helping governments turn pledges to reduce carbon emissions into action through replicable and scalable projects that can be tailored to local conditions. This approach is unique and serves several important functions, including demonstrating how targets can be met in practice, informing further policy decisions, and compressing the timeframe of achieving real emissions reductions. It is no longer an option to wait for an internationally agreed-upon roadmap before devising and implementing projects that could be delivered today.

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CCI helps cities around the world improve the energy efficiency of street and traffic light systems by advising on project management, purchasing, financing, and technology. CCI works directly with cities to initiate new projects and to move existing projects forward more quickly and cost-effectively. The core services of Technical Assistance, Financial Advisory, and Project Assistance are provided to CCI’s partners at no cost.
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APPENDIX B: Review of Technologies

Incumbent Technologies

This paper focuses on mercury vapor and high-pressure sodium — the two most abundant incumbent technologies — as well as the newer technologies, LED and induction.

Mercury Vapor

In 1938, the first mercury vapor (MV) lamps were used for street lighting applications. Mercury vapor lamps — a gas discharge light source — offer relatively long lamp life of up to 28,000 hours at a low initial cost. Unfortunately, these limited benefits come at the price of low lamp efficacy (<60 lumens/watt) and color rendition (CRI <60). In addition, light output over the life of lamp (lumen depreciation) is extremely poor resulting in lamps that use the same amount of energy for very little light output. For the past two decades, municipalities and utilities have regularly and successfully converted old mercury vapor street lights to high-pressure sodium street lights.

High-Pressure Sodium

High-pressure sodium (HPS) lamps were first commercialized in 1970; the technology was touted as an energy-efficient alternative to incandescent and mercury vapor lamps, the prevailing street lighting technologies. It delivered this value, doing so at a low initial cost and with a comparatively high lamp efficacy. The technology gradually achieved broad global market penetration through the 1970s and 1980s due to its relative energy efficiency and significant lumen output, in spite of low color rendition. Relative to LED and induction technologies, HPS offers shorter life, with rated lamp life of 20,000-24,000 hours.

A vast majority of municipalities and utilities still regard the familiar high-pressure sodium as the most inexpensive and energy-efficient lighting technology available. Some global lighting manufacturers reinforce this perception of high-pressure sodium and dismiss new technologies as ineffectual and with exaggerated claims.

The benefits of high-pressure sodium lamp efficacies of typically 70-120 lumen/watt are unfortunately diminished by their typical installation into cobrahead and shoebox street light fixtures that achieve only 40-50% optical efficiency, reducing net fixture efficacy to 35-60 lumens/watt. Further, relative to wider-spectrum light sources, the technology’s poor color rendition (CRI of 22) may compromise visibility and, according to some city residents, cast an aesthetically displeasing light onto city streets. When fixture efficacy and color of light are taken into consideration, high-pressure sodium looks less favorable.

New Technologies

Light-Emitting Diodes (LEDs)

An LED is a solid-state lighting device that generates a narrow band emission when direct current is applied. First developed by National Aeronautic and Space Agency (NASA) scientists in 1962, and initially utilized as indicator lights, LEDs have recently been used in general illumination applications, including street and area lighting, parking lot lighting, and parking garage lighting. When properly utilized in street lighting fixtures, LED technology offers potential advantages, including:
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- **Energy savings**, with potential for >50% savings over high-pressure sodium;
- **Long fixture life**, with fixtures rated at >50,000 hours operation until end-of-life, defined as less than 70% of original lumen output;
- **Instant on/off**;
- **Ability to integrate dynamic controls**;
- **Directional light emission** that allows, with the proper optics, highly efficient fixtures;
- **Improved color rendition**, often over 70 CRI; and,
- **Potential for enhanced visibility** due to its broader spectral distribution (white light).

However, while the LED device itself is rapidly evolving, the use of LEDs for the aforementioned applications is still relatively new — early adopters must therefore take precautions to ensure that they select quality products. xxv With some manufacturers making unrealistic claims about product quality and performance, the precautions must be even more deliberate. Critical technological pitfalls to beware of include:

- **Improper thermal management**, leading to undesirably high junction temperatures and driver operating temperatures that cause premature product failure;
- **Poorly binned LEDs**, causing poor color uniformity and, over time, color shift;
- **High blue light content** in higher color temperature products, raising environmental and aesthetic concerns;
- **Deficient fixture optics**, causing poor optical performance, including glare; and,
- **Variable fixture warranties**, potentially exposing early adopters to undue risk of failure.

These pitfalls can all be avoided through responsible project planning and specifications.

LED fixture efficacies have been improving and costs have been declining sharply. One multi-phase study in Oakland, California, found a 36% decrease in LED fixture cost over the course of 11 months, or one product generation. While prices will likely not fall at an equivalently steep rate in years to come, the decline will indeed continue, perhaps on the order of 5-15% per year. LED chip innovation and increased fixture manufacturing volume are the two most significant drivers of this cost decline. Volume purchasing is another driver for retrofit projects; 50 fixtures will be significantly more costly per unit than 5,000 fixtures.

Due to declining prices, a question about cost of delay becomes relevant: Could municipalities save more by delaying implementation for 1-2 years to allow prices to fall further? The economics of this decision will depend on each municipality, but analysis suggests that prices would need to fall nearly 15% annually for municipalities to recover the energy and maintenance savings lost by delay. Municipalities cannot recover the additional greenhouse gas emissions from a one-year delay, even if fixture efficiency improves by up to 15 percent during that time. xxvi

**Induction Lighting**

Induction lighting is an electrode-less fluorescent light source that, by exciting gas enclosed in the lamp via electromagnetic induction instead of a current applied through an electrode, reliably produces broad-spectrum light. Induction fixtures have been commercially available for over two decades; with a rated life of 100,000 hours, many induction light sources are still illuminating roadways after more than 10 years of operation xxvii. The benefits offered by induction technology are manifold and similar to many benefits of LED:
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- **Excellent energy savings**, frequently with >50% savings over high-pressure sodium vapor, and >70% savings over mercury vapor;
- **Long fixture life**, with fixtures rated at >100,000 hours operation until end-of-life, at which point 50% of fixtures are still in operation;
- **Instant on/off**;
- **Ability to integrate dynamic controls**;
- **Improved color rendition**, often over 70 CRI; and,
- **Potentially enhanced visibility** due to a broader spectral distribution.

As with LEDs, pitfalls exist for induction lighting as well:

- **Inadequate or improper thermal management**, leading to an undesirably high operating temperature in the generator that causes premature product failure; and,
- **Less-efficient fixture optics**, with poorer fixture efficiency than LED.

With effective project planning, these technology pitfalls can be overcome.

Unlike LED technology, induction technology has neared a plateau in fixture efficacy. Even so, decreases in cost with volume purchasing can be significant.

**Other Energy-Efficient Options**

LED and induction are by no means the best or only energy-efficient light sources that municipalities can use for retrofit projects. Another popular option, a new generation of high-efficacy ceramic metal halide product, CosmoPolis, has emerged as a viable, cost-effective alternative in the past five years.

Metal halide is another form of gas discharge light source that uses either a quartz (older) or ceramic (newer) arc tube containing mercury, argon and metal halides to generate broad-spectrum light. While older quartz and ceramic metal halide lamps offered shorter lamp life of 14,000 hours and lower lamp efficacies of 61 to 85 lumens per watt, the new generation of product can achieve lamp efficacies of up to 117 lumens per watt, with lamp life of 24,000 to 30,000 hours. Smaller lamps offer improved fixture optical efficiency, and electronic ballasts minimize ballast loss, preserving the high lamp efficacy. Savings over high-pressure sodium can span 30-50%, depending on the application. With integrated dynamic controls, the savings grow even larger. xxiii The technology is proprietary, limiting the pool of fixture suppliers.

**Control Systems**

While control technologies providing basic on/off functionality such as photocells and timers have long been available, two new classes of control systems have entered the outdoor lighting market in the past five years: dimming controls and on/off controls. Both control systems offer two-way communication with fixtures by radio frequency (RF), wireless mesh network (WiFi), existing power lines (PLC), or some combination of these channels. Control systems are compatible with many lighting technologies — high-pressure sodium vapor, ceramic metal halide, incandescent, induction and LED can all be dimmed with the appropriate system. However, some technologies lend themselves more naturally to dimming than others.
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In Europe, over 80,000 controllable fixtures have been deployed and are operating successfully today, allowing municipalities to monitor fixture performance in order to closely manage fixture outages and to dim fixtures during off-peak hours in accordance with CIE adaptive standards.

Standards

Presently two bodies are responsible for setting baseline roadway lighting standards internationally: the International Lighting Committee (CIE), and the Illuminating Engineering Society of North America (IESNA). CIE standards are more prevalent through Europe, Africa, the Middle East and Asia. IESNA-recommended practices are cited throughout North and South America. While this broad regional breakdown is somewhat representative, it is by no means precise. Individual nations, states and municipalities may craft from CIE or IESNA standards a modified set of standards all their own; others may adopt their own standards altogether.

Many municipalities are understandably cautious about deviating from local recommended practices for roadway lighting. However, a municipality can easily mitigate any liability risk stemming from the introduction of a new fixture technology or control system by developing its own specific municipal lighting code. Most standards today unfortunately do not capture the full benefit of broad-spectrum light for visibility. As a research consensus has begun to emerge around improved vision under broad-spectrum light — first for peripheral vision, more recently for foveal vision — CIE and IESNA are revising their standards to allow for the benefits of white light to be accounted for in lighting system designs. British Standards now require higher light levels on residential roadways when using narrow-spectrum fixtures like high-pressure sodium, than for broad-spectrum, fixtures like LED or induction.
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APPENDIX C: Detailed Review of Funding Sources

Government

Governments at the national, state/provincial and local level in many cases provide funding, often at low- or no-cost of capital, for energy saving projects through a variety of programs. No international compendium of government financing programs for energy efficiency projects currently exists. However, in the United States, the DSIRE database, available at www.desireusa.org, provides a comprehensive and searchable list of government and utility programs at the state and federal level.

Examples of government programs used to fund lighting retrofit projects include:

- **Energy Efficiency and Conservation Block Grant (EECBG),** a US federal program funded by the American Recovery and Reinvestment Act (ARRA), represents a source of flexible funds provided by the federal Department of Energy directly to municipalities of over 35,000 people. Municipalities can use these funds to pay down all or a portion of a street lighting retrofit project.

- **California Energy Commission’s Energy Conservation Assistance Account** revolving loan program and the **Ann Arbor Municipal Energy Fund** revolving loan program represent a state and local program, respectively, that offer municipalities undertaking energy saving lighting retrofit projects access to low- or no-cost loans. In California, the CEC loan program offers California municipalities 1% interest loans for terms of 15-years with a maximum of $3 million per loan. In Ann Arbor, Michigan, the Municipal Energy Fund revolving loan program provides municipal facilities with 0% interest financing for energy saving projects for up to 80% of the estimated energy savings.

**Utility Sources of Funds**

Utilities are another common source of finance for energy saving projects. Typically, utilities provide funding for energy efficiency projects, including outdoor lighting projects, in the form of rebates. For lighting retrofit projects, the rebates are often provided on the basis of kWh saved. For example, in Los Angeles the Los Angeles Department of Water and Power, the local utility, provided a rebate of $0.24 cents per kWh reduced by the municipality’s LED retrofit project. This provided financing for 29% of the total project cost.

Another type of utility financing, although less commonly available in large scale, is on-bill financing. On-bill financing programs are utility loan programs in which the borrower repays the cost of the project via a line item charge on their utility bill. In many cases the utility will provide funds at 0% interest rates. On-bill programs typically seek to ensure that the energy savings match or exceed the loan payments, with the overall effect of the utility bill dropping or remaining stable, energy prices being equal. On-bill programs are often used to finance energy efficiency building retrofit projects sponsored by small businesses, residential homeowners and municipalities. In some cases, they are also used to finance municipal street light retrofit projects. On-bill programs can be found throughout the US and in Canada.

**Internal Sources of Capital**

Internal sources of capital, when available, may represent the fastest and most cost effective way for a municipality to finance a project given that the funds may be deployed quickly, minimizing the cost of delay, and may often be deployed without financing or transaction costs. The strong and stable payback profile of these
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projects also provides a compelling argument when there is competition for internal funds. In the case of Los Angeles, the municipality chose to self-finance its LED retrofit project through internal structured loans and using funds provided by the municipally-owned utility, Los Angeles Department of Water and Power due to ease of execution and ability to structure the internal loan around the projected energy savings, thereby not constraining city resources. Furthermore, municipalities can achieve high returns on their investment in energy efficiency lighting retrofit projects, with energy savings produced by the project serving as the source of repayment. For instance, the Los Angeles LED retrofit project is projected to provide a 23.4% Internal Rate of Return over 10-years.

Debt

The ability of municipalities to borrow directly and the types of products that might be available may vary significantly across the globe. In the United States, municipalities typically have access to tax-exempt finance, which lowers the overall cost of borrowing. Tax-exempt sources of debt include:

- **Tax Exempt Lease Purchase (TELP)** agreements are a popular form of financing outdoor lighting projects. Under a TELP, a municipality purchases the equipment through scheduled lease payments to the lessor. TELPs are available in most states in the United States. TELPs are often treated as “off balance sheet” transactions given the presence of “non appropriations” or “abatement” language in the lease itself.
- **Bonds** may be issued by municipalities directly to finance energy efficiency projects either as stand alone projects or in conjunction with other capital improvements.

Structured Debt may provide medium-term debt, with amortization structured around timing of energy and other savings associated with the project. This may be tax-exempt or may be structured in other markets.

Third Party Equity

There is an emerging group of investors interested in placing equity in Energy Efficiency projects, recognizing potential for strong and solid returns on investment. Though nascent in its application to public lighting projects, this appears to be a growing area of promise. Equity investment may come in the form of direct upfront capital investment in the project for a portion of total project costs, deploying a shared savings model where the equity provider may also provide debt financing and receives both equity and debt returns on the project, or through structures involving direct third party ownership of the fixtures. In the latter case, the equity party would seek to maximize value of the lighting infrastructure assets by making energy efficiency improvements. Applicability and appropriateness of these and other equity options will vary from city to city depending on the ownership and maintenance structure currently in place and on the investment objectives of the city itself.

Carbon Finance

Carbon Finance has been explored extensively for larger projects in India and other locations where there is possibility to consolidate projects in multiple cities. Though the process has proven challenging, several firms continue to explore the possibility of carbon finance for public outdoor lighting projects on a programmatic basis.
Endnotes

i Assuming IEA 2007 global average emission factor of 0.5067 kg CO2/kWh.

ii For more information, see:
   - C40 Cities: http://www.c40cities.org/
   - US Conference of Mayors Climate Protection Agreement: http://www.usmayors.org/climateprotection/agreement.htm

iii Certain investor-owned and municipal utility companies — particularly those in California — have been highly supportive of new technologies. By providing rates and incentives for new street lighting technologies, they have empowered municipalities to pursue retrofit projects.
   - Pacific Gas & Electric has issued rates for LED equipment, and have been approved by the California Public Utilities Commission: http://www.pge.com/tariffs/tm2/pdf/ELEC_SCHDS_LS-2.pdf
   - Pacific Gas & Electric has also generated rebates for LED equipment installed by its customers: http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/ref/lighting/lightemittingdiodes/incentives/index.shtml

iv For more information, see project press release: http://www.muni.org/Departments/Mayor/PressReleases/Pages/CITYINSTALLSFIRSTOF16,000LEDSTREETLIGHTS.aspx

v For more information, see CCI Los Angeles LED Retrofit Program Report

vi For more information, see Anchorage analysis conducted by Dr. Ron Gibbons, Virginia Tech Transportation Institute: http://www.vtti.vt.edu/PDF/TRBVS_presentations/Gibbons_Visibility%20Performance%20Under%20New%20Lighting%20Technologies.pdf

vii Assuming EU 2007 emission factor of 0.410 kg CO2/kWh (Eurelectric 2007 – PRIMES Model), and U.S. emission factor of 0.718 kg CO2/kWh (US EPA – eGRID2007 Model).


x Cite a few cities here

xi Emissions from street lighting are calculated based on the electricity use of equipment; the contribution of maintenance to emissions — and specifically maintenance truck operation — is not considered here. Due to the longevity of LED and induction fixture technologies, as well as control systems, maintenance-associated emissions should fall as well.


xvi Data for street lighting market share are aggregated from market reports prepared for the United States Department of Energy and the European Commission. These data reflect the existing installed base of street lighting equipment


xxii For more information, see Anchorage analysis conducted by Dr. Ron Gibbons, Virginia Tech Transportation Institute: http://www.vtti.vt.edu/PDF/TRBVS_presentations/Gibbons_Visibility%20Performance%20Under%20New%20Lighting%20Technologies.pdf

xxiii For more information, see Los Angeles Bureau of Street Lighting website: http://www.lacity.org/BSL/


xxv For more information, see following site: http://www1.eere.energy.gov/buildings/ssl/outdoor.html

http://www1.eere.energy.gov/buildings/ssl/outdoor.html

xxvi Assuming a ten year project period.
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For more information, see Philips case study on the San Diego Gas Lamp Quarter:

For more information on CMH, see various sources:
- http://www.iclei.org/index.php?id=6624#c27565
- http://www.maygurney.co.uk/customers/14.html

For more information on intelligent controls, see E-Streetlight project site:

Such a process of revisiting and revising municipal lighting codes has been undertaken in 2008 by Anchorage, Alaska; and in 2009 in San Diego and San Jose, California.

See CIE TC 1-58 “Visual Performance in the Mesopic Range” and IESNA TM-12 Spectral Effects of Lighting on Visual Performance at Mesopic Light Levels

For more information, see: www.energy.ca.gov/efficiency/financing/index.html#amounts

For more information, see:
www.a2gov.org/government/publicservices/systems_planning/energy/Pages/EnergyFund.aspx

For a comprehensive review of on-bill programs, see: Brown, Matthew, “Brief #3: Paying for Energy Upgrades Through Utility Bills,” Alliance to Save Energy: http://ase.org/content/article/detail/5476