Introduction to LED Street Lighting Technology

MI Retreat on Facilitating Municipal LED Street Light Conversions
8.22.2016
About MEEA

The Trusted Source on Energy Efficiency

We are a nonprofit membership organization with 160+ members, including:

• Utilities
• Research institutions
• State and local governments
• Energy efficiency-related businesses

As the key resource and champion for energy efficiency in the Midwest, MEEA helps a diverse range of stakeholders understand and implement cost-effective energy efficiency strategies that provide economic and environmental benefits.
What’s on tap...

Topics and Goals

Topics
1. LED Street Lighting Technology
2. Control Networks, Adaptive Lighting and Ancillary Benefits
3. Operations and Maintenance
4. Financing and Financial Analysis
5. Resources, References and Events

Goals
1. Share resources
2. Learn to ask the right questions
3. Engage the right stakeholders and learn from peers
4. Build momentum by making progress visible

MEEA
Midwest Energy Efficiency Alliance
### Background

**Street Lighting in the United States**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value/Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Streetlights (est.)</td>
<td>26.5 – 44 million</td>
</tr>
<tr>
<td>Energy Consumption Equivalent</td>
<td>1.9 Million households (~half the households in Michigan)</td>
</tr>
<tr>
<td>GHG Emissions Equivalent</td>
<td>2.6 Million cars (~half the cars registered in Michigan)</td>
</tr>
<tr>
<td>Annual Energy Costs</td>
<td>$2 Billion</td>
</tr>
<tr>
<td>Annual O&amp;M Costs</td>
<td>$4-6 Billion</td>
</tr>
<tr>
<td>Funded by</td>
<td>90% Public taxes, 10% Coops/other</td>
</tr>
<tr>
<td>Ownership</td>
<td>60%+ Private/IOUs</td>
</tr>
<tr>
<td>Technology Used</td>
<td>80% High pressure sodium, 10% Metal halide, 5% Mercury vapor, 5% other (including LED)</td>
</tr>
</tbody>
</table>

Source: MSSLC “State of LED Streetlight Adoption in U.S.”
### Technology Guidance

**Key LED Benefits**

<table>
<thead>
<tr>
<th>Energy</th>
<th>Reduces electricity consumption by more than 50%</th>
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<tr>
<td>Costs</td>
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<td>Maintenance (estimated annual savings of $50/lamp: NEEP, 2015)</td>
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<td>Reduced light pollution at night</td>
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<tr>
<td>Community</td>
<td>Increased lighting quality (better uniformity, improved nighttime visibility, better color rendering, reliable lighting)</td>
</tr>
<tr>
<td></td>
<td>Greater perceived security</td>
</tr>
<tr>
<td>Smart City</td>
<td>Can incorporate advanced controls</td>
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<td></td>
<td>Auxiliary benefits</td>
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Technology Guidance

Payback

MI power supply + delivery charges: ~ $0.08-$0.12/kWh
Simple Payback: ~ 4-5 year payback using MSSLC Retrofit Analysis Tool

Actual savings projected/reported in city reports:

<table>
<thead>
<tr>
<th>City</th>
<th>Scope</th>
<th>Annual $ Savings</th>
<th>Simple Payback</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detroit</td>
<td>88,000 HPS 65,000 LED</td>
<td>$2,944,296</td>
<td>2.3 years</td>
<td>PNNL: [link]</td>
</tr>
<tr>
<td>Grand Rapids</td>
<td>17,500 HPS to LED</td>
<td>$530,000</td>
<td>17 years (?)</td>
<td>Mlive: [link]</td>
</tr>
<tr>
<td>Ann Arbor</td>
<td>7,400 HPS to LED</td>
<td>$200,000</td>
<td>4.4 years</td>
<td>Ann Arbor Webpage: [Link]</td>
</tr>
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Energy Savings

Technology Guidance

Avg. 81 lumens/watt
Technology Guidance

Fixtures
Control Networks Capabilities

**Current**
- Asset management & remote monitoring
- System reporting, maintenance
- Lighting control (on/off/dim)
- Adaptive lighting

**Emerging Capabilities**
- Small cells (wireless connectivity)
- Parking availability & metering
- Interactive billboards
- Weather reporting
- Air quality reporting
- Gunshot detection
- Snow/trash removal route optimization
- Illegal dumping detection

Credit: Michael Poplawski, PNNL
Control Networks
The Basics
Public Perception

Operations & Maintenance

In general, public complaints about LEDs are low due to:
- Higher customer satisfaction
- Quicker municipal response time
- Lower 411 call volume

Most complaints relate to:

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<td>• People can sometimes be unprepared for the change.</td>
<td>• Light trespass can be a big issue (especially with small set-backs and bedrooms at the front of house)</td>
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<td>• Consider a demo installation.</td>
<td>• Invest in house shields so light does not shine into rooms.</td>
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<td>• Let the city council know ahead of time that there may be complaints so they can be prepared.</td>
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Available funding models (discussed in depth later)

- Self-funding
- Utility financing for municipally-owned infrastructure
- Grants/rebates
- Third-party financing
  - ESPCs (e.g.: tax exempt lease financing, off-debt capacity, pay-from savings financing, installment payment financing)
  - Vendor financing
- Key consideration: system ownership and maintenance model
  - City or utility owned and maintained
  - City or utility owned and third-party maintained
## Case Studies – Midwest

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<td><strong>IOWA</strong></td>
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### Resources & References

#### Case Studies – Chicago’s Process

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<th>Activities</th>
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| **Preparation** | • Meet with experts and review DOE resources  
                      • Complete initial financial analysis  
                      • Secure political buy-in |
| **RFI**    | • Explore technology options  
                      • Meet organizations and thought leaders |
| **RFQ**    | • Define scope: fixtures + future-proof network  
                      • Short-list respondents |
| **RFP**    | • Hone scope and define specifications  
                      • Select successful prime bidder(s) |
| **Contract** | • Perform formal infrastructure inventory and repairs  
                      • LED fixture replacement  
                      • Control network deployment |
Resources & References

Part I

- Organizations & Initiatives
  - U.S. DOE Outdoor Lighting Resources
  - The U.S. DOE Municipal Solid-State Street Lighting Consortium (MSSLC)

- LED Fixtures
  - The MSSLC Model Specification for LED Roadway Luminaires
  - MSSLC Successful Selection of LED Streetlight Luminaires Webinar
  - Product Lists
    - DesignLights Consortium (DLC) Qualified Products List (QPL)
    - U.S. DOE's LED Lighting Facts website

- Control Networks & Adaptive Lighting
  - Model Specification for Networked Outdoor Lighting Control Systems
  - Adaptive Lighting Parts I and II
  - Connected Outdoor Lighting Systems for Municipalities
  - UC Davis' Campus-Wide Networked Adaptive Controls LED Lighting case study
  - Northwest Energy Efficiency Alliance’s (NEEA) Seattle LED Adaptive Lighting Study
Resources & References

Part II

• Financing & Financial Analysis
  – U.S. DOE’s MSSLC Financing Options webpage
  – MSSLC’s Retrofit Financial Analysis Tool
  – U.S. DOE’s “Iowa Municipalities Unite to Save Energy with LED Street Lighting” report

• Planning
  – LED Street Lighting Decision Tree Tool
  – Street Lighting Retrofit Plans Library
  – Case Study Library

• Operations & Maintenance:
  – Maintenance practices for LED Street Lights Webinar

• Events
  – The IES Street & Area Lighting Conference
Thank you!

Rose Jordan
Midwest Energy Efficiency Alliance
rjordan@mwalliance.org
Appendices:
Technology Guidance
Control Networks
Operations and Maintenance
Financing and Financial Analysis
Street Lighting and Human Health
Resources, References and Events
Technology Guidance
<table>
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Technology Guidance
Energy Savings

Average 81 lumens/watt

Graph showing the trend of Mean Luminous Efficacy (lm/W) from 2009 to 2014, with different categories such as Area/Roadway, Canopy, Garage, and Directional. The chart indicates a steady increase in efficacy over time.
The MSSLC Model Specification for LED Roadway Luminaires
• guides fixture selection,
• maximizes system design
• drives economic performance.

MSSLC Successful Selection of LED Streetlight Luminaires webinar further examines and explains these topics with presenters from major LED street lighting manufacturers, Cree and Philips.
DesignLights Consortium (DLC) Qualified Products List (QPL) lists ~60 products in the "Outdoor Pole/Arm-Mounted Area and Roadway Luminaires" category.

U.S. DOE's LED Lighting Facts website is recognized as an industry tool for reporting accurate performance about LED products, including roadway lighting. As of early 2015, area and roadway lighting accounts for 18.3 percent of listed products (8,283 total).
Control Networks
Control Networks
The Basics
Control Networks Capabilities

Current
• Asset management & remote monitoring
• Reporting, maintenance
• Basic lighting control (on/off/dim)
• Adaptive lighting

Emerging Capabilities
• Small Cells
• Parking Availability
• Parking Metering
• Interactive Billboards
• Weather Reporting
• Air Quality Reporting
• Illegal Dumping Detection

Credit: Michael Poplawski, PNNL
Control Networks
Market Adoption Issues

Challenges
• **Expertise**: municipal staff learning about network management.
• **Cost**: high upfront cost can hinder speedy payback.
• **ROI**: challenging to calculate ROI on new value propositions.
• **Monetizing saving**: Fixed-rate tariffs are a barrier to adaptive/real-time pricing

Coming Solutions
• **Integration**: embed control system functionality into the luminaire to reduce cost.
• **Interoperability**: standards will continue to simplify control integration.
• **New paradigms**: future city visions, interdepartmental or municipal-utility collaboration models, business models
• **Innovation**: new value propositions offer new revenue opportunities

Credit: Michael Poplawski, PNNL
Control Networks
Adaptive Lighting

- Deeper energy and cost savings; less light pollution
- Two-way communication (fixtures and controls)
- Easier to monitor, adjust and maintain light fixtures
- Automatic (e.g., motion sensor) or manual (e.g., emergency services) ability to dim and brighten lights
Adaptive Lighting Part I: City of San Jose, CA, and the California Lighting Technology Center at UC Davis discussed their experiences as early adopters of these smart street lighting systems.

Adaptive Lighting Part II: the City of San Jose, CA and Pacific Northwest National Laboratory explored the MSSLC’s recently released Model Specification for Adaptive Control and Remote Monitoring of LED Roadway Luminaires.

Connected Outdoor Lighting Systems for Municipalities:
http://energy.gov/eere/ssl/connected-outdoor-lighting-systems-municipalities
Control Networks
Adaptive Lighting – Case Studies

UC Davis' Campus-Wide Networked Adaptive Controls LED Lighting case study describes a large-scale deployment of over 1,500 network-controlled LED streetlights and outdoor lighting fixtures on the UC Davis campus. In total, the installation reduced annual energy use by an estimated 1,231,758 annual kWh, saving $120,909 annually in energy and maintenance costs.

Northwest Energy Efficiency Alliance's (NEEA) Seattle LED Adaptive Lighting Study explores the hypothesis that "a lower quantity of better-quality light provides equal or better detection distance" to investigate opportunities for dimming-related savings potential.
Operations & Maintenance
Sources of Observed Failures

- Driver failures (manufacturer should replace)
- Water leakage into LED chamber
- Flash/strobe effect
- Major system failures due to legacy system
Public Perception

- Public complaints about outages are low due to:
  - Higher customer satisfaction
  - Quicker municipal response time
  - Lower 411 call volume

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Operations & Maintenance
Tips from the Trenches

- Ensure LEDs are easy to repair and replace
- Consider coordinating a mock-up installation using samples and let workers try them out
  - Workers can assess ease of installation
  - Discover potential issues before the city-wide install
- Be ready to make infrastructure upgrades (e.g., don’t put a new spark plug on an old engine and expect it to work)
- Invest in uniform color temperature city-wide
- Include 10-year warranty in the specification
- Invest in long-life photocells (20 year)
Financing & Financial Analysis
U.S. DOE’s MSSLC Financing Options webpage offers resources to understand the funding models available. 
• self-funding 
• utility financing for municipally-owned infrastructure 
• grants/rebates 
• third-party financing  
  – ESPCs (e.g.: tax exempt lease financing, off-debt capacity, pay-from savings financing, installment payment financing)  
  – vendor financing 
• Key consideration: system ownership and maintenance model  
  – City or utility owned and maintained  
  – City or utility owned and third-party maintained
MSSLC’s Retrofit Financial Analysis Tool

- Evaluates costs and benefits of LED conversion
- Performs detailed analysis and provides numerous outputs, including:
  - Annual energy and energy-cost savings
  - Annual maintenance savings
  - Annual greenhouse gas reductions
  - Simple payback, IRR
  - Net present value
Financing & Financial Analysis
Other Creative Solutions

• Bulk Purchasing
  – Cost-saving bulk purchase opportunities are not limited to large municipalities and utility territories
  – Read more: U.S. DOE’s “Iowa Municipalities Unite to Save Energy with LED Street Lighting” report demonstrates how

• Bidding savings into the grid
• Fixture recycling
Street Lighting & Health
Street Lighting & Health

Background

Interest in the effects of color temperature on visibility and human health is on the rise.

Researchers are working to better understand the implications so prudent restrictions, requirements and recommendations may be made.

It is important to better understand the impacts and trade-offs of colored light in night due to the potential effects on alertness, visibility, circadian rhythms and human health.
### Street Lighting & Health

**Background**

Three visual states:

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Photopic</th>
<th>Scotopic</th>
<th>Mesopic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime</td>
<td>Daytime</td>
<td>Nighttime</td>
<td>Dawn/Dusk</td>
</tr>
<tr>
<td>Nighttime</td>
<td></td>
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<table>
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<th>Melatonin</th>
<th>Photopic</th>
<th>Scotopic</th>
<th>Mesopic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Alert</td>
<td>Sleepy</td>
<td>Wake up/Fall asleep</td>
</tr>
<tr>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lowering/Rising</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>

- The hormone **melatonin** controls our circadian rhythms (wake-sleep patterns).
- We’re alert during the day because this hormone is suppressed by a naturally **blue-rich light** environment.
- We fall asleep at night when light is less blue.
- Light’s **“melanopic content”** determines the biological response.
Street Lighting & Health

Background
Street Lighting & Health

Background

Correlated Color Temperature Chart

2000K  3000K  4500K  6500K  9000K

Candle Light  Summer Sun Light  Blue Sky Light

AMA Recommendations

Street Lighting & Health

1. **An intensity threshold** for optimal LED lighting (recommended maximum of 3000K) that minimizes blue-rich light to:
   - Avoid nighttime glare for drivers
   - Avoid suppressing human melatonin at night

2. **Shielding** lighting to minimize:
   - Glare for drivers
   - Light trespass into home (because of possible effects on human circadian rhythms).
   - Environmental effects (e.g., impacts to some wildlife)

3. **Dimming** LED lighting for off-peak time periods
1. Spectral content (not CCT) determines light’s **melanopic content** – we should not mandate that all LED streetlights be <3000K because that may not have the desired outcome (reduced melatonin suppression).

2. The **theoretical** melanopic content produced by a light source does not represent the **actual measured** melanopic content in situ. LED light distribution and dimming play a large role in reducing the content.
   - Further studies are needed to determine whether exposure to blue light at night has a causal relationship with symptoms such as reduced sleep times, dissatisfaction with sleep quality, excessive sleepiness, impaired daytime functioning and obesity.
   - It is unclear whether street lighting offers the intensity and duration of exposure to create these effects.

3. LEDs offer us flexibility to **tailor the light** to the application.
Street Lighting & Health

U.S. DOE Response

Bottom line – agreement among AMA and lighting professionals that LEDs will allow us to satisfy mutual goals to:

• save energy
• reduce overall light levels
• put light only where it’s needed
• control glare
Resources & References
1. **The U.S. DOE Municipal Solid-State Street Lighting Consortium (MSSLC)**
   - Dedicated to helping cities and organizations conduct retrofits of LED street and area lighting products.
     - Learn more about the organization
     - Become a member
     - Receive their newsletter: The Light Post

   - A challenge program providing municipalities with resources and case studies of peer cities who are also upgrading their streetlights to LEDs.
   - President’s goal to install 1.5 million LED street lights on poles throughout the United States by May 2016.

3. **Street Lighting Retrofit Plans Library**
   - A range of public entities, utility organizations, and manufacturers have published retrofit planning documents to aid other jurisdictions.
Resources & References

**Decision Tree**

1. Assess the economic opportunity and choosing a financing model
2. Select the highest impact technology and estimating its savings potential
3. Consider the process and strategies for buying back your street lights
4. Collaborate with key stakeholders, utilities, and other cities

Resources & References

Decision Tree

Lighting inventory

Conducting a ‘wall to wall’ inventory of the lighting system is an important first step in negotiating for purchasing or upgrading that system, with all parties and to be used in cost estimates. It will also be essential to the municipality, to clarify boundaries and responsibilities and to support any disputes that may arise.

A widespread perception exists among both municipalities and their residents that an accurate count of the numbers, sizes of locations, and their approximate ages and physical condition is often difficult to obtain, even when individual lights or light circuits are added to or removed from the system. Anecdotal reports claim that the difference between annual costs and the actual claims of lights actually installed can often be ±10-15%, or more than $30 million per year.

A completed inventory might include, but not be limited to:

- Age and physical condition of both poles and fixtures
- Number of fixtures on pole if more than one
- Fixture type
- Lamp type and wattage
- System operating voltage
- Date of last servicing (if known), and
- GPS location.

Conducting the inventory yourself

Municipalities with sufficient staff and budget may wish to conduct the inventory of their street lighting systems themselves. However, in many cases, the level of commitment is so substantial that it may be best to select a professional firm to perform the work.

Undertaking the approval process

A number of resources exist that can help an agency make the case to undergo a lighting transition. These include case studies, product information, and other materials. The following resources contain information of value for assembling a case to undergo the transition:

- **MARC Smart Lights Final Report** — Summary results of a lighting transition program across several municipalities in the Kansas City metropolitan area. Includes estimated maintenance, energy and environmental savings, community reaction and the strategy and approach developed by this program that replaced 5700 street lights.
- **Massachusetts Metropolitan Area Planning Council (MAPC) ‘How To’ Document, Retrofit Streetlights with LEDs** — A step-by-step guide outlining the planning process for a lighting transition, describing options for implementing projects, and summarizing available resources for cities and towns in Massachusetts.
- **Street Lighting in New York State: Opportunities and Challenges** — NYSERDA report presenting an analysis of savings of and barriers to upgrading to LED street lighting in New York.


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|                              | • LED fixture replacement  
|                              | • Control network deployment  

**MEEA**

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The IES Street & Area Lighting Conference

- September 18-21, Hollywood, CA
  - Dedicated to improving the outdoor lighting business of electric utilities and energy service companies.
  - Open forum for end-users: discuss relevant products for specific application, lighting controls, benchmarks and milestones reached by municipalities, utilities and DOT’s.
  - 900+ attendees and growing, includes managers, technical and marketing specialists, lighting consultants and engineers from electric utilities, municipalities, cooperatives, energy service companies and manufacturers.
- Learn more: http://www.ies.org/salc