SCHOOL OF NATURAL RESOURCES & ENVIRONMENT
UNIVERSITY OF MICHIGAN

University of Michigan Master's Project Report

Creating a Plan to Convert Streetlights in Southeast Michigan to Energy Efficient LEDs by 2025

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Abstract

Street lighting plays an important role in the human landscape, providing public safety and place-making benefits. However, it is also the largest energy expense for many municipalities and accounts for significant environmental impacts. By converting their street lighting to LED bulbs, communities throughout Southeast Michigan have a great opportunity to save money, reduce their environmental impacts, and realize safety and aesthetic benefits for residents. However, municipalities' participation in street lighting conversion projects has thus far been limited due to lack of information and communication about available community lighting options. This report, prepared on behalf of the Southeast Michigan Regional Energy Office (SEMREO), explores the following perspectives of the proposed LED streetlight conversion projects: technical feasibility, street lighting policy, environmental impact analysis, social and community analysis, and financial analysis of available funding mechanisms.

For the technology analysis section, we performed a literature review of available street lighting technologies, with a focus on highlighting the energy and cost benefits of LED conversion project implementation. With their high efficacy and long lifetimes relative to conventional bulbs, LEDs were proven the best option for streetlight upgrades in Southeast Michigan. We also performed a policy analysis, examining policy incentives and disincentives for LED street lighting conversion projects in the state of Michigan, including utility incentives, legislative activities, and federal policy drivers. For our environmental analysis, we quantified the emissions reductions attributed to the demand reduction from the LED conversion project, and determined its potential as a cost-effective emissions reduction mechanism. In addition, we met with community members and identified the needs and preferences of the Eastpointe community, a SEMREO member, and found that participants were interested in the possibilities of solar-powered streetlights. Finally, we evaluated financing options and discussed financial barriers for undergoing such projects.

This comprehensive analysis includes a simple streetlight conversion plan for communities in Southeast Michigan region and several recommendations for municipalities participating in SEMREO's Street Lighting Consortium. First, we found this conversion plan to be economically favorable, saving municipalities an average of 55% of energy savings and 32% of annual expenses savings, with an average simple payback period of 3.7 years. For our recommendations, we emphasize that upgrading streetlights to LEDs creates significant economic, environmental and social benefits: communities should continue being Consortium members, take advantages of economies of scale, and remain active in public consultation processes. Additionally, we recommend that the Consortium continue to advocate for energy efficiency-friendly policies, such as stricter energy optimization standards and inclusion of LED conversion projects in the State Carbon Implementation Plan (SCIP), and that the Consortium style itself as an advocacy and resource organization with dues-based membership. Finally, it is recommended that SEMREO members increase their outreach opportunities with the public to gain more support for streetlight conversions. An integrated approach such as the one laid out in this report could accelerate LED implementation process, assess the benefits, and help to increase participation in future programs. Our results could also be applied to municipalities in Michigan outside of SEMREO's target region, but further large-scale data analysis would be needed to support this project at a state-level scale.

Acknowledgments

The team would like to extend our thanks to several individuals and organizations for their assistance with this project. We would like to thank our client, the Southeast Michigan Regional Energy Office (SEMREO), and most especially Rick Bunch and Jennifer Young for extending the opportunity, support and encouragement to undertake this project. Our advisor, Dr. Jeremiah Johnson, has also been an enormous asset to our project, and we would like to thank him for his constant guidance and suggestions throughout this project as we progressed.

We would also like to thank the municipalities that took the time to assist us with this research. The City of Eastpointe staff deserve especial credit for their assistance in organizing and hosting a focus group, as well as the Eastpointe residents who took the time to participate in this study. We also thank Nathan Geisler for sharing his experience about the success with Ann Arbor's street lighting project.

Additionally, several individuals have generously shared their knowledge with us as we conducted our research, and we would like to extend our thanks here. In particular, we thank Douglas Jester for sharing his insights on the rate case and about the prospects of LED street lighting conversion projects in general. We also thank Prof. Yang Huang for her support in terms of excel-based data analysis, a key component of our environmental analysis research. Finally, we thank David Wang for speaking with us about exploring the possibility of carbon credits, and Amy Chiang for her help in quantifying the monetary value of pollution mitigation.

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Executive Summary

As an opus requirement for the Master of Science degree at the University of Michigan School of Natural Resources and Environment, our team of five graduate students completed a project with Southeast Michigan Regional Energy Office to create a plan to convert streetlights in southeast Michigan to energy-efficient LEDs by 2025, and recommend strategies for improvement. This project has five objectives:

1. Perform a literature review with general background information on street lighting, build a streetlight conversion model for Southeast Michigan, and estimate the energy and cost savings of the conversion based on current street lighting system.
2. Analyze policies at the utility, state, and federal level to determine incentives and resources for energy efficiency projects, and develop recommendations for governance of the street lighting consortium projects.
3. Conduct data analysis to identify which power plants will reduce electricity output as a result of streetlight conversion, quantify the associated emissions reduction, and determine the projects' potential as a cost-effective emissions reduction mechanism.
4. Perform social analysis to determine the wants and needs of communities regarding street lighting.
5. Evaluate all feasible financing options based on the Consortium's financial health and regulatory environment, uncover financial barriers for municipalities, and recommend funding mechanisms to undertake community projects in the short- and long-term.

Streetlights are a little-noticed but indispensable element in the human landscape, providing public safety and place-making benefits. Traditionally, high intensity discharge (HID) technologies such as mercury vapor (MV), high pressure sodium (HPS), and metal halide (MH), have dominated the street lighting market, while in recent years, the penetration of LED has increased dramatically from 0.1% in 2011 to 13% in 2014. Upgrading streetlights to energy-efficient LEDs could yield considerable benefits, including significant reductions in municipal energy expenditures and environmental impacts (i.e. $MtCO_2e$ reduction), due to the relative efficiency of LED lighting and public safety and aesthetic benefits resulting from LED's reliability, color temperature, coverage precision and full-spectrum illumination.

A literature review of current streetlight technology and market trend was initially conducted to demonstrate the advantages of LED streetlights, including extremely long lifetime and high efficacy. Then, based on current light systems in Southeast Michigan communities and reports from Michigan Public Service Commission, a simple streetlight conversion model was built. To maintain adequate light levels in the regions, the basic conversion plan resulted in a 54.9% annual energy savings, 32.2% annual expenditure savings, and an average simple payback period of only 3.7 years when taking cost of conversion into account. (Shown in the figure below.) The falling price of LED technologies could increase their competitiveness dramatically in the whole lighting market.

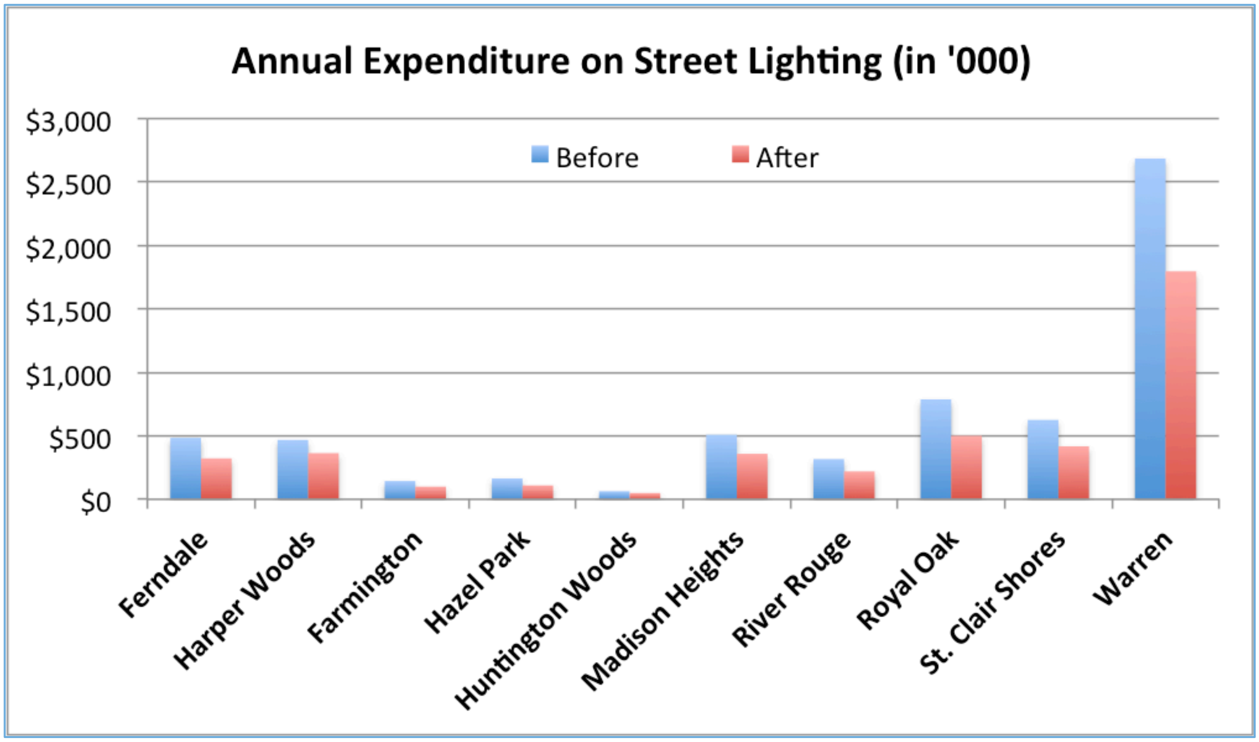

Figure ES.1: A Comparison of Annual Expenditure on Street Lighting before and after Converting Current Streetlights to LEDs in Southeast Michigan Communities.

We also examined key policy drivers at the utility, state, and federal level, including additional case studies of successful street lighting conversion schemes. At the utility level, there are several market disincentives for utility participation in this project: investor-owned utilities in the state of Michigan are incentivized to own assets, such as streetlights, making them unlikely to sell streetlights to municipalities such that street lighting can be transferred to local control; in addition, large utilities also profit from selling high volumes of electricity, creating a natural disincentive for energy efficiency initiatives. At the state level, there is currently strong support for energy efficiency among the Snyder administration, but several less-favorable Republican proposals are also being floated, as well as several more-favorable Democratic proposals are more favorable. At the federal level, Department of Energy initiatives are also discussed. Finally, case studies from street lighting consortiums in Kansas City, MO and the state of California provide valuable insights on differing consortium governance models, including metropolitan planning organization (MPO) and dues-based organizational models.

For the environmental analysis, data analysis was conducted using the 2014 dataset from the EPA Acid Rain Program. Sixty-six generating units were identified as adjusting their electricity output in response to demand changes during streetlight operating hours within Michigan. In total, the LED conversion project will result in at least 44,229 metric tons of CO_2 emission reduction throughout the project's lifespan. The project is also priced at $4/metric ton CO_2 or less mitigation cost, making it a much more cost-effective than most mitigation options. LED conversion projects are thus strong candidates for compliance with regulatory policies.

Social analysis was conducted through structured focus groups, an important tool in conducting work with communities. A literature review was performed to determine best practices in conducting focus groups, and then a study was developed and questions for residents were created. A focus group took place in the Eastpointe community in March to determine the street lighting needs of Eastpointe residents.

Six financing options were identified for street lighting conversion projects. In the short term, a combination of funds sourced from federal and state grants, utility programs, vendor financing and budgetary allocations are suggested. In the long term, exploring partnerships with energy saving contractors (ESCOs) that guarantee energy and cost savings and bear additional risks is advised, and raising funds by issuing municipal bonds is another option that the Consortium can use going forward. While researching on state-specific grants it came to light that about 50% of consortium members fell under the category of distressed communities and hence seeking state-specific grants for distressed communities was strongly emphasized. Waiting for the cost of LEDs to decrease further is inadvisable, as the annual "cost of waiting," excluding maintenance cost, for the representative community of Southgate was estimated to be nearly 60% of electricity costs for the current system.

Based on our analysis, we recommend that municipalities in Southeast Michigan should continue to participate in the Consortium and start upgrading streetlights to LED bulbs as soon as possible. Our key recommendations are summarized below:

- **Recognize the benefits of LED streetlight upgrades.** For our research, only a small number of communities participating in the Consortium provided us with energy bills and local street lighting information, thus limiting the amount of community-specific financial analysis we were able to conduct. We recommend that the communities utilize our model to research LED implementation for their own purposes, with a focus on cost and energy savings. Without active involvement, municipalities will have little opportunity to recognize the benefits from upgrading streetlights to more efficient LEDs.
- **Approach a phased conversion plan**. While converting streetlights as quickly as possible will produce the fastest possible results, in reality, a streetlight conversion project takes significant time and financing. We recommend a 10% per year conversion rate, but further analysis will be needed as to the exact location of streetlights being converted, and may depend on the needs of specific communities located in these areas.
- **Find balance between lighting standards and project cost**. Not all communities currently meet recommended street lighting standards, and thus the region will need to expand the total amount of streetlights in addition to converting existing bulbs to LEDs. Expansion largely increases cost and will compromise the benefits brought by simple conversion. Thus a balance should be drawn between meeting standards and the economic and environmental feasibility of the project.
- **Research the possibilities and implications of installing solar-powered and self-reporting streetlights.** In the future, solar-powered streetlights could potentially generate large energy savings, as solar panels convert free renewable energy into electricity. These panels could also be tied into the energy grid such that streetlights could maintain light even during cloudy days. Additionally, self-reporting streetlight technology that notifies the utility when a bulb burns out may be available in the future. This feature is important because burned-out or damaged lights should be replaced as soon as possible in order to improve safety immediately.

For the near term, we recommend that the Consortium involve itself in advocacy, rather than strictly a technical role, and that the Consortium serve as a forum for member municipality staff to share knowledge and ideas. In particular, the Consortium should advocate for strong energy optimization standards; increased streetlight buyback options; and community participation in creating the State Carbon Implementation Plan (SCIP), the state of Michigan's response to the Clean Power Plan. SEMREO may additionally consider favoring revenue decoupling schemes and increased retail open access, should these issues come to a vote before Michigan's Congress.

1. Introduction

1. 1 Background

Street lighting is a key public service provided by public authorities at the local and municipal level. Good lighting is essential for road and personal safety and urban ambience; it ensures visibility in the dark for motorists, cyclists and pedestrians, and thereby reducing road accidents. Street lighting also indirectly facilitates crime prevention by increasing residents' perception of personal safety, as well as enhancing the security of adjacent public and private properties.[1] As the population grows and urbanization increases, the amount of energy needed for street lighting increases as well; thus, choosing an efficient lighting technology and planning for conversion projects should significantly reduce municipal energy expenditures and associated environmental impacts (i.e. $MtCO_2e$).

Within the U.S., there is a growing awareness among municipalities for the need to have energy efficient LED street lights. To date, several successful implementation projects have already been completed in the U.S. However, the capacity for municipalities undertake these projects varies regionally and depends on a variety of factors, including state regulatory environment and municipal financial health; in Southeast Michigan, many communities have not yet recovered from the economic downturn of 2008, and thus will be reluctant to commit to LED conversion projects. Our goal is to surmount these financial and regulatory barriers, in order to help communities realize the social, economic, and environmental benefits associated with this conversion.

1. 2 Problem Statement

The Southeast Michigan Municipal Street Lighting Consortium (hereafter referred as "Consortium") is a collaboration of local nonprofits and municipalities that aims to upgrade all public street lights to LEDs throughout the metropolitan Detroit region by 2025. The Consortium's hope is that this project will return significant savings to local governments with fiscally constrained budgets, while also creating environmental, aesthetic, and public safety benefits for participating communities. In this project, our team of five graduate students has developed a framework for reaching the Consortium's goal of full street lighting conversion in the region within ten years. Our team has created a plan for implementing an ideal street lighting system through the lens of five key perspectives: technology, policy, environmental impact, social benefits, and financial impact.

The Energy Information Administration (EIA) estimates that in 2012, about 461 billion kWh of electricity was used for lighting by the residential and commercial sectors; specifically, commercial and institutional buildings and public street and highway lighting consumed about 274 billion kWh for lighting in that year.3 With rising electricity prices, as well as increased awareness of the environmental impact of electricity generation, energy-efficient street lighting is becoming an increasingly more attractive proposition for municipalities. The Consortium seeks a plan for converting all streetlights in the greater Detroit region to LED bulbs by 2025, which will benefit more than 20 communities through municipal energy and cost savings. There are several environmental and social reasons why LED streetlights are a potential boon for the Southeast Michigan area: these bulbs are energy-efficient, cost-effective, and provide brighter and more focused light than preexisting technologies. However, there are considerable challenges associated with this project, including how to finance the upfront costs of installing LED light bulbs, as well as taking the different priorities of affected communities into consideration during implementation. This report describes our team's comprehensive analysis by category, the ideal vision for future street lighting in Southeast Michigan, and provides recommendations for implementing the new street lighting system.

1. 3 Areas of Research

The objective of our research is threefold. First, we wish to identify an ideal vision for street lighting in Southeast Michigan, in which as many lights as possible are fully converted to LEDs. Our research will encompass finding reasonable answers to a broader question of how communities convert all public streetlights to LED bulbs by 2025. Our second goal is to analyze the potential benefits of this project to communities from the energy, environmental, and economic perspectives: if an LED streetlight system were found to be more affordable than current alternatives, then many communities would likely embrace the new technology owing to its environmental and social benefits. Third, we aim to understand the community perspective on street lighting, including residents' opinions on advanced technologies and perceptions of the relationship between street lighting and incidence of crime. The geographical scope of the project involves all streetlights within the Consortium member communities, which stretch west to Washtenaw County, north to Flint, and south to the Ohio border, corresponding approximately with the DTE service area. (**Appendix 1**)

Hypotheses and Project Framework

Our team has identified several research hypotheses for this project. First, we hypothesize that LED streetlights will bring large economic, environmental, and social benefits to communities in the Southeast Michigan region, given the coal-heavy nature of the local electricity mix. To this end, we propose to evaluate the technological, environmental, economic, financial, and social benefits of this project, as well as identify relevant policy considerations and best practices for communicating our vision.

Research Questions

The following are pertinent research questions that this report aims to address:

- How has LED technology developed over the last recent years, and what available technologies are most appropriate for municipalities to use?
- What emerging technologies could be integrated with LED streetlights in the future?
- What are the environmental, economic, and social impacts of this conversion?
- What are some of the current policy incentives for street lighting conversion projects, and how might SEMREO take advantage of these incentives?
- What policy disincentives might hinder project implementation, and how might these be addressed?

- Will these conversions help communities save money and/or attract new businesses to their areas? If so, how?
- What kinds of environmental benefits can we expect to see from this project - reduced CO_2 emissions? Improved air quality by reducing SO_2, NO_x
- What are each community's lighting needs, and how can we create a plan that is sensitive to those needs?
- What is the relationship between crime and street lighting?
- Are there different psychological impacts of LED vs HPS streetlights?
- How can we fund this project in such a way that all communities will be able to access LED streetlights?
- What national and state level policies can drive conversion of streetlights at municipal level in Southeast Michigan and beyond?
- What are the best ways to educate the public and create awareness about a proposed conversion?

1. 4 Report Organization

The results of this research project are organized in the following manner, and the figure below summarizes the connection between each section:

Technology Review | A comprehensive literature review on current streetlight technology will be performed to highlight the advantages of LED streetlight implementation, which generate considerable energy and cost savings based on the conversion model.

Policy Issues in Streetlight Expansion | A comprehensive examination of utility incentives for energy efficiency projects, street lighting policy at the state level in Michigan, and federal policy resources.

Environmental Analysis | Includes time- and generating unit-specific data analysis on the environmental benefits of LED conversion projects, including CO_2, SO_2 and NO_x emissions reductions, avoided health impacts, and efficiency as a CO_2 mitigation mechanism. The sensitivity of analysis results against conversion speed is tested, and implications from changes in the political situation are discussed.

Social Analysis | Describes the planning and implementation of community focus groups, which were designed to determine the desires and needs of communities regarding streetlight upgrades and future lighting possibilities.

Financial Analysis | Addresses key financial barriers for undertaking the LED street lighting conversion project and identifies six financing options for the Consortium.

Ideal Vision and Recommendations | Outlines actionable recommendations for SEMREO to implement street lighting upgrades and increase community participation in the Consortium, with the ultimate goal of converting all streetlights to energy efficient LEDs by 2025.

A list of acronyms and several appendices are also provided for the convenience of the reader.

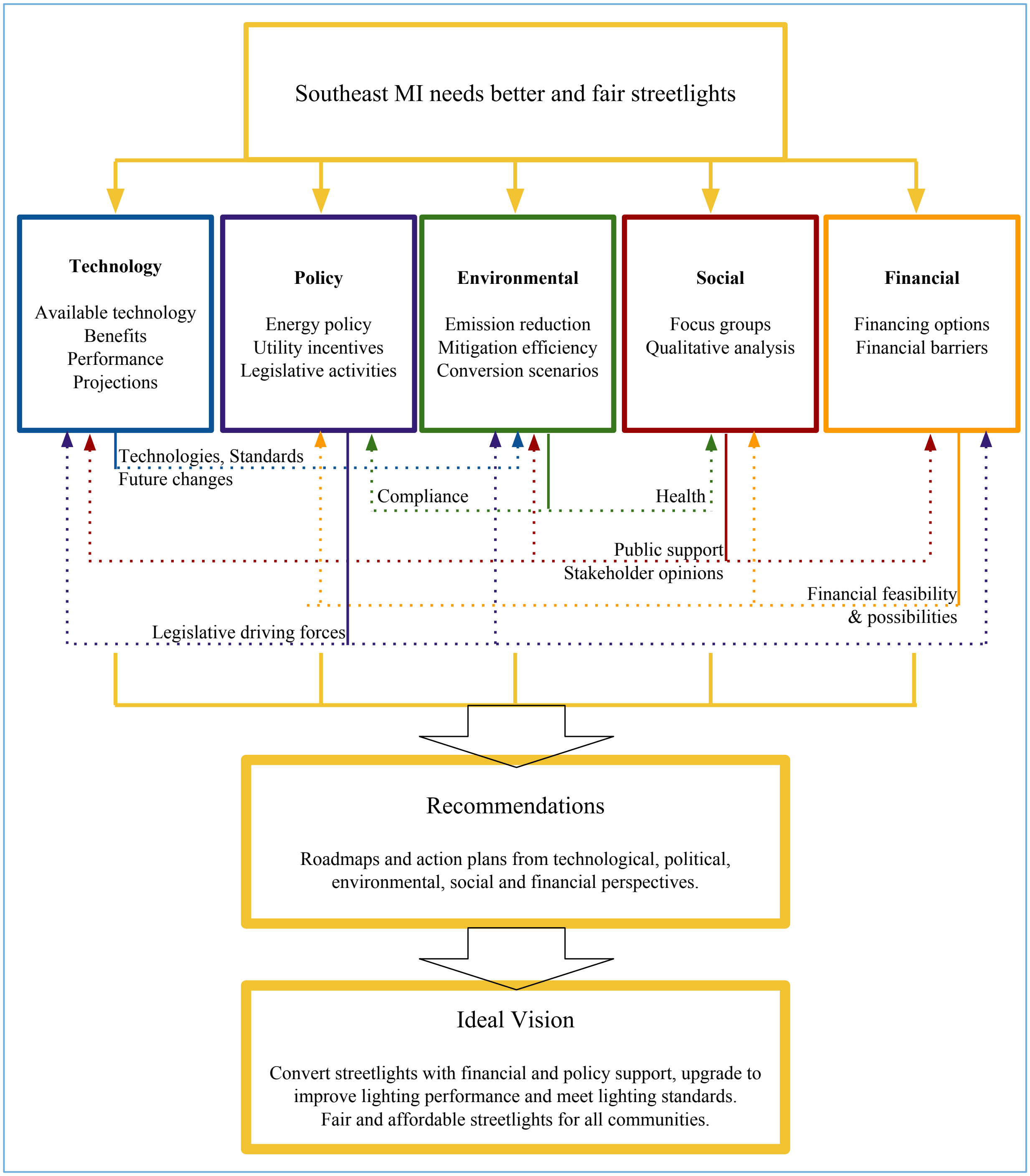

Figure 1.1. Project Working Process Flowchart

2. Technology overview

2.1 History of Street Lights and LEDs

The need for street lighting has existed for a long time. On January 28, 1807, Pall Mall in London witnessed the first street lighting powered by gas. About 70 years later, the first electric street lighting was invented by Russian Pavel Yablochkov.[1] Street lighting is a key public service provided by authorities at the local and municipal level, offering illumination to ensure walkway and roadway safety, but it can consume as much as 40 percent of a city's energy budget. Nowadays, many lighting technologies have been developed and used for outdoor illumination. The US Department of Energy estimates that there are 52.6 million roadway fixtures installed in the United States, including 26.5 million streetlights and 26.1 million highway fixtures.[2] Traditionally, high intensity discharge (HID) technologies such as mercury vapor (MV), high pressure sodium (HPS), and metal halide (MH), have dominated the street lighting market; more specifically, HPS is the most common technology deployed for streetlights across the US. The market share and the total number of lamps by application and technology type are depicted in **Table 2.1**.

Table 2.1. Estimated Roadway Light Installation in 2011

Application	Lamp Type	Percentage	Number of Lights
Street Lighting	Incandescent	0.1%	18
	Mercury Vapor	15.9%	4200
	Low Pressure Sodium	0.4%	100
	High Pressure Sodium	80.9%	21500
	Metal Halide	2.5%	700
	LED	0.2%	60
	Total	**100.0%**	**26500**
Highway Lighting	Induction	8.5%	2200
	Low Pressure Sodium	0.4%	100
	High Pressure Sodium	86.1%	22500
	Metal Halide	5.0%	1300
	Total	**100.0%**	**26100**

A Light Emitting Diode (LED) is a two-lead semiconductor light source. It is a type of Solid State Lighting (SSL), with a unique mechanism of generating light: whereas traditional light sources produce light by heating a filament to incandescence or establishing an electrical arc through a gas mixture, LEDs emit light from a small semiconducting chip when a current is applied. The earliest LEDs appeared as practical components in 1962, emitting low-intensity infrared light.[3] Until 1968, visible and infrared LEDs were extremely costly, in the order of US$200 per unit, and as such had little practical use.[4] In 1995, the first LED with white light from luminescence conversion was presented and was launched on the

[1] Pohl F. Hutchinson, Chronology of World History, Vol.3. Helicon Publishing; 2006.

[2] Navigant Consulting Inc. for DOE 2011. Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications,

[2] Navigant Consulting Inc. for DOE 2011. Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications,
http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/nichefinalreport_january2011.pdf

[3] N. Holonyak, Jr., 2004, Lemelson-MIT Prize Winner, Lemenson-MIT Program, Retrieved August 13, 2007

[4] E. F. Schubert, 2003, "1". Light-Emitting Diodes, Cambridge University Press. ISBN 0-8194-3956-8

market two years later. Twelve years later, in 2007, the Italian village of Torraca was the first city in the world to convert its entire street lighting illumination system to LEDs.[5] Today, LEDs have been competing successfully with conventional lighting sources across a variety of applications due to their ability to offer high quality and cost effective performance. As shown in **Figure 2.1**, the progress of replacing HID installations with LEDs was very impressive in recent years. By the end of 2014, LEDs have made up an estimated 13% of the installed base.

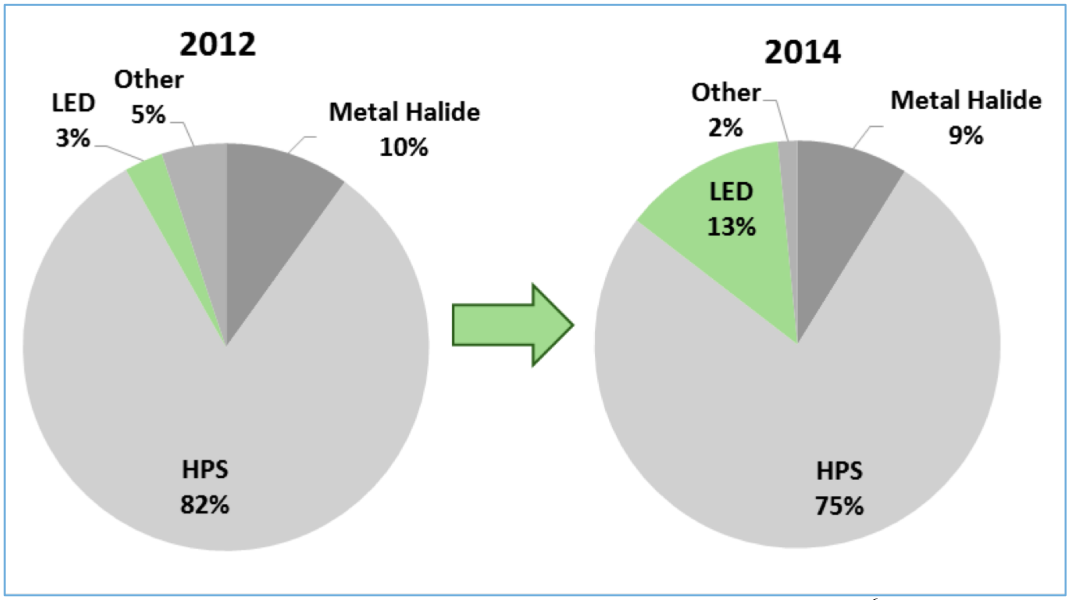

Figure 2.1: Evolution of Area/Roadway Installed Base[6]

[5] LED There Be Light, Scientific American, March 18, 2009 http://www.scientificamerican.com/article/led-there-be-light/
[6] U.S. DOE SSL Program, Adoption of Light-Emitting Diodes in Common Lighting Applications. Prepared by Navigant Consulting, July 2015.

2.2 Comparison of Street Lighting Technologies

Incandescent Lamps are considered the "standard" for electric light bulbs. Introduced by Thomas Edison more than 125 years ago, they generally have the lowest initial cost, but also use significantly more energy to produce the same amount of light. Incandescent technology produces light by heating up a metal filament enclosed within the lamp's glass. However, more than 90 percent of the energy used by an incandescent light bulb escapes as heat, with less than 10% producing light.[7]

High Intensity Discharge (HID) is a type of electrical gas-discharge light source. It produces light by means of an electric arc between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube. This tube is filled with both gas and metal salts, which facilitate the arc's initial strike. HID lamps include:

> **Low-pressure sodium (LPS) lamps -** the most efficient electrical light sources, but their yellow light restricts applications to outdoor lighting.
> **High-pressure sodium (HPS) lamps -** have a broader spectrum of light than LPS, but still poorer color rendering than other types of lamps.
> **Mercury Vapor Lamp -** a gas discharge lamp that uses an electric arc through vaporized mercury to produce light. The arc discharge is generally confined to a small fused quartz arc tube mounted within a larger borosilicate glass bulb. The outer bulb may be clear or coated with a phosphor; in either case, the outer bulb provides thermal insulation, protection from the ultraviolet radiation the light produces, and a convenient mounting for the fused quartz arc tube.

An **LED** is a semiconductor light source, generally used for indicator lamps in many devices and increasingly used for general lighting. Appearing as practical electronic components in 1962, early LEDs emitted low-intensity red light, but modern versions are available across the visible, ultraviolet, and infrared wavelengths, with very high brightness.[8]

LEDs are particularly advantageous in outdoor lighting applications because their inherent characteristics address many of the key issues associated with these types of lighting. LEDs offer extremely long lifetimes, are directional light sources, and thus able to limit light pollution and light trespass, are highly efficacious, function well in cold temperatures, are greatly resilient to vibration, and are able to provide a high quality light. However, the major obstacle to greater market penetration continues to be the initial cost of LED luminaires. A review of DOE SSL Gateway Demonstrations revealed that the initial cost of outdoor LED luminaires is between three to seven times more than equivalent HID luminaires.[9] **Table 2.2** gives a comprehensive comparison of street lighting technology.

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[7] U.S. DOE Office of Energy Efficiency and Renewable Energy, Comparing Light Bulbs, http://www1.eere.energy.gov/education/pdfs/efficiency_comparinglightbulbs.pdf

[8] A. McWilliams, Light-Emitting Diodes (LEDs) for Lighting Applications, BCC Research, October 2014.

[9] More information on the Gateway Demonstrations can be found at http://www1.eere.energy.gov/buildings/ssl/gatewaydemos.html

Table 2.2. Street Lighting Technology Comparison[10]

Light Technology	Life time	Lumens per watt	Color temperature	CRI (color rendering index)	Ignition time	Considerations
incandescent light	1,000 - 5,000	11 - 15	2,800K	40	instant	very inefficient, short life time
mercury vapor light	12,000 – 24,000	13 - 48	4,000K	15 - 55	up to 15 min	very inefficient, ultraviolet radiation, contains mercury
metal halide light	10,000 – 15,000	60 - 100	3,000-4,300K	80	up to 15 min	high maintenance UV radiation, contains mercury and lead, risk of bursting at the end of life
high pressure sodium light	12,000 – 24,000	45 - 130	2,000K	25	up to 15 min	low CRI with yellow light, contains mercury and lead
low pressure sodium light	10,000 – 18,000	80 - 180	1,800K	0	up to 15 min	low CRI with yellow light, contains mercury and lead
fluorescent light	10,000 – 20,000	60 - 100	2,700-6,200K	70 - 90	up to 15 min	UV radiation, contains mercury, prone to glass breaking, diffused non-directional light
compact fluorescent light	12,000 – 20,000	50 - 72	2,700-6,200K	85	up to 15 min	low life / burnout, dimmer in cold weather (failure to start), contains mercury
induction light	60,000 – 100,000	70 - 90	2,700-6,500K	80	instant	higher initial cost, limited directionality, contains lead, negatively affected by heat
LED light	50,000 – 100,000	70 - 150	3,200-6,400K	85 - 90	instant	relatively higher initial cost

Correlated color temperature (CCT), or color temperature, describes the relative color appearance of a white light source, and indicates whether it appears yellow/gold or blue in hue. The color rendering index (CRI) is an important measure of color quality used by the lighting industry. The CRI indicates how well a light source renders colors, on a scale of 0 to 100, compared to a reference light source of similar color temperature.

Lamp lifetimes are of particular interest to facility managers as they directly affect maintenance costs, which can be an important part of the economic equation, as outdoor lights are often spread out over a large geographic region and owned by one organization. Unlike traditional HID lamps, LEDs typically do not fail by "burning out" after some period of time; rather, LEDs will gradually become dimmer over long periods of time.

Lighting designed for outdoor applications must address multiple issues such as proper light distribution, energy use, light pollution, and lifetime. Lifetimes are of particular interest to facility managers as they directly affect maintenance costs, which can be an important part of the economic equation as outdoor lights are often spread out over a large geographic region and owned by one organization. As shown in **Figure 2.2**, unlike traditional HID lamps, LEDs don't typically fail by "burning out" after some period of time. Rather, over long periods of time LEDs will gradually simply become dimmer.

[10] GRAH Lighting, Street lighting technology comparison, Retrieved October 31, 2015, http://www.grahlighting.eu/learning-centre/street-lighting-technology-comparison

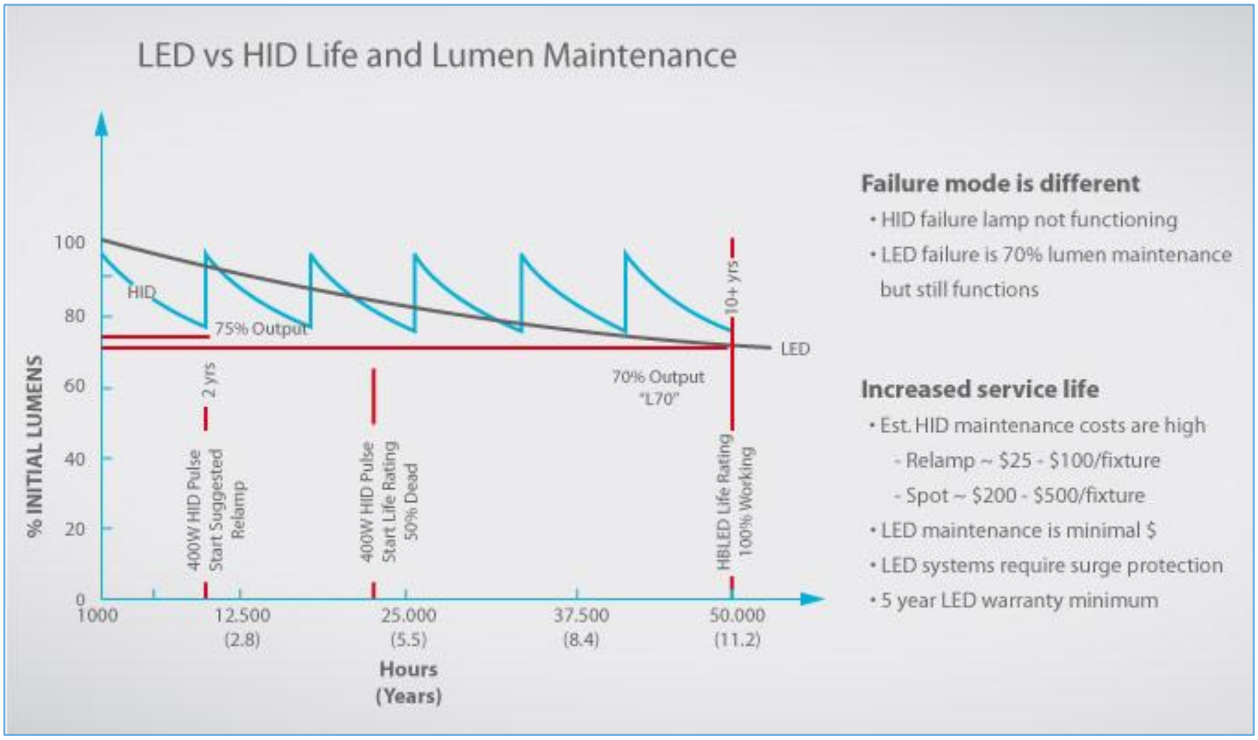

Figure 2.2: LED vs HID Life and Lumen Maintenance

2.3 Energy and Cost Benefits

In the United States, street and highway lighting accounted for 52.8 terawatt-hours in 2010, representing 7% of all lighting energy use, according to the DOE.[11] Five years ago, roadway lighting had an LED penetration of only 0.72%, however, in 2014, this value has increased to 13%. If all of these streetlights are converted to LED technology, the estimated energy savings will be 17.2 TWh/year.[12]

The City of Los Angeles has completed a citywide street lighting replacement program and has installed over 150,000 LED streetlights, reducing energy usage by 63%, and saving $8 million in annual energy costs.[13] Although still more expensive than incumbent HPS, MH, and MV technologies, which are typically priced at $1.2/klm, $2.1/klm, and $2.0/klm respectively, the typical price of area and roadway luminaires has been nearly halved between 2010 and 2014 to about $58/klm (or about $300/fixture).[14] According to the LED Lighting Facts database, the average efficacy of area and roadway luminaires is 87 lm/W, with efficacies reaching as high as 137 lm/W.[15] A basic comparison of the efficacy for several major lamp technologies is provided in **Figure 2.3**, with raw lamp or package efficacy shown with black boxes and typical luminaire efficacy shown with shaded areas.[16]

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[11] Navigant Consulting Inc. for DOE 2011. Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/nichefinalreport_january2011.pdf
[12] Navigant Consulting, 2010. Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications, U.S. Department of Energy: Building Technologies Program.
[13] City of Los Angeles Department of Public Works Bureau of Street Lighting: http://bsl.lacity.org/downloads/led/LED_Energy_Savings_010215.pdf
[14] U.S. DOE SSL Program, Solid-State Lighting R&D Plan, May 2015. http://www.energy.gov/sites/prod/files/2015/06/f22/ssl_rd-plan_may2015_0.pdf
[15] LED Lighting Facts database as of May 6, 2015, http://www.lightingfacts.com/products
[16] U.S. DOE EERE, Building Technologies Program: Solid-State Lighting Technology Fact Sheet. March 2013.

The energy efficiency of LED products is typically characterized using efficacy, which in basic terms is the ratio of power input to light output—or more technically, emitted flux (lumens) divided by power draw (watts).

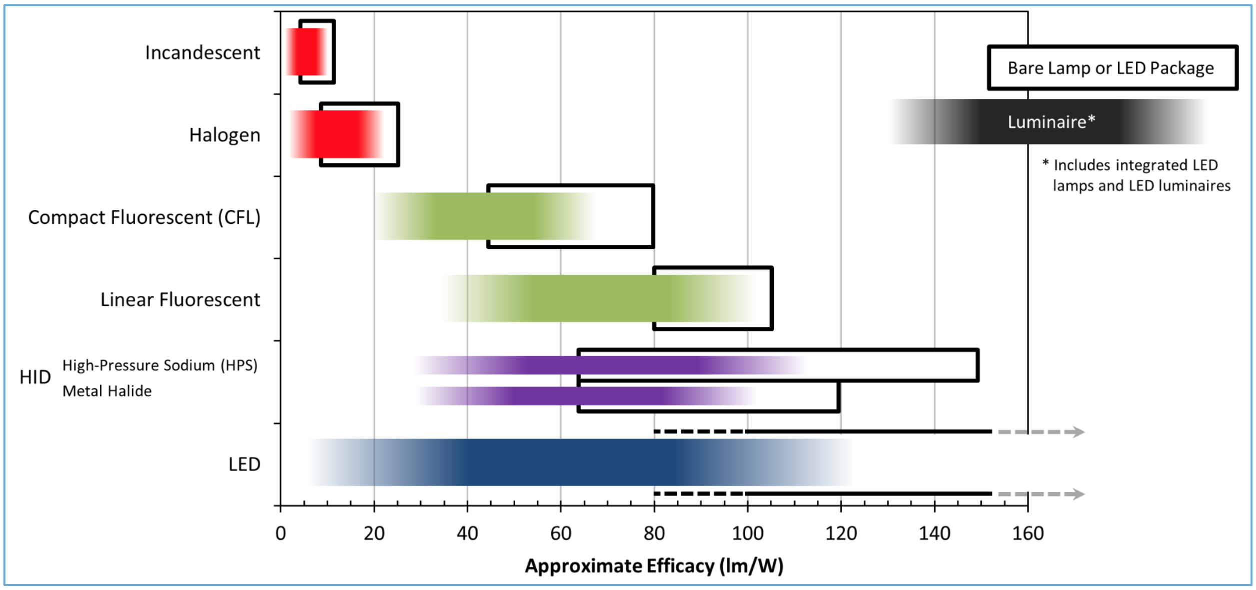

Figure 2.3: Approximate Range of Efficacy for Various Common Light Sources.

In this project, quantitative electrical power measurements are taken to compare the baseline performance of existing streetlamps in the region, which are generally high pressure sodium and metal halide bulbs, with that of the LED replacement luminaires. In southeast Michigan region, 10 communities have provided their streetlight bills, which provide information on the numbers of different types of streetlights and monthly expenditure rates. In addition, information about City/Village Allocation Factors, provided by Michigan Departments of Transportation, includes the primary and local miles for every city/village participating in the consortium, which is used for lighting power density analysis.

2.3.1 Model

The streetlight conversion model is built based on U-17767 MSLCDE-1 Lighting Model and Case No. U-18014, and simplified for the project. All assumptions can be found in the appendix. Our model is designed to initially maintain the same amount of light (in lumens) after full conversion. Additionally, the number of fixtures remains the same in the baseline case. The cost of conversion is obtained from the original conversion plan put forth by DTE Electric, the local utility, which includes the cost of the LED bulbs, photocells and labor. Energy optimization is an add-on option in the model, to be discussed in more detail later in this report.

2.3.2 Results

The model demonstrates results for all 10 Southeast Michigan communities, summarized in Table 2.3. On average, this conversion plan would cut down annual expenditure by 32.2%, and reduce energy consumption by 54.9%. The average simple payback period is 3.7 years.

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http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led_energy_efficiency.pdf

Table 2.3 Summary of results from LED Conversion Plan.

	After Conversion		
City	**Annual Savings**	**Energy Savings (kWh)**	**Payback Period (yrs)**
Ferndale	$161,748.22	977,634	3.3
Harper Woods	$103,709.42	425,313	3.4
Farmington	$44,067.45	243,285	3.8
Hazel Park	$54,802.93	375,312	3.6
Huntington Woods	$13,800.70	48,216	4.6
Madison Heights	$150,326.06	704,466	3.6
River Rouge	$96,903.92	559,125	3.7
Royal Oak	$286,924.37	1,691,088	2.8
St. Clair Shores	$208,038.97	1,254,792	4.2
Warren	$888,898.06	5,326,041	4.1

2.3.3 Lighting Power Density Analysis

For this project, lighting power density analysis is expressed as wattage per mile. The trend lines shown in **Figure 2.4** represent the typical lighting power density (LPD) for street lighting in these 10 communities. The results show that street lighting density in these communities is on average 6087.20 W/mile, and includes 28.26 fixtures/mile.

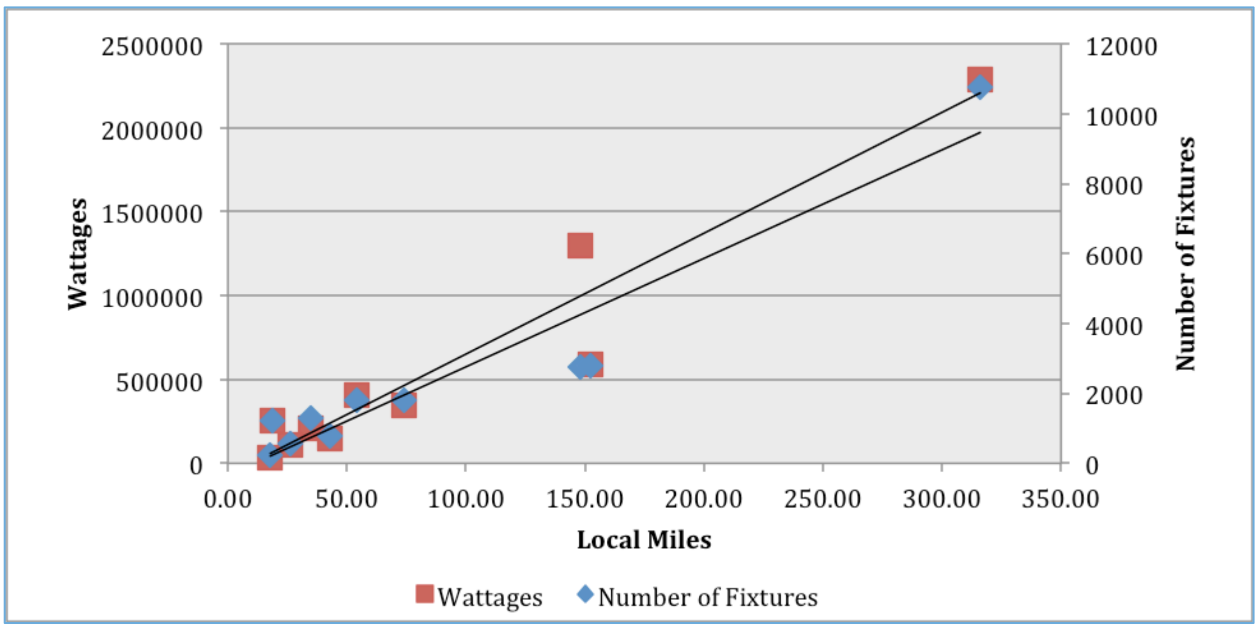

Figure 2.4: Local Miles vs Street Light Wattage

2.4 Lighting Performance

Light, measured in lumens, is defined according to the visual sensation it produces in "daytime" conditions. However, the visibility of light varies with external conditions. During "daytime" or indoor lighting conditions, where there is a high level of ambient light, the eye uses its cone sensors to perceive light. This type of vision is referred to as photopic (photon-rich) vision. During "night time" conditions, where there is a low level of ambient light, the eye uses its rod sensors to perceive light. This type of vision is referred to as scotopic (scarcity of photons) vision. The rods have a different color response than the cones in the eye, as shown in the photopic and scotopic V-λ curves, **Figure 2.5**. Under outdoor lighting at night, the eye operates in an intermediate range, called mesopic vision, using both rods and cones.

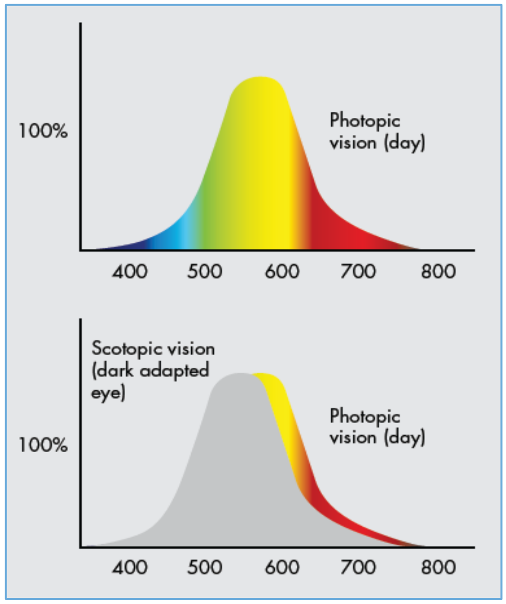

Figure 2.5: Photopic and scotopic luminous curves

Today, street lighting commonly uses high-intensity discharge lamps, often high pressure sodium lamps. Such lamps provide the greatest amount of photopic illumination for the least consumption of electricity. When scotopic/photopic light calculations are used, it can be seen how inappropriate HPS lamps are for night lighting. New street lighting technologies, such as induction or LED lights, emit a white light that provides high levels of scotopic lumens allowing street lights with lower wattages and lower photopic lumens to replace existing street lights. Some representative S/P ratios are given in **Table 2.3**.

Table 2.3. Scotopic/photopic ratios of various common light sources.

Light Source	S/P ratio
Incandescent	1.36
Fluorescent (3500K)	1.36
Fluorescent (5000K)	1.97
Metal Halide (warm white)	1.20
Metal Halide (daylight)	2.40
High Pressure Sodium	0.65
Low Pressure Sodium	0.25
LED (3500K)	1.39
LED (6000K)	2.18

Figure 2.6 shows an aerial view of Los Angeles, California in 2008, and the same view in 2012 after a four-year, citywide LED streetlight replacement program. The images shows that the LED streetlights significantly decreased the amount of light pollution compared to the incumbent high intensity discharge (HID) fixtures.[17] More figures can be found in the appendix demonstrating how improved light utilization of LED-based outdoor lighting fixtures affects the street view.

[17] J. Edmond, Reinventing Lighting, DOE SSL R&D Workshop, San Francisco, CA, 27 January 2015. http://www.energy.gov/sites/prod/files/2015/02/f19/edmond_reinventing_sanfrancisco2015.pdf

Figure 2.6: Los Angeles, CA Citywide Streetlight Retrofit (2008-2012)

2.5 Standard of Streetlights

Standardization plays a key role in our complex society, helping to maximize compatibility, interoperability, safety, repeatability, or quality between and among technologies. There are thousands of standards across a variety of industries, including lighting. The Illuminating Engineering Society (IES) is a professional organization that develops lighting standards and recommendations. The primary determinant of whether the LED luminaires perform sufficiently to be feasible replacements for the base case luminaires is whether they provide adequate lighting. Commonly accepted guidelines for street lighting are laid out in Standard Practice for Roadway Lighting, RP-8-00, which provides the design basis for lighting roadways, adjacent bikeways and pedestrian ways.[18] Generally, LEDs consume less energy to produce the same lumens than other light sources do. Communities and municipalities should refer to the standards and the test methods from American National Standard Practice for Roadway Lighting for the implementation of LED replacement.

2.6 Technology Barriers

The field of available LED street lighting products has changed drastically in recent years. The industry has hosted a rapid advancement in lumen/watt efficacy, a rapid decrease in costs per unit, and a stunning proliferation of products and manufacturers in the marketplace. LED technology is vastly different from legacy street lighting technologies and requires new and different approaches in using it. With this, new tools and expertise are needed to successfully implement LED street lighting upgrade projects. Municipalities need expertise in how to evaluate street lighting systems, design new systems, procure high quality and reliable LED products, understand regulatory tariffs; and evaluate the economics of street lighting upgrades.

Many municipalities in Southeast Michigan lack the resources and the technical expertise needed to design and implement successful LED street lighting upgrade projects. Providing municipalities with tools, resources and expertise offers a significant opportunity regionally and nationally to accelerate adoption of LED street lighting. One of the most effective solutions could be encourage development of regional information sharing forums, on-line resource center and identified expertise.

[18] American National Standard Practice for Roadway Lighting. ANSI / IESNA RP-8-00, Approved 6/27/2000 Reaffirmed 2005. Page 8

2.7 Additional Services

Traditionally, street lighting is controlled either by light sensors (dusk to dawn) or, alternatively, a time-based device, such as an astronomical time switch or system time clock, wired to or built into a lighting control panel (curfew lighting). In recent years, progressive facility owners and prevailing energy codes have pursued significant energy cost savings by reducing lighting when it needs to remain available but is not in use.

To successfully realize this light reduction control strategy, four components are essential:

1. Capability for scheduled automatic lighting reduction, with system intelligence residing centrally (e.g., at a control panel) or distributed (i.e., within each luminaire).
2. A means of automatically raising the luminaire back to full output when the luminaire is required to return to use because light is needed by an occupant.
3. The ability for the luminaire to automatically return to its energy-saving dim state after the lighted area becomes unoccupied again.
4. Dual-circuiting of the controlled load, allowing bi-level switching, or a dimmable ballast or driver allowing continuous or step dimming.

Occupancy sensors play a critical role in components #2 and #3, providing a 0–10 V control signal to the luminaire to raise or lower light levels and power based on whether the controlled area is occupied or vacant. Depending on the settings, up to 86% energy savings may be achieved over standard luminaire operation while in the dimmed state (LED luminaires). Studies suggest strong resulting energy savings potential as high as 75%, but proper commissioning is essential.[19]

Smart lighting, connected lighting, intelligent lighting, and adaptive lighting are some of the terms that describe recent innovations in the lighting industry enabled by the emergence of SSL. SSL is fundamentally dimmable, instant on/off, and can be engineered to be spectrally tunable, providing for new levels of control. The convergence of many technologies with SSL is providing new opportunities for connectivity with lighting. We are rapidly moving towards a future where all building systems, including lighting, HVAC, and security, will be networked through internet-enabled components, which will change the way lighting is valued. The integration of inexpensive and compact sensors, wireless network technology, smart phones, and sophisticated analytics is leading to new possibilities in the area of building energy management systems and could possibly lead to completely new business models such as offering lighting as a service. **Figure 2.7** shows how these systems could work together.

[19] U.S. DOE EERE, Exterior Lighting Control Guidance, August 2013. https://www4.eere.energy.gov/alliance/sites/default/files/uploaded-files/exterior-lighting-control-guidance.pdf

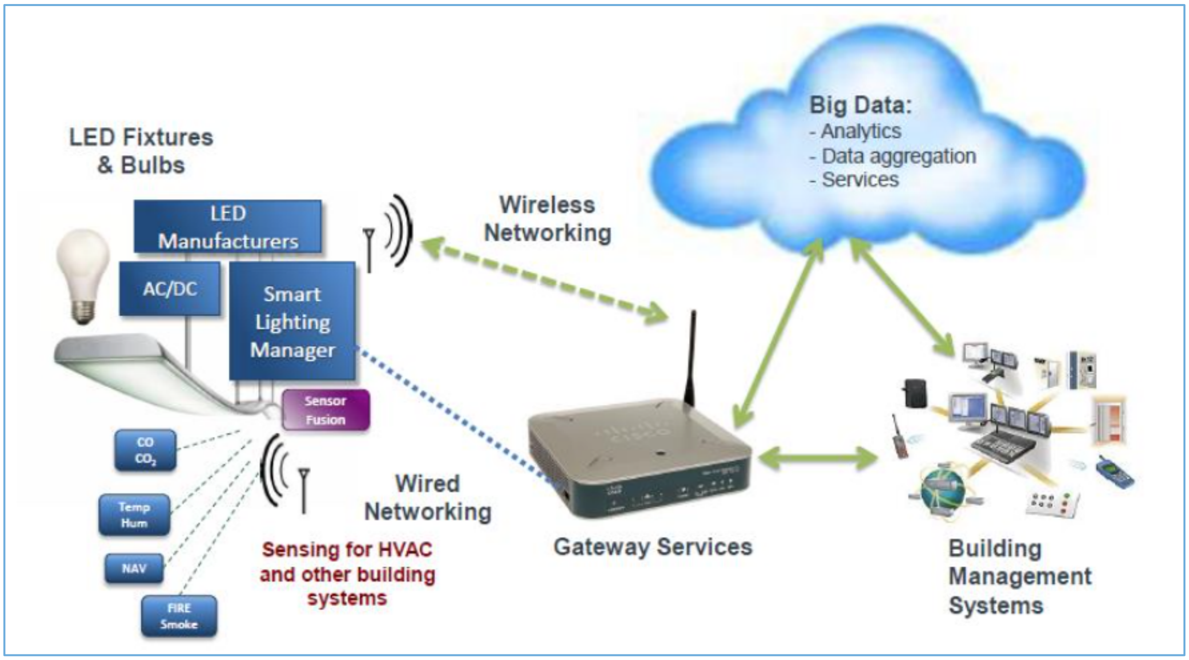

Figure 2.7: Lighting as Part of an Integrated Control System[20]

A networked building energy management system can provide simplified access to all pertinent energy systems' information and produce real-time reporting of energy consumption. This information would allow building managers to monitor energy consumption across all devices comprising the system, providing the ability to respond to specific energy consumption patterns; for example, unplugging devices that consume energy but are not being used, or turning off lights in unoccupied spaces. However, the implementation of a fully networked system can bring challenges of its own, such as integrating and managing disparate systems with varying communications protocols, both open source and proprietary, without compromising reliability and security.

[20] T. Griffiths, Integrating the Internet of Awareness into our smart SSL systems (MAGAZINE), 23 February 2015. http://www.ledsmagazine.com/articles/print/volume-12/issue-2/features/connectivity/integrating-the-internet-of-awareness-into-our-smart-ssl-systems.html

2.8 Projections

In 2013, in this submarket LEDs already held an impressive 14% market share, while high pressure sodium (HPS) and metal halide made up the majority of the remainder. **Figure 2.8** shows the DOE's estimate for the installed base of LED area and roadway luminaires from 2012 to 2014. In 2012, there were 1.3 million LED area and roadway installations, which increased more than four times to 5.7 million LED luminaires installed by the end of 2014, while at the same time the cost of LED installation continued to decline.[21]

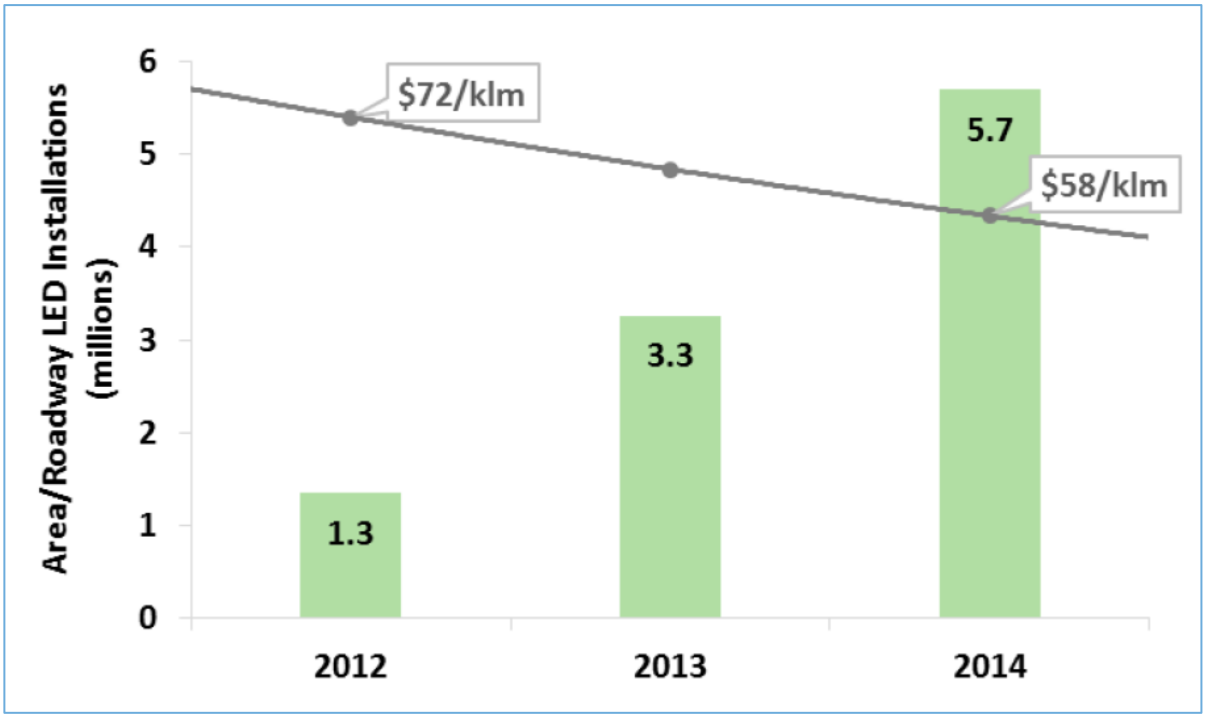

Figure 2.8. Installed Base and Price Estimates for Area/Roadway LEDs[22]

[21] U.S. DOE SSL Program, Adoption of Light-Emitting Diodes in Common Lighting Applications. Prepared by Navigant Consulting, July 2015.
[22] U.S. DOE SSL Program, Adoption of Light-Emitting Diodes in Common Lighting Applications. Prepared by Navigant Consulting, July 2015.

The lighting market analysis projects LED market share to increase rapidly, reaching 50% of all lumen-hour sales as early as 2017 (**Figure 2.9**). The lighting market model projects that nearly 100% of the street and roadway lighting installed base will be LED bulbs by 2030. This almost complete saturation with LED technologies will result in site electricity savings of nearly 30%, which is impressive considering that many of the HID technologies being displaced by LEDs are also quite efficient.[23]

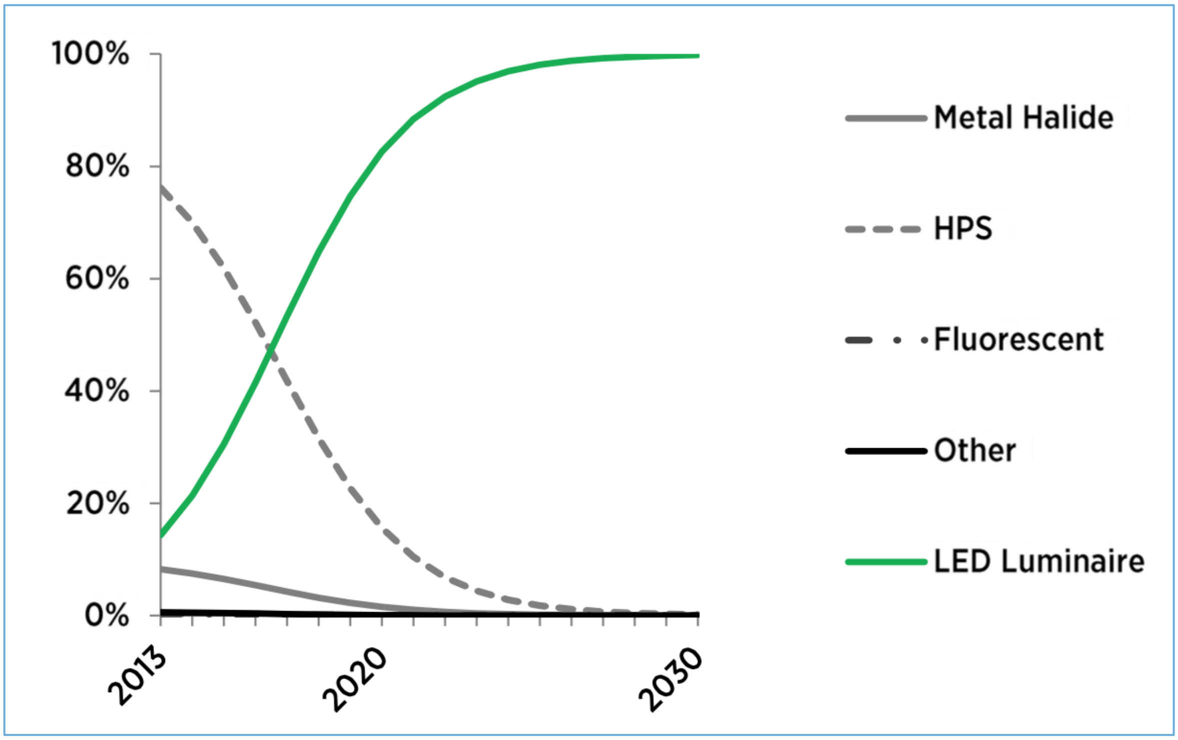

Figure 2.9: Street and Roadway Market Share (% of lm-hr sales) Forecast, 2013 to 2030.[24]

[23] U.S. DOE SSL Program, Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, Prepared by Navigant Consulting, August 2014. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/energysavingsforecast14.pdf

[24] U.S. DOE SSL Program, Adoption of Light-Emitting Diodes in Common Lighting Applications. Prepared by Navigant Consulting, July 2015.

3. Policy Issues in Streetlight Expansion

3.1 Introduction

In order for the Southeast Michigan Regional Energy Office (SEMREO) to successfully create a regional streetlight authority and implement LED upgrades within its jurisdiction, it will be necessary to understand the state and local political landscape surrounding energy efficiency issues. This report aims to provide a thorough understanding of policies at the municipal, regulatory, state, and federal levels, and provide recommendations for advocacy to change policies that may discourage energy efficiency or renewable energy efforts.

3.2 Overview of State Energy Policy

At present, Michigan's state-level policies relating to renewable energy and energy efficiency are moderately favorable, if not radical in scope. The passage of Public Act 295 in 2008 introduced Energy Optimization Standards, which require publicly regulated utilities to file energy efficiency plans with the state.[25] The current standards require utilities to achieve an energy savings of 1% annually on retail electric sales, which have been held constant from 2012 to 2015. The same bill also introduced a Renewable Energy Standard for the state, requiring 10% of electricity to be produced from renewable sources by 2015.[26]

In 2000, the state's retail electricity market was deregulated with the passage of Public Acts 141 and 142, which opened up the supply of power to the competitive market.[27] Under retail open access, or "electricity choice," non-utility energy providers known as alternative energy suppliers could provide competitive alternatives to utility-provided electricity.[28] However, restructuring was rolled back somewhat in 2008 by House Bill 5524, which imposed a cap of 10% on the percentage of a utility's load that may be served by competitive retail suppliers.[29] This load is currently fully subscribed.[30]

3.3 Utility Incentives

To understand the nature of the conflict between utility and municipal interests, it is crucial to examine the electric utility business model. Traditionally, electric utilities were vertically-integrated, investor-owned companies, owning and operating electricity generation, transmission, and distribution facilities in or near their service areas.[31] Today, thanks to the restructuring efforts of the 1970s and 1980s, electricity markets are much more complex: many states, including Michigan, belong to power pools run by Independent System Operators (ISOs) that operate the grid and dispatch electricity, while utilities may

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[25] Michigan Agency for Energy. Energy Efficiency. http://www.michigan.gov/energy/0,4580,7-230-72200_68204_54284---,00.html

[26] Michigan State Legislature. Oct 6, 2008. Clean, Renewable and Efficient Energy Act (Act 295 of 2008). http://www.legislature.mi.gov/(S(kvotsp2ptquvgdbsllopsmbp))/mileg.aspx?page=getObject&objectName=mcl-Act-295-of-2008

[27] Michigan State Legislature. June 5, 2000. Enrolled Senate Bill No. 937. https://www.legislature.mi.gov/documents/1999-2000/publicact/pdf/2000-PA-0141.pdf

[28] LARA. What is electric choice? http://www.michigan.gov/mpsc/0,1607,7-159-16377_17111-42250--,00.html

[29] Michigan State Legislature. October 6, 2008. Enrolled House Bill No. 5524. http://www.legislature.mi.gov/documents/2007-2008/publicact/pdf/2008-PA-0286.pdf

[30] American Coalition of Competitive Energy Suppliers. State-by-state information: Michigan. http://competitiveenergy.org/consumer-tools/state-by-state-links/#michigan

[31] Joskow, Paul. "Transmission Policy in the United States," *Utilities Policy*, 2005, 13: 95-115.

own and operate generation or other system components.[32] However, the electric utility industry is still heavily regulated by states, through governmental bodies known as public utility commissions (PUCs). PUCs use a process called a rate case to determine the amount of profit a utility can reasonably collect from its consumers.[33] Ostensibly, the purpose of this regulation is to ensure that utilities are able to obtain the amount of revenue needed to ensure reliable and high quality electricity services, while also maintaining rates that are affordable and fair to consumers.

The term "total revenue requirement" refers to the amount of revenue a utility must obtain in order to cover its costs while also maintaining a reasonable profit. In order to determine the total revenue requirement for utilities, PUCs use the following (simplified) formula:

Total revenue requirement = (rate base x allowed rate of return) + expenses[34]

A utility's rate base refers to its total assets for generation, transmission and distribution, subtracted by the accumulated depreciation of these assets.[35] Expenses include all operating costs associated with generation, transmission, and distribution, including fuel costs if the utility owns generation facilities.[36] The allowed rate of return consists of the costs of debt payments to investors plus interest, combined with a return on equity (ROE) set by the PUC; the ROE represents the portion of revenue that the utility is allowed to keep as profit.[37] The average ROE for American utility companies is 10.30%, compared to an average of 14.49% across all firms in the U.S. market;[38]

From an environmental perspective, there are several inefficiencies in utility business models. First, the "total revenue requirement" system encourages utilities to build or accumulate assets, as these will be factored into the utility's rate base and all expenses passed on to the consumer. In practice, this often means that utilities will choose to build power plants rather than invest in energy efficiency projects; additionally, utility-owned streetlights are considered assets in this equation, meaning that utilities have little to no incentive to sell streetlights to municipalities. Second, the utility business model also incentivizes selling as much electricity as possible, as utilities earn revenue per KWh of electricity sold, and thereby disincentives energy efficiency projects. State regulators often circumvent these disincentives with energy efficiency requirements, such as the state of Michigan's energy optimization standards; however, utilities may still oppose specific energy efficiency projects, as described below in rate case U-17767.

3.3.1 State Regulatory Agency Profile: Michigan Public Service Commission

The Michigan Public Service Commission (MPSC) is the state's PUC, regulating both investor-owned and rural cooperative electric utilities, but not municipal utilities. The MPSC's current activities include providing regulatory oversight on rate cases, assisting utilities in adopting advanced technologies such as renewables and energy efficiency, and providing customers with electricity alternatives.[39] The MPSC is

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[32] Ibid.
[33] Giruoard, Coley. April 23, 2015. "How do electric utilities make money?" Advanced Energy Perspectives blog. http://blog.aee.net/how-do-electric-utilities-make-money
[34] Ibid.
[35] Joskow, Paul. "Transmission Policy in the United States," *Utilities Policy*, 2005, 13: 95-115.
[36] Ibid.
[37] Giruoard, Coley. April 23, 2015. "How do electric utilities make money?" Advanced Energy Perspectives blog. http://blog.aee.net/how-do-electric-utilities-make-money
[38] Ibid.
[39] MPSC. About the MPSC. http://www.michigan.gov/mpsc/0,4639,7-159-16400-40495--,00.html

also responsible for implementing constitutional and legislative requirements, such as the energy optimization standards of 2008.

3.3.2 Utility Profile: DTE Electric

DTE Electric is the main electricity provider for Southeast Michigan, serving 1.9 million residential and 197,000 commercial customers annually, or about 45% of all electricity customers in the state of Michigan.[40] DTE Electric follows a traditional investor-owned, vertically-integrated business model: as a subsidiary of DTE Energy, Inc., the utility owns a large number of generation assets in Southeast Michigan, including the Fermi 2 nuclear plant and 7 of the largest coal-fired power plants in the state.[41] [42] As of December 11, 2015, the utility's authorized return on equity (ROE) is 10.30%, close to the national average ROE of 10.13%.[43]

3.3.3 Rate Cases in Michigan: An Overview

In general, a rate case is a legal process in which a utility must obtain permission from a PUC to increase rates paid by its customers. This is a legal process presided by an administrative law judge. In Michigan, a rate case begins when a utility files for a rate change with the MPSC.[44] Shortly afterwards, the MPSC will schedule public hearings on the proposed changes, typically involving a period of public comment; during this time, other parties may petition to be included in the case. At any point before the administrative hearing, parties may request a discovery, in which parties exchange information about evidence involved; during a utility rate case, this often involves one party submitting written questions to the other, requiring that they be answered under written oath.[45] The administrative hearing is then held, during which all parties present arguments and evidence. The administrative law judge issues a proposal for decision, to which any party may file an exception; the MPSC will take the judge's ruling and any exceptions into account, but will ultimately make the final decision. The MPSC issues an opinion and an order, which parties may appeal by requesting a rehearing or reconsideration of the order.[46]

3.3.4 Summary of Events: MPSC Case No. 17767 (2014-15)

In December 2014, DTE Electric filed a rate case with the MPSC requesting, among other items, a rate schedule that raised electricity rates for LED streetlights such that the cost of operating LEDs would be roughly the same as the cost of operating conventional high-pressure sodium bulbs.[47] While DTE claimed that the rate increases were justified in that LED bulbs were costing the utility more than it had previously

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[40] Powersuite. Michigan Utilities: DTE Electricity. http://powersuite.aee.net/portal/states/MI/utilities
[41] DTE Energy. 2014. Fact sheet/Backgrounder. https://dteenergy.mediaroom.com/index.php?s=26823
[42] Sourcewatch. DTE Energy. http://www.sourcewatch.org/index.php/DTE_Energy.
[43] MPSC. December 11, 2015. Case No. U-17767. http://efile.mpsc.state.mi.us/efile/docs/17767/0485.pdf
[44] MPSC. July 2015. The rate case: how utility rates are set. https://www.michigan.gov/documents/mpsc/mpsc-ca_ratecase2_211317_7.pdf
[45] American Bar Association: Division for Public Education. Glossary of Terms. http://www.americanbar.org/groups/public_education/resources/law_related_education_network/glossary/glossary_d.html#discovery
[46] MPSC. July 2015. The rate case: how utility rates are set. https://www.michigan.gov/documents/mpsc/mpsc-ca_ratecase2_211317_7.pdf
[47] Solo Jr, Michael J. December 19, 2014. In the matter of the Application of DTE ELECTRIC COMPANY for authority to increase its rates, amend its rate schedules and rules governing the distribution and supply of electric energy, and for miscellaneous accounting authority. Case U-17767. https://efile.mpsc.state.mi.us/efile/docs/17767/0001.pdf

anticipated, many municipalities felt that they were the victims of a "bait and switch,"[48] and on January 21, 2015, SEMREO petitioned to intervene in the rate case on behalf of local municipalities against these hikes.[49]

On March 25, 2015, SEMREO submitted a list of twenty-three discovery questions for DTE, mostly requesting the specific information that DTE used to calculate its new rate increases.[50] In response, the utility stated that capital costs reflect costs of series conversions, outage restoration, post replacement, and the company's contribution to converting mercury vapor and metal halide bulbs to other technologies.[51] DTE claims that its figures are based on those of Michigan peers with similar unbundled rate structures, Consumers Energy and the Lansing Board of Water and Light, and that LED conversions have minimal impacts on operation and maintenance costs. [52]

Notably, DTE stated that the company has no plans to upgrade, replace, or provide for continuation of services when technologies become obsolete.[53] While the Energy Policy Act of 2005 prohibits manufacturers from selling mercury vapor bulbs after 2008, DTE uses a 22-year lifespan assumption for mercury vapor and HPS technologies. [54]This assumption, in combination with a lack of upgrade planning, could mean that mercury vapor lamps could remain in service as late as 2030 if conversions are unable to move forward. In contrast, the company uses a shorter 15-year lifespan for LED bulbs; the source of this figure is unclear. [55]

DTE generally refused to respond to any questions pertaining to the energy use of specific municipalities on account of confidentiality concerns, likely not recognizing SEMREO as a legitimate actor on behalf of these communities. Additionally, DTE revealed that it does not track operation and maintenance costs at the light fixture level of detail, suggesting oversights in the company's bookkeeping that could inhibit future lighting conversions.

After the discovery process was complete, the administrative hearing was held in July of 2015, in which the presiding ALJ recommended against the rate increase for LED streetlights. On December 11, 2015, the MPSC officially sided with the ALJ and ruled against the tariff increase, and SEMREO counted a major victory for municipalities. Although DTE has since proposed a new rate case, U-18014, on February 1, 2016, the new rate proposal proposes less stringent rate increases on LED streetlights. Additionally, the utility shows increased signs of willingness to negotiate with SEMREO, suggesting that the municipal coalition has successfully increased the company's awareness of stakeholders' views.

3.4 Overview of State Legislative Activities

Upon his election to office in 2011, Governor Rick Snyder (R) has been a strong supporter of energy efficiency standards, stating that "energy efficiency is the best example of a no-regrets policy Michigan

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[48] Moran, K. Michelle. March 12, 2015. Proposed DTE increase on LED streetlights leaves local cities split. Grosse Points. https://drive.google.com/drive/u/1/folders/0B6lhKcZaz4EfU0d2WVN3aGp5RUU
[49] Rosier, Leland R. January 21, 2015. Petition to intervene of the Municipal Coalition. Case No. U-17767. https://efile.mpsc.state.mi.us/efile/docs/17767/0058.pdf
[50] Liskey, John R. March 25, 2015. Discovery Requests.
[51] Maquera, David S. April 7, 2015. DTE Electric Company's Responses to Municipal Street Lighting Consortium's First Discovery Request.
[52] Ibid.
[53] Ibid.
[54] Ibid.
[55] Ibid.

can have. It makes us more reliable, more affordable and protects our environment."[56] Accordingly, the Snyder energy plan contains many incentives for energy efficiency and renewable energy deployment: the plan would mandate an additional 15% energy efficiency savings by 2025, will 11-24% of energy coming from renewable sources during the same time period.[57] The plan proposes several specific energy efficiency policies to help achieve this goal: it calls for eliminating the expenditure cap on utility energy efficiency investments, encourages demand response, and would legalize on-bill financing.[58] However, the bill would also maintain the current 10% cap on retail open access, and poses additional restrictions on alternative energy suppliers, such as requiring them to demonstrate adequate capacity to serve customers for five years.[59]

On the Democratic side, Michigan's current energy plans have come under fire for not being stringent enough. Several Democratic senators and representatives have proposed legislation that would double energy optimization standards to 2% per year,[60] increase the renewable portfolio standard to 20% by 2022, and create an "affordable long-term strategy" to unify the Michigan electricity market.[61] In the Senate, three bills, S.B. 295,[62] 296,[63] and 297,[64] (2015) have been proposed in 2015 related to this plan, but thus far all three have stalled in the Energy and Technology committee; the House has also introduced three similar bills, H.B. 4055,[65] 4518,[66] and 4519[67] (2015), none of which have come to a vote on the House floor. While Democrats are not currently politically powerful in the Michigan State Legislature, comprising 46 out of 110 members in the House of Representatives and only 11 out of 38 Senators,[68] these bills are nonetheless an important demonstration of support for clean energy policies within the state legislative body.

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[56] Michigan State Legislature. Oct 6, 2008. Clean, Renewable and Efficient Energy Act (Act 295 of 2008). http://www.legislature.mi.gov/(S(kvotsp2ptquvgdbsllopsmbp))/mileg.aspx?page=getObject&objectName=mcl-Act-295-of-2008

[57] Bunch, Rick. April 7, 2015. Policy advocacy opportunities and options for the Coalition. Memorandum to Michigan Street Lighting Coalition Executive Committee.

[58] Ibid.

[59] Ibid.

[60] Gomberg, Sam. "Democrats' proposal to strengthen Michigan's renewable energy and energy efficiency standards is an important step forward, but state could go further with renewables." Union of Concerned Scientists. April 23, 2015. http://www.ucsusa.org/news/press_release/Michigan-renewables-0491#.VnjtTRUrIU2

[61] Bunch, Rick. April 7, 2015. Policy advocacy opportunities and options for the Coalition. Memorandum to Michigan Street Lighting Coalition Executive Committee.

[62] Michigan State Legislature. Senate Bill 0295 (2015). History. http://www.legislature.mi.gov/(S(yrnihegywth0jdn5eg4eoetp))/mileg.aspx?page=GetObject&objectname=2015-SB-0295

[63] Michigan State Legislature. Senate Bill 0296 (2015). History. http://www.legislature.mi.gov/(S(jabvcnemhkry0byg2yw5tgno))/mileg.aspx?page=getobject&objectname=2015-SB-0296

[64] Michigan State Legislature. Senate Bill 0297 (2015). History. http://www.legislature.mi.gov/(S(pzuhwkxcksedfaxwhedo0byw))/mileg.aspx?page=GetObject&objectname=2015-SB-0297

[65] Michigan State Legislature. House Bill 4055 (2015). History. http://www.legislature.mi.gov/(S(xwlo3eahao4pg50fvejiurxt))/mileg.aspx?page=GetObject&objectName=2015-HB-4055

[66] Michigan State Legislature. House Bill 4518 (2015). History. http://www.legislature.mi.gov/(S(rcycwexzwd5f2cr2e1gpyhcn))/mileg.aspx?page=GetObject&objectname=2015-HB-4518

[67] Michigan State Legislature. House Bill 4519 (2015). History. http://www.legislature.mi.gov/(S(ngvqx2zs2d4hfnu1up1lmdfk))/mileg.aspx?page=GetObject&objectname=2015-HB-4519

[68] Powersuite. Michigan: Legislature Party Sizes. http://powersuite.aee.net/portal/states/MI/legislature

However, several Republican plans proposed in the state Congress are considerably less hospitable to energy efficiency and renewables. In the state Senate, Sen. Mike Nofs (R- 19th District) proposed Bill 0437 (2015) which would eliminate energy optimization standards and the state renewable energy standard completely.[69] The bill would also restrict energy choice in the state of Michigan even further, prohibiting new retail open access customers after December 2015 and legally requiring alternative energy customers wishing to return to regulated service to stay on regulated service permanently after doing so.[70]

A similar bill in the state House of Representatives proposed by Rep. Aric Nesbitt (R- 66th District), H.B.4297, would also repeal the energy optimization standard and eliminate retail open access, but would leave the renewable energy standard intact.[71] Thus far, neither of these bills has passed their respective chambers of legislature: S.B.0437 stalled in committee,[72] while H.B.4297 was approved by the House Energy Committee in November 2015 but has yet to be passed by the House of Representatives as a whole. [73] While the two plans are sometimes referred to collectively by utilities as the "Nofs-Nesbitt Plan," there is in fact no official connection between the two plans, as each was proposed separately.[74]

3.5 Case studies: Street Lighting Consortium Models in Other U.S. Metropolitan Areas

In order to determine the best method of governing street lighting conversions as a regional entity, it may be instructive to review cases of other U.S. regions organizing around street lighting policies. This section will review two examples of street lighting consortium models in the U.S.: the Kansas City, MO area, and the California Street Lighting Association (CALSLA).

3.5.1 Kansas City, MO Region: The Metropolitan Planning Organization Approach

Kansas City, MO has achieved some success in converting area streetlights to LEDs through its regional metropolitan planning organization, the Mid-America Regional Council (MARC). A metropolitan planning organization (MPO) is an organization required by the Federal Aid Highway Act of 1962[75] to carry out the metropolitan transportation planning process, with one MPO designated for each urban area with a population of 50,000 or more;[76] many MPOs have branched out into planning processes beyond transportation. The scope of MARC includes programs in economic development, social programs, emergency services, environmental quality, energy use, and governmental services as well as the more

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69 Michigan State Legislature. July 1, 2015. Senate Bill No. 0437. http://www.legislature.mi.gov/documents/2015-2016/billintroduced/Senate/pdf/2015-SIB-0437.pdf

70 Bunch, Rick. April 7, 2015. Policy advocacy opportunities and options for the Coalition. Memorandum to Michigan Street Lighting Coalition Executive Committee.

71 Michigan State Legislature. March 5, 2015. House Bill No. 4297. http://www.legislature.mi.gov/documents/2015-2016/billintroduced/House/pdf/2015-HIB-4297.pdf

72 Michigan State Legislature. Senate Bill 0437 (2015). History. http://www.legislature.mi.gov/(S(0gupdllr0myhrbgbxsyrdvuj))/mileg.aspx?page=getobject&objectname=2015-SB-0437&query=on

73 Michigan State Legislature. House Bill 4297 (2015). History. http://www.legislature.mi.gov/(S(r5m5lr4wxwsitnh2j503odhq))/mileg.aspx?page=GetObject&objectname=2015-HB-4297

74 Lawler, Emily. December 2, 2015. "Utilities stress urgency of Michigan energy overhaul as it spills into 2016." MLive.http://www.mlive.com/lansingnews/index.ssf/2015/12/utilities_stress_urgency_of_mi.html#incart_river_home

75 Association of Metropolitan Planning Organizations. About MPOs: A Brief History. Excerpts from U.S. DOT's 1988 Report, Urban Transportation Planning in the United States: An Historic Overview. http://www.ampo.org/about-us/about-mpos/

76 U.S. DOT. Transportation Planning Capacity Building. https://www.planning.dot.gov/mpo.asp

traditional arenas of transportation and regional planning.[77] MARC serves 119 cities and nine counties in the Kansas City region.[78]

The Smart Lights for Smart Cities program was a MARC-supervised street lighting project implemented between 2010 and 2013, involving 25 municipalities with populations under 35,000.[79] This project was funded by an Energy Efficiency and Conservation Grant from the Department of Energy, a block grant made possible through the American Recovery and Reinvestment Act of 2009.[80] Project supervision and community outreach was provided by the Smart Lights Coalition, a steering committee organized through MARC, consisting of representatives from the 25 affected communities and the three local utilities impacted (Kansas City Power and Light (KCP&L), Westar Energy, and Platte-Clay Electric Cooperative).[81] KCP&L and other utilities not only cooperated with the project, but contributed analysis of best lighting protocols and vetted vendors on behalf of the coalition.[82] MARC owned the streetlights until the project's completion in the summer of 2013, when ownership was transferred to municipalities.[83] Ultimately, 5,700 LED streetlights were installed in the 25 member communities.[84]

3.5.2 California Street Lighting Association (CALSLA): The Nonprofit Advocate Approach

The California Street Lighting Association (CALSLA) is a nonprofit organization created to ensure fair street lighting rates for municipalities throughout California. CALSLA's origins date to 1981, when a group of Marin County municipalities, angry over perceived unfair street lighting rate increases by PG&E, sued the large utility under California's eminent domain law and won the right to acquire all street lighting for less than PG&E's valuation.[85] Today, the major functions of CALSLA are to represent municipalities in rate cases, which occur every three years in California;[86] collect annual street lighting assessments; and arrange biannual conferences on street lighting technology and policy.[87] The organization is governed by an Executive Committee consisting of representatives from member municipalities; paid staff include an executive director, a rate analyst, and legal staff.[88] Funding for the organization and its activities derives from membership dues, which are based on population and range from several hundred to five thousand dollars per year.[89]

Although all cities and counties who take streetlight service from California's three regulated, investor-owned utilities are eligible for CALSLA's services, not all are dues-paying members.[90] A list of dues-paying CALSLA members has not been identified at this time. While CALSLA has expressed support for LED streetlights as a cost-saving measure, there is no evidence that the organization has been directly

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[77] MARC. What is MARC? http://www.marc.org/About-MARC/General-Information/What-is-MARC
[78] Ibid.
[79] MARC. "Smart Lights for Smart Cities: Final Report." October 2013. http://www.marc.org/Environment/Energy/pdf/Smart-Lights-Final-Report.aspx
[80] U.S. DOE. Energy Efficiency and Conservation Block Grant Program. http://energy.gov/eere/wipo/energy-efficiency-and-conservation-block-grant-program.
[81] MARC. "Smart Lights for Smart Cities: Final Report." October 2013. http://www.marc.org/Environment/Energy/pdf/Smart-Lights-Final-Report.aspx
[82] Ibid.
[83] Ibid.
[84] MARC. Smart Lights for Smart Cities. http://www.marc.org/Environment/Energy/Conservation-and-Efficiency/Smart-Lights-for-Smart-Cities
[85] CALSLA. About California Street Lighting Association. http://www.calsla.org/about.html
[86] CALSLA. FAQ: How are street light rates set? http://www.calsla.org/FAQRetrieve.aspx?ID=51011&Q=
[87] CALSLA. About California Street Lighting Association. http://www.calsla.org/about.html
[88] Ibid.
[89] CALSLA. FAQ: How much are membership dues? http://www.calsla.org/FAQRetrieve.aspx?ID=51015&Q=
[90] CALSLA. FAQ: Which cities and counties are members of CALSLA? http://www.calsla.org/FAQRetrieve.aspx?ID=51013&Q=

involved with any California municipalities' street light conversion projects; nor that California utilities have proposed rate increases directly related to the energy efficiency of bulb technology, as Michigan's DTE has attempted to do.

3.5.3 Choosing a street light consortium model that works for SEMREO: MPO vs. Advocacy Organization

While there are several advantages to the MPO coalition structure, its feasibility for the Detroit region is unclear. The main advantage of using an MPO as the vehicle of streetlight conversion is its ability to attract consistent funding sources: as a well-established, partially-federally-funded organization, an MPO may be an attractive vehicle for large-scale federal grants such as those provided by ARRA in 2009. Additionally, as a well-established organization, an MPO is likely to be trusted and well-connected among other organizations in the region, thus facilitating outreach about the project and its goals. However, the Southeast Michigan region contains several structural barriers that might make this model impractical. First, the Detroit-area MPO, the Southeast Michigan Council of Governments (SEMCOG), has no history of involvement in energy issues, focusing mainly on transportation, air and water quality, and economic development.[91] Second, many streetlights in the Southeast Michigan region are owned by the utility, DTE Energy, rather than by the municipalities themselves, complicating streetlight conversion projects. Third, the federal stimulus provided by ARRA is no longer available, and other public or private sources of funds would need to be obtained. It remains unclear whether either SEMCOG or DTE is open to collaboration, or if large-scale public sources of funding such as ARRA will be available in the future.

CALSLA, in contrast, is mainly an advocacy organization, and does not own or maintain any streetlights itself. CALSLA's main role is to lobby for municipal ownership of street lighting, and to negotiate on behalf of municipalities during street lighting purchase agreements. Becoming a CALSLA-like advocacy group could be a viable strategy for the Coalition, given that its parent organization SEMREO, as an independent, energy-focused nonprofit, already has strong connections with community organizations in Southeast Michigan. These partners include Metro Matters, the Michigan Municipal League (MML), and EcoWorks, which have helped the group forge connections in the region and gain public trust. However, to imitate the CALSLA model, the Coalition would need to build up its legal and analytical expertise, either directly by hiring 1-2 legal professionals with utility policy experience, or by association through forging connections with environmental law firms or legal nonprofits in the region. As the coalition appears to be heading in a collaborative direction with DTE, it is unclear if a legalistic approach is appropriate at this time, or if the Coalition would be best served as a mediator body or other non-legal organization.

It is also unclear at this time if municipalizing of streetlights is a viable strategy in Michigan, given that the MPSC has no authority to coerce utilities to sell assets to municipalities. In theory, there are some financial benefits to having a utility cover the costs of maintenance: at this time, many Coalition member communities may be too financially- and resource-strapped to afford the staff and equipment needed to perform regular maintenance duties.

3.6 Other Policy Resources

3.6.1 State Level: Creation of the Agency for Energy

In March 2015, Governor Rick Snyder created the Michigan Agency for Energy (MAE), which "coordinates, analyzes, advises on, and advocates for the state's policies, proposals, and programs related

[91] SEMCOG. What we do. http://www.semcog.org/About-SEMCOG/What-We-Do

to energy," through Executive Order 2015-10.[92] This new agency brings together the Michigan Energy Office (MEO), a federally-designated state agency providing technical and funding assistance to reduce energy waste and lower costs; the Retired Engineer Technical Assistance Program, a former program of the Department of Environmental Quality in which retired energy professionals assist businesses and institutions with pollution prevention; and the Michigan Public Service Commission (MPSC), which continues to operate autonomously, into one regulatory body.[93] The MAE also coordinates with the Michigan Department of Environmental Quality (MDEQ) to ensure that all new energy projects are in compliance with air emissions standards for criteria pollutants such as particulate matter, sulfur dioxide, and nitrous oxide.[94] The Director of the MAE is Valerie Brader, a former policy advisor and Deputy Legal Counsel to Gov. Snyder with a background in environmental and corporate law.[95]

The current activities of the MAE include creating a "Reasonable and Prudent" portfolio plan, involving review of utilities' integrated resource plans and setting statewide parameters for these plans.[96] The MAE is also in the planning stages of Michigan's Energy Roadmap, which seeks to review the state's energy policy goals and explore new and innovative ratemaking structure.[97] Finally, the MAE oversees Qualified Energy Conservation Bonds, which will be discussed in greater depth during the financing section of this report.[98]

3.6.2 Federal Level: Department of Energy Activities

At present, there are no energy conservation standards in place for any of the lamp types currently used in street lighting. The high-intensity discharge (HID) lamps used in conventional street lighting, which include high-pressure sodium, mercury vapor, and metal halide lamps, have not been regulated by DOE energy conservation standards in the past.[99] While no LED energy efficiency standards exist currently, the DOE proposed a set of procedures in July 2015 that would test lumen output, input power, lamp efficacy, color temperature, color rendering index (CRI), power factor, lifetime, and standby mode.[100]

However, the DOE also offers a testing program, the Commercially Available LED Product Evaluation and Reporting (CALiPER) program, in which accredited test labs examine existing LED products in order to discourage low-quality products and inflated manufacturer claims.[101] CALiPER's 2014 report on outdoor lighting noted that 16,759 outdoor products were commercially available, with efficacy and lumen output from these products continuing to rise.[102] However, the agency also notes that issues with color, reliability, dimming, flicker, and glare still exist in the present market.[103]

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[92] MAE. About MAE. http://www.michigan.gov/energy/0,4580,7-230-72048---,00.html
[93] Michigan Agency for Energy: Programs. http://www.michigan.gov/energy/0,4580,7-230-72052---,00.html
[94] Michigan DEQ. Air Quality. http://www.michigan.gov/deq/0,4561,7-135-3310---,00.html
[95] MAE. About MAE. http://www.michigan.gov/energy/0,4580,7-230-72048---,00.html
[96] MAE. Administration's proposal to ensure a more reasonable and prudent portfolio plan. http://www.michigan.gov/energy/0,4580,7-230--362162--,00.html
[97] MAE. Energy Roadmap. http://www.michigan.gov/energy/0,4580,7-230-72052_72054_73554---,00.html
[98] MAE. Qualified Energy Conservation Bonds. http://www.michigan.gov/energy/0,4580,7-230-72052_72054_73979---,00.html
[99] Building Technologies Office. "High Intensity Discharge Lamps." U.S. Department of Energy. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/60
[100] Federal Register. Energy Conservation Program: Test procedures for integrated Light-Emitting Diode lamps; Supplemental notice of proposed rulemaking. July 9, 2015. http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-TP-0071-0040
[101] Department of Energy. "CALiPER Testing." http://energy.gov/eere/ssl/caliper-testing
[102] Building Technologies Office. "CALiPER Snapshot: Outdoor Area Lighting." http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/snapshot2014_outdoor-area.pdf
[103] Department of Energy. "CALiPER Testing." http://energy.gov/eere/ssl/caliper-testing

Another relevant DOE offering is the Municipal Solid-State Street Lighting Consortium, which serves as a resource for municipalities and utilities looking to share technical information and experiences, as well as provide objective information on new street lighting technologies.[104] This organization provides useful information in the form of financial analysis, market reports, implementation briefs, webinars, and other resources.[105] Three Michigan communities, Dearborn, Detroit, and Ann Arbor, are already members of this consortium.[106].

[104] Department of Energy. "About the Municipal Solid-State Street Lighting Consortium." http://energy.gov/eere/ssl/about-doe-municipal-solid-state-street-lighting-consortium
[105] Department of Energy. Outdoor Lighting Resources. http://energy.gov/eere/ssl/outdoor-lighting-resources
[106] Municipal Solid-State Street Lighting Consortium. Primary Participant Organizations. April 2013. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/consortium-participant-list.pdf

4. Environmental Analysis

4.1 Introduction

4.1.1 The EPA's Clean Power Plan and its Implications for Michigan

In September of 2015, the EPA announced the Clean Power Plan, which allows for carbon dioxide to be regulated as a pollutant under the federal Clean Air Act of 1970.[107] Following this announcement, prominent voices in Michigan were divided over the merits of this plan: Attorney General Bill Schuette sought to fight this rule in court, but Governor Rick Snyder declared that Michigan would comply with the order and create its own State Carbon Implementation Plan (SCIP).[108] However, after the Supreme Court granted a stay on the Clean Power Plan after several states challenged its legality in court,[109] temporarily suspending implementation of the bill, Gov. Snyder halted the state's compliance efforts, on the grounds that the state should wait for the high court's decision.[110] Although the fate of the Clean Power Plan is still uncertain, the following is a description of what implementation of this plan could mean for Michigan, and what incentives may be available for energy efficiency.

Under the Clean Power Plan, states have flexible options for meeting the EPA's targets. States have discretion over the timing of their policies, whether rate-based or mass-based approaches are chosen, and policy design.[111] In designing policies, the EPA recommends a Best System of Energy Reduction (BSER) containing 4 building blocks: (1) coal plant heat rate improvements, (2) increased use of existing natural gas, (3) renewables and nuclear development, and (4) end-use energy efficiency.[112] States also may choose from several strategies for compliance, including goal or standard-setting; market incentives; or other regional collaborations with other states, such as cap-and-trade schemes. [113]

Several technical analysts suggest that block 4 of the BSER, energy efficiency, will play a major role in successfully implementing Michigan's Clean Power Plan targets. The EPA's recommended breakdown for emissions reductions using the BSER places roughly equal weight on blocks 2 and 4, suggesting that Michigan could achieve almost the same emissions reductions through energy efficiency (11%) as through expanding natural gas use (12%).[114] A study conducted by 5 Lakes Energy examined two scenarios: one in which natural gas prices remain at levels predicted by the EIA (higher-cost), and one in which natural gas prices are lower than predicted (lower-cost). In both scenarios, energy efficiency remained the highest cost-effective reduction measure, making up 38% of reductions in the higher-cost

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[107] EPA. Clean Power Plan. http://www2.epa.gov/cleanpowerplan.

[108] Egan, Paul. "Michigan will comply with carbon reduction plan." Detroit Free Press. September 1, 2015. http://www.freep.com/story/news/2015/09/01/michigan-comply-carbon-reduction-plan/71505248/

[109] Adler, Jonathan H. February 9, 2016. "Supreme Court puts the brakes on EPA's Clean Power Plan." Washington Post. https://www.washingtonpost.com/news/volokh-conspiracy/wp/2016/02/09/supreme-court-puts-the-brakes-on-the-epas-clean-power-plan/

[110] Vanhulle, Lindsay. February 16, 2016. "Michigan to suspend Clean Power Plan compliance effort pending federal court decision." Crain's Detroit Business. http://www.crainsdetroit.com/article/20160216/NEWS/160219871/michigan-to-suspend-clean-power-plan-compliance-effort-pending

[111] Macedonia, Jennifer. "EPA's proposed Clean Power Plan: Overview and state goals." 2014. Bipartisan Policy Center: Washington, D.C.

[112] Ibid.

[113] NRDC. "Michigan's Clean Energy Future." March 2015.

[114] Macedonia, Jennifer. "EPA's proposed Clean Power Plan: Overview and state goals." 2014. Bipartisan Policy Center: Washington, D.C.

scenario and 50% of reductions in the lower-cost scenario.[115] Additional analyses demonstrate economic incentives for energy efficiency: an NRDC paper notes that energy efficiency measures cost $0-50 per MWh, as opposed to the next most affordable option, $60-90/MWh for a combined-cycle natural gas plant.[116]

4.1.2 Research Questions

Converting all streetlights in Southeast Michigan into LEDs is expected to greatly improve energy efficiency and reduce energy consumption, thus helping the state in compliance with CPP. However, quantifying actual emissions reductions is a challenge, and conducting environmental analysis is necessary to fulfill this task. In this section, four main questions will be explored:

> 1) How much will a conversion to LED bulbs help to reduce GHG and ambient air pollutant emissions?
> 2) How can these emission reductions help to improve air quality and reduce health risks for communities?
> 3) How is this method comparable to other mitigation mechanisms in terms of cost, implementation, and other factors?
> 4) How can this analysis help to match the project with policies that could bring financial advantages or overcome financial barriers for communities?

4.2 Terms and Assumptions

Technical terms related to electricity generator dispatch, streetlight operation, carbon accounting etc. are explained here to facilitate understanding of the following environmental analysis. Technical assumptions are provided alongside relevant terms.

> **Streetlight operating hours** vary day by day. Streetlights operate from dusk to dawn, but is simplified here as following sunset to sunrise (**Table 4.1**). Sunset-sunrise table is based on data from University of Oregon Solar Radiation Monitoring Laboratory (SRML) Sun Chart Program (See **Appendix 4.1** for more explanation).

[115] Jester, Douglas B, principal. "Michigan and the Clean Power Plan: Clarifying the options." February 17, 2015. 5 Lakes Energy, LLC: Lansing, MI.
[116] NRDC. "Michigan's Clean Energy Future." March 2015.

Table 4.1. Sunset-sunrise table and resulting streetlight operating hour (based on SRML data)

University of Oregon SRML			
Sponsor: BPA		City	Detroit, MI
Lat	42.33	Long	-83.05
(Standard) Time Zone			-5
Date	**Sunset**	**Sunrise**	**Note**
21-Jan	17:20	7:55	
20-Feb	18:20	7:30	
20-Mar	19:30	7:30	DST applied
20-Apr	20:20	6:50	DST applied
21-May	21:00	6:20	DST applied
21-Jun	21:20	6:00	DST applied
21-Jul	21:00	6:20	DST applied
22-Aug	20:20	6:40	DST applied
22-Sep	19:20	7:30	DST applied
21-Oct	18:30	7:50	DST applied
21-Nov	17:00	7:40	
21-Dec	17:00	8:00	

Peak hours are defined as the hours between 06:00 and 22:00 EST Monday through Friday, excluding holidays. (MISO, 2013)[117]

The **state electricity profile** includes information related to the electricity consumption of each state, including energy sources, capacity, generation, consumption, and emissions.[118] It is assumed that the energy electricity profile remains unchanged before and after the streetlight conversion.

Generating unit refers to units in a power plant that convert other forms of energy, such as coal or natural gas, into electricity.[119]

In the **Generating unit dispatch algorithm,** dispatch starts with the lowest marginal cost unit from generation sources. The output of this generation unit is increased until load demand is met, or the unit reaches its maximum capacity, whichever occurs first. If the unit reaches maximum capacity, then the second-cheapest generation unit is started, and its output is increased until load or its capacity is reached. This process goes on with the next-least-expensive generating unit being activated until the load demand is met. Fixed costs of generating units are not considered in this dispatch process, but only costs that are directly related to operation. For fossil-fuel powered plants, which includes all units in our analysis, marginal costs are largely determined by primary fuel.[120]

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[117] MISO. 2013. "Day-Ahead Pricing Report Readers' Guide". Available at: <https://www.misoenergy.org/Library/Repository/Report/Readers%20Guide/Day-Ahead%20Pricing%20Report%20Readers%20Guide.pdf >

[118] EIA. 2016. "Electricity: State Electricity Profiles". Available at: <http://199.36.140.204/electricity/state/hawaii/index.cfm>

[119] Energy Vortex. 2016. Energy Dictionary: Generating Units. Available at: <https://www.energyvortex.com/energydictionary/generating_unit.html>

[120] Blumsack, Seth. "Economic Dispatch and Operations of Electric Utilities." Penn State University EME 801 Energy Markets, Policy and Regulation. Penn State University Department of Energy and Mineral Engineering, 2014. Web. 20 Nov. 2015. <https://www.e-education.psu.edu/eme801/node/532>.

There are three types of generating units:

Base load generating units normally operate 24 hours/day, 365 days/year. [121]
Peaking generators generally only operate when hourly loads reach maximum capacity.[4]
Intermediate generating units operate between base load and peaking generators.[4]
Load following units are the main units of concern in this analysis. These units include both intermediate generating units and peaking generators, and are defined as marginal units that follow load changes, rather than operating consistently, as do base load units. By converting from HPS streetlights into LED streetlights, we are reducing demand on these units.

Emission factors studied here include those of NO_x, SO_2 and CO_2. Emission factors differ in all power generating units, and vary from hour to hour. The reasons for this variation are that (1) different generating units have different fuel sources, such as coal, natural gas, coal refuse, diesel oil, liquefied petroleum gas, or nuclear; and (2) the fact that different combination of units are dispatched each hour of the day. The **Weighted emission factor** is a weighted yearly value based on emission factors of all load following units during streetlight operation hours and their generating contribution (%) to the total streetlight energy consumption. This factor was created specifically for this analysis.

The **Social discount rate** is used to evaluate the value of funds invested in social projects. The value is highly controversial, and can vary from 3% to 7% in developed countries. 3% is chosen in this project, since it is widely used in similar projects.[122]The **Social cost of carbon** is a metric that the EPA and other federal agencies use to evaluate environmental benefits of policies.[123] It is a useful tool to evaluate the benefits brought by CO_2 emission reductions.[124] There have been heated debates which discount rate to use, but for this analysis, a 3% average discount rate (ie. $36 per metric ton in 2015-2019, $42 in 2020-2024, and $46 in 2025) was chosen, as it has been the most widely used so far.

The conversion plan based on the baseline scenario is designed as 10% conversion each year, with the full conversion realized in 2025.

4.3 Scope of analysis

Currently, the Southeast Michigan Regional Energy Office (SEMREO) Street Lighting Consortium consists of twenty-five communities in Southeast Michigan. For most member communities of this consortium, a high share of streetlights is owned and operated by the local utility DTE Energy; however, the consortium has devoted great effort into researching how best to change the ownership structure and rate plan, in addition to converting HPS streetlights to LEDs. In this analysis, calculations are based on data from communities that have already undergone LED streetlight conversions. An environmental analysis will be conducted to quantify the avoided environmental and human health impacts from CO_2, SO_2 and NO_x emissions released in electricity generation, as well as determine the carbon mitigation cost of this project.

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[121] EIA. 2012. “Electric generator dispatch depends on system demand and the relative cost of operation”. Today in Energy. <http://www.eia.gov/todayinenergy/detail.cfm?id=7590>
[122] EPA. 2016. “Discounting Benefits and Costs”. TTN/Economics & Cost Analysis Support OAQPS Economic Analysis Resource Document. <https://www3.epa.gov/ttnecas1/econdata/Rmanual2/8.3.html>
[123] EPA. 2016. “The Social Cost of Carbon”. Climate Change. <https://www3.epa.gov/climatechange/EPAactivities/economics/scc.html>
[124] Wihbey., John. 2015. “Understanding the social cost of carbon – and connecting it to our lives”. Yale Climate Connections. <http://www.yaleclimateconnections.org/2015/02/understanding-the-social-cost-of-carbon-and-connecting-it-to-our-lives/>

4.4 Methods

4.4.1 Data acquisition

Energy consumption and energy generation data was used in this analysis. Energy consumption before the conversion can be determined using community streetlight energy bills provided by SEMREO. Energy consumption after the conversion can be determined using current quantity of streetlights, lumen requirements for local streets, the projected quantity of streetlights, the technical parameter of the chosen light model, and operating hours. Energy generation data was obtained from the EPA Air Markets Program Data (AMPD) Acid Rain Program (ARP), an hourly regional electricity supply dataset that contains detailed information for each generating unit. We have used the operating schedule; CO_2, SO_2 and NO_x emission factors; and gross load information of all Michigan generating units to conduct this analysis, with one weekday and one weekend day sampled from each month of 2014. (**Appendix 4.3**)

4.4.2 Data analysis

1. Identify load following units that operate during streetlight operating hours

For each generating unit, the variation of its hourly gross loads (MW) was computed on each sample day. Units with more than 5 MW variation in one day were identified as load following units for that day; smaller changes in load were considered more likely to be due to a temporary ancillary service adjustment or abnormal generator performance.

Figure 4.1 illustrates the relation between streetlight operation and total electricity demand change. It is clear that streetlight operating hours (**Table 4.1**) and peak hours do not entirely overlap. Thus it is not enough to only identify load following units that respond to peak demand; by adding a temporal filter, streetlight operating hours, we can analyze only the operation of the load following units in our analysis time period.

2. Calculate emission factors and weighted emission factors

For each of the identified load following units, NO_x, SO_2 and CO_2 emission factor is calculated using formula [1]:

[1] Emission Factor = Emission/ Gross load (lbs/MWh)

Emission factors of each unit change slightly every hour, and daily averages are calculated for each emission type. Then, the gross load of each load following unit that operates during streetlight operating hours are ranked, and each of their contributions to the time period of demand to which they respond is calculated using formula [2]:

*[2] Percentage load = (Unit specific load during streetlight operating hours / Total load of all load following units during streetlight operating hours) * 100%*

Next, a weighted emission factor for each day and each emission type can be calculated using formula [3]:

[3] Weighted emission factor =$\sum_{i=1}^{n} Emission\ Factor\ (Unit\ i) * Percentage\ Load\ (Unit\ i)$

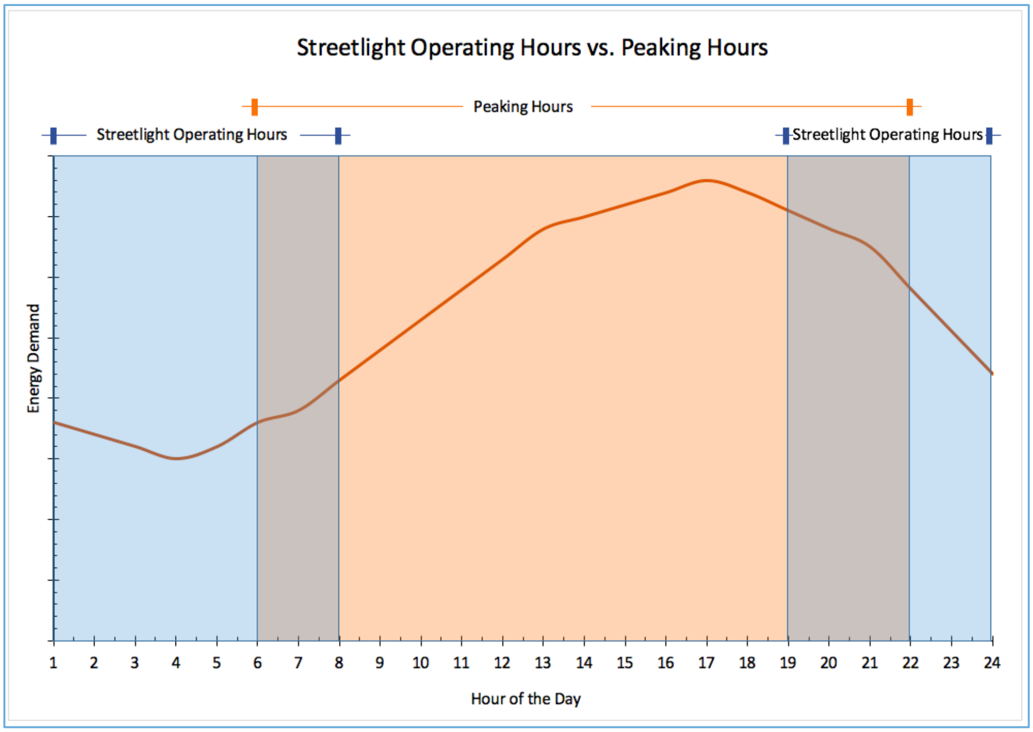

Figure 4.1: Relation between streetlight operation and total electricity demand

3. Yearly streetlight electricity consumption reduction, conversion cost, and savings

Energy bills provided by communities display the model types, wattage, and monthly energy use of existing streetlights. This information is used as a baseline to determine energy use after the conversion, and thus the yearly total consumption reduction realized after full conversion can be calculated.

4. Calculate total avoided emissions

As we assumed that electricity profile remains unchanged, the same emission factors were used for each emission type before and after the streetlight conversion. Formula [4] is used:

*[4] Yearly avoided emission at full conversion = Weighted emission factor * Yearly streetlight electricity consumption reduction*

Since the conversion does not happen overnight, yearly avoided emissions through the project's ten-year timeframe (2015-2025) increase as the conversion proceeds. The total for avoided emissions is calculated as:

[5] Total avoided emission = NPV (Social discount rate, [avoided emission of each year])

5. Calculate CO_2 mitigation efficiency

A 10% conversion cost is allocated to each year until conversion completion, and discounted using the same social discount rate as applied to avoided emissions. The CO_2 mitigation efficiency is calculated as:

[6] CO_2 mitigation efficiency = NPV (total conversion cost-total savings) / NPV (Total avoided CO_2 emission)

6. Quantify avoided social damages of GHG (CO_2) and ambient pollutant (NO_x, SO_2) reduction

The social cost of carbon, as published by the EPA,[125] is used to measure benefits regarding avoided CO_2 emissions. (**Appendix 4.4**) The Air Pollution Emission Experiments and Policy analysis (APEEP)[126] model developed by Prof. Nick Muller is used to quantify the avoided damage of NO_x and SO_2. APEEP is an integrated assessment model (IAM) that monetizes the damage caused by the physical effects of air pollution exposure, in form of county-specific marginal damage value expressed in $USD (2000). The total avoided emissions, as calculated using formula [5] above, is used to quantify health benefits brought by the emission reduction through LED conversion. Unlike CO_2, SO_2 and NO_x have a much larger localized health impact, and thus the benefits brought by avoided pollution are also concentrated in areas near the power generating units. (**Appendix 4.5**)

4.5 Results

1. Identified load following units that operate during streetlight operating hours

There are a total of 103 facility generating units in the MI area, 66 of which have been identified as responding to load demand in streetlight operating hours. (**Figure 4.2**) The responding units are sorted according to their average responding rate across the year. Results show that the 28 highest-ranking units (**Figure 4.3**) account for 90% of the total responding load. Only these 28 units are shown here, and the full list of all units is provided in **Appendix 4.5**. No cut-off was used, and all 66 load-following units were included in the analysis. Notably, most of these units are coal fired power plants.

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[125] EPA. 2016. "The Social Cost of Carbon". Climate Change. <https://www3.epa.gov/climatechange/EPAactivities/economics/scc.html>

[126] Muller., Nicholas. 2011. AP2 (APEEP): The Air Pollution Emission Experiments and Policy analysis (APEEP) model. <https://sites.google.com/site/nickmullershomepage/home/ap2-apeep-model-2>

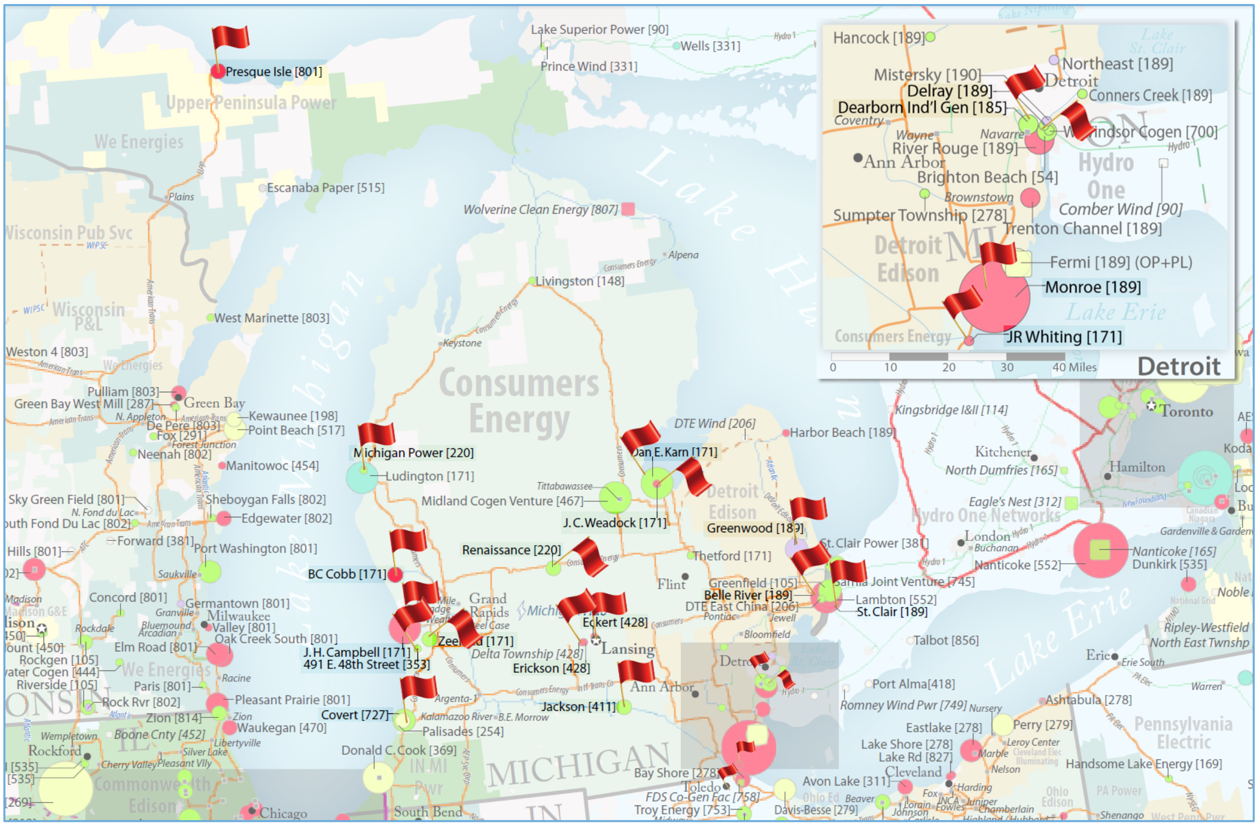

Figure 4.2: Location of identified load following facility generating units during streetlight operating hours (marked with red flags). Generating units of the same power plant are marked as one.

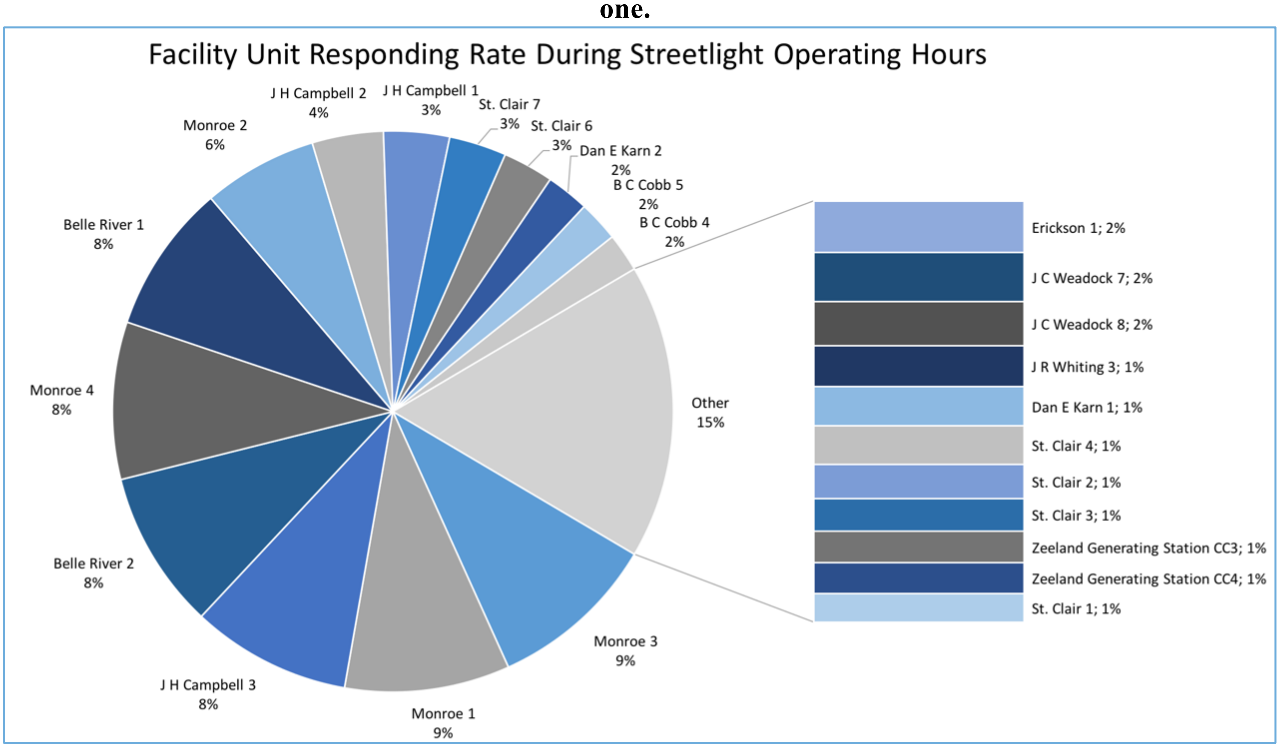

Figure 4.3: Top 90% Load following units and load contribution (% gross load) during streetlight operating hours

2. Emission factors and weighted emission factors

The emission factor for all 66 load-following units running during streetlight operating hours on each day were calculated and provided in supplementary Excel spreadsheets [Loadtracking1, ~, Loadtracking12]. Weighted emission factors during streetlight operating hours on each day, and yearly average are summarized in **Table 4.2**. From **Figure 4.4**, we can see how emission factors vary across the year in different seasons. One reason behind it is electricity demand change and related generating unit dispatch change. SO_2 emission rate vary in a much larger range than that of CO_2 and NO_x.

Table 4.2. Weighted emission factors during streetlight operating hours on each sample day

	Streetlight Operating Hours Weighted Emission Factor		
Sample Days	**SO_2 (lbs/MWh)**	**NO_x (lbs/MWh)**	**CO_2 (short tons/MWh)**
1/15/14	6.996	1.922	0.989
1/19/14	6.465	1.845	1.003
2/12/14	4.757	1.473	0.902
2/16/14	4.969	1.572	0.964
3/12/14	4.916	1.808	1.012
3/16/14	4.903	1.558	1.008
4/16/14	2.524	0.947	0.884
4/20/14	2.915	1.124	0.965
5/14/14	3.965	1.431	0.997
5/18/14	5.679	1.879	1.059
6/18/14	5.009	1.545	0.956
6/22/14	5.091	1.756	1.010
7/16/14	4.066	1.693	1.035
7/20/14	3.175	1.793	1.054
8/13/14	4.578	1.686	1.051
8/17/14	4.388	1.666	1.042
9/17/14	2.082	1.075	0.572
9/21/14	1.726	0.826	0.489
10/15/14	3.774	1.752	0.998
10/19/14	4.442	1.543	1.066
11/12/14	3.874	1.500	1.024
11/16/14	3.126	1.356	1.017
12/17/14	4.292	1.377	1.014
12/21/14	5.142	1.607	1.049
Yearly average	4.286	1.531	0.965

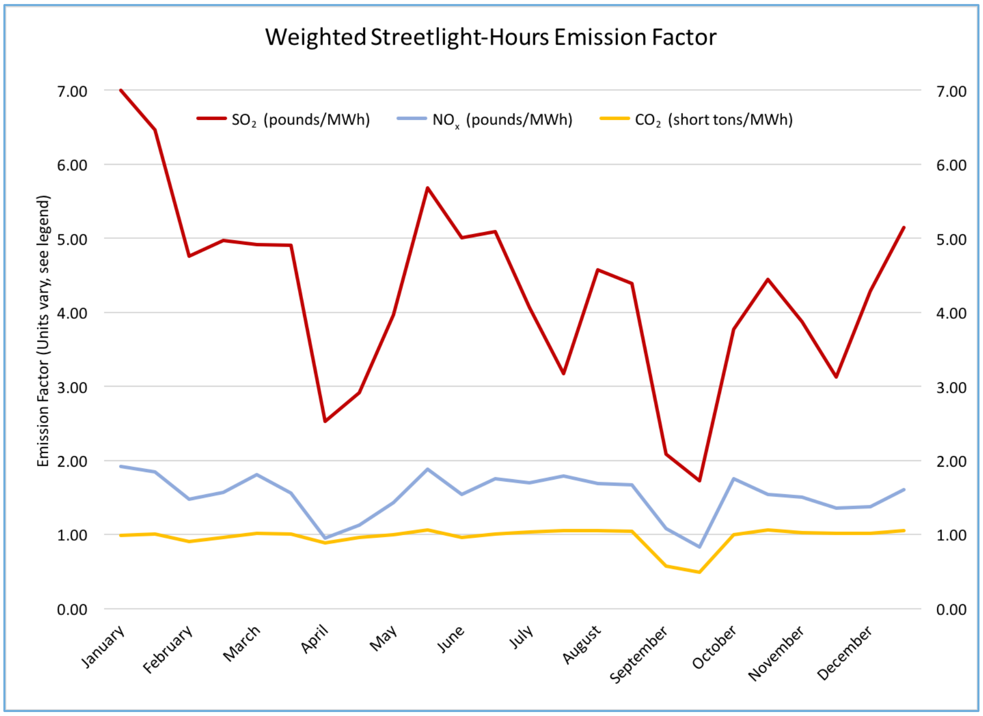

Figure 4.4: Weighted emission factors during streetlight operating hours on each day

3. Calculation of early streetlight electricity consumption reduction, conversion cost, and savings.

Results are shown in **Table 4.3**. Please refer to the model in supplementary spreadsheet [Energy Bills and LED Conversion] for calculation details.

Table 4.3. Yearly energy savings, conversion cost and annual savings at full conversion

For the Ten communities with available energy bills (Baseline Scenario, 10%/year conversion)			
Now		Future at full conversion	
Operation Hours per Year	4200	Operation Hours per Year	4200
Total Current Watt	5,029,515	Total Future Watt	2,266,355
Total Current Energy Consumption (kWh)	21,123,963	Total Future Energy Consumption (kWh)	9,518,691
Comparison			
Energy Savings (kWh)	11,605,272		
Total conversion cost	$ 7,982,592		
Total annual savings	$ 1,522,137		

4. Calculation of total avoided emissions

Using formula [4] Yearly avoided emission at full conversion = Weighted emission factor * Yearly streetlight electricity consumption reduction, results are calculated for CO_2, SO_2 and NO_x (**Table 4.4**).

Table 4.4. Yearly avoided emissions at full conversion

	SO_2	NO_x	CO_2
Energy Savings (kwh)		11,605,272	
Weighted Emission Factor	4.286 lbs/MWh	1.531 lbs/MWh	0.965 short tons/MWh
Yearly Avoided Emission	49,734 lbs	17,764 lbs	11,199 short tons
	24.87 short tons	8.88 short tons	10,160 metric tons

5. CO_2 mitigation efficiency

Net present value of avoided emissions (**Table 4.5**) and project cost (**Table 4.6**) are used to compute project CO_2 mitigation efficiency.

Table 4.5. Net present value of avoided emissions (Discount rate, 3%)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Completion	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Avoided Emission											
SO_2 (Short ton/yr)	0.00	2.49	4.97	7.46	9.95	12.43	14.92	17.41	19.89	22.38	24.87
No_x (Short ton/yr)	0.00	0.89	1.78	2.66	3.55	4.44	5.33	6.22	7.11	7.99	8.88
CO_2 (metric ton/yr)	0.00	1015.99	2031.98	3047.97	4063.96	5079.95	6095.94	7111.93	8127.92	9143.91	10159.90
Discounted Total NPV											
SO_2 (Short ton)	108.25										
No_x (Short ton)	38.67										
CO_2 (metric ton)	44229.12										

Table 4.6. Net present value of project cost (Discount rate, 3%)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Completion	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cost	$ 798,259	$ 798,259	$ 798,259	$ 798,259	$ 798,259	$ 798,259	$ 798,259	$ 798,259	$ 798,259	$ 798,259	$ -
Savings	$ -	$ 152,213.7	$ 304,427.4	$ 456,641.1	$ 608,854.8	$ 761,068.5	$ 913,282.2	$ 1,065,495.9	$ 1,217,709.6	$ 1,369,923.3	$ 1,522,137
Net cost	$ 798,259	$ 646,045	$ 493,832	$ 341,618	$ 189,404	$ 37,191	$ (115,023)	$ (267,237)	$ (419,450)	$ (571,664)	$ (1,522,137)
Discounted Total NPV											
3%	$182,993										

CO_2 mitigation efficiency = \$182,993/44229.12 Metric ton CO_2 = \$4/Metric ton CO_2

A normal passenger car emits 5.5 metric tons[127] of CO_2 annually. The avoided CO_2 emissions is equivalent to taking 8050 cars out of the road.

6. Avoided social damages of GHG (CO_2) and ambient pollutant (NO_x, SO_2) reduction

Using the avoided emission results from **Table 4.4** and **Table 4.5**, and the monetary value of emission reductions in **Appendix 4.4** and **Appendix 4.5**, we can determine the avoided social damages of GHG (CO_2) and the ambient pollutant (NO_x, SO_2) reduction in monetary value **(Table 4.7)**. *Note: 2007 dollars and 2000 dollars have been discounted to 2015 dollars using the consumer price index rate*[128].

[127] EPA OTAQ. 2005. "Emission Facts: Greenhouse Gas Emissions from a Typical Passenger Vehicle." <https://yosemite.epa.gov/oa/eab_web_docket.nsf/filings%20by%20appeal%20number/d67dd10def159ee28525771a0060f621/$file/exhibit%2034%20epa%20ghg%20emissions%20fact%20sheet...3.18.pdf>

[128] Bureau of Labor Statistics. 2016. "Consumer Price Index" <http://www.bls.gov/cpi/>

Table 4.7. Monetary value of avoided emissions, project total (Discount rate, 3%)

Monetary Value	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
SO_2 (2000$/yr)	$ -	$ 7,531	$ 15,062	$ 22,592	$ 30,123	$ 37,654	$ 45,185	$ 52,715	$ 60,246	$ 67,777	$75,308
NO_x (2000$/yr)	$ -	$ 390	$ 780	$ 1,170	$ 1,560	$ 1,950	$ 2,340	$ 2,730	$ 3,120	$ 3,510	$3,900
CO_2 (2007$/yr)	$ -	$ 36,576	$ 73,151	$ 109,727	$ 146,303	$ 213,358	$ 256,030	$ 298,701	$ 341,373	$ 384,044	$ 467,356
C Social price (2007$	36	36	36	36	36	42	42	42	42	42	46
SO_2 (2015$/yr)	$ -	$ 13,138	$ 26,276	$ 39,415	$ 52,553	$ 65,691	$ 78,829	$ 91,967	$ 105,106	$ 118,244	$ 131,382
NO_x (2015$/yr)	$ -	$ 680	$ 1,361	$ 2,041	$ 2,722	$ 3,402	$ 4,083	$ 4,763	$ 5,444	$ 6,124	$ 6,805
CO_2 (2015$/yr)	$ -	$ 45,330	$ 90,661	$ 135,991	$ 181,321	$ 264,427	$ 317,312	$ 370,197	$ 423,082	$ 475,968	$ 579,220
Total	$ -	$ 59,149	$118,298	$ 177,447	$ 236,596	$ 333,520	$ 400,224	$ 466,928	$ 533,632	$ 600,336	$ 717,407
NPV	$ 2,873,055										

4.6 Discussion

4.6.1 Expansion scenario based on baseline scenario

As discussed in the technology section, another issue that many SEMREO communities face is a lack of adequate street lighting. According to a streetlight performance report from the National Lighting Product Information Program (NLPIP),[129] a suggested distance of 180 feet between streetlight poles is recommended for optimal lighting performance. This figure was used to develop an expansion scenario (**Table 4.8**), in which communities that already meet the standard will maintain their current fixture numbers, while those with streetlight numbers below this standard will add fixtures accordingly. **Tables 4.9 – 4.11** show the results of the expansion scenario. Please see the supplementary spreadsheet [Energy Bills and LED Expansion] for further details.

Table 4.8. Baseline scenario conversion plan and expansion plan (Elec: Electricity). Local mileage data source, Michigan department of transportation[130]

	Baseline Scenario basics				Baseline Scenario metrics			LED conversion		Expansion Scenario	
SEMREO communitie	**Local Mile**	**Fixtures**	**kw (HPS)**	**kw (LED)**	**feet/fixture**	**kw/mile (HPS)**	**kw/mile (LED)**	**Elec (kWh) HPS**	**Elec (kWh) LED**	**target 180 feet/fixture**	**Elec (kWh) LED**
Ferndale	53.91	1810	403	170	157	7.5	3.2	402,925	170,155	-14%	170,155
Harper Woods	34.94	1276	210	109	145	6.0	3.1	210,475	109,210	-24%	109,210
Farmington	26.11	546	113	55	252	4.3	2.1	112,500	54,575	29%	70,244
Hazel Park	42.83	781	147	58	290	3.4	1.3	146,925	57,565	38%	79,345
Huntington Woods	17.8	243	30	18	387	1.7	1.0	29,940	18,460	53%	28,329
Madison Heights	74.01	1804	342	175	217	4.6	2.4	342,400	174,670	17%	204,195
River Rouge	18.84	1209	253	120	82	13.4	6.4	252,795	119,670	-119%	119,670
Royal Oak	148.01	2762	649	246	283	4.4	1.7	648,545	245,905	36%	335,373
St. Clair Shores	17.01	2806	593	294	32	34.9	17.3	592,825	294,065	-462%	294,065
Warren	316.01	10774	2290	1022	155	7.2	3.2	2,290,185	1,022,080	-16%	1,022,080
Total (kwh)								5,029,515	2,266,355		2,432,666
Savings (kwh)									2,763,160		2,596,849

[129] NLPIP. 2011. The objective source of lighting product information: Streetlights for local roads" <http://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SR_StreetlightsLocal.pdf>

[130] Michigan Department of Transportation. 2010. City Street Miles. <www.michigan.gov/documents/mdot/mdot_city_village_allocation_factors_11-2010_341734_7.xls>

Table 4.9. Yearly energy savings, conversion cost and annual savings at full conversion (Expansion Scenario)

For the Ten communities with available energy bills (Expansion Scenario)				
Now			Future at full conversion	
Operation Hours per Year		4200	Operation Hours per Year	4200
Total Current Watt		5,029,515	Total Future Watt	2,432,666
Total Current Energy Consumption (kWh)		21,123,963	Total Future Energy Consumption (kWh)	10,217,196
Comparison				
Energy Savings (kWh)		10,906,767		
Total conversion cost	$	8,586,204		
Total annual savings	$	1,147,397		

Table 4.10. Expansion Scenario net present value of avoided emissions (Discount rate, 3%)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Completion	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Avoided Emission											
SO_2 (Short ton/yr)	0.00	2.34	4.67	7.01	9.35	11.69	14.02	16.36	18.70	21.03	23.37
No_x (Short ton/yr)	0.00	0.83	1.67	2.50	3.34	4.17	5.01	5.84	6.68	7.51	8.35
CO_2 (metric ton/yr)	0.00	954.84	1909.68	2864.52	3819.36	4774.20	5729.04	6683.88	7638.72	8593.55	9548.39
Discounted Total NPV											
SO_2 (Short ton)	101.74										
No_x (Short ton)	36.34										
CO_2 (metric ton)	41,567										

Table 4.11. Expansion Scenario net present value of project cost (Discount rate, 3%)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Completion	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Cost	$ 858,620	$ 858,620	$ 858,620	$ 858,620	$ 858,620	$ 858,620	$ 858,620	$ 858,620	$ 858,620	$ 858,620	
Savings	$ -	$ 114,740	$ 229,479	$ 344,219	$ 458,959	$ 573,699	$ 688,438	$ 803,178	$ 917,918	$ 1,032,657	$ 1,147,397
Net cost	$ 858,620	$ 743,881	$ 629,141	$ 514,401	$ 399,662	$ 284,922	$ 170,182	$ 55,442	$ (59,297)	$ (174,037)	$ (1,147,397)
Discounted Total NPV											
3%	$2,329,242										

CO_2 mitigation efficiency = $2,329,242/ 41,567Metric ton CO_2 = $56/Metric ton CO_2

4.6.2 Mitigation Cost in comparison with other mitigation mechanism

The 10% per year conversion plan used as a baseline scenario is relatively slow, but may be more financially feasible for communities. Nevertheless, even this baseline scenario has a low mitigation cost of $4/Metric ton CO_2. This is much lower than projected mitigation cost in meeting the 25% expansion target of Michigan Portfolio Standard, which is $28 ~ $34/Metric ton CO_2.[131] Results of the sensitivity analysis on the speed of conversion shows that a faster conversion rate will decrease this carbon mitigation cost even further (**Figure 4.5**). Within financial limits, the faster the conversion, the better.

On the other hand, the expansion scenario is less desirable in terms of carbon mitigation. While communities end up with better street lighting conditions, the CO_2 mitigation efficiency is significantly decreased, and is no longer an efficient leverage for the conversion plan.

[131] Johnson., Jeremiah. Novacheck., Joshua. 2015. "Emissions Reductions from Expanding State-Level Renewable Portfolio Standards". Environmental Science & Technology. 49.5318-5325.

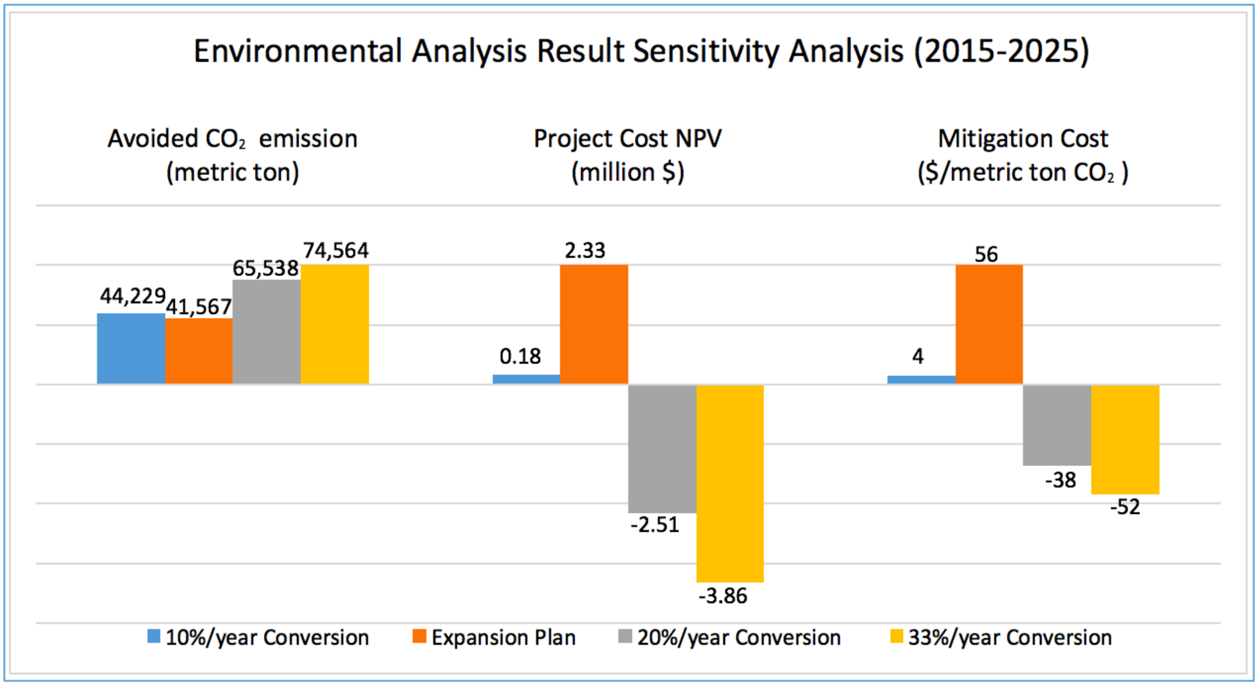

Figure 4.5: Sensitivity Analysis of environmental analysis results (10%/year conversion is the baseline scenario)

4.6.3 Coal power plant retirement

For this analysis, it was assumed that the energy source profile remains unchanged before and after the conversion project is implemented. In reality, however, the implementation of the Clean Power Plan will lead to the retirement of some coal plants in the region during the ten-year period in which this project takes place. It is necessary to consider this actual change, and quantify its impact on the mitigation potential for efficient street lighting: as coal power plants are taken offline and substituted with natural gas and nuclear units, reduced energy demand before and after the conversion will be not as carbon intensive.

In response to Clean Power Plan, a total of 25 coal-fired units are scheduled to retire at the following power plants: Harbor Beach (DTE), Trenton Channel (DTE), BC Cobb plant in Muskegon (Consumers Energy), JC Weadock plant in Essexville (Consumers Energy), JR Whiting plant in Erie (Consumers Energy), Endicott plant in Litchfield (Michigan South Central Power Agency), DeYoung (Holland Board of Public Works, Eckert (Lansing Board of Water and Light), and Presque Isle (Wisconsin Electric).

A total of 7 power plants from the list match power plants in **Appendix 4.5**:

Consumers Energy's BC Cobb plant in Muskegon
Consumers Energy's JC Weadock plant in Essexville
Consumers Energy's JR Whiting plant in Erie
Michigan South Central Power Agency's Endicott plant in Litchfield
Lansing Board of Water and Light's Eckert plant
Wisconsin Electric's Presque Isle plant

It is not clear which units in each power plant are retiring, and thus quantifying the influence of these retirements is imprecise. However, while this will certainly lead to reduced benefits brought by the LED conversion project, coal plant retirement nevertheless will contribute to the reduction of the carbon intensity of energy sources in Michigan, which ultimately contributes towards the same environmental goals as the LED conversion plan.

4.6.4 Connecting to the Clean Power Plan

All reported results in this analysis are based on data from only ten communities. The slow pace baseline scenario is estimated to generate 0.012 TWh energy savings, or 11,605,272 kWh (**Table 4.4**), compared with the target set by Clean Power Plan of reducing coal powered electricity by 23.9 TWh[132]. Although 0.012 is only 0.05% of the target, SEMREO's contribution could easily double if all 25 of its community members were to participate in the conversion project. If all 276 communities in Michigan were to participate, many of which are than the communities used for this analysis, the total contribution of LED street lighting could make up at least 1.3% of the CPP target reduction. These projects can all be realized with low cost; please see supplementary spreadsheet [Energy Bills and LED Conversion] for calculation details.

[132] Jester., Douglas. 2015. Michigan and the Clean Power Plan: Clarifying the Compliance Options. 5LakesEnergy LLC.

5. Social Analysis

5.1 Introduction

There are several reasons to utilize social research in planning for municipal street lighting conversion projects. First, feedback is important for manufacturers, in order to best determine what types of products to offer municipalities and highway commissions. Second, and most importantly for this project, social research can also determine how the community feels about lighting: specifically, whether or not the amount of lighting is sufficient to meet the community's needs, whether a conversion to LED lighting would help them to meet those needs, and whether or not community members are willing to pay increased taxes to fund the project.

Ethical and effective communities design and plan according to the needs of their members. Thus, the purpose of the Master's Project Streetlight focus groups is to ascertain the opinions, wants, and needs of residents, business owners, and municipal employees regarding streetlights, These focus groups will help to create a 10-year vision for street lighting in the community, and how best to implement LEDs.

5.2 About Focus Groups

Focus groups have been used since World War II to assess the opinions, thoughts, and attitudes of groups targeted for research studies.[133] The focus group method is invaluable in gaining insights through short-term qualitative research. Besides obtaining information about specific individuals' beliefs, thoughts, opinions, and attitudes, focus groups also encourage group discussion and collaboration within a community, as participants' thoughts build off one another rather than being prompted by scripted questions.[134]

As communities across the U.S. and Canada transition to LED streetlights, many of these municipalities use focus groups to gain feedback from their residents. During the province's LED streetlight conversion project, Ontario formed a group of member municipalities and surveyed administrators on barriers and incentives to the transition.[135] Similarly, the city of St Louis, Minnesota held focus groups to determine what items should to be added or improved to St. Louis Park, in which lighting issues came up as points of concern. [136] The Remaking Cities Institute in Pittsburgh, Pennsylvania, also used focus groups as part of its LED Streetlight Research Project, holding interviews with business leaders in the community and gaining valuable insights about what types of lighting business owners did and did not want.[137] In these groups, participants voiced concern over the quality of street lighting in the areas in question, and stressed

[133] Del-Rio Roberts, M. 2011. How I learned to Conduct Focus Groups. *The Qualitative Report*, (16) 1.
[134] Ibid.
[135] Li, S. 2014. *Procurement of LED Streetlights in Ontario: A Survey*. Retrieved from: http://www.ontarioenergyboard.ca/oeb/_Documents/EB-2012-0383/Report_Procurement_of_LED_Streetlights.pdf
[136] Health in the Park Steering Group. 2014. *Preliminary Report of "Health in the Park" Focus Group Findings*. Retrieved from: http://www.stlouispark.org/webfiles/file/ir/focusgroupreport_docx-final_20140114.pdf
[137] Remaking Cities Institute. 2011. *LED Street Light Research Project*. Retrieved from: http://www.cmu.edu/rci/documents/led-updated-web-report.pdf

a need for increased lighting to improve safety; in all cases, this research resulted in the determination of measures of success and prioritized impactful actions for future LED transitions.

5.3 Methodology

Major topics to be discussed during the focus groups were decided in collaboration with the Southeast Michigan Regional Energy Office (SEMREO) Street Lighting Consortium. A literature review was conducted to gain insight into the proper running of focus groups. Packer-Multi (2010) stress the importance of an easily accessible location and providing refreshments for participants to guarantee their comfort. [138] The article also outlined the importance of facilitation by the focus group interviewer, noting the necessity of redirecting off-topic conversations and asking follow-up questions to participants. To create questions for our focus groups, we examined the experiences of other streetlight focus groups: for their study, the Remaking Cities Institute had simply asked "What do you like about the present street lighting?", "What don't you like about the present street lighting?", and "If you could have new street lighting, what would you like to achieve with the new lighting?"[139] The University of Michigan Institutional Review Board determined that the nature of the study posed no risk to participants, so the study was exempt from IRB monitoring.

It was decided that a group of six individuals from six communities would be chosen for the groups. These communities would represent the demographic, technical, and financial diversity among municipal members of the SEMREO Streetlight Consortium, in order to create a vision plan that would suit the largest number of communities in Southeast Michigan. Ideally, the six members chosen by each municipality would be a mix of residents, business owners, and municipal employees, in order to gain a full understanding of street lighting needs from multiple residents' perspectives.

The foci of questions asked of the group included safety, lighting preferences, and ideas about future light possibilities. Each group was conducted on a Thursday for two hours at a municipal building, with group participants given the incentive of a free catered dinner. Members were identified by first name only. Comments were recorded on a voice recorder and hand recorded by an assistant, while the principal researcher conducted the group.

The six municipalities chosen for focus groups were Ann Arbor, Eastpointe, Ferndale, Harper Woods, Southgate, and Highland Park. These communities were selected to cover a broad spectrum of demographics, income, and technology. However, due to logistical difficulties, only the focus group from the city of Eastpointe was able to be carried out within the project timeframe. Researchers from our team plan to hold similar focus groups in the other five communities during the summer of 2016.

Prior to the focus group, participants were given a short 10-question survey to gather demographic data. The following questions were posed:

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[138] Packer-Multi, B. 2010. Conducting Focus Groups. *The Qualitative Report*. 15(4).
[139] Remaking Cities Institute. 2011. *LED Street Light Research Project*. Retrieved from: http://www.cmu.edu/rci/documents/led-updated-web-report.pdf

Survey Questions:

1. Opening question: What type of bulbs do you have in your home?
2. What do you see as the benefits of street lighting?
3. What do you think about the street lighting in your community in general?
4. What are your concerns about lighting in regard to pedestrian and driver safety?
5. What are your concerns about lighting in regard to bicycle safety?
6. What are your concerns about lighting in regard to crime?
7. Does your community have too little lighting, too much lighting, or just the right amount?
8. Do you think streetlights should only illuminate the street and sidewalks, or is it important that they light up nearby yards and houses as well?
9. How do you think street lighting influences the image of your community?
10. Which of these three would be most important to you in converting streetlights to LED-cost reduction, energy efficiency, or public safety?
11. What do you think about the color that streetlights produce? Some lights produce a yellow or orange light, while others produce a white light.
12. How do you feel about solar powered streetlights?
13. What is your opinion on smart-grid capabilities of LED lights? For example, smart grids can provide WiFi through streetlights, streetlights can strobe to indicate a 911 call, self-report outages, or streetlights can be used to indicate an evacuation route in case of an emergency.
14. Would the previously listed benefits be worth the extra investment?
15. New streetlights have the capability to dim or shut off when the space is unoccupied. This means that spaces would have lights, but the space would be dark from time to time. Is this a technology that you would like to see in your community? Why or why not?

5.4 Analysis

5.4.1 Eastpointe

Eastpointe is a city of 32,000 residents, with a racial makeup of 66% Caucasian, 30% African American, 1% Asian, and 2% Latino residents. The economy is production-based. The average annual income is $46,000, and the crime rate is 1.5 times the national average. For the focus group, participants consisted of 1 African-American and 5 Caucasian residents, with an even split between men and women.

In the focus group, participants stated that there were current issues with street lighting, such as too few residential lights and existing streetlights being blocked by adjacent trees. All agreed that light trespass in residential areas is not wanted, although it is helpful in business districts. Respondents felt that light was a deterrent to crime, and believed that street lights could help give their community a positive image. When asked whether lower electricity cost, safety, or environmental impact were more important in an LED conversion project, all respondents felt that all three factors were equally important.

Respondents generally had positive views of solar powered streetlights. However, they were concerned that solar lights might not work in Michigan winters, and felt that any solar light should be integrated with the power grid to ensure light is available at all times. Respondents did not have strong opinions on the color emitted by streetlights, although they all agreed that LEDs were the brightest light source. When asked about smart grid capabilities, respondents had negative views of all options except for self-reporting outages ability. All participants stated that they would not be willing to pay increased taxes on smart grid capabilities except for self-reporting outages.

Participants responded negatively to the idea of streetlights that dim when no one is present. All felt that dimmed lights would decrease safety, and one respondent noted that if a light goes out, it would be difficult for residents to know if the light was supposed to be intermittent in the first place. When asked about pedestrian, bicycle, and automobile safety, respondents felt that a lack of light in residential areas posed the greatest risk to pedestrians and automobiles. They felt that increased light was not a significant factor in bicycle safety, as other factors contributed more strongly to bicycle safety.

6. Financial Analysis

6.1 Introduction

Street lighting upgrades are extremely promising from a financial perspective, as these projects bring inherent energy and maintenance saving benefits. Of the several hurdles for municipalities in implementing these projects, financing is perhaps the most prominent. This section will focus on evaluating all financing options available for Southeast Michigan Regional Energy Office (SEMREO) Street Lighting Consortium, and recommend the most affordable options based on the state of local regulatory frameworks, municipalities' financial condition, and the implementation capacity of member communities. It will also examine select global, national and regional case studies, in order to learn from the successful implementation of street light conversion regimes. Finally, this section will discuss barriers to implementation from a municipal perspective and possible ways to tackle these barriers.

Financing options for municipal authorities depend on many factors, including municipal financial condition and creditworthiness, the predictability of revenues and budget transfers, local legal and regulatory frameworks, the commercial financing environment, the nature of the energy efficiency project, implementation capacity, and the available delivery mechanisms. In addition, the size of a municipal authority plays a part in influencing these factors: it has been observed, in general, that a large municipality faces different challenges than smaller ones[140].

A study done by Navigant Consulting estimates the expected future adoption of LEDs based on the current trajectory for the technology. The market penetration of LEDs is projected to drive a 40% reduction in energy consumption, or a total energy savings of 3.0 quads, in 2030 alone, which is nearly the total energy consumed by 24 million United States homes today[141].

A guidance note for mayors on financing municipal energy efficiency projects, developed by the Energy Sector Management Assistance Program (ESMAP) at the World Bank, suggests that mechanisms utilized by municipalities around the world can be broadly grouped under following four categories:

- **Budget financing**, including use of municipal budgets, external grants, and budget capture mechanisms.
- **Energy efficiency (EE) funds**, including self-sustaining revolving funds carved out from the general budget or donor funds.
- **Public support**, consisting of funds available from donors and/or national or regional governments to support or leverage commercial financing, and,

[140] *Financing Municipal Energy Efficiency Projects* (Vol. 018/14, Mayoral Guidance Note 2). (n.d.). Retrieved April 13, 2016, from https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_MGN1-Municipal Financing_KS18-14_web.pdf.

[141] Navigant Consulting, & U.S. Department of Energy. (2014). *Energy Savings Forecast of Solid-State Lighting in General Illumination Applications* (Publication). Retrieved April 13, 2016, from http://www.energy.gov/sites/prod/files/2015/05/f22/energysavingsforecast14.pdf

- **Commercial financing**, which mainly consists of bank loans or funds raised by issuing municipal bonds.

The types of funds encompassing each of these funding mechanisms is best illustrated by the following 'financing ladder':

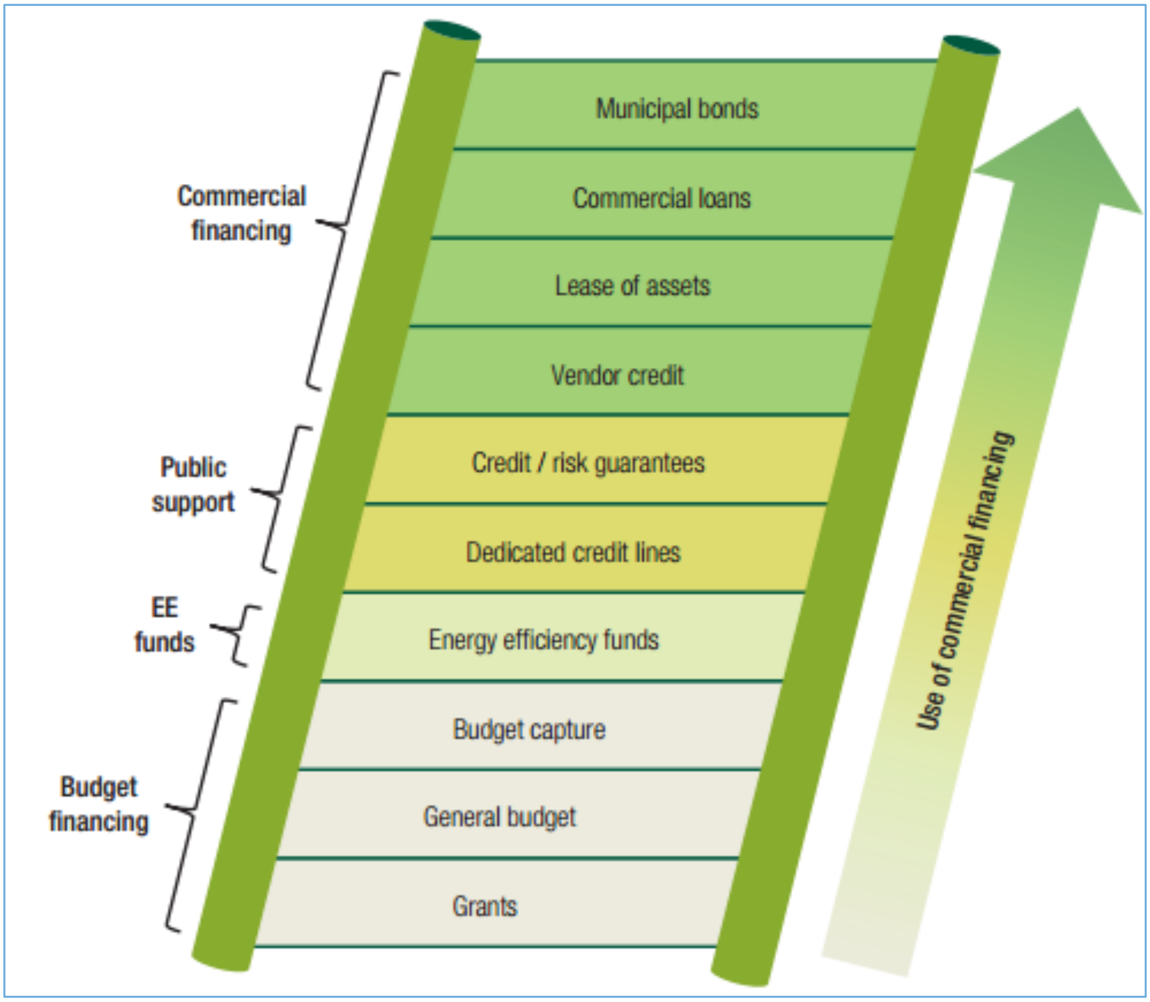

Figure 6.1: Financing Ladder, Source: Mayoral Guidance Note 2, ESMAP[142]

As we climb up the financing ladder, the mechanisms demand prompt repayments on investments. Repayments can only be ascertained by consistent cash flows driven by energy cost reduction and verifiable savings.

According to the Office of Energy Efficiency and Renewable Energy,[143] there are a variety of options available for financing a street lighting conversion program, mainly based on the project's system

[142]*Financing Municipal Energy Efficiency Projects* (Vol. 018/14, Mayoral Guidance Note 2). (n.d.). Retrieved April 13, 2016, from https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_MGN1-Municipal Financing_KS18-14_web.pdf.
[143] Financing Options. (n.d.). Retrieved April 13, 2016, from http://energy.gov/eere/ssl/financing-options

ownership and maintenance model. Most of SEMREO's member communities have an arrangement of utility-owned and maintained street lights.

6.2 Street lighting project financing options

In the following section, potential sources of funding that have been used or considered by other cities across the U.S. will be discussed. Of the following options, two or even three financing types could be combined in order to achieve the most favorable financing package for individual municipalities' street light conversion projects.

6.2.1 Self-Funding (Budget financing)

Consortium communities can make use of flexible, unallocated capital or O&M budgets. A city with a significant operating budget can arrange funds accrued by the energy savings of a previous phased conversion. The New York City Department of Transportation (NYCDOT) was able to use operational cost-savings resulting from a first phase of LED conversions to subsequently invest in additional LED street light conversions:[144]

Table 5.1 NYCDOT Street lighting project details

Particulars	Costs (in US $)	Budget share
Annual street lighting construction expenditure and associated capital costs	25 million	3% of capital budget
Annual street light maintenance budget	33 million	4% of operating budget
Annual street light energy budget	72 million	10% of operating budget

In most cases, municipalities that strive to reduce maintenance will allocate a smaller portion of their budgets in subsequent years, thereby leaving little opportunity for reinvestment. Additionally, Michigan was the U.S. state most severely impacted by the 2008 recession, and state property tax revenue declined most sharply in southeast Michigan.[145] In light of these historical and operational factors, it is assumed that most consortium community members are faced with budget constraints, and therefore financing through self-funding may not be a feasible option in the near term.

[144] *New York - Self Funding* (Publication). (n.d.). Retrieved from http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/financing_nyc-brief.pdf

[145] Lupher, E. W. (n.d.). Financial Condition of Michigan Local Governments - 2015. Citizens Research Council of Michigan. Retrieved April 13, 2016, from http://crcmich.org/PUBLICAT/2010s/2015/WSU_Local_Govt_Financial_Condition-061115.pdf

6.2.2 Federal Government and State Programs (Budget financing)

In the past, cities have made use of grants from 2009 American Recovery and Reinvestment Act (ARRA), but these funds are no longer available. Las Vegas, NV[146] has used funds from these grants, in combination with issuing bonds and energy rebates to perform LED conversions.

Energy efficiency and renewable energy loans for Michigan businesses are currently eligible through the Michigan Agency for Energy. To be eligible, the consortium will be required to show energy consumption reduction by minimum 20%. Applications for these loan funds are solicited until they are available. Loan requests should be between $50,000-350,000, and limited to supplies, materials and equipment costs only.

Alternatively, grants are also made available periodically through the Michigan Economic Development Corporation (MEDC). In 2012, MEDC provided $ 400,000 to the City of Detroit for an LED conversion project.[147] In addition, with an intent to provide one stop shop, the state of Michigan has a website, Electronic Grant Administration and Management System (EGrAMs), which can be used by organizations to access and find grants across State Departments.[148]

In Feb 2015, Gov. Rick Snyder awarded $8 million to eleven municipalities to fund various improvement projects, including water system and street lighting enhancements and technology upgrades through the Financially Distressed Cities, Villages, and Townships Grant Program. Municipalities are eligible for the grants if they are experiencing one or more conditions indicative of "probable financial stress," as defined by Public Act 436 of 2012, the Local Financial Stability and Choice Act. Under the grant program, funding may be used to pay for specific projects, services, or strategies that move a city, village, or township toward financial stability. There was $8 million appropriated for the program with a $2 million cap, per local unit. The following cities and townships are allocated funds from this program targeted for streetlight upgrades:

1. City of Ecorse - $ 350,000
2. City of Hamtramck - $ 404,600
3. City of River Rouge - $ 591,508149
4. Royal Oak Township - $ 86,559

50% of the 24 consortium member communities were found to have 'distressed community' status, suggesting a large potential to utilize this monetary source in the future.

The Energy Efficiency & Conservation Block Grant (EECBG) program in Michigan has historically only been available for communities with population less than 35,000,[150] indicating 'population' as a key metric in allocating grant funds. 17 out of SEMREO's 24 (~70%) member communities were found to

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[146] Page 9 - http://usdn.org/uploads/cms/documents/mi-led-streetlight-convening-report_final-01-27-14.pdf
[147] http://www.huffingtonpost.com/2012/01/20/detroit-wins-grant-for-led-streetlights_n_1218987.html
[148] The file was last updated by the state government was last updated in 2014 and hence few opportunities listed may have expired.
[149] includes funds for infrastructure upgrade in City Hall
[150] Slide 4, http://www.michigan.gov/documents/dleg/Jan_Patrick_286781_7.pdf

have populations less than 35,000, which could be leveraged by the consortium to seek funding from future grants having eligibility criteria on similar lines.

6.2.3 Utility Programs (Energy Efficiency funds)

Investor owned utilities may provide financial assistance to communities in the form of a low-cost or market-rate loan that is repaid with project savings. This model has been largely successful for smaller municipalities in the state of Iowa and larger municipalities such as Los Angeles and Seattle. Pacific Gas & Electric's program (PG&E) in Northern California included special tariffs, rebates and a turnkey installation program that provided a project as a complete package.

A snapshot of the Los Angeles street lighting project is provided below:

- 7 years, $40 MM Loan at a rate of 5.25 % repaid through energy and maintenance savings.
- Loan provided by City Utility (LADWP) and City Funds.
- Bureau of Street Lighting contributed $ 3.5 MM directly from the Street Lighting Maintenance Assessment fund.
- LADWP provided rebate of $ 0.24 per kWh reduced by the project, totaling $ 16.39 MM.[151]

Local utility DTE Electric also runs street lighting improvement programs for municipalities and communities. DTE provides modest assistance in the form of rebates from the energy optimization program, but demands municipalities to fund initial costs of conversions, as was recently challenged in rate case U-17677. This rebate program will likely be discussed in detail during the upcoming negotiation process ordered by the MPSC.

In Michigan, Governor Rick Snyder's energy plan[152] encourages utilities to come up with methods like on-bill financing (OBF) for new devices. OBF lets a municipality finance qualified energy efficiency projects interest-free, and provides benefits such as zero percent interest loans, no fees or loan costs, and convenient loan repayment through monthly bills. OBF is usually offered through utilities: Southern California Edison[153] and Pacific Gas and Electric have been offering attractive OBF options for their customers. A simple example of an OBF program is provided below:

[151]http://www.dvrpc.org/energyclimate/eetrafficstreetlighting/pdf/CCI_Los_Angeles_LED_Streetlighting_Retrofit_Program_Report.pdf

[152] Michigan's crisis: Can the coal-heavy state embrace renewables and efficiency? (n.d.). Retrieved April 13, 2016, from http://www.utilitydive.com/news/michigans-crisis-can-the-coal-heavy-state-embrace-renewables-and-efficien/375497/

[153]Southern California Edison. (n.d.). *On-Bill Financing* (Publication). Retrieved April 13, 2016, from https://www.sce.com/wps/wcm/connect/30cbbaa3-7358-4302-8ef7-899e9bc9d1f1/OBF+Fact+Sheet+0114+r3.pdf?MOD=AJPERES.

Project cost	$10,000
Energy efficiency rebates and/or incentives	($2,500)
Loan amount (remaining costs to be funded)	$7,500
Estimated monthly energy savings from retrofit	$300
Monthly loan installment billed on PG&E utility bill	$300
Simple payback period (loan amount divided by monthly payment amount)	25 months

The loan terms for the customer in this example would be $300 per month for 25 months.

Figure 6.2: On Bill financing example, Source: PG&E On Bill financing flyer[154]

Unfortunately, the major investor-owned utilities in Southeast Michigan, DTE Energy and Consumers Energy, have yet to unveil and develop such mechanisms. This may be a topic that SEMREO would wish to lobby for in the near future.

6.2.4 Energy Saving Contractors or ESCOs (Energy Efficiency funds)

ESCOs are private energy efficiency service providers that can finance, purchase and install fixtures and deliver guaranteed savings to Consortium members. ESCOs expect repayment over several years out of energy and maintenance savings. ESCO provides the financing and carries the credit and performance risks as well. At the end of the energy performance contract period, the municipality can take back the ESCO's tasks and benefit from the lower energy costs. [155]

Despite many benefits of employing an ESCO, the use of this type of financing is largely limited to streetlight governance under municipal ownership, in which municipalities may maintain luminaries themselves or contract with a third party for maintenance. However, municipal ownership is more common with larger municipalities, rather than the smaller communities typical of SEMREO's

[154]Pacific Gas & Electric. (n.d.). *On Bill Financing for Energy Efficiency Upgrades* (Rep.). Retrieved April 13, 2016, from http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/rebatesincentives/taxcredit/onbillfinancing/fs_obf.pdf

[155]*Streetlight Refurbishment with Energy Performance Contracting Guide* (Rep.). (n.d.). Retrieved from http://www.managenergy.net/lib/documents/1398/original_STREETLIGHT_REFURBISHMENT_WITH_EPC_GUIDE.pdf

membership.[156] In cases where street lighting is owned by DTE Electric, ESCO financing is not applicable.

6.2.5 Manufacturers' Programs or Vendor Financing (Commercial funding)

Large street light manufacturers also provide financing options for conversion projects, including project materials, labor, and even third party equipment. A vendor would seek these funds through local bank financing and allocate them to municipalities based on creditworthiness. An example of how this option works is illustrated below:

Typical Energy-Efficient Lighting Upgrade Project	
Project Cost incl. Labor	$30,000.00
Annual Energy & Maintenance Savings	$17,000.00
Simple Payback Period	1.76
Finance period rounded up to the nearest full year term	2 years
Simple Payback Cash Flow	
Monthly Energy & Maintenance Savings	$1,416.67
Estimated monthly finance payment	$1,309.98
Monthly Positive Cash Flow	$106.69

Economics Considering Impact of EPAct and Utility Rebate	
Project Cost incl. Labor	$30,000.00
Potential utility rebate	$2,500.00
Additional first year cash flow	$2,500.00
Net investment less estimated incentives	$27,500.00
Annual Energy & Maint Savings	$17,000.00
Potential payback period with incentives	1.62
Customer Rate	*4.38%

*Actual rates are determined by the creditworthiness of the borrower and financing term

Figure 6.3: Vendor Financing, Source: Hubbell Lighting Inc., Cash Flow Positive program[157]

6.2.6 Municipal Bonds and Qualified Energy Conservation Bonds Subsidies (Commercial funding)

Municipalities can also self-fund an investment in LED street lights by issuing a bond. To get this funding, cities are required to establish a bond rating with a rating agency like S&P. The better the bond rating, the lower the interest rate that the city has to pay for bond financing.

One option for communities considering a bond issuance is a Qualified Energy Conservation Bond (QECB). A QECB is a type of taxable bond that can be issued by state, local, and tribal governments to finance energy conservation projects. QECBs are allocated to the states by the federal government according to population, with the expectation that each state will sub-allocate a portion of their QECBs to large local governments and municipalities (populations of 100,000 or more).

A major barrier limiting the use of QECBs for small projects is the high transaction costs associated with their issuance. No more than 2% of a bond's proceeds can be used to finance its cost of issuance[158].

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[156] Page 12, North East Energy Efficiency Partnerships. (2015). *LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic* (Publication). Retrieved from http://www.neep.org/sites/default/files/resources/DOE_LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic_1-27-15.pdf

[157] *Funding Solutions for Municipal Lighting Projects* (Working paper). (n.d.). Hubbell Lighting. Retrieved April 13, 2016, from http://www.hubbelllighting.com/content/resources/financing/downloads/Finance_14Muni.pdf

In May 2011, the city of Las Vegas, NV issued a $5.87 million 15 year QECB to Bank of America. Of this issuance, $2.9 million of the QECB proceeds were used to complete approximately 6,600 LED street light upgrades. The bond was sold to Bank of America as an installment purchase contract secured to the light fixtures. These upgrades are expected to yield annual energy savings of $350,000 and annual maintenance savings of approximately $50,000. These upgrades are part of a larger initiative in which the city plans to replace almost all of its 52,000 street lights as part of its five-year capital improvement plan. The cost of issuing the QECBs was $117,486, 2% of bond proceeds.[159]

6.3 Financial barriers from municipal perspective

6.3.1 High upfront costs

The higher upfront cost of LED technology may seem prohibitive to the Consortium, despite recent plummeting costs trends. This may be a significant roadblock and may demand more funding resources. Yet when examined on a life-cycle basis, reductions in energy usage and maintenance costs have made LED streetlight conversions an attractive financial proposition even before factoring in the recent decline in LED cost. Pooling financial resources and combining appropriate financing mechanisms may help mitigate issues with high upfront costs. Where possible, bringing in ESCOs that guarantee energy and maintenance savings may support Consortium decision making in implementing a project.

6.3.2 First mover dilemma

Some Consortium members may be reluctant to invest in LED street lights given that the costs have been rapidly falling. Additionally, growing competition in the LED market may further decrease prices in the near future. This perceived first mover dilemma can discourage or delay utility or municipal LED street light investments.

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[158] Page 17, North East Energy Efficiency Partnerships. (2015). *LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic* (Publication). Retrieved from http://www.neep.org/sites/default/files/resources/DOE_LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic_1-27-15.pdf

[159] Lawrence Berkeley National Laboratory. (2012). *Using QECBs for Street Lighting Upgrades: Lighting the Way to Lower Energy Bills in San Diego* (Issue brief). Retrieved from http://energy.gov/sites/prod/files/2014/06/f16/street-lighting-qecb.pdf

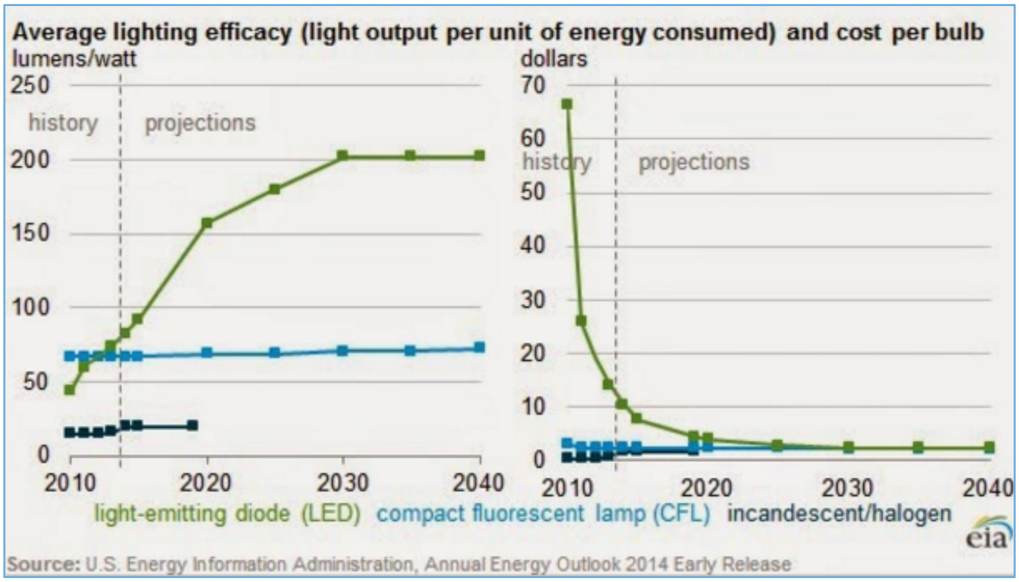

Figure 6.4: LED cost and efficacy projections, Source: U.S Energy Information Administration

However, according to analysis of the product and operational cost savings of installing LED technology now, as compared to the cost savings if the technology is installed in the future, it is more economically beneficial to install the technology now.[160] It will ultimately cost a municipality or utility more to wait, referred to as the "cost-of waiting." The estimated cost of waiting for one of the Consortium members; Southgate (**Appendix 6.1**) was found to be $ 7,344 per month and $ 88,139 per year.[161]

6.3.3 Stranded Assets

Stranded asset costs are another obstacle in the shift to the widespread adoption of LED street lights. A stranded asset is an investment which seemed prudent at the time of its purchase, but due to changing circumstances was unable to depreciate to the end of its useful life. In the context of LED street light conversions, conventional street lights installed within the last 20 years represent potential stranded assets because they may not be fully depreciated when municipalities seek to replace them with new LED technology. In the context of utility-owned equipment, most street lighting tariffs in a region require any municipality requesting technology conversion to compensate the utility for stranded asset costs related to the former luminaire.

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[160]North East Energy Efficiency Partnerships. (2015). *LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic* (Publication). Retrieved from http://www.neep.org/sites/default/files/resources/DOE_LED Street Lighting Assessment and Strategies for the Northeast and Mid-Atlantic_1-27-15.pdf

[161] Based on GE Lighting Tool. Refer Appendix for the model.

7. Ideal Vision and Recommendations

7.1 Ideal vision and recommendations

Ideally, the communities should convert their streetlights as fast as politically and financially feasible, with a balanced expansion schedule that provides fair and affordable lighting, as upgrading street lighting provides clear and inherent benefits to communities. The following are our recommendations for how to successfully achieve such conversions within a ten-year timeframe.

7.2 Technical and Environmental Recommendations

Approach a phased conversion plan: Streetlight conversion projects take time and expenditure, and cannot be completed overnight. Our analysis has tested a 10% per year conversion rate as a baseline scenario, as well as faster conversion rate scenarios, and results show that the emissions reduction, project cost NPV and mitigation efficiency all become more desirable as the conversion accelerates. Thus communities should convert as fast as politically and financially feasible.

Find balance between lighting standards and project cost: To meet lighting standards, it is not enough to convert existing streetlights, but also to add additional streetlights to areas that may lack adequate lighting. Adding more fixtures will increase the project's NPV from the baseline, $0.18 million, to $2.3 million. Communities will still consume less than half of the energy used under present conditions, but the expansion cost may burden their budget; nevertheless, emissions reduction in the expansion scenario is appreciable (**Figure 7.1**). While sufficiency and affordability of lighting are equally important to communities, a fair balance between these two aspects is needed when implementing the plan.

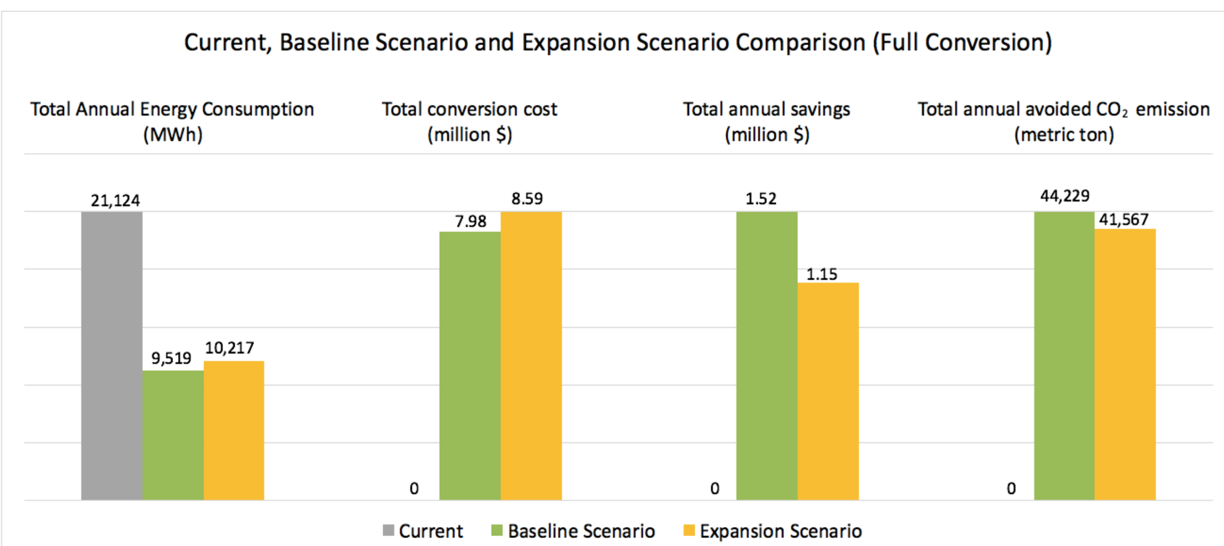


Figure 7.1: Comparison among current situation, baseline scenario and expansion scenario

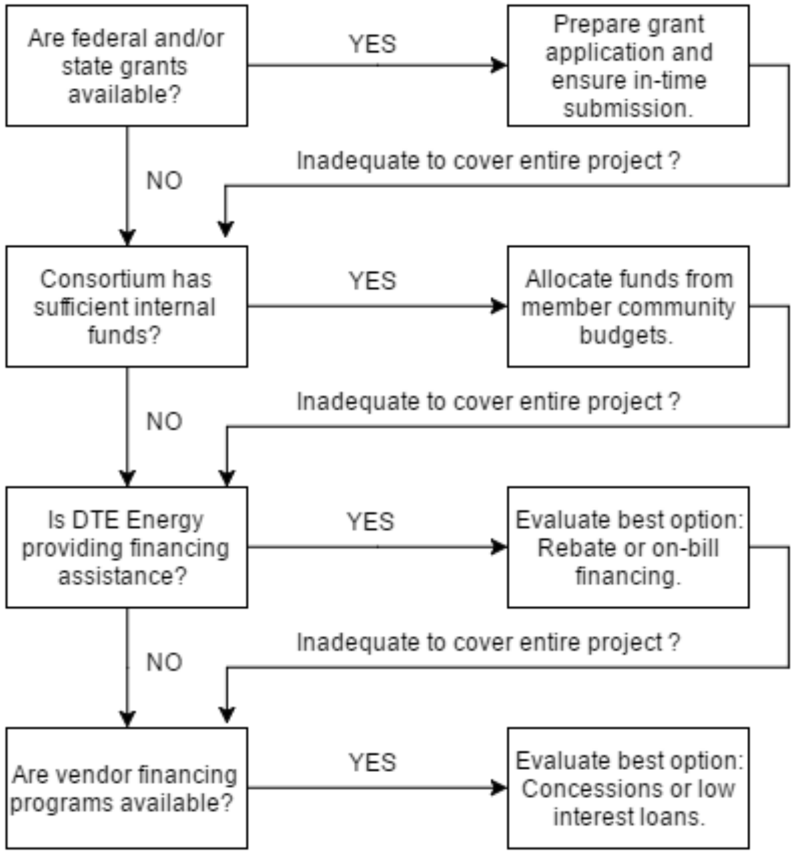
Research Solar: Eastpointe respondents were very interested in the capabilities of solar-powered streetlights, and appreciated the look as well as the cost-saving benefits of solar-powered lights. Their only major concern was whether the lights could maintain themselves during Michigan's dark, long winters. It is recommended that SEMREO explore solar-powered lights as an option, with a preference for lights that are tied into the energy grid so that they are able to maintain functionality even under dark or cloudy conditions.

Self-service streetlights: Safety was a major concern for Eastpointe respondents, and thus they were very interested in self-reporting streetlights. A self-reporting light will notify the utility when a bulb burns out, which respondents felt was very important because getting burned-out or damaged lights replaced as soon as possible improves safety. Respondents stated they didn't feel safe when a bulb burned out in their neighborhood. Residents responded negatively or indifferently to other technology upgrades, such as lights that strobe to indicate an emergency evacuation route, broadcast Wi-Fi; or turn off when no one is present. In particular, respondents were very negative about lights that turned off when no one was present, believing that this was a threat to safety, even more so if the lights aren't self-reporting. Thus, the major technological upgrade that SEMREO should pursue is that of self-reporting streetlights.

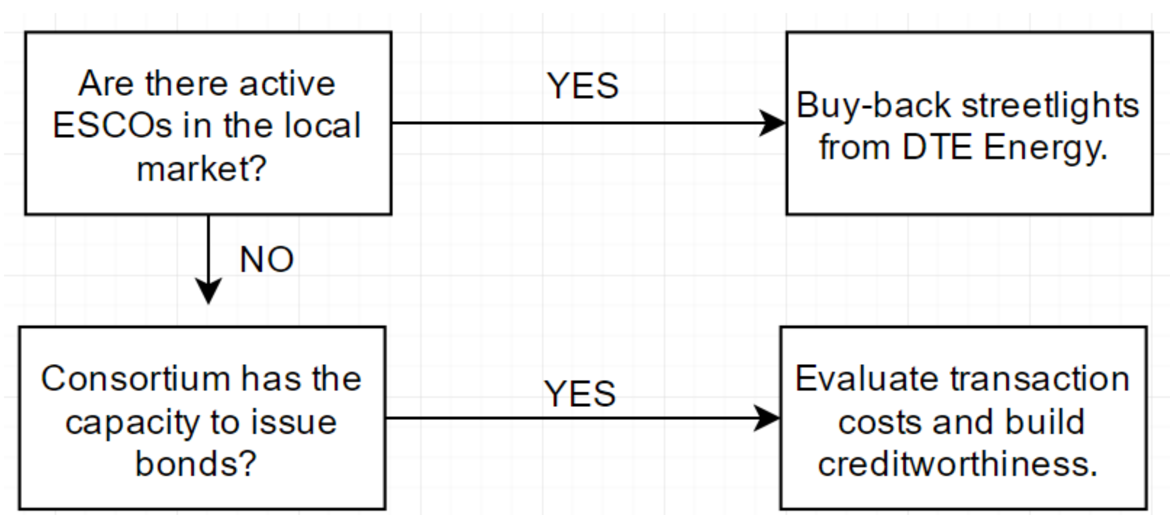
7.3 Financing Recommendations

Combine multiple mechanisms: The Consortium is encouraged to combine multiple mechanisms to address different sets of challenges. Many cities across the U.S. have made use of multiple financing mechanisms to fund street lighting conversions: for example, when Foster City, CA chose to convert 100 % of its 2000 streetlights to LEDs, the city combined funds from PG&E utility rebates, funds from utility on-bill financing (0% interest rate), its own municipal budget, and ARRA grants.

In order to evaluate the best financing mechanism, the following chart can be used as an illustrative guide:



In the short term, the Consortium should look out for Federal and State grants. Then, based on the adequacy of these grants to fund the entire project, the Consortium should pursue budget allocations, DTE assistance and vendor financing sequentially. In the long term, ESCO model should be followed by issuing municipal bonds.



Validate actual savings with Pilot projects: The Consortium may wish to start with small pilot projects using grants or pooled budget transfers. However, since grants and budgetary funds may be inadequate going forward, the Consortium may want to pursue commercial financing, which would require improving technical and financial capacities.

Seek federal and state grants: As discussed earlier, since most Consortium communities in Southeast Michigan may lack the budgetary resources to pursue street lighting conversion projects, it is highly recommended that these communities seek federal and state grant opportunities. Grants have low or negligible expectations in terms of returns and repayments; additionally, a major advantage of grants is that they help to decrease the payback period of a project.

Strengthen Consortium membership base: The Consortium may wish to increase the number of member municipalities in Southeast Michigan. By pursuing a bundled or aggregated street light conversion project, the Consortium may be able to take advantage of economies of scale and reduced transaction costs. The Consortium may also expect greater cash in hand due to pooled financial resources.

Track City of San Jose street lighting project developments: The City of San Jose is planning to convert 40,000 outdated street lights to LED lights at project costs of $32 million. The City seeks private sector partnership and bring up innovative financing mechanisms. Partnership possibilities include but are not limited to leasing City's real estate, naming buildings in honor or recognition of a person or entity etc. Proposals invited by the City seeks partnership to install new lights or make an in-lieu cash payment to the City. It is expected that innovative financing options of interest, which did not exist traditionally, may come out of this process, and thus new developments in this case may prove instructive to Southeast Michigan municipalities.

7.4 Options for Future Governance

Our research lends support to two possible governance options for SEMREO: (1) the organization could act as an advocacy organization, or (2) the group could restructure itself as a technical management organization. In option (1), the group would not actually own or operate any street lighting itself, but would represent the interests of municipal groups wishing for fairer street lighting rates and greener technologies, both in negotiations with the utility and as a policy advocate at the state level. Option (2) would be a technical governance option, in which SEMREO could negotiate with the utility to purchase streetlights, connect these streetlights to a microgrid powered by renewable energy, and then serve as a "municipal utility" that manages and operates this microgrid. Based on policy analysis, we conclude that Option (1) is the better choice for the 10-year timeframe of this project.

Option (1) is preferable for several reasons. First, it is the most easily scalable option within the ten-year timeframe of the conversion project: given that the LED conversion project is most economically beneficial to those communities that participate earlier, an advocacy organization could utilize existing resources to connect communities to information and lobby for friendly policies at the state level. SEMREO could instead focus on spreading its message as an organization and building its membership base to a greater number of communities. Second, the organization would be able to sidestep many of the expenses and legal hassle associated with buying back streetlights from the utility. SEMREO would not necessarily need to hire expensive specialized experts to implement this option, although hiring a community organizer and possibly a legal adviser would be recommended. A potential drawback to this plan might be that SEMREO's role would then overlap with other organizations that already advocate for municipal interests in Lansing, such as the Michigan Municipal League. However, SEMREO is the only municipal advocate that works in the energy sphere specifically, meaning that there may be relatively little overlap in content; SEMREO could also work with other organizations to pool financial resources and lobbying power if necessary.

Option (2) is a possibility in the longer term, but may not be viable due to political, technical, and financial uncertainties. As mentioned previously, there are few incentives for investor-owned utilities to sell streetlight assets, and the MPSC has little ability to enforce a sale between DTE and municipalities. Furthermore, little research has been done on the technical feasibility of a streetlight microgrid project in Southeast Michigan; solar-powered streetlights are of particular concern because these would require storage options, as solar panels do not provide electricity after dusk. Finally, even if the political and technical hurdles to municipal ownership of street lighting were addressed, the cost of owning, maintaining, and operating street lighting could prove insurmountable for financially distressed communities in Southeast Michigan.

7.5 Policies to Support

As an advocacy organization, there are several policies that SEMREO should promote at the state level:

Strong Energy Optimization Standards: Utilities have thus far achieved the 1% annual energy optimization standard, and some analyses suggest that significant cost-effective energy savings could be realized if Michigan increased the standard to 1.5%, which neighboring Minnesota has achieved. It may be in SEMREO's best interest to lobby in favor of stricter energy optimization standards, as this will likely result in increased state support for measures such as LED lighting projects.

Participate in State Carbon Implementation Plan: While the fate of Michigan's SCIP is still in question, should the Clean Power Plan ultimately be upheld by the Supreme Court, there are clear opportunities for SEMREO to advocate for strong efficiency measures in the state plan. The main financial advantage of LED street lighting conversions, as compared to other carbon mitigation plans, is that street lighting conversions are compensated by the project's net energy savings: according to our analysis, LED conversions in Southeast Michigan have a payback period of 3.7 years, meaning that the project pays for itself within this very short time frame, and that municipalities will realize energy savings for the remaining life of the LED bulbs. Street lighting conversions have a lower mitigation cost compared with other CPP compliance measures: this proposed project, with a modest conversion rate of 10% per year, has an expected mitigation cost of \$4 per metric ton of CO_2, compared with an expected cost of \$28 - \$34 per metric ton CO_2 for the proposed 25% expansion on current MI RPS target. Mitigation costs are expected to decrease even further if conversions could be accelerated to 20% and 33% per year. Additionally, SEMREO should advocate for across-the-board energy reductions rather than demand-response, as street lighting is active during off-peak hours, and thus improvements would not be incentivized under demand response schema.

Street lighting buyback options: Currently, most streetlights in Southeast Michigan are owned by DTE Energy. Ideally, municipalities would maximize energy and cost savings if the Consortium could buy back and municipalize these street lights, as municipalities would cease to pay maintenance fees to the utilities. In some states, such as Massachusetts, state laws allow municipalities to buyback street lights in return of a compensation to the utility, through a deliberation process that can last as long as two years. However, state law in Michigan does not require the MPSC to enforce the sale of streetlights from utilities to municipalities. As an advocacy organization, SEMREO should consider lobbying for policies to facilitate such sales.

Advocate for Clean Energy Incentives Program: The Clean Power plan also includes the option for states to participate in a Clean Energy Incentives Program, which would drive energy efficiency investment in low-income communities. SEMREO should advocate for Michigan to participate in this program, as it would likely help the consortium's low-income member communities.

Revenue Decoupling for Utilities: Some states, such as California, have adopted policies that change utility business models such that instead of profiting from increased electricity sales, utilities profit from number of customers served. A well-designed revenue decoupling policy would not shift risks from the utilities to the consumers, but instead would incentivize utility performance, reliability, and service. However, it is important to note that decoupling on its own would not necessarily increase investment in energy efficiency or renewable energy: it will be important to advocate for increased efficiency and renewable energy standards as well.

Consider Retail Open Access Options: At present, local utility DTE has shown a willingness to negotiate street lighting electric rates with the Consortium, suggesting a potential for rate case disputes to be resolved with minimal outside policy influence. However, should the utility be unwilling or unable to provide reasonable support for the LED conversion project, or should the Consortium decide to pursue microgrids and distributed renewable energy projects for streetlights in the future, then SEMREO may wish to compare DTE's offerings with those of an alternative energy provider. Under current Michigan Retail Open Access law, no more than 10% of electricity sold within a utility's service area may be purchased from alternative sources. However, the threat of lobbying for a relaxing of this limit could be used as a leverage point in negotiating for fairer rates from DTE or increased assistance for technology conversion projects.

Join DOE Municipal Solid-State Street Lighting Consortium: The Consortium must consider becoming a primary member of the Department of Energy Municipal Solid-State street lighting Consortium ('DOE Consortium'). Members form part of an international knowledge base and peer group, receive updates on tools and resources, receive the Consortium E-Newsletter, and help steer the work of the DOE Consortium by participating on a committee.

7.6 Outreach: Spreading SEMREO's Message to Southeast Michigan Communities

It could be argued that the best municipal projects are ones with strong community support. To that end, SEMREO's communities should do as much outreach as possible to gain community support for LED conversion projects, especially true in areas where tax increases may be needed to finance the conversion. When attempting to organize focus groups, one of the largest barriers that we repeatedly encounters was that employees who worked in the city's energy department did not appear to have many contacts with the public. Municipal energy departments can improve their interfacing with the public through increased outreach; thus, SEMREO could provide assistance in networking municipal staff with their regional counterparts, as well as other relevant contacts.

SEMREO should also make itself more visible in member communities. SEMREO provides invaluable services including technical, advising, and lobbying efforts, and the more visible SEMREO is to communities in its service area, the greater the possibilities of gaining community support. SEMREO should work with member communities to expand awareness of energy issues and efficiency opportunities in their communities. To this end, SEMREO may wish to hire a community organizer or align with an existing community organizing agency in order to raise awareness among member communities. Community support will be essential to implementing LED conversion, as the ultimate decision to convert streetlights rests with members of the communities themselves. By making this project easily understood and establishing trust within communities, SEMREO could help unite the Southeast Michigan region behind LED street lighting conversions and other sustainable energy projects.

List of Acronyms

ALJ- Administrative Law Judge
AMPD - EPA Air Markets Program Data
APEEP - Air Pollution Emission Experiments and Policy analysis
ARP - Acid Rain Program
ARRA - American Recovery and Reinvestment Act
BSER - Best System of Energy Reduction
CALiPER- Commercially Available LED Product Evaluation and Reporting
CALSLA- California Street Lighting Association
CRI- Color Rendering Index
CPP - Clean Power Plan
DOE - Department of Energy
DTE - Detroit Edison Energy
EECBG - Energy Efficiency & Conservation Block Grant
EE Fund - Energy Efficiency Fund
EGrAMS - Electronic Grant Administration and Management System
ESCOs - Energy Saving Contractors
ESMAP - Energy Sector Management Assistance Program
HID- High-Intensity Discharge
HPS - High Pressure Sodium
IAM - Integrated assessment model
ISO- Independent System Operator
LADWP - Los Angeles Department of Water and Power
LED - Light Emitting Diode
MAE - Michigan Agency for Energy
MARC- Mid-America Regional Council
MDEQ- Michigan Department of Environmental Quality
MEDC - Michigan Economic Development Corporation
MEO- Michigan Energy Office
MH - Metal Halide
MISO - Midwest Independent Transmission System Operator
MML- Michigan Municipal League
MPO- Metropolitan Planning Organization
MPSC- Michigan Public Service Commission
MV - Mercury Vapor
NLPIP - National Lighting Product Information Program
NYCDOT - New York City Department of Transportation
OBF - On Bill financing
O&M - Operations and Maintenance
PG&E - Pacific Gas and Electric
PUC- Public Utilities Commission
QECB - Qualified Energy Conservation Bond
ROE- Return on Equity

RPS - Renewable Portfolio Standard
SCIP - State Carbon Implementation Plan
SEMCOG- Southeast Michigan Council of Governments
SEMREO - Southeast Michigan Regional Energy Office
S&P - Standard and Poor's
SRML - University of Oregon Solar Radiation Monitoring Laboratory

Appendix

Appendix 1.1
DTE Service Area:

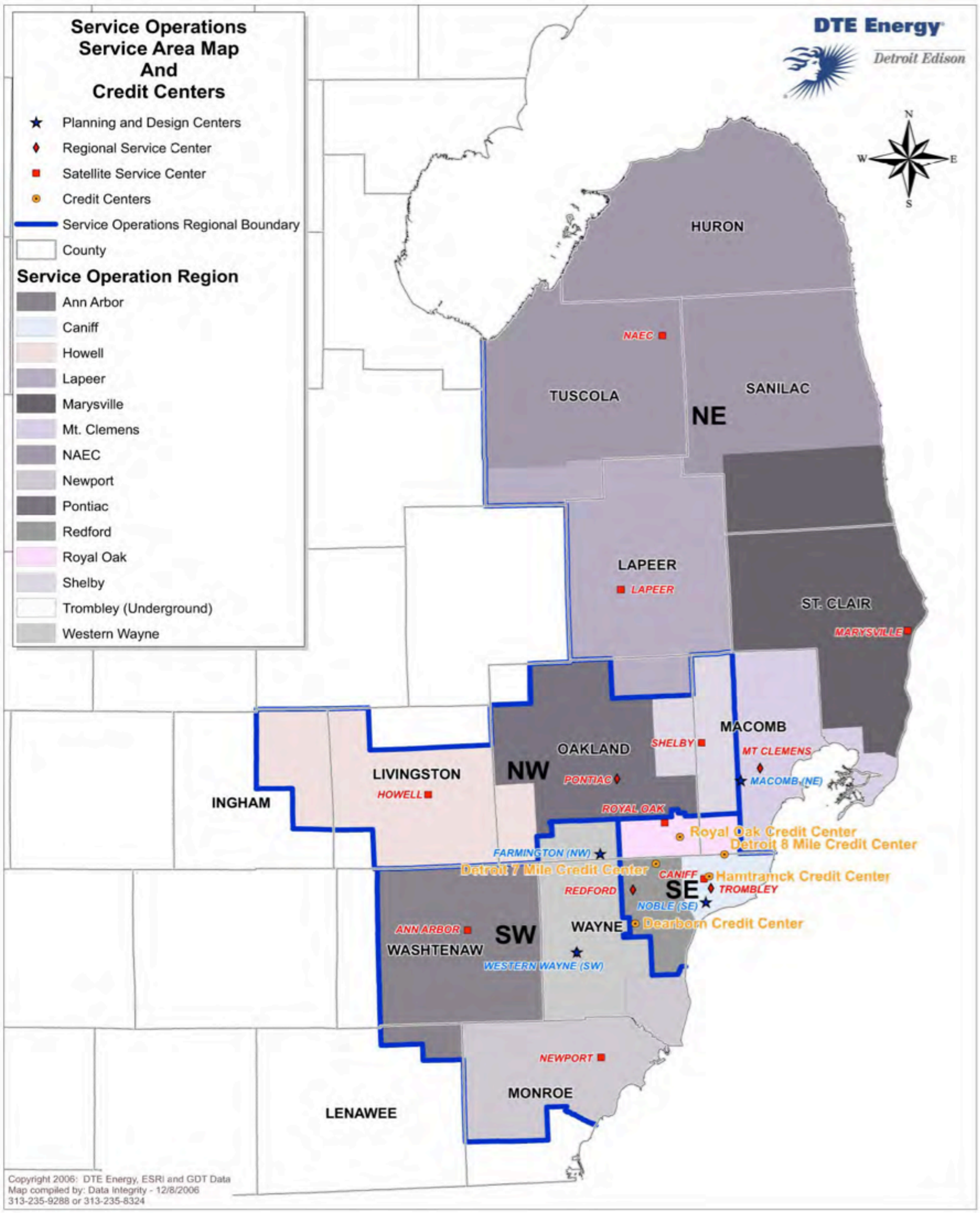


Figure: DTE Service Area Map

Appendix 2.1
LED Conversion Plan Model Assumptions:

- The process of conversion would follow the mechanism below, which ensures sufficient amount of light provided after conversion.

Current		Future	
Current Watt	**Type**	**New Watt**	**Type**
100	MV	65	LED
175	MV	65	LED
250	MV	135	LED
400	MV	135	LED
1000	MV	280	LED
70	HPS	65	LED
100	HPS	65	LED
150	HPS	135	LED
250	HPS	135	LED
400	HPS	280	LED
1000	HPS	280	LED

- Cost to convert includes following parts:

Cost of LED per LUM with Long Life Photocell	Labor	Total Cost per Fixture	New Wattage
$181.26	$56.00	$237.26	65
$324.74	$56.00	$380.74	135
$560.51	$56.00	$616.51	280

- The operation time is assumed to be 4200 hours per year, according to DTE Electric Company Rate Book for Electric Service, Sheet No. D-53.00.

Appendix 2.2

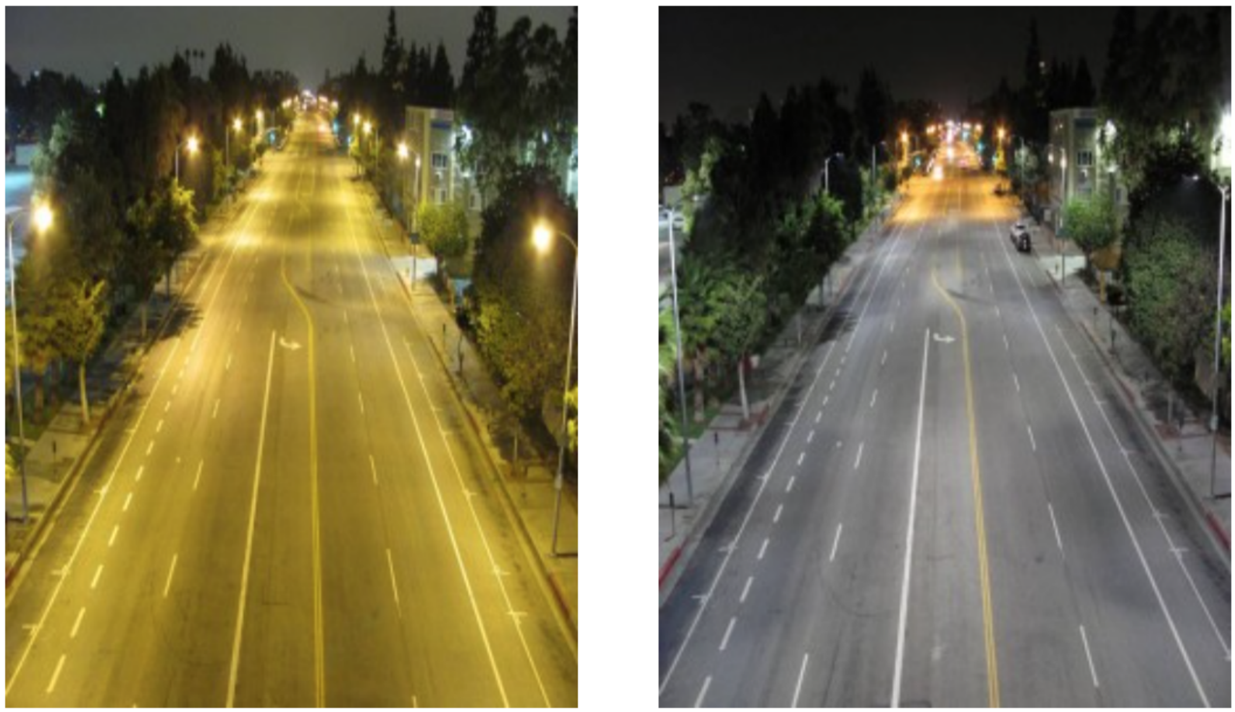


Figure: Los Angeles' Hoover Street before and after the conversion to LED street lighting. Credit: Los Angeles Bureau of Street Lighting.

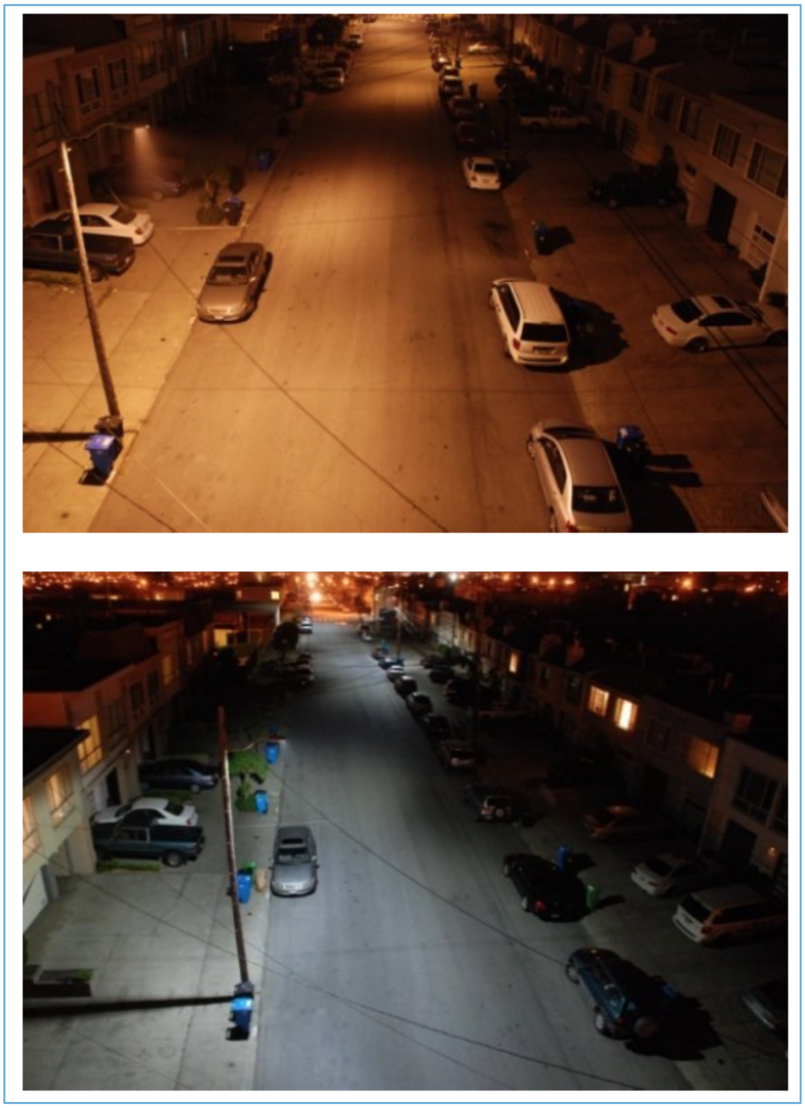


Figure: San Francisco comparison of HPS and LED streetlights – Sunset District.[162]

[162] Bay Area Climate Collaborative (BACC) and Energy Solutions, Next Generation Streetlights: LED Technology and Strategies for Action. http://baclimate.org/wp-content/uploads/2014/01/nextgen_streetlight_guide.pdf

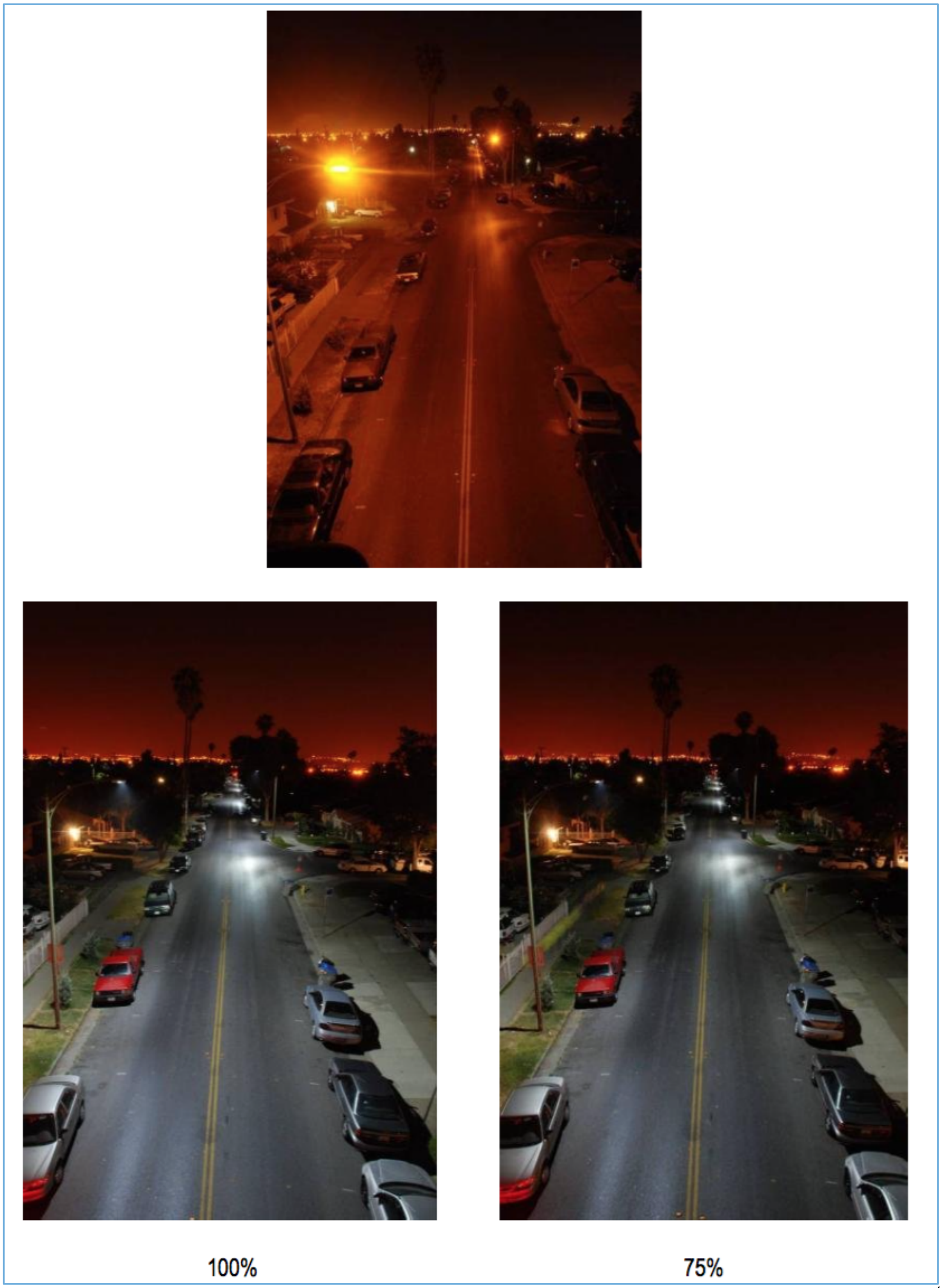
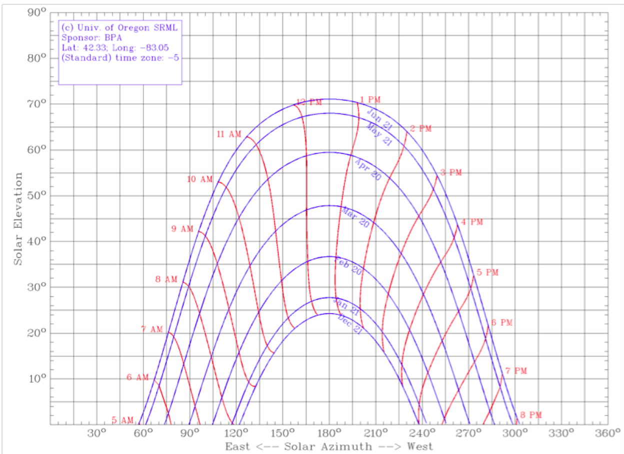


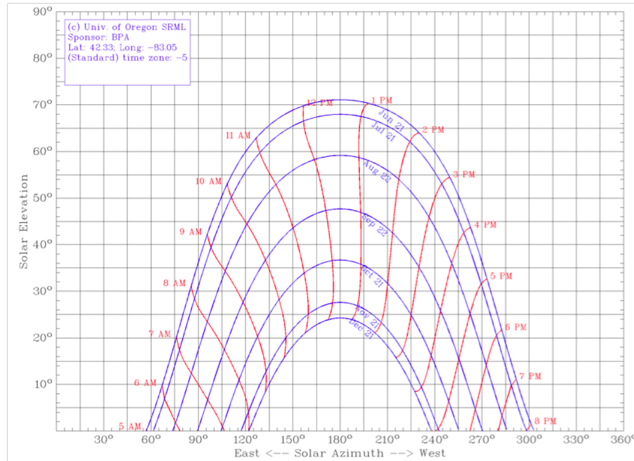
Figure: San Jose comparison of LPS and dimmable LED streetlights at 100% and 75% power.[163]

[163] Bay Area Climate Collaborative (BACC) and Energy Solutions, Next Generation Streetlights: LED Technology and Strategies for Action. http://baclimate.org/wp-content/uploads/2014/01/nextgen_streetlight_guide.pdf

Appendix 4.1. Sun Path diagram for Detroit, MI (SRML, 2008).

Sunrise and sunset time is obtained from University of Oregon Solar Radiation Monitoring Laboratory (SRML) Sun Chart Program. This program creates sun charts for "typical" dates of each month. Latitude and longitude of Detroit MI is applied. Dates 30 or 31 days are plotted apart, between solstices, December through June. Hours are plotted in local standard time, and thus Daylight saving time is applied March through October. From the sun-path charts, sunrise and sunset time table is generated (Table 4.1).





Appendix 4.2. Data Acquisition from Acid Rain Program (ARP)

Hourly regional electricity supply data can be obtained in the EPA Air Markets Program Data (AMPD): Acid Rain Program (ARP). Goal of the project is to provide analysis that guide future plans, thus most up-to-date complete data set, data for year 2014 is used in the analysis. Data query is conducted using following steps.

- Annual Programs: Acid Rain Program (ARP)
- Data sets: Emissions, Unit Level, no aggregation; Facility Attributes
- Time Frame: Hourly, From 01/01/2014 to 12/31/2014; Start Time, 0, End Time, 23.
- Criteria: State, MI
- Unit Operating Status: Operating
- Variables: Emission - unit, Associated stacks, Program, Gross Load (MW), SO_2 (pounds), Avg. NO_x Rate (lb/MMBtu), NO_x (pounds), CO_2 (short tons), Heat Input (MMBtu), Owner, Operator, Operating Status, Fuel Type (Primary), Fuel Type (Secondary), SO_2 Control(s), NO_x Control(s), PM Control(s), Hg Control(s).

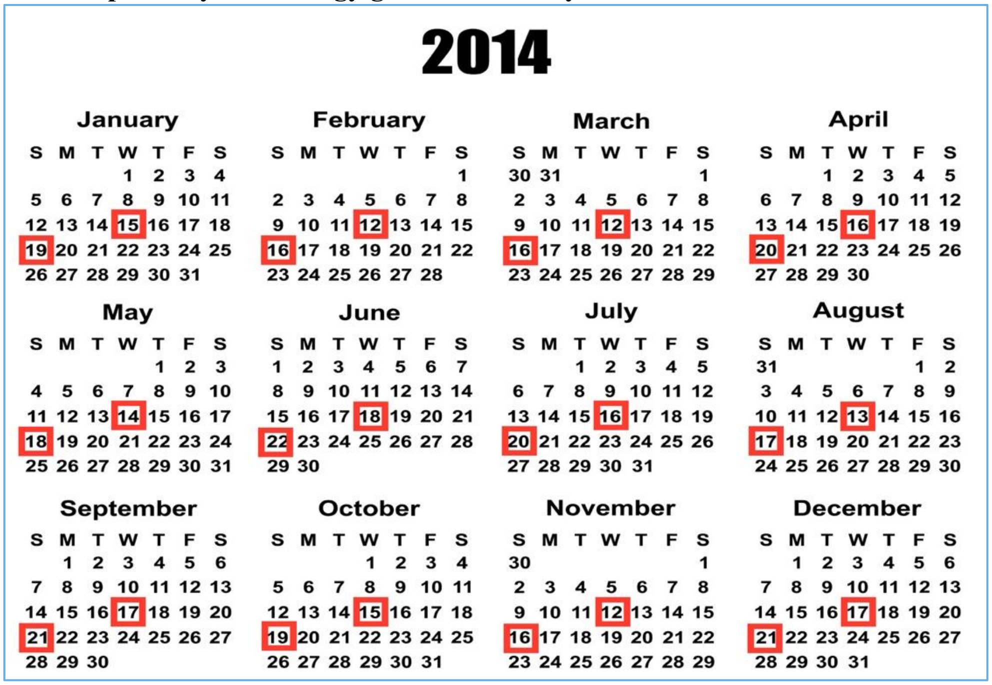
It should be noted that data for nuclear powered units is not reported in the program. In the United States, nuclear power plants are normally operated invariably at maximum output, functioning as baseload (EIA, 2012[164]), thus absent data does not impact accuracy of the analysis.

FERC data was considered, but units aggregated provided in Form 714 database cannot provide information in sufficient detail.

Technical parameters of current sodium-vapor streetlights and LED streetlights are obtained based on models chosen by communities.

[164] EIA. 2012. Electric generator dispatch depends on system demand and the relative cost of operation. <http://www.eia.gov/todayinenergy/detail.cfm?id=7590>

Appendix 4.3. Sampled days for energy generation analysis



Appendix 4.4. Social cost of carbon value table from EPA[165].

Social Cost of CO_2, 2015-2050 [a] (in 2007 Dollars per metric ton CO_2)

Source: Technical Support Document (PDF, 21 pp, 1 MB): Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866 (May 2013, Revised July 2015)

Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2015	$11	$36	$56	$105
2020	$12	$42	$62	$123
2025	$14	$46	$68	$138
2030	$16	$50	$73	$152
2035	$18	$55	$78	$168
2040	$21	$60	$84	$183
2045	$23	$64	$89	$197
2050	$26	$69	$95	$212

a The SC-CO_2 values are dollar-year and emissions-year specific.

165 EPA. 2016. "Climate Change: The social cost of carbon".
<https://www3.epa.gov/climatechange/EPAactivities/economics/scc.html>

Appendix 4.5. APEEP damage value assigned to each generating unit

All Values Expressed in year 2000 $/ short ton

Power Plant	Plant Responding Rate	County	NOx	SO2
Monroe	31.46%	Monroe County	338.2	3345.2
Belle River	16.17%	St. Clair County	274.0	3106.4
J H Campbell	15.40%	Ottawa County	722.7	3020.3
St. Clair	10.47%	St. Clair County	274.0	3106.4
B C Cobb	4.10%	Muskegon County	686.6	2860.8
Dan E Karn	3.65%	Bay County	511.6	2061.6
J C Weadock	3.40%	Bay County	511.6	2061.6
J R Whiting	3.22%	Monroe County	338.2	3345.2
Zeeland Generating Station	2.68%	Ottawa County	722.7	3020.3
New Covert Generating Project	2.20%	Van Buren County	604.3	2710.2
Presque Isle	2.04%	Marquette County	246.4	1199.2
Erickson	1.86%	Eaton County	740.2	3183.0
Eckert Station	0.81%	Ingham County	783.5	3187.9
Shiras	0.57%	Marquette County	246.4	1199.2
Endicott Generating	0.45%	Hillsdale County	646.8	2952.9
Jackson Power Facility	0.36%	Jackson County	725.4	3350.4
J B Sims	0.33%	Ottawa County	722.7	3020.3
Lansing BWL REO Town Plant	0.31%	Ingham County	783.5	3187.9
Michigan Power Limited Partnership	0.27%	Mason County	345.6	1718.4
Renaissance Power	0.21%	Gratiot County	1295.9	2132.2
Kalkaska Ct Project #1	0.03%	Wayne County	248.1	5072.0
Greenwood	0.01%	Sanilac County	424.6	1939.5
Dearborn Industrial Generation	0.003%	Wayne County	248.1	5072.0
48th Street Peaking Station	0.003%	Allegan County	793.7	3266.3
Delray	0.002%	Wayne County	248.1	5072.0
Grand Total	**100.00%**	MI value	439.2	3028.4

Appendix 4.6. All load following units that operate during streetlight operating hours (continued)

Facility Name	Unit ID	Responding Rate	Yrly Responding Rate Trend	Primary Fuel Type
Monroe	3	9%		Coal
Monroe	1	9%		Coal
J H Campbell	3	8%		Coal
Belle River	2	8%		Coal
Monroe	4	8%		Coal
Belle River	1	8%		Coal
Monroe	2	6%		Coal
J H Campbell	2	4%		Coal
J H Campbell	1	3%		Coal
St. Clair	7	3%		Coal
St. Clair	6	3%		Coal
Dan E Karn	2	2%		Coal
B C Cobb	5	2%		Coal
B C Cobb	4	2%		Coal
Erickson	1	2%		Coal
J C Weadock	7	2%		Coal
J C Weadock	8	2%		Coal
J R Whiting	3	1%		Coal
Dan E Karn	1	1%		Coal
St. Clair	4	1%		Coal
St. Clair	2	1%		Coal
St. Clair	3	1%		Coal
Zeeland Generating Station	CC3	1%		Pipeline Natural Gas
Zeeland Generating Station	CC4	1%		Pipeline Natural Gas
St. Clair	1	1%		Coal
New Covert Generating Project	2	1%		Pipeline Natural Gas
J R Whiting	2	1%		Coal
New Covert Generating Project	3	1%		Pipeline Natural Gas
J R Whiting	1	1%		Coal
Presque Isle	8	1%		Coal
Shiras	3	1%		Coal
Endicott Generating	1	0%		Coal
Presque Isle	9	0%		Coal
New Covert Generating Project	1	0%		Pipeline Natural Gas
Eckert Station	6	0%		Coal
Presque Isle	7	0%		Coal
Presque Isle	5	0%		Coal
J B Sims	3	0%		Coal
Presque Isle	6	0%		Coal
Michigan Power Limited Partner	1	0%		Pipeline Natural Gas
Eckert Station	5	0%		Coal

Appendix 4.6. All load following units that operate during streetlight operating hours (end)

Zeeland Generating Station	CC1	0%	Pipeline Natural Gas
Lansing BWL REO Town Plant	100	0%	Pipeline Natural Gas
Zeeland Generating Station	CC2	0%	Pipeline Natural Gas
Belle River	CTG131	0%	Coal
Jackson Power Facility	7EA	0%	Pipeline Natural Gas
Eckert Station	4	0.096%	Coal
Lansing BWL REO Town Plant	200	0.093%	Pipeline Natural Gas
Renaissance Power	CT4	0.090%	Pipeline Natural Gas
Renaissance Power	CT2	0.090%	Pipeline Natural Gas
Belle River	CTG121	0.067%	Coal
Eckert Station	3	0.056%	Coal
Jackson Power Facility	LM4	0.044%	Pipeline Natural Gas
Jackson Power Facility	LM3	0.044%	Pipeline Natural Gas
Jackson Power Facility	LM5	0.043%	Pipeline Natural Gas
Jackson Power Facility	LM6	0.043%	Pipeline Natural Gas
Jackson Power Facility	LM1	0.042%	Pipeline Natural Gas
Jackson Power Facility	LM2	0.042%	Pipeline Natural Gas
Renaissance Power	CT1	0.035%	Pipeline Natural Gas
Belle River	CTG122	0.032%	Coal
Kalkaska Ct Project #1	1A	0.026%	Pipeline Natural Gas
Greenwood	CTG111	0.009%	Pipeline Natural Gas
Dearborn Industrial Generation	GTP1	0.003%	Pipeline Natural Gas
Greenwood	1	0.003%	Pipeline Natural Gas
48th Street Peaking Station	9	0.003%	Pipeline Natural Gas
Delray	CTG121	0.002%	Pipeline Natural Gas

Appendix 5.1

Pre-Focus Group Survey Questions

1. In your opinion, is street lighting improvement a “public good”?
2. Will you be willing to pay for street lighting improvements in your community?
3. How much would you be willing to pay annually per household for street lighting improvements?
4. Do you think improved street lighting in your area will reduce crime?
5. Will you feel safe walking alone in a well-illuminated street in your community?
6. Do you think LED street lighting will create too much light in your community?
7. What is your race?
8. What is your gender?
9. What is your income level?
10. What is your age?

Appendix 6.1 - 'Cost of Waiting' for Southgate

						Cost of Electricity		Cost of Waiting	
Fix. Type	Curent Tech.		Proposed Tech.		Qty.	Current System	Proposed System	Per month	Per Year
UG	MV	175 W	LED	60 - 69 W	45	$ 3,307.00	$ 1,228.50	$ 173.25	$ 2,079.00
UG	MV	400 W	LED	130 - 139 W	1	$ 168.00	$ 56.70	$ 9.28	$ 111.30
UG	HPS	100 W	LED	60 - 69 W	169	$ 7,098.00	$ 4,613.70	$ 207.03	$ 2,484.30
UG	HPS	150 W	LED	60 - 69 W	7	$ 441.00	$ 191.10	$ 20.83	$ 249.90
UG	HPS	250 W	LED	130 - 139 W	58	$ 6,090.00	$ 3,288.60	$ 233.45	$ 2,801.40
UG	HPS	400 W	LED	130 - 139 W	248	$ 41,664.00	$ 14,061.60	$ 2,300.20	$ 27,602.40
UG	LED	80 - 89 W	N/A	N/A	116	-	-	-	-
UG	LED	150 - 159 W	N/A	N/A	6	-	-	-	-
OH	MV	175 W	LED	60 - 69 W	818	$ 60,123.00	$ 22,331.40	$ 3,149.30	$ 37,791.60
OH	MV	400 W	LED	130 - 139 W	25	$ 4,200.00	$ 1,417.50	$ 231.88	$ 2,782.50
OH	HPS	100 W	LED	60 - 69 W	80	$ 3,360.00	$ 2,184.00	$ 98.00	$ 1,176.00
OH	HPS	250 W	LED	130 - 139 W	189	$ 19,845.00	$ 10,716.30	$ 760.73	$ 9,128.70
OH	HPS	400 W	LED	280 - 289 W	40	$ 6,720.00	$ 4,788.00	$ 161.00	$ 1,932.00
OH	LED	80 - 89 W	N/A	N/A	10	-	-	-	-
OH	LED	150 - 159 W	N/A	N/A	172	-	-	-	-
					Total	$ 1,53,016.00	$ 64,877.40	$ 7,344.95	$ 88,139.10

Assumptions:
1. Average number of hours 'on' per year = 4200 hrs (Source: DTE Energy E1 Street Lighting Rate Case.)
2. Electricity cost (in $ per kWh) = 10 cents per kWh
3. Cost of waiting estimated using GE Lighting "Cost of Waiting Estimator'

Appendix 6.2 - 'Distressed' Consortium communities

Community Name	Distressed Community? (Y/N)	Area ($miles^2$)	Population	Population Density
Dearborn	Y	24.4	95,884	4050
Eastpointe	Y	5.14	32,627	6311.7
Farmington	N	2.66	10,557	3899
Ferndale	Y	3.88	20,257	5129
Grosse Pointe	N	2.25	5,316	5114
Grosse Pointe Shores	N	19.23	2,456	2615.7
Grosse Pointe Woods	N	3.25	15,862	4964.6
Hazel Park	Y	2.82	16,615	5823.4
Highland Park	Y	2.97	10,441	3965
Huntingdon Woods	N	1.47	6,356	4243.5
Lathrup Village	N	1.5	4,148	2716.7
Lincoln Park	Y	5.89	37,313	6476
Madison Heights	Y	7.09	30,226	4188.2
Mount Clemens	Y	4.2	16,399	4008.4
River Rouge	Y	2.65	7,676	2982.3
Roseville	N	9.83	47,555	4811.7
Royal Oak	N	11.79	58,946	4854.6
Saint Clair Shores	N	11.62	60,070	5139
South Lyon	N	3.73	11,626	3036.7
Southgate	N	6.85	29,487	4386.4
Sterling Heights	N	36.8	1,31,224	3552.4
Warren	Y	34.38	1,34,873	3899.2
Wayne	Y	6.02	17,163	2922.4
Ypsilanti	Y	4.33	19,809	4489
Average		8.95	34,287	4315.79

County Name	Distressed Community? (Y/N)	Area	Population	Population Density
Washtenaw County	N	706	3,44,791	488

Note:
1. Data *below average* in each of the Columns (Area, Population and Population Density) have been marked in Red.
2. Twelve cities out of 24 are 'Distressed' commmunities i.e. 50% of the consortium member cities are distressed.

Appendix 6.3 - Project details of Foster City, CA

	Phase I	Phase II	Total
Lights Installed	269	1,762	2,031
Completion Dates	February 2011	March 2013	
Project Cost	$157,426	$1,093,939	$1,251,365
ARRA Grant	$157,426	$747,939	$905,365
0% Loan (On-Bill Financing)	N/A	$196,000	$196,000
City Cost	$0	$150,000	$150,000
Rebate Amounts	$33,825	$171,750	$205,575
kWh Savings/Year	141,240	859,449	1,000,689
Energy Savings/Year	$17,615	$112,468	$130,083
Maintenance Savings/Year	$1,883	$12,334	$14,217
CO_2 Reductions	74,010	450.351	524,361