CLINTON FOUNDATION

CLINTON CLIMATE INITIATIVE

STREET LIGHTING RETROFIT PROJECTS:

IMPROVING PERFORMANCE WHILE REDUCING COSTS AND GREENHOUSE GAS EMISSIONS

JUNE 2010

CLINTON CLIMATE INITIATIVE, 383 DORCHESTER AVENUE, SUITE 400, BOSTON, MA 02127 USA
www.clintonfoundation.org/cci

EXECUTIVE SUMMARY

Street lighting can constitute a significant portion of a city government's electricity costs and greenhouse gas emissions. As concern about greenhouse gas emissions and the cost of energy increases among cities, the Clinton Climate Initiative (CCI) offers a range of programs and services that reduce municipal emissions in cost-effective, practical ways. Retrofitting street lighting systems — replacing existing equipment with more efficient and functional new technology — not only lowers greenhouse gas emissions but also presents a compelling economic opportunity for cities. By enhancing the performance of street lighting systems through retrofits, cities can reduce energy bills and maintenance costs significantly.

Globally, street lighting is believed to account for 159 terawatt hours (TWh) of electricity use per year, or more than the annual power produced by 36 power plants of 500-megawatt (MW) capacity. Reducing this consumption by 50 percent – an achievable goal – would eliminate almost 80 TWh of electricity consumption and over 40 million metric tons of carbon dioxide (CO_2) – the most prevalent greenhouse gas – emissions annually.[i]

New and emerging technologies have brought attention to retrofit projects, enabling cities to take action today and achieve near-term energy-efficiency, cost, and performance benefits.

This white paper examines the potential of energy-efficient streetlight retrofits in cities, and provides a blueprint for a successful retrofit program, using the experience of leading urban projects and the CCI assessment of the market. While the paper focuses primarily on cities, 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.

In this white paper, the following observations and project-planning recommendations are explored:

ENERGY USE OF STREET LIGHTING

Street lighting can represent from 5 percent to more than 60 percent of a city government's electricity bill, depending on the city's size, the services it offers, and the efficiency of its street lighting system. An improvement in street lighting efficiency will be a critical step for many cities toward meeting their climate goals and reducing government spending. Due to the typically centralized ownership structure of street lighting systems, many cities are able to act directly and swiftly.

ADVANCED TECHNOLOGIES ENABLE RETROFIT PROJECTS

Advanced technologies, such as light-emitting diodes (LEDs), induction lighting, and some ceramic metal halide lighting, along with improved control and monitoring systems, present cities with an array of high-quality cost-effective options.[ii] These technologies can offer superior efficiency and more appealing light than incumbent technologies such as mercury vapor and high-pressure sodium vapor. While these advanced technologies yield diverse benefits, it is critical that city governments take caution to select quality products.

RETROFIT OPPORTUNITIES AND CHALLENGES

Intelligent planning and deployment of street lighting retrofit projects can enable cities 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 10 years and, in some cases, with a positive project cash flow starting in the first year. Recent and current projects in Anchorage, Alaska, and Los Angeles, California, demonstrate the efficacy of lighting retrofits, yet are among only a handful of examples worldwide.

Cities' negligible adoption of new lighting technologies 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 (six to 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

How cities finance projects depends on their needs and priorities. Options that cities 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, cities can mount successful retrofit projects that convert their street lighting systems to the new energy-efficient and cost-efficient technologies.

The Clinton Climate Initiative (CCI) is a program of the William J. Clinton Foundation, an international nonprofit organization. Through the Outdoor Lighting Program, CCI aims to help cities around the world improve the energy efficiency of street lighting systems and reduce the greenhouse gas emissions these systems produce. Services made available to cities 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 streetlight 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 prompted cities to assess how they might reduce their greenhouse gas emissions in cost-effective and expedient ways. Indeed, many cities have pledged to reduce greenhouse gas emissions markedly and on aggressive time scales; now they must act to meet these commitments.[iii]

To date, a few proactive cities have focused on their street lighting systems, where both new and existing technologies present opportunities to save energy.[iv] Through thoughtfully implemented retrofit projects, cities have found vastly enhanced performance, significant energy and other cost savings, and impressive greenhouse gas emission reductions. These cities have looked to broad-spectrum (white) light sources, including LED and induction, paired with 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.[v] To date, 4,650 LED fixtures have been installed by the Anchorage Department of Public Works; energy use has dropped by 45-58 percent, according to measurements taken from metered circuits, surpassing the city's initial projections. With high electricity prices – 12 cents per kilowatt-hour (kWh) – the city anticipates achieving a full payback in six and a half years.

Shortly after Anchorage deployed its first fixtures, in February 2009, the City of Los Angeles, California, decided to convert 140,000 of its residential streetlights to LED, in a CCI-supported project that is being carried out over five years. By planning and implementing the retrofit project, the Los Angeles Mayor's Office and the Bureau of Street Lighting – which manages the city's 209,000-fixture public lighting system – avoided future budget shortfalls due to rising electricity prices. Debt service today, they found, was less burdensome than energy costs tomorrow. The fixtures will reduce electricity use by greater than 50 percent; 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.[vi]

Reduced energy bills and avoided greenhouse gas emissions are two incontrovertible benefits of these cities' street lighting projects. But these are only two of the numerous benefits to cities when street lighting projects are well-planned and use appropriate equipment. Other benefits include: reduced maintenance costs, decreased light pollution, decreased light trespass, and, most importantly for the safety of residents, enhanced visibility and performance.[vii]

This white paper will review these benefits and explain how cities can achieve them. The paper will first consider the energy consumption and emissions of municipal street lighting. Next, it assesses the new fixture and controls technologies that make retrofit projects profitable today, while identifying how to overcome obstacles to successful product selection. It will then review project finance strategies, as well as available sources of funding. Finally, the paper describes a process for retrofitting street lighting systems within current standards to help cities seize a savings opportunity in the near-term.

ENERGY USE OF STREET LIGHTING

In a review of regional market assessments, CCI observes that street lighting consumes approximately 1.3 percent of European Union and 0.9 percent of United States end-use electricity, accounting for 66,000,000 megawatt-hours (MWh) of electricity use and 36,000,000 tons of carbon dioxide equivalent (CO_2e) emissions collectively.[viii]

Extrapolating from these regional market assessments as well as United Nations data on street lighting energy use, CCI estimates that public lighting on a global scale consumes 159,000,000 MWh of electricity annually, generating 80,745,000 tons of CO_2e emissions.

Taking 50 percent as a conservative present-day benchmark for energy savings potential,[xi] this suggests that in the United States and Europe alone, 33,000,000 MWh of electricity use and 18,000,000 tons of CO_2 emissions could be avoided annually through near-term intervention by street lighting equipment owners.[xii] Globally, 79,000,000 MWh of electricity use and 40,500,000 tons of CO_2 emissions could be avoided annually through near-term intervention.

Table 1: Street Lighting - Annual Electricity Use and Emissions

Region	Share of end-use electricity consumed by street lighting	Magnitude of end-use electricity consumed by street lighting	Estimated ghg* emissions from street lighting	Estimated number of streetlights installed
Europe [EU-25][ix]	1.3%	35 TWh**	14 MT***	56.2 million
United States[x]	0.9%	31 TWh	22 MT	37.9 million
Global	0.9%	159 TWh	81 MT	219.8 million

**GHG: greenhouse gas emissions **1TWh=1,000,000 MWh;*
**** MT= Megaton=1,000,000 metric tons*

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

Many cities own and operate their street lighting systems and therefore *can act directly and swiftly to implement a retrofit program that reduces emissions and utility bills.*

Table 2. Greenhouse Gas Emissions from City Street Lighting

City	Share of City Government's GHG* Emissions from Street Lighting	Magnitude of City Government's GHG Emissions from Street Lighting
New York City [xiii]	3.2%**	136,621 metric tons/year
Houston [xiv]	4.5%	90,542 metric tons/year
Boston [xv]	17.8%	36,737 metric tons/year
Sydney [xvi]	37.0%	14,023 metric tons/year
Melbourne [xvii]	53.1%	5,309 metric tons/year

** GHG: greenhouse gas emissions **Includes traffic signals*

ADVANCED TECHNOLOGIES ENABLE RETROFIT PROJECTS

The recent, rapid development of solid-state lighting devices, chiefly LEDs, for general illumination has substantially disrupted the traditional street lighting market, elevating the dialogue on whether new broad-spectrum light sources might be more effective, more aesthetically appealing, and safer alternatives to previous street lighting technologies. The emergence of LED street lighting has also renewed focus on another broad-spectrum light source – induction. Complementing these technologies is a new generation of ceramic metal halide lighting, a broad-spectrum light source with long life and high efficiency. Additionally, new central management systems (CMS) allow cities 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 advanced technologies will be considered, alongside their incumbent alternatives. Table 3 outlines various technologies currently used for street lighting.[xviii] 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 (lm/w) – of various streetlight technologies. "Typical Fixture Efficiency" stipulates the efficiency with which streetlight fixtures direct lamp lumens toward the target surface, that is, a roadway or sidewalk. "Typical Net Efficacy" reflects the efficiency of the system, including lamp and fixture. The data reflect a range of performance, demonstrating a considerable variance in the quality of products for each technology. The upper limit of each technology range represents the best products available.

Table 3: Market Share and Performance of Street Lighting Technologies

	% Market Share		Performance Profile				
	United States[xix]	Europe (EU-25)[xx]	Typical Lamp Efficacy (lm/w)	Typical Fixture Efficiency	Typical Net Efficacy (lm/w)	Currently Dimmable with CMS[1]	Net Efficacy Improvement
High-pressure Sodium	59%	47%	70 - 150	45%	32 - 68	Yes	No
Low-pressure Sodium	10%	9%	68 - 177	25%	17 - 44	No	No
Mercury Vapor	20%	32%	34 - 58	30%	10 - 17	No	No
Metal Halide[2]	5%	3%	61 - 85	35 - 40%	21 - 34	Yes	No
Compact Fluorescent	2%	8%	50 - 70	60%	30 - 42	Yes	No
Incandescent	4%	0%	10 - 17	60%	6 - 10	Yes	No
LED	0%	0%	50 - 100	60 - 90%	30 - 90	Yes	Yes, rapid
Induction	0%	0%	60 - 80	60 - 80%	36 - 64	Yes	Yes, limited
HE Ceramic Metal Halide[3]	0%	0%	95 - 120	60 - 80%	57 - 96	Yes	Yes, limited

Data for high-pressure sodium, low-pressure sodium, mercury vapor and MH Performance from Eurelectric 2004,[xxi] Fluorescent and incandescent data from US DOE and Efficiency Vermont.[xxii]

[1] Dimmable ballasts or drivers are required for dimming functionality.

[2] "Metal Halide" excludes CosmoPolis system, which merits treatment separate from other metal halide products.

[3] "HE (High-Efficacy) Ceramic Metal Halide" refers to new, highly efficient ceramic metal halide CosmoPolis system.

Although the range of high-pressure sodium lamp efficacy reaches up to 150 lm/w, most high-pressure sodium lamps used for street lighting operate at a peak efficacy of 120 lm/w. When fixture efficiency is considered, this reduces the net efficacy for high-pressure sodium street lighting to 54 lm/w – superior to mercury vapor lighting, but lower than LED, induction, or high-efficacy ceramic metal halide products with high fixture efficiencies.

The wide range in LED net efficacy – from a poor 30 lm/w to an impressive 90 lm/w – 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 use of electronic ballasts and CMS systems.

Over-lighting of streets to levels that are considerably higher than the required minimum standards is common by municipal governments. Most choose to do so in order to promote safety and improve visibility – the core functions of a public lighting system. When utilizing broad-spectrum light sources like LED, induction, or HE Ceramic Metal Halide, many municipal governments have found they can reduce light levels and still meet their safety and visibility requirements thanks to the brighter appearance and potential for enhanced visual performance under the broad-spectrum light.[xxiii]

For additional analysis of incumbent and new technologies, refer to Appendix B.

RETROFIT OPPORTUNITIES AND CHALLENGES

Cities can significantly lower 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 10 years. In some cases, such a project can be cash-flow positive starting in the first year.

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

EXAMPLE PROJECTS

To demonstrate the efficacy of these projects, consider two examples of cities 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 fixtures on residential streets to 82W and 111W LED fixtures, respectively. The project will achieve simple payback in 6.5 years; the energy savings is 45-58 percent. Enabling its retrofit project, the City of Anchorage rewrote its municipal lighting ordinance to account for a new luminaire classification system; backlight, uplight, glare (BUG) ratings, per IESNA TM-15-07; 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.[xxv]
- **Los Angeles, California,** after testing both LED and induction fixtures to replace high-pressure sodium fixtures, began a retrofit of 140,000 residential streetlights to LED technology to take place over the next five 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 kWh per year of electricity demand and avoid 40,500 tons of CO_2e emissions. The project will be financed through a rebate provided by the Los Angeles Department of Water and Power and a seven-year $40 million loan at an interest rate of 5.25 percent; it will be repaid through energy and maintenance savings.[xxvi]

FINANCE

One of the most commonly cited obstacles to retrofit projects is finance: cities often have several projects competing for internal funds; they may be restricted from increasing indebtedness; or they may not be aware of the range of external funding sources that may be available.

No single, all-purpose 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.

Table 4 provides a broad outline of potential finance options; however, it is important to note that finance options may vary significantly by geography and according to project details. Detailed information on each source of funding can be found in Appendix C.

Table 4: Finance Options for Building Retrofits

Source	Description
Government	Stimulus funds, state/provincial programs, municipal programs
Utility Company	Utility-based rebates, incentives, and on-bill finance programs
Internal	Municipal government funds/budget allocations; could be structured as inter-city loan
Debt	Equipment leases, including: • Capital leases • Operating leases • Tax-exempt lease purchases (TELP) Bonds • Tax-exempt Structured finance • Medium-term structured loans from commercial banks or other third party financiers
Third Party Equity	Institutional investors or private equity funds looking for medium-term stable returns
Carbon Finance	Potential to fund a portion of the project with carbon credits via the technology provider or a carbon fund.

RETROFIT ROADMAP

Anchorage and Los Angeles defined successful project plans on which other entities can build. By following several common retrofit process steps, detailed in Table 5, cities can capitalize on significant energy and maintenance savings, while avoiding any missteps caused by a conversion to new technologies.

Table 5: Retrofit Roadmap

Step	Activity	Timeline
1	Define high-level project goals. Review these goals within the context of other municipal goals and 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.	2 weeks
2	Evaluate existing equipment and define opportunities for system improvement.	2 weeks
3	Choose replacement fixture technologies to consider: for example, LED and induction. Choose control systems to consider: for example, wireless network or power line carrier (PLC). Review projects that have tested and deployed these technologies, and solicit their evaluation results and specifications.	2 weeks
4*	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 street lighting standards incorporating results of pilot tests.	3-6 months
5	Concurrent with Step 4, conduct detailed economic analysis to assess whether full-scale deployment is financially feasible. During economic analysis, conduct an assessment of local finance options available to your municipality or utility.	3-6 months (concurrent)
6	With results from Steps 4 and 5, craft a business case for full-scale implementation.	1 month
7	Navigate local approvals process; finalize the finance plan.	1 month

**Note: If the city or utility has already begun or completed pilot testing, it can proceed directly to step 5 and 6, drafting a detailed economic analysis and business case.*

APPENDIX A: THE CLINTON CLIMATE INITIATIVE

The William J. Clinton Foundation launched the Clinton Climate Initiative (CCI) to create and advance solutions to the core issues driving climate change. CCI takes a holistic approach, addressing the major sources of greenhouse gas emissions and the people, policies, and practices that affect 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:

- CCI operates at the nexus of business, politics, and environmental groups, where there is tremendous opportunity for bridging understanding
- CCI takes an analytical approach to complex problems and produces viable business solutions
- CCI has global scale and reach as well as the ability to convene leading experts from the private, public, and academic sectors around ongoing partnerships or specific projects

A large part of CCI's 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.

OUTDOOR LIGHTING PROGRAM

CCI helps cities around the world improve the energy efficiency of street and traffic lighting 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 advising and project assistance are provided to CCI's partners at no cost.

Technical Assistance

- Cost Analysis- detailed retrofit cost modeling
- Energy & GHG impact analyses
- Pilot test planning support
- Keen technology, market and product insight

Financial Advisory

- Project finance advisory services
- Lending institution introductions
- Manufacturer introductions

Project Assistance

- Stakeholder engagement
- Stakeholder coordination
- Project coordination

APPENDIX B: REVIEW OF TECHNOLOGIES

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

INCUMBENT TECHNOLOGIES

MERCURY VAPOR

In 1938, the first mercury vapor 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 (less than 60 lm/w) and color rendition (CRI less than 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 streetlights to high-pressure sodium streetlights.

HIGH-PRESSURE SODIUM

High-pressure sodium 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 advanced technologies, high-pressure sodium offers shorter life, with rated lamp life of 20,000-24,000 hours.

A vast majority of cities 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 70-150 lm/w are unfortunately diminished by their typical installation into cobrahead and shoebox streetlight fixtures that achieve only 40-50 percent optical efficiency, reducing net fixture efficacy to 35-68lm/w.[xxvii] 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.

ADVANCED TECHNOLOGIES

LIGHT-EMITTING DIODES

A light-emitting diode (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 and signals, 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:

- **Energy savings,** with potential for 50 percent savings over high-pressure sodium
- **Long fixture life,** with fixtures rated at greater than 50,000 hours operation until end-of-life, defined as less than 70 percent 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
- **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.[xxviii] 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 [xxix]
- **Deficient fixture optics,** causing poor optical performance, including glare
- **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 percent 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 percent 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 one to two 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 percent 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.[xxx]

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 more than 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.[xxxi] The benefits offered by induction technology are manifold and similar to many benefits of LED:

- **Excellent energy savings,** frequently with 40 percent savings over high-pressure sodium vapor, and more than 60 percent savings over mercury vapor
- **Long fixture life,** with fixtures rated at more than 100,000 hours operation until end-of-life, at which point 50 percent of fixtures are still in operation
- **Instant on/off**
- **Ability to integrate dynamic controls**
- **Improved color rendition,** often over 70 CRI
- **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
- **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.

HIGH-EFFICACY CERAMIC METAL HALIDE

Another popular option, a new generation of high-efficacy ceramic metal halide product called CosmoPolis, has emerged as a viable, cost-effective alternative in the past five years. Traditional metal halide is a gas discharge light source that generates broad-spectrum light using either a quartz (older) or ceramic (newer) arc tube containing mercury, argon, and metal halides. Older quartz and ceramic metal halide lamps offered shorter lamp life of 14,000 hours and lower lamp efficacies of 61 to 85 lm/w; the new CosmoPolis equipment can achieve lamp efficacies of up to 120lm/w, with lamp life of 24,000 to 30,000 hours. The 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 20-40 percent, depending on the application. With integrated dynamic controls, the savings grow even larger.[xxxii] The technology is proprietary, limiting the pool of fixture suppliers.

The benefits of high-efficacy ceramic metal halide include:

- **Excellent energy savings,** with 20-40 percent savings over high-pressure sodium, and more than 60 percent savings over mercury vapor
- **Compact lamp and gear,** allowing for highly efficient fixture optics
- **Ability to integrate dynamic controls**
- **Improved color rendition,** over 60 CRI
- **Potential for enhanced visibility** due to white light

One drawback of this system, relative to other white light sources, is:

- **Poorer lamp life** than LED or induction at 24,000 to 30,000 hours.[xxxiii]

As with LED and induction, decreases in cost with volume purchasing can be significant.

CONTROLS AND CENTRAL MANAGEMENT SYSTEMS

While control technologies providing basic on/off functionality such as photocells and timers have long been available, a new approach to controls has developed the outdoor lighting market in the past five years: central management systems (CMS) that from a central terminal offer remote monitoring of equipment, allow remote on/off control, and can provide step dimming or continuous dimming of light fixtures. CMS offer two-way communication with fixtures by radio frequency (RF), wireless mesh network, existing power lines, or some combination of these channels. CMS technology is 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.

In Europe, more than 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 International Lighting Committee adaptive standards.[xxxiv]

STANDARDS

Presently, two bodies are responsible for setting baseline street lighting standards internationally: the International Lighting Committee (CIE) and the Illuminating Engineering Society of North America (IESNA). CIE standards are more prevalent throughout 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 cities may craft from CIE or IESNA standards a modified set of standards all their own; others may adopt their own standards altogether.

Many cities are understandably cautious about deviating from local recommended practices for street lighting. However, a city 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.[xxxv]

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.[xxxvi] 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.

APPENDIX C: DETAILED REVIEW OF FUNDING SOURCES

GOVERNMENT

Governments at the national, state/provincial, and local levels 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 Database of State Incentives for Renewables & Efficiency(DSIRE), available at www.dsireusa.org, provides a comprehensive and searchable list of government and utility programs at the state and federal levels.

Examples of government programs that fund lighting retrofit projects include:

- **Energy Efficiency and Conservation Block Grant,** a U.S. federal program funded by the American Recovery and Reinvestment Act, represents a source of flexible funds provided by the federal Department of Energy directly to municipalities of more than 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 (CEC) Energy Conservation Assistance Account** revolving loan program and the Ann Arbor Municipal Energy Fund revolving loan program represent a state and local program, respectively, which offer cities undertaking energy-saving lighting retrofit projects access to low- or no-cost loans. In California, the CEC loan program offers cities 1 percent interest loans for terms of 15years with a maximum of $3 million per loan.[xxxvii] In Ann Arbor, Michigan, the Municipal Energy Fund revolving loan program provides municipal facilities with 0 percent interest financing for energy saving projects for up to 80 percent of the estimated energy savings.[xxxviii]

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, the Los Angeles Department of Water and Power, the local utility, provided a rebate of 24 cents per kWh reduced by the city's LED retrofit project. This provided financing for 29 percent 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 percent 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 cities. In some cases, they are also used to finance municipal streetlight retrofit projects. On-bill programs can be found throughout the United States and in Canada.[xxxix]

INTERNAL SOURCES OF CAPITAL

Internal sources of capital, when available, may represent the fastest and most cost-effective way for a city to finance a project. Funds may be deployed quickly and without financing or transaction costs, helping cities to capture the energy cost savings as early as possible. The strong and stable payback profile of these projects also provides a compelling argument when there is competition for internal funds. In the case of Los Angeles, the city chose to self-finance its LED retrofit project through internally structured loans and by using funds provided by the municipally owned utility, Los Angeles Department of Water and Power. Los Angeles chose this method due to the ease of execution and the ability to structure the internal loan around the projected energy savings, thereby not constraining city resources. Furthermore, cities 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 percent internal rate of return over 10 years.

DEBT

The ability of cities to borrow directly and the types of products that might be available may vary significantly across the globe. In the United States, cities 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, which are a popular form of financing outdoor lighting projects. Under a TELP, a city 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,** which may be issued by cities directly to finance energy-efficiency projects either as standalone projects or in conjunction with other capital improvements.
- **structured debt,** which may provide medium-term debt, with amortization structured around the 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 the 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. In the shared savings model, the equity investor may also provide debt financing to the project or structures involving third-party ownership of the fixtures, and thereby receive both equity and debt returns. Here, the equity investor would seek to maximize the 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

Many including CCI have explored carbon finance 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 C02/kWh.

ii. "Some ceramic metal halide lighting" refers only to ceramic metal halide products with lamp efficacies of up to 120 lumens/watt, and with lamp lives >24,000 hours.

iii. For more information, see:

- C40 Cities: http://www.c40cities.org/
- US Conference of Mayors Climate Protection Agreement: http://www.usmayors.org/climateprotection/agreement.htm

iv. Certain investor-owned and municipal utility companies – particularly those in California – have been highly supportive of advanced street lighting technologies. By providing rates and incentives for advanced street lighting technologies, they have empowered cities 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_SCHEDS_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

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

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

vii. 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

viii. Assuming EU 2007 emission factor of 0.410 kg CO_2/kWh (Eurelectric 2007 – PRIMES Model), and U.S. emission factor of 0.718 kg CO_2/kWh (US EPA – eGRID2007 Model).

ix. Van Tichelen, P., et al. Final Report Lot 9: Public Street Lighting. Vito, 2007.

x. Navigant Consulting. US Lighting Market Characterization, Volume 1: National Lighting Inventory and Energy Consumption Estimate. 2002.

xi. Cities achieving approximately 50% energy savings with new technology include: Los Angeles, Anchorage, San Francisco, and Oakland, among others.

xii. 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.

xiii. City of New York. "Inventory of New York City Greenhouse Gas Emissions." September 2008.

xiv. City of Houston. "Emissions Reduction Plan." August 2008.

xv. City of Boston. "FY2006 Municipal Greenhouse Gas Inventory." December 2008.

xvi. http://cityofsydney.nsw.gov.au/Environment/images/emissions2.gif

xvii. City of Melbourne. "Greenhouse Action Plan 2006-2010." September 2006.

xviii. 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

xix. Navigant Consulting. US Lighting Market Characterization, Volume 1: National Lighting Inventory and Energy Consumption Estimate. 2002.

xx. Van Tichelen, P., et al. Final Report Lot 9: Public Street Lighting. Vito, 2007.

xxi. http://www.uie.org/library/REPORT_FINAL_July_2004.pdf

xxii. http://www.state.vt.us/psb/document/StreetlightingTariffs/EVT-LEDStreetlightingFinal5-24-09.pdf

xxiii. For more information on visibility under broad-spectrum light sources, see: Mutmansky, Michael, Todd Gilver, and Nancy Clanton, "Street Lighting Survey for Commercial Areas in the Municipality of Anchorage." Oct. 2009. Print.

xxiv. Light's Labors Lost: Policies for Energy-efficient Lighting. Paris: International Energy Agency, 2006.

xxv. 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

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

xxvii. Light's Labors Lost: Policies for Energy-efficient Lighting. Paris: International Energy Agency, 2006.

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

xxix. Although research findings remain mixed, some studies suggest that light sources with high CCT more strongly impact nocturnal wildlife and sky glow than light sources with low CCT. US DOE asserts the need for more research, and the lack of conclusive analysis, here: http://www.lightsearch.com/lightnow/2010/0110/documents/JIM%20BRODRICK%20IDA%20Letter%20Final.pdf

xxx. Assuming a ten year project period.

xxxi. For more information, see Philips case study on the San Diego Gas Lamp Quarter: http://www.greenerfacilities.org/admin/data/case_studies/San_Diego_Gas_Lamp_Quarter-Lighting.pdf

xxxii. For more information on CMH, see various sources:

- http://www.iclei.org/index.php?id=6624#c27565
- http://www.iclei.org/fileadmin/user_upload/documents/South_Asia/Thane_Workshop/opportunities_in_lighting_systems.pdf
- http://www.maygurney.co.uk/customers/14.html
- http://www.eib.org/attachments/general/events/forum2007_19_verhaar.pdf

xxxiii. With proper maintenance, fixture life should far exceed lamp life.

xxxiv. For more information on intelligent controls, see E-Streetlight project site: http://ec.europa.eu/energy/intelligent/projects/doc/factsheets/e-street.pdf

xxxv. 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.

xxxvi. 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

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

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

xxxix. 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