FINAL REPORT

OPPORTUNITIES ON THE STATE HIGHWAY SYSTEM TO GENERATE REVENUE OR OFFSET EXPENDITURES FOR THE STATE OF FLORIDA

FDOT Contract No.: BDK80 977-34

Mehmet Emre Bayraktar, Ph.D., Associate Professor

Yimin Zhu, Ph.D., Associate Professor

Nahid Vesali Mahmoud, Graduate Research Assistant

OHL School of Construction
College of Engineering and Computing
Florida International University
10555 West Flagler St.
Miami, FL 33174

COLLABORATORS

Good Company

Douglas J. Tindall

Jolanda Prozzi

Submitted to:

Florida Department of Transportation
Research Center
605 Suwannee Street, MS30
Tallahassee, FL 32399

October 2013

DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		TEMPERATURE (exact degrees)		
ºF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	ºC

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle **Opportunities on the State Highway System to Generate Revenue or Offset Expenditures for the State of Florida**		5. Report Date **October 28, 2013** 6. Performing Organization Code
7. Author(s) **M. Emre Bayraktar, Yimin Zhu, Nahid V. Mahmoud, Good Company, Doug J. Tindall, Jolanda Prozzi**		8. Performing Organization Report No.
9. Performing Organization Name and Address **OHL School of Construction** **Florida International University** **10555 West Flagler Street, EC 2900** **Miami, FL 33174**		10. Work Unit No. (TRAIS) 11. Contract or Grant No. **BDK80 977-34**
12. Sponsoring Agency Name and Address **Florida Department of Transportation** **605 Suwannee Street** **Tallahassee, FL 32399**		13. Type of Report and Period Covered **Final Report** **June 2012 – October 2013** 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

As state DOTs seek solutions to funding issues, their attention has turned to identifying alternative and innovative sources of revenue and cost savings. One potential source of new revenue and cost savings that has gained recent attention is value extraction from highway rights-of-way. This research first established the state-of-the-practice of value extraction projects and initiatives in highway rights-of-way. In the next step, the research team conducted the required analyses and developed the tools to be used by FDOT as decision support in implementing three high-priority value extraction projects chosen by FDOT including (i) solar photovoltaic, (ii) LED lighting, and (iii) haying or planting in highway rights-of-way. The research team analyzed the legal framework affecting implementation of value extraction projects in highway rights-of-way, conducted case studies to collect additional data, and developed a tool for feasibility screening of these value extraction projects.

17. Key Word		18. Distribution Statement **No restriction**	
19. Security Classif. (of this report) **Unclassified**	20. Security Classif. (of this page) **Unclassified**	21. No. of Pages **175**	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

EXECUTIVE SUMMARY

The Florida Department of Transportation (FDOT), along with most other state DOTs, is increasingly challenged by inadequate funding from traditional motor fuel taxes. These taxes were conceived in the 1950s as an indirect charge to recover the costs of vehicle travel on the U.S. highway system. In recent years, however, the financial limitations of the current system have become evident as revenues have failed to keep pace with the demands for additional highway investment. Inadequate funding from motor fuel taxes together with increased demand for transportation and increasing maintenance needs resulting from an aging highway system have resulted in significant funding problems for state highway agencies.

As state DOTs seek solutions to funding issues, their attention has turned to identifying alternative and innovative sources of revenue and cost savings. One potential source of new revenue and cost savings that has gained recent attention is value extraction from highway rights-of-way. Several state transportation agencies are now not only optimizing rights-of-way for mobility efficiency, but are also exploring other non-traditional functions, such as renewable energy development and leasing of rights-of-way to utilities. These value extraction projects have the potential to provide state DOTs with additional revenues or secure cost savings while operating transportation systems.

Although the collective experience with the non-traditional use of highway rights-of-way for value extraction is steadily growing, state DOTs typically face various uncertainties in developing such projects due to factors mainly related to the legal framework, technical and economic feasibility, environmental considerations, and potential impacts on stakeholders.

This research first investigated the state-of-the-practice of value extraction projects and initiatives in highway rights-of-way and provided FDOT with a complete set of choices related to the non-traditional use of highway rights-of-way (Phase 1). This was achieved through (i) a literature search which supplemented the extensive literature review that the members of the research team conducted during past sponsored research projects by reviewing published consultancy reports, documented research, and other publicly available information sources and (ii) an online survey of State DOTs which requested information on non-traditional uses of highway rights-of-way.

Upon completion of the literature search and the State DOT survey, the research team discussed the findings during an internal team meeting, and identified the most relevant and credible projects and programs for further evaluation. From this internal meeting the research team delivered a draft memo of findings and accompanying bibliography to FDOT. The draft memo contained an inventory of viable value extraction projects, which provided FDOT with a complete set of choices related to the non-traditional use of highway rights-of-way. In the next step, the research team held a meeting with FDOT via phone conference to discuss the list of viable value extraction projects and develop a shortlist of “high-priority” projects for an in-depth analysis in Phase 2 of the project. This effort led to a shortlist with three project types, including (i) solar photovoltaic, (ii) LED lighting, and (iii) haying or planting in highway rights-of-way.

In Phase 2, the research team conducted the required analyses and developed the tools to be used by FDOT as decision support in implementing the high-priority value extraction projects identified in Phase 1. In this phase, our team analyzed the legal framework affecting implementation of value extraction projects, conducted case studies to collect additional data, and developed a tool for feasibility screening of the three value extraction projects chosen by FDOT.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 Background

The Florida Department of Transportation (FDOT), along with most other state DOTs, is increasingly challenged by inadequate funding from traditional motor fuel taxes. These taxes were conceived in the 1950s as an indirect charge to recover the costs of vehicle travel on the U.S. highway system. In recent years, however, the financial limitations of the current system have become evident as revenues have failed to keep pace with the demands for additional highway investment. Inadequate funding from motor fuel taxes together with increased demand for transportation and increasing maintenance needs resulting from an aging highway system have resulted in significant funding problems for state highway agencies.

As state DOTs seek solutions to funding issues, their attention has turned to identifying alternative and innovative sources of revenue and cost savings. One potential source of new revenue and cost savings that has gained recent attention is value extraction from highway rights-of-way. Several state transportation agencies are now not only optimizing rights-of-way for mobility efficiency, but are also exploring other nontraditional functions, such as renewable energy development and leasing of rights-of-way to utilities. These value extraction projects have the potential to provide state DOTs with additional revenues or secure cost savings while operating transportation systems. Typically, benefits that could be realized from implementing these projects in highway rights-of-way include: (i) revenue streams; (ii) cost savings; and (iii) broader societal or environmental benefits, which may not be quantifiable in monetary terms.

1.2 Project Objectives

Although the collective experience with the nontraditional use of highway rights-of-way for value extraction is steadily growing, state DOTs typically face various uncertainties in developing such projects due to factors mainly related to the legal environment, technical and economic feasibility, environmental considerations, and potential impacts to stakeholders.

Feasibility Screening

Value extraction projects for highway rights-of-way are not necessarily feasible in all geographic/spatial contexts, nor are they necessarily equal in their financial attributes, i.e., required initial investment, OandM costs, revenue generation /cost saving potential, and potential business models and financing options. In addition to conforming to regulatory frameworks, potential projects must be carefully scrutinized in order to see if they meet FDOT management criteria and match the local resources and conditions – both technical and financial. In this respect, the primary objective of this research was to develop for FDOT a "Feasibility Screening Tool" which will provide FDOT with a thorough analysis of various technical and financial criteria for each specific project type included in this research.

The technical analysis section of the Feasibility Screening Tool aims to help FDOT managers and Districts determine what value extraction projects match their local resources and provide guidance in determining where and under what circumstances to pursue the implementation of which value extraction project. As the implementation of any value extraction project requires an upfront investment by the state DOT and/or private investors, the financial analysis section of the Feasibility Screening Tool includes data and methods to analyze factors such as estimated timeline and project development schedule, estimated project life-cycle costs (capital costs, OandM costs, etc.), estimated project revenues (income, incentives, tax credits, payback period, savings to investment ratio, etc.), and potential business model options and financing (public-private partnerships, different lease structures, etc.).

Policy Landscape

State and Federal legislation, regulations, and guidelines may limit or prevent state DOTs from implementing nontraditional uses of highway rights-of-way as the existing legal framework which is designed to support the primary DOT mission of providing safe vehicle transportation routes with adequate capacity may not necessarily support/permit nontraditional uses. Therefore, while many of the value extraction projects discussed in this proposal seem promising, each must be evaluated and assessed given Federal Highway Administration (FHWA) guidance and the current legal framework in the state in which these applications are considered. Any proposed alternative use of highway rights-of-way must comply with existing regulations and legal issues must be addressed at the outset, as they can thwart further progress if let unresolved.

Based on the discussion above, another objective of this research was to assess the legal framework under which FDOT can potentially extract additional value from its highway rights-of-way.

1.3 Methodology

This research study was conducted in two phases: Phase 1 and Phase 2.

PHASE 1: State-of-the-Practice of Value Extraction from Highway Rights-of-Way

Phase 1 established the state-of-the-practice of value extraction projects and initiatives in highway rights-of-way. The primary goal of Phase 1 was to compile a comprehensive inventory of potentially viable value extraction projects and provide FDOT with a complete set of choices to choose from for an in-depth analysis in Phase 2.

PHASE 2: Analyses and Tools for Development of Value Extraction Projects in Florida

In Phase 2, the research team conducted the required analyses and developed the tools to be used by FDOT as decision support in implementing the high-priority value extraction projects identified in Phase 1. In this phase, our team analyzed the legal framework affecting implementation of value extraction projects, conducted case studies to collect additional data, and developed a tool for feasibility screening of the three value extraction projects chosen by FDOT including (i) solar photovoltaic, (ii) light emitting diode (LED) technology, and (iii) haying and planting in highway right-of-way.

2. LITERATURE REVIEW

2.1 Introduction

A number of state DOTs have investigated and implemented projects and programs designed to extract economic and social value from highway ROWs. The discussion below highlights some of the most common value extraction activities considered and put in place.

2.2 Solar Photovoltaic

Solar photovoltaic (PV) systems use solid-state semiconductors to convert the energy in sunlight into electricity. A typical solar PV system includes: a set of interconnected PV panels; a steel or aluminum mounting structure; and electric equipment to connect the system to electrical grid. PV systems range in size depending on the application and installation location. Small residential rooftop systems are typically 2-10 kiloWatt (kW), while rooftop commercial systems can be as large as several megaWatts (MW). Ground-mounted utility scale systems are typically greater than 100 MW. Ground-mounted systems typically require 4-5 acres per megawatt (Denholm and Margolis, 2007).

For many years, state DOTs have used solar photovoltaic (PV) technology at a small scale in a range of highway applications such as portable variable message signs and traffic signals. More recently, state DOTs have turned their attention toward medium-scale deployments of solar PV. While many of these installations have been on the rooftops of agency facilities, a number of DOTs have now considered and installed ground mounted solar PV systems in the highway ROW.

While it has been postulated that PV panels could be embedded directly in the roadbed, such technology is not yet commercially viable.

<u>States with Existing Programs and Projects</u>

<u>Oregon</u>: The Oregon Department of Transportation was the first state DOT to install a solar array through a public-private partnership with Portland General Electric in

December 2008. The project is comprised of a 104-kilowatt (kW) solar array situated at the interchange of I-5 and I-205. The project supplies about one-third of the energy needed to illuminate the interchange in that area (Oregon DOT, 2011b).

In 2012, Oregon completed installation of the state's second solar array (1.75 megawatts) in the highway ROW at the I-5 northbound Baldock Safety Rest Area south of Wilsonville; and currently another array is on the drawing board for installation at the Oregon DOT Maintenance storage facility in West Linn on the north side of I-205. To date, the Oregon projects have been developed under the state's utility accommodation policy (Oregon DOT, 2011b).

In 2011, Oregon DOT published a guidebook to provide other state DOTs an overview of the process of developing solar PV installations. The guidebook includes a review of: regulatory constraints and policy incentives; considerations for assembling a project team and identifying potential project sites; typical business models; and key contracting issues (Ponder et al., 2011).

Ohio: The Ohio Department of Transportation's Veterans' Glass City Skyway Bridge Solar Array Project is another example of solar energy harvesting in the highway ROW. In 2010, Ohio DOT, in conjunction with the University of Toledo, installed a 100-kW solar array in the highway ROW off I-280 in Toledo, Ohio. Electricity generated by the solar array is sent to the energy grid and indirectly offsets the electricity demand of the Veterans' Glass City Skyway Bridge, which has a 196-foot lighted pylon containing 384 light-emitting diode fixtures. Ohio DOT is testing rigid and flexible PV panels, both of which are manufactured in Ohio, to determine the viability of each in potential future applications (Ohio DOT, n.d.).

Massachusetts: In June 2012, the Town of Carver, Massachusetts, in cooperation with the Massachusetts DOT (MassDOT), completed a 112-kilowatt PV system along a divided state highway. The project is located 65-feet from the roadway on a south facing cut slope beyond the ditch line and behind a guardrail. MassDOT granted the town an airspace lease for the state-owned land in exchange for annual rental payment of $880. The electricity generated by the project is used by the town to offset power consumption at a nearby wastewater treatment facility (Volpe Center, 2012).

<u>States that have conducted Initial Feasibility Research</u>

<u>Florida</u>: In 2009, the Florida Turnpike Enterprise commissioned a study to determine the technical and financial feasibility of installing solar PV at the Turkey Lake Service Plaza in Ocoee, FL. The final report, released in early 2010, showed that with grants, tax credits and other incentives, certain configuration were both technically and financially feasible and could more than offset the facilities expected electricity consumption (Kibert et al., 2010).

<u>California</u>: California Department of Transportation (Caltrans) and the Sacramento Municipal Utility District, in 2008, partnered to develop solar energy projects at an expected capacity of 1.4 MW. Caltrans drafted an airspace lease agreement so that SMUD would be able to govern the use of the ROW. However, when the project went out for the construction bid, only one firm responded with a price that SMUD determined to be too high (Volpe Center, 2012).

Republic Solar Highways is a company working on developing a pilot project with project sites in Santa Clara County, California (Thirve! Morgan Hill, 2012). None of the projects appear to have broken ground yet. The projects could generate up to 15 megawatts combined.

<u>New Jersey</u>: As part of the national “Adopt-A-Watt Program,” New Jersey Department of Transportation is researching the potential for building solar light poles and PV arrays at rest areas (Volpe Center, 2012).

<u>Nebraska</u>: The University of Nebraska-Lincoln is working on developing dual solar-wind power technology to go on light posts (Energy Plus Roadways, 2009).

Washington State and New York DOTs are also considering solar installations along interstates and rest areas (Volpe Center, 2012).

2.3 Wind

Wind can be used to generate electricity through the use of wind turbines. The amount of energy wind turbine systems can produce currently ranges from less than 100 kW for small wind turbines to 2.5 MW for utility-scale turbines. While the size of the highway ROW is typically too small to accommodate mid- (100 kW to 1 MW capacity) and utility-scale turbines, recent advances in smaller and micro wind (1.5 kW capacity) turbine technologies may provide an opportunity to exploit wind energy resources in locations not previously feasible, such as along roadways. Micro-wind technology allows wind turbines to start generating electricity at much lower wind speeds than traditional turbines. Another advantage of micro-turbines is that they can be mounted in unconventional locations where small turbines cannot fit.

To date, only a few state DOTs have examined the feasibility of installing wind turbines in the highway ROW or at highway rest areas.

States with Existing Programs and Projects

Missouri: Missouri Department of Transportation installed two Windspire, 1.2-kW wind turbines, in a rest area converted into a welcome center in Conway, Missouri, off of I-44 (Windspire Energy Inc., 2010)

Texas: The Texas Department of Transportation (TxDOT) helped Alternative Energy Institute and USDA Bushland Research Center personnel install two 50-kW wind turbines at two rest stops – on IH 40 close to Amarillo and close to Lubbock - in 2003 (Alternative Energy Institute, 2013). Each turbine cost approximately $2 million and supplies part of the electricity used by the rest area (Prozzi, et al., 2012).

States that have conducted Initial Feasibility Research

Ohio: The Ohio Department of Transportation is installing a small 32 kW wind turbine at a maintenance facility adjacent to I-68 in Northwood, Ohio. The electricity the turbine produces will be used on site, and Ohio DOT anticipates that it will help meet up to 65 percent of the maintenance facility's electricity needs (Volpe Center, 2012).

Massachusetts: The Massachusetts Department of Transportation is exploring the feasibility of locating wind turbines on Massachusetts DOT-owned land to meet the renewable energy targets established for all Massachusetts State agencies. Following a statewide analysis of potential wind turbine sites along the Massachusetts Turnpike, the agency determined that a 68-acre site adjacent to its Blandford service area was suitable for wind power development. In 2009, Massachusetts DOT began working with a developer to construct a 400-foot tall, 1.5 MW wind turbine. However, in 2011, town residents voted against a wind power-zoning bylaw that would have allowed the development of the proposed turbine, putting the future of this project in question (Volpe Center, 2012).

Illinois: The Illinois Department of Transportation sponsored a study, performed by the University of Illinois at Urbana Champaign through the Illinois Center for Transportation, to look at the potential of wind for providing electrical power at highway rest areas, weigh stations and team section buildings. The study identified several favorable sites where small wind turbines could be economically feasible. It also found that the cost of the wind turbines was one of the most important determinants of return on investment and viability (Chapman and Wiczkowski, 2012).

Washington: The Washington State Department of Transportation examined the idea of installing wind turbines on the Tacoma Narrows Bridge as part of the Columbia River Crossing project. However, no specific proposals were received to actually bring the project to fruition (Volpe Center, 2012).

Other states investigating the potential of wind turbines on state-owned land include Minnesota and Nebraska (Volpe Center, 2012).

Internationally, small-scale wind turbines on the highway ROW are being examined. For example, in Israel, a project is being initiated to put small turbines on lighting poles on the highway that runs along the Mediterranean Sea (Volpe Center, 2012).

2.4 Cultivating Biomass for Heat, Power and Transportation Fuel

A number of technologies can convert biomass, organic materials from plants or animals, into heat, electricity, or transportation fuel. The three most common biomass conversion technologies are the direct combustion of wood and wood derived fuels for heat and/or power (electricity), the fermentation of sugar and starch crops like corn to produce ethanol for transportation fuel, and the transesterification of vegetable oils and animal fats to produce biodiesel for transportation fuel.

Additionally, considerable research and development efforts are underway to commercialize new biomass energy technologies like cellulosic ethanol, gasification and pyrolysis that hold the promise of converting lignocellulosic feedstocks like switchgrass and bagasse into solid, liquid or gaseous fuels. At this time these technologies are not generally considered commercially viable.

At least five states have investigated the possibility of intentionally cultivating dedicated energy crops in the ROW or harvesting existing ROW biomass to supply existing or prospective bioenergy conversion facilities. These states have experimented with cultivating oilseeds as a source of vegetable oil to convert to biodiesel and switchgrass as a feedstock for a demonstration scale cellulosic ethanol plant and harvesting existing grassy biomass for combustion in a biomass-fired electric power plant.

To date, these projects have been limited both in terms of duration and scale of production with a focus on identifying the agronomic, operational and economic issues associated with utilizing the highway ROW as a location to grow bioenergy feedstocks.

States with Existing Programs and Projects

North Carolina: Since 2009, the North Carolina Department of Transportation (NCDOT) and North Carolina State University (N.C. State) have partnered to explore the cultivating of oilseed crops in highway ROWs for biodiesel production. Through this partnership, NCDOT plants and maintains the crops while N.C. State conducts research on the plantings. The goal of the pilot project is to determine the yield potential and management strategies that are required to grow oilseeds in the compacted and highly disturbed soils found in the ROW.

The project has included plantings of sunflower, canola and safflower in test plots in both the Coastal Plain, a mostly rural, flat, low elevation region in the eastern part of the state, and the Piedmont, a mostly urban, hilly, rolling land in the central part of the state.

The project's initial plantings of canola on four 1-acre plots yielded about 2,900 pounds of seed, which produced 108 gallons of crude canola oil which was processed into about 100 gallons of B100 biodiesel by N.C. State researchers. The B100 biodiesel was taken by NCDOT to their regional fuel storage facility where it was splash blended with conventional ultra-low sulfur diesel on a 1 to 4 basis to make B20 to be used in fleet vehicles and equipment (NCSU CALS, 2011).

Michigan: Faculty from Michigan State University (MSU) developed a project to explore the possibility of cultivating bioenergy crops on nontraditional lands such as highway ROWs and vacant urban plots including airport grounds. To date, the project has completed or initiated two of three planned phases. The first phase of the project, concluded in 2010, consisted of: the establishment of a partnership network to conduct the research, a review of the potential barriers and opportunities associated with growing bioenergy crops on nontraditional lands, the identification and quantification of the lands potentially available for cultivation, a preliminary cost/benefit economic analysis and planning for a series of demonstration plots to be planted in the second phase.

The second phase of the project started in 2011 and includes the establishment of a variety of bioenergy crops on six ROW demonstration sites, two airport sites, two urban area sites, and two agricultural sites in state game areas. The small test plot areas were hand harvested to measure yield. The 1-acre plot areas where mowed after hand harvest. Canola yields from the ROW test plots ranged from 500 to 600 lb/acre, compared to test trials in farmer fields of 1200-1300 lb/acre (Pennington, et al., 2012).

Utah: The Utah Freeway to Fuels project was the first effort in the nation to explore the opportunity to grow bioenergy feedstocks on highway ROWs. The "Freeways to Fuels" (F2F) projects are actively examining the feasibility of growing, harvesting, and utilizing bio-energy crops on nontraditional cropland, including along roadways and vacant urban lots for biofuels, heat, and electricity production. In 2007 and 2008, researchers from Utah State University (Utah State) with the cooperation of the Utah Department of Transportation (UDOT), established five test plots along the roadside in four Utah regions along the I-15 corridor (Whitesides and Hanks, 2011).

Each test plot included plantings of canola and safflower. While the test plots did not produce economically viable yields, the low yields were site, weather, and equipment related. Some sites were not suitable due to elevation or soil conditions. Annual precipitation during the study period was below average, which also lowered expected yields (Whitesides and Hanks, 2011).

The planting equipment that was available for the project was not ideal and presented some problems with stand establishment in the highly compacted soils found in the ROW. The researchers conducted follow-up experiments at a Utah State research center to evaluate alternative agronomic practices to improve yields (Whitesides and Hanks, 2011).

The experiments included alternative planting methods to relieve compaction and the application of compost to aid soil fertility. Notably, the experiments successfully increased the yield of safflower plantings to a level considered cost-effective. The researchers believe that the most important factor for viable oilseed plantings in the ROW is soil compaction. The Utah State researchers continue to explore the viability of growing bioenergy crops on marginal lands. Currently test plots are being grown near the Salt Lake International Airport. There are no current plans to continue plantings in the highway ROW (Whitesides and Hanks, 2011).

Tennessee: In the spring of 2010, the Tennessee Department of Transportation (TDOT) with the support of Genera Energy LLC established four test plots of switchgrass on interstate ROW. Genera Energy, a for-profit bioenergy firm wholly owned by the University of Tennessee Research Foundation, and DuPont Cellulosic Ethanol partnered to develop the first and only commercial switchgrass to cellulosic ethanol plant operating in the U.S. The demonstration-scale plant, located in Vonore, Tennessee has the capacity to produce 250,000 gallons of ethanol per year and began operating in January 2010.

The purpose of the pilot was to determine if switchgrass growing in the ROW could reduce mowing needs, provide increase erosion control, and to explore the future possibility of producing biomass for energy. None of the test plots were harvested in the growing season so no yield information is available. According to Genera Energy, the area that was allocated to plant the switch grass did not produce a large enough yield to deem harvesting. Estimated yield from the identified locations would not support any financially feasible harvest. There are no current plans to expand or repeat the demonstration.

Wisconsin: A pilot project in south central Wisconsin sought to determine the feasibility of harvesting naturally occurring grassy biomass from the roadside and evaluate its suitability as a feedstock for combustion at a biomass power plant. The pilot project was a public-private partnership with Derr Solarmass LLC, a family-owned farm, the Wisconsin Office of Energy Independence (OEI) and Wisconsin's Department of Transportation (WisDOT). The Biomass Energy Resource Center (BERC) and faculty from the University of Wisconsin—Madison (UW—Madison) provided additional technical support (Derr, 2011).

The pilot project occurred in the fall of 2010 along a 2.2-mile section of U.S Highway 151 northeast of Madison, WI. The project participants reported that the farm equipment used to mow and bale the biomass met performance expectations. Yields were a respectable 2 tons per acre or about 5.5 pounds per mile based on a 30-foot mowing swath (Derr, 2011).

However, laboratory analysis of the harvested material found high levels of ash (10.7% by weight on average) and chlorides (5,475 µg/g on average) - unacceptable values for biomass fuels. Plans to test the material as a blendstock in a real world setting were cancelled when the intended recipient project was reconfigured and its biomass boiler was eliminated. There are no current plans to expand or repeat the demonstration (Derr, 2011).

States that have conducted Initial Feasibility Research

Kentucky: Kentucky State University performed a study to calculate the potential ethanol production or electricity generation from growing switchgrass on the highway ROW. The results of the study found there was a potential to harvest 137,000 tons of switchgrass per year, resulting in either 45 million liters of ethanol or 137 gW hours of electricity generation. Assuming no change in freeway traffic volume, the switchgrass could potentially offset 1.1% of freeway fuel use in the case of ethanol and 1.8% of freeway fuel use in the case of electricity generation (Bomford, et al., n.d.).

Missouri: Legislation has been introduced in Missouri to authorize the state Department of Transportation to enter into agreements for the harvest of existing grassy biomass and for the cultivation of switchgrass in the highway ROW (Volpe Center, 2012).

Ohio: An economic development committee in the town of Etna, Ohio are advocating for planting bio-energy crops in the ROW of I-70 (Jarman, 2010).

2.5 Carbon Sequestration

Despite the absence of Federal policy to create market mechanisms to reduce greenhouse gas emissions, a number of states and private enterprises continue to pursue market-based strategies to address concerns about climate change. These efforts have created a market for carbon credits, or carbon offsets-- tradable, environmental commodities that represent the reduction, avoidance or sequestration of greenhouse gases below a business-as-usual level. According to the World Bank, in 2009 the global market for carbon offsets totaled 283 million metric tons of carbon dioxide equivalent with a value of nearly $3.4 billion (Kossy and Guigon, 2012).

Some have suggested that utilizing highway ROWs to enhance carbon sequestration may provide DOTs an opportunity to tap into these markets. By intentionally planting vegetation or changing management practices, the amount of carbon stored above or below ground can be increased. Hypothetically, this increased volume of stored carbon could be quantified, verified, and monetized in the marketplace.

While carbon markets may eventually open up significant revenue streams, it is important to note that carbon markets in general, and the market for agriculture, forestry, and other land use carbon sequestration offsets in particular, are still emerging. Moreover, there is no clear pathway to bring offsets from projects developed in the highway ROW to market. While hypothetically possible, there would be significant first-mover transaction costs associated with developing such a project that it would be difficult to financially justify. Additionally, the vegetation types with the greatest carbon opportunity (i.e., trees) generally conflict with ROW management considerations.

States that have conducted Initial Feasibility Research

Federal Highway Administration Carbon Sequestration Pilot Program: Between 2008 and 2010, the Federal Highway Administration and the John A. Volpe National Transportation Systems Center (Volpe Center) conducted research to evaluate the potential for highway ROW in the National Highway System (NHS) to generate carbon offsets from carbon sequestration projects.

To quantify the scale of the opportunity, the project's research team developed a methodology, using geographic information system (GIS) analysis, to estimate the acreage in the NHS ROW and land cover by state. The study estimated that there are about 5 million acres of ROW in the NHS of which approximately 3.4 million is unpaved. The estimate of unpaved area includes the medians between divided highways, as well as the roadside extending from the edge of pavement to the outer ROW boundary. Based on these land area estimates, the researchers sought to quantify the amount of carbon that could be sequestered in NHS ROW and determine the potential market value (Volpe Center, 2010).

Findings from the study estimate that the National Highway System's ROW has about 91 million metric tons of carbon currently sequestered; is annually sequestering approximately 3.6 million metric tons of carbon per year; and has the potential, at its carbon equilibrium, to sequester a total somewhere between 425 and 680 million metric tons of carbon. The study further places an economic value on this potential total of $8.5 to $14 billion (Volpe Center, 2010).

Critically, in making this estimation, the researchers did not distinguish between project activities that might generate saleable carbon offsets and the continuation of business-as-usual practice. The estimate for both the carbon sequestration potential and the associated economic value is based on sequestration rates that assume a change in management practice. However, the report does not consider the cost or operational feasibility of changing existing management practice.

In order to generate a saleable carbon offset, there must be a change in the standard practice that results in a net gain in the amount of carbon sequestered, a concept referred to as additionality. So, while the method in the FHWA report may provide a coarse estimation of the business-as-usual sequestration it likely overestimates the potential economic value of highway ROW carbon sequestration.

Concurrent with the analysis of the potential for the entire NHS to sequester carbon, the FHWA selected two states – i.e., New Mexico and Minnesota - to investigate specific opportunities in their state to develop pilot projects.

New Mexico: In July 2008, the New Mexico Department of Transportation was selected by the FHWA to participate in the Carbon Sequestration Pilot Program (CSPP). When the FHWA selected NMDOT for the pilot project, it was assumed that the process to quantify, verify, and market carbon sequestered in the highway ROW would involve four components: An estimate of the total ROW acreage available for carbon sequestration; the identification of possible changes in management practices that would lead to enhanced levels of sequestered carbon and the associated costs; an estimate of the carbon offsets that might be generated by implementing the identified changes in management practices; and the validation and verification of net increases in levels of sequestered carbon that would lead to the issuance of high quality offsets that could be traded in an appropriate greenhouse gas emissions market or used to meet agency or state greenhouse gas emissions reduction goals (FHWA and Volpe Center, 2009).

Some of the highlights from the pilot project include:

- A decision to focus on managing grasslands and ruling out afforestation activities due to concern for motorist safety;
- No methodology for generating saleable offsets was available off-the-shelf; and,
- NMDOT had little to no data related to the current level of carbon sequestered in the ROW and didn't have the expertise to establish a baseline (FHWA and Volpe Center, 2009).

In the fall of 2010, NMDOT issued a request for proposals (RFP) to assess the baseline level of carbon sequestered in soils found within the state ROW, inventory current management practices, and recommend practices to increase the net amount of carbon sequestered. A consultant team, led by Ecosystem Management, Inc., was selected in early 2011. NMDOT plans to issue a second RFP to quantify actual changes in net carbon sequestered resulting from the implementation of new management practices and to generate marketable carbon offsets. As of February 2012, NMDOT had only initiated the assessment of baseline levels of carbon sequestration.

Minnesota: The Minnesota Department of Transportation (MnDOT) was also selected to participate in the FHWA's Carbon Sequestration Pilot Program (CSSP). MnDOT participated in the project by providing GIS data for the CSSP final report and by identifying potential sequestration activities, sites, and constraints. MnDOT conceived of three different potential project activities: 1) reforesting either through intentional tree planting areas outside of the clear zone; 2) replacing existing grassy vegetation with native prairie; and 3) improving management, through selective thinning, of forested areas in the ROW.

MnDOT identified more than 15,000 acres of ROW, out of a total statewide ROW area of approximately 185,000 acres that could support one of these potential sequestration activities. Of the 15,000 acres, approximately 9,800 acres were identified for grassland enhancement, 4,200 for forest management, and 1,100 for reforestation. These estimates were based on an informal assessment of land holdings.

In general, MnDOT reported that the potential volume of carbon sequestered and associated revenue did not appear to justify the cost and level of effort required to implement these project activities. MnDOT estimated it could cost upwards of $1,000 per acre to implement reforestation activities and as much as $1,600 per acre for grassland enhancement. It appears no formal cost benefit analysis was conducted, but based on these cost estimates MnDOT did not proceed with implementing any of the project activities. Further discouraging MnDOT from pursuing implementation was the absence of a clear pathway to bring any projects to the marketplace (Kenneth Graeve, Personal Communication, January 2012).

Florida: Florida's Department of Transportation Central Environmental Management Office and State Maintenance Office also took an initial look at the process for becoming a provider (seller) of carbon credits and preliminary cost considerations through a study completed in 2009. The study concluded that it was premature as FDOT would need to both establish baseline criteria for the Chicago Climate Exchange (CCX) and also revise its management practices of the ROW (Kalbli, 2009).

California: Caltrans began a preliminary investigation in order to identify literature that quantifies the economic and environmental value of carbon sequestration from vegetation in the ROW and strategies to increase sequestration. The research also looks to other DOTs for guidance regarding vegetation management practices for carbon sequestration. The final step is to examine large-scale sequestration projects to assemble lessons learned that might be applied to Caltrans projects in the ROW. Caltrans is considering several next steps including: comparing FHWA's NHS acreage estimates with Caltrans' ROW data; using FHWA's Carbon Sequestration Estimator tool to calculate the amount of carbon that could be sequestered in California ROW; and contacting Florida, New Mexico and Minnesota's DOTs to learn more about their research findings (CTC and Associates LLC, 2010).

NCHRP 25-35: The National Cooperative Highway Research Panel commissioned a study to develop a guidebook for DOT managers to follow in evaluating and identifying opportunities to utilize the highway ROWs to generate saleable carbon offsets. Preliminary findings from this research suggests that given current establishment costs, expected carbon offset prices, transaction costs, and potential rates of carbon sequestration, the opportunity to utilize highway ROWs to generate saleable carbon offsets at a reasonable return appears unlikely.

2.6 Electric Vehicle Charging Infrastructure

Facilities within highway rights-of-way such as travel plazas, rest areas, and scenic overlooks may offer convenient locations to deploy electric vehicle (EV) charging technology. Installing a network of EV charging stations along highways may help increase the deployment of EVs by providing the infrastructure necessary to allow EV motorists to travel long distances. Most current EV models have a mileage range of 100 miles or less.

EV charging stations, also known as electric vehicle supply equipment (EVSE), fall into three different categories. Level 1 equipment charges an EV in 12+ hours using standard 120-volt power at 15 to 20 amperes (amps). Level 2 equipment charges an EV in 4 to 6 hours using 240-volt power at up to 40 amps. A DC fast charger (also known as Level 3 or quick charger) charges an EV in less than 30 minutes using 480-volt direct current power at 100+ amps.

Title 23 United States Code 111 prohibits automotive service stations and commercial establishments from being constructed in the ROW of the Interstate System. This section has been interpreted by FHWA as including a prohibition on the installation of fee-based EV charging stations. However, FHWA has permitted the installation of charging stations that do not collect fees as "demonstration" projects because they provide a public education benefit. This prohibition has prompted states to develop public-private partnerships to install charging stations at truck stops and other retail facilities located directly outside of the ROW (FHWA HEPR, 2012).

The federal prohibition on commercial establishments does not extend to nonInterstate highways, such as state expressways and turnpikes, and commercial travel plazas along these highways remain an opportunity to develop fee-based EV charging stations.

When looking at the feasibility of installing EV charging infrastructure the following should be considered: type of charging infrastructure being installed (i.e., Level 1, Level 2 or DC fast chargers), cost of installation, available electricity or needed electrical upgrades at rest areas or other installation sites, site selection, and way-finding signage to locate the charging equipment.

States with Existing Programs and Projects

Washington: The Washington State DOT (WSDOT) is currently installing electric charging stations on I-5, as part of the West Coast Green Highway. WSDOT first tried to get a waiver from the Title 23 provisions under FHWA's SEP 15 program. This would have allowed WSDOT to proceed with the project as a trial evaluation of a new public-private partnership idea. However, FHWA rejected the application. WSDOT consequently worked with businesses along the I-5 corridor to encourage charging station installation at private retail locations. The charging stations installed are privately owned, operated and hosted through a public-private partnership except for installations at two rest areas. The latter charging stations do not conflict with Title 23 because they are free to use and provide a public benefit as an educational demonstration. The rest area charging stations are Level 2 while the privately owned stations provide DC fast chargers (FHWA HEPR, 2012).

Oregon: Oregon DOT received two rounds of funding from the federal government's TIGER-II grant program to support the installation of 33 new electric vehicle charging stations along the I-5 corridor in the northwest part of the state. Oregon DOT also received federal stimulus funding to install, as part of the West Coast Green Highway program, eight DC fast chargers between Eugene and Ashland. The projects are both public-private partnerships managed by Oregon DOT's Office of Innovative Partnerships (Oregon DOT, n.d.).

Virginia: Virginia DOT has free EV charging stations at rest areas that were installed at no cost to the state. The first stations were installed at the New Kent Safety Rest Area on I-64. While the Virginia DOT and energy company, Dominion Resources, planned to open additional stations at more rest areas along major highways, only one is operating today. Near Williamsburg, at New Kent, on westbound I-64, a Level 1 station is installed and can be used at no cost. The downside is that the station takes up to 15 hours to fully charge a vehicle battery (Harper, 2010).

States that have conducted Initial Feasibility Research

Florida: The Florida Turnpike Enterprise has plans to install charging stations along the Florida Turnpike, beginning with several stations at the Turkey Lake Service Plaza. Currently, the stations have not been installed (Volpe Center, 2012).

Pennsylvania: The Pennsylvania Department of Environmental Protection (DEP) has awarded a $1 million grant to Car Charging Group Inc. to help develop EV infrastructure on the Pennsylvania Turnpike. Car Charging Group Inc. will install Level 2 and Level 3 charging stations at 17 turnpike service plazas. The stations will be installed at the service plazas in three phases. First, ongoing service-plaza renovations will incorporate charging station installations. This includes service plazas between Harrisburg, Pa., and

New Jersey. The following phases will include service plazas between Harrisburg and Ohio. The project is expected to be completed by June 30, 2013. Electric upgrades at the plazas will be funded in part by $500,000 committed by the Turnpike Commission, in order to ensure charging stations have the necessary voltage. The DEP grant is provided through the Alternative Fuels Incentive Grant Program, which is funded by a portion of the gross utilities receipts tax (Blanco, 2011).

Nevada: An EV task force was formed by the Nevada DOT to look at the potential for adding charging stations operated by a third party on the Interstate or other ROW (Volpe Center, 2012).

Tennessee: Tennessee DOT is looking into a proposal to install a charging station at a rest area (Volpe Center, 2012).

2.7 Airspace Leasing – Buildings

Air right agreements establish development rights above (or below) a transportation facility in exchange for a financial contribution. This is common practice in many parts of the country. The FHWA notes that airspace leasing activities are most common in states with high population densities and high land values in urban areas (Prozzi, et al., 2012).

Federal stature 23 CFR §710.405 (b) allows state DOTs to grant rights for permanent or temporary occupancy or use of the interstate system airspace for nonhighway purposes as long as such airspace is not required presently or in the foreseeable future for the safe and proper operation and maintenance of the ROW. Prior approval is, however, required from FHWA before the DOT can lease the airspace. Federal rules also require the charging of fair market rent and any revenue must be used for transportation purposes. Airspace lease agreements must reflect planning, environmental, design, construction, maintenance, financial, legal, insurance, safety, and security requirements (Prozzi, et al., 2012).

Other items for DOTs to be mindful of before entering into a leasing agreement include unanticipated future needs like lane expansion and clearance under a permanent structure.

States with Existing Programs and Projects

Washington: In 1984, the Washington Convention and Trade Center signed an agreement with the Washington State DOT for the air space lease above I-5 in Seattle, where part of the convention center would soon be located. The lease agreement called for periodic appraisals of the fair market value of the property to be used to update the amount of rent charged. The first review was to take place 15 years after the first beneficial lease of the convention center in 1986, making the review year 2003. In 2003, the review was not performed as WSDOT determined that the cost to obtain a current fair market value of the property would exceed the amount the Department could increase the rental fee. The next scheduled reevaluation is in 2013. The convention center also received a substantial number of "rent credits" to go towards the lease payments. The rent credits earned were in connection to aspects of the project construction that improved or directly benefited WSDOT, such as fire control improvements, public overcrossings and walkways, etc. The current lease agreement is for an annual rent of $238,597. Currently, the rent credits from construction are still covering the rent due (Washington State Auditors Office, 2010).

Massachusetts: The Massachusetts Turnpike Authority (now housed under the Massachusetts Department of Transportation (MassDOT)) has multiple airspace lease agreements for buildings. Several examples are Copley Place, the Columbus Center, and One Kenmore. Copley Place was built in 1986 and consists of a hotel, retail store, office space, housing and parking (Prozzi, et al., 2012). The Columbus Center also has a hotel, retail store, housing and parking, along with a health club and restaurant. One Kenmore is currently being constructed and will house similar tenants to that of the completed project. An air rights premium was assigned for each project and rent was determined from that value (Campbell, 2004). The City of Boston and the Massachusetts Turnpike Authority agreed on guidelines for air rights development in 2001 for remaining parcels over the highway in Boston. MassDOT is continuing to promote development of air space. In 2011 MassDOT solicited proposals for the long-term lease and development of the land, surface, and/or air rights of a parcel created by the construction of the Central Artery/Tunnel Project.

Illinois: Illinois has several air space lease examples in the form of commercial rest areas built over the tollways. Most (five of seven) of the rest areas were constructed at the same time as the highway in 1958. Between 2003 and 2005 all of the rest areas were redeveloped/renovated by a private developer. The cost of the renovations was completely covered by private parties. The lease agreement for the airspace is between the private developer and the Illinois State Toll Highway Authority (ISHA). The lease agreement is for 25 years and guarantees ISTHA a percentage of the vendor sales or at a minimum $750,000 per year (Prozzi, et al., 2012).

California: Caltrans uses ROW for a variety of tenant airspace leases including restaurants, manufacturing, mini-storage, community park facilities, etc. The income generated from these tenants goes to the Public Transportation Account and not to Caltrans (Prozzi, et al., 2012).

Arizona: In 1990, the final piece of the Papago Freeway in Phoenix was constructed. Part of the project was built as a tunnel that formed the base of a 29-acre urban park. The half-mile length of freeway through the middle of Phoenix disappears under the Margaret T. Hance Park. The City of Phoenix pays $300 per year for a 50-year air rights lease from the State of Arizona (Parsons Brinckerhoff Quade & Douglas, 2001).

Nevada: In Reno, Nevada there was a freeway deck built, concurrent with the I-80 construction in 1973. The deck was originally intended for development of a multi-story building. However, the original development plans fell through, leaving the deck unused until 2000, when a new party became interested to build a single-story commercial building to be leased to Walgreens. Thought the initial lease rate was difficult to assess, it has remained at $31,000 per year through 2065, when the lease expires (Parsons Brinckerhoff Quade & Douglas, 2001).

2.8 Airspace Leasing – Parking Lots

Many urban areas (e.g., financial districts, commercial areas, and downtown areas) have inadequate parking to satisfy demand. Existing garage parking tends to be very expensive and insufficient. Use of existing areas beneath viaducts and ramps, as well as DOT land lots, as parking lots is a relatively simple value extraction project. The feasibility of these projects mostly depends on the location (e.g., business attractiveness, demand, and accessibility) and required safety measures (e.g., access, fence, surveillance, curbs, and prohibition of flammable substances and some vehicle types).

States with Existing Programs and Projects

California: Caltrans has entered into both short- and long-term airspace lease agreements for parking lots. Caltrans leases to the private sector as well as community centers. Currently, Caltrans has approximately 400 parking lot leasing agreements. These lease agreements, along with ROW leasing for telecommunication antennas, generated about $25 million in 2010 (Prozzi, et al., 2012).

Texas: Texas has some examples of parking lots beneath roadways. However, the lease agreement usually involves another public agency and does not provide any monetary benefit to the TxDOT (Prozzi, et al., 2012).

2.9 Accommodating Pipeline, Utility and Communication Infrastructure

In general, nonhighway uses of Interstate highway ROW are subject to federal airspace leasing requirements, except for public utility facilities that serve the public interest. These types of facilities can be sited in the highway ROW under a state's FHWA approved Utility Accommodation Plan. The types of utility facilities permitted under these plans vary by state but may include, electric power transmission and distribution, natural gas and oil pipelines, water and wastewater conveyances, and telecommunications equipment. Fees charged for utility accommodation are at a state's discretion and may be used for transportation or nontransportation purposes.

Notably, FHWA guidance on utility accommodation in the ROW makes a distinction between "public" and "private" utilities. When the facility provides service to the general public it can be sited in the Interstate ROW as long as the facility also complies with the state's utility accommodation plan. If the facility serves a "private or proprietary interest" it may still be sited in the ROW but would have to follow airspace lease requirements.

States with Existing Programs and Projects

Florida: The Florida DOT leased its limited access ROW to Lodestar Towers, Inc. in a 30-year agreement that included compensation in the form of a percentage from the gross profit Lodestar received from renting antenna space to commercial wireless service providers. The lease agreement was developed in compliance with FDOT's Telecommunication Policy (Prozzi, et al., 2012).

California: Caltrans received $1.3 million in revenue in FY 2008 from 52 cell towers. Caltrans's Leasing Program Administration personnel regard the cost-effectiveness of cell towers to be a major benefit, as cell towers do not require extensive on-site maintenance and they generate reasonable revenues (Markham, 2009).

New York: The New York State Thruway Authority uses two types of agreements. The first is for the design, construction, maintenance, and operation of ducts of fiber optics along its ROW. The second is for agreements with wireless companies that pay a monthly leasing fee in exchange for being allowed to install antennas on towers, buildings, sign posts, bridges, and undeveloped ROW (Prozzi, et al., 2012).

Virginia: Virginia DOT's revenue from site leases for cell towers in 2010 was $4.5 million (Prozzi, et al., 2012).

2.10 LED Lighting

Improvements in lighting technology has encouraged recent evaluations of the competitiveness, both in performance and cost, of light emitting diode (LED) technology for outdoor applications compared to the commonly employed high intensity discharge (HID) light sources such as high pressure sodium (HPS) and metal halide (MH). The prospect that LED street lighting technology will provide more efficient light distribution and increased uniformity, as well as save energy and reduce maintenance costs is leading to further investigation by the U.S. Department of Energy (DOE) and multiple municipalities.

The U.S. DOE has collaborated with multiple municipalities including Philadelphia, Seattle, and Sacramento as part of a program called the Solid-State Lighting GATEWAY

Demonstrations, which is designed to showcase emerging LED lighting products. The DOE also formed the Municipal Solid-State Street Lighting Consortium to share technical information and experiences related to LED street and area lighting pilot projects. The stated goal of the consortium is to "build a repository of valuable field experience and data that will significantly accelerate the learning curve for buying and implementing high-quality, energy-efficient LED street and area lighting (EERE, 2013).

One resource that may be particularly useful for state DOTs is the AASHTO resource recently updated titled *An Informational Guide for Roadway Lighting*. The update reflects current practices in roadway lighting. The guide provides a general overview of lighting systems from the point of view of the transportation departments and recommends minimum levels of quality (AASHTO, 2012).

States that have conducted Initial Feasibility Research

Pennsylvania: Philadelphia's lighting demonstration project was conducted as part of DOE's GATEWAY Solid-State Lighting Technology Demonstration Program. Philadelphia has been actively looking for alternatives to existing HPS street lighting for the past several years. The City traditionally follows design criteria from AASHTO. The GATEWAY study included three sites with different lighting conditions and characteristics. The study found that the LEDs studied matched the delivered illuminance levels of the comparable HPS technology. Also, the LEDs had higher application efficacies and delivered more lumens per watt of input power to the roadways and sidewalks they were lighting. The LEDs were also more energy efficient, drawing 10-40% less power than the HPS counterpart. The study did not include an economic analysis as the LEDs were donated. According to estimates, energy savings alone were not expected to create a reasonable payback period. However, with cost savings from reduced maintenance needs, citywide transition to LEDs could prove cost effective (Royer, et al., 2012a).

Washington: There are approximately 84,000 street and area lights, predominantly HPS luminaires, in the Seattle City Light (SCL) street lighting system. SCL launched the LED Streetlight Application Assessment Project because of the potential benefits of installing LED luminaires as a replacement for HPS lights. The study was intended to evaluate LEDs for photometric performance, energy efficiency, economic performance, and the impact of the new lights on SCL streetlight system. The study found using simple economic payback calculations that LED luminaires could be an economical alternative. The findings from the study will be used by SCL to develop a strategy for the installation of LED streetlights in developing an energy efficient lighting system. The study was conducted in collaboration with Pacific Northwest National Laboratory and as part of the DOE Solid-State Lighting GATEWAY Demonstration program (DKS Associates, 2009).

California: A pilot project was conducted in Sacramento by the Pacific Northwest National Laboratory, as part of the DOE Solid State GATEWAY Demonstration, to assess the performance of LED technology in ornamental post-top street lights. The goal of the study was to characterize best-in-class performance for LED products relative to the existing 100 W HPS luminaires. After evaluating the simple payback period and life-cycle costs for each product the results indicated that the four LED products evaluated would not represent cost-effective replacements for the existing HPS.

New York: The New York City (NYC) DOT announced expansion of its energy-efficient LED-light installations citywide. The expansion included significant upgrades to the City's lighting infrastructure to provide energy and cost savings while also providing quality light to these public spaces. In 2009, the NYC DOT, along with the Climate Group and the U.S. DOE, started a study to quantify the benefits for cities to use LED technology versus traditional fixtures. The highest energy saving observed in the study was up to 83%. Because of the findings and multiple strategic city plans, the DOT will start replacing all 1,600 metal-halide fixtures in Central Park. This is expected to deliver up to 62% in energy savings. The LED program is expected to save nearly $300,000 in annual energy and maintenance costs in fiscal year 2013.

2.11 Natural Resource Extraction

It has been suggested that state ROWs present an opportunity to extract valuable natural resources including timber and hay.

While several states have a permitting mechanism in place to allow the collection and harvesting of roadside grasses from the highway ROW, it is apparently an uncommon practice. A review of the literature identified only one published study (dated 1984) on the frequency and feasibility of the practice. That report identified 18 states that allow the practice as long as certain permit conditions were met. The report concluded, based on field evaluations in the state of Indiana, that it was not economically feasible to harvest hay in the ROW, even when taking into account a state's avoided maintenance costs (Sinha et al, 1984).

The FHWA Office of Planning, Environment, and Realty website refers to the Colorado DOT Handbook on Haying the Rights-of-Way as a resource for transportation managers. The CDOT guidelines allows for the harvest of existing grasses in the ROW by adjacent landowners only and harvest can only occur along that adjacent property (FHWA HEPR, 2013).

No studies or reports on the frequency or experience of state DOTs executing timber sales were found in the literature. However, Internet searches revealed several solicitations for timber services suggesting that the practice does occur. What remains unclear is if this practice occurs mostly in conjunction with clearing and grubbing associated with new highway construction or if it occurs along existing forested ROW.

2.12 Advertising and Sponsorships

Many DOTs have evaluated and implemented various programs to create a revenue stream from leasing space on the ROW for advertising, or offsetting maintenance costs through private sponsorships. Particularly the high costs of maintaining rest areas has led DOTs to explore advertising and sponsorship programs at these locations. Other potential revenue streams include the sponsorship of wireless internet access at rest areas, selling or leasing naming rights to toll roads or highway corridors.

A variation to advertising in the ROW is offsetting management costs to the DOT through sponsorship programs. Two national examples of this are the Adopt-a-Highway Program, which focuses on litter removal, and the less recognizable Adopt-a-Watt Program, where companies can sponsor or fund a clean energy project in exchange for having their name advertised.

DOTs thinking about implementing advertising programs need to be aware of regulations and laws that may prove prohibitive. FHWA has an advertising control program that regulates the number, size, and location of advertisement signs. There are also some FHWA regulations that prevent advertisements on overhead and roadside signs. Multiple states have laws that may also present barriers to creating an advertising program. For example, some states have Highway Beautification programs that may prevent roadside signs. Additionally, it is important to include associated costs that may be incurred from additional staff time required to manage an advertising program (Prozzi, et al., 2012).

States with Existing Programs and Projects

Massachusetts: Prior to the Massachusetts Turnpike Authority becoming part of the Massachusetts DOT, it received $500,000 a year through a fast lane sponsorship with Citizens Bank. Once the Authority merged with the MassDOT, it was required to discontinue the Citizen Bank sponsorship because it now falls under federal guidelines that do not allow advertising on federal highways (Prozzi, et al., 2012).

Pennsylvania: The Pennsylvania Turnpike generated $519,000 in 2009 through permitted advertisements on tollbooth windows and ticket machines (Prozzi, et al., 2012).

Florida: After a contract to manage the Tourist-Oriented Directional Signs program expired with Florida Interstate Logos, the Florida DOT decided to manage the program in-house. FDOT increased advertisement prices by up to 200% in some instances as a function of location, traffic volume, and market condition (Prozzi, et al., 2012).

States that have conducted Initial Feasibility Research

Texas: The Texas DOT provides free wireless access to travelers at rest areas and information centers. By providing this service, TxDOT hopes it will encourage drivers to stop and take a break. The website that travelers are sent to when getting wireless access informs travelers of road conditions, traffic delays, etc. The website also currently allows advertising. TxDOT has been exploring the possibility of offsetting the cost of providing wireless access by sharing in the revenue from website advertisements (Prozzi, et al., 2012).

Georgia: The Georgia DOT is also looking at wireless internet sponsorship as a likely successful revenue stream. Travelers would have to watch a commercial from a sponsor prior to being allowed wireless access. The GDOT estimates that through various advertisements and sponsorships at rest areas, it could generate $1.4 million a year (Prozzi, et al., 2012).

California: California is taking a creative approach and going as far as considering passing a state bill that would allow advertising on Caltran's vehicle license plates (Prozzi, et al., 2012).

3. SURVEY OF STATE DEPARTMENTS OF TRANSPORTATION

3.1 Introduction

Chapter 2 presented the results of the literature review on the subject matter conducted by reviewing published consultancy reports, documented research, and other publicly available information sources. Following the literature review, to ensure that no pilot or demonstration projects in the early stages of development were missed, a comprehensive survey of state Departments of Transportation (DOTs) was conducted. An online questionnaire was sent to DOTs to collect data from all states, with the exception of Florida. The survey form was divided into two sections, "A. Contact" and "B. Your State DOT's Experience with Value Extraction Projects." Under "A. Contact," the respondent was first asked to provide his or her contact information. The fields included the name of the respondent, title/designation, organization, phone number, and e-mail address.

In the next section, "B. Your State DOT's Experience with Value Extraction Projects," the survey then asked the following three questions about value extraction strategies and/or the alternative use of the highway ROW to generate revenue or offset expenditures:

1. Has your state **implemented** any value extraction strategy/alternative use of the highway ROW to generate revenue or offset expenditures?
2. Is your state currently **exploring/considering** the implementation of any value extraction strategy/alternative use of the highway ROW to generate revenue or offset expenditures?
3. Has your state explored/considered the implementation of any value extraction strategy/alternative use of the highway ROW to generate revenue or offset expenditures in the past, but **decided not to proceed?**

If the DOTs answered "Yes" to any of the above, they were asked to describe the applicable past or current project(s), and to provide a contact for further information.

They were also asked to include a link to the relevant website(s) and any supporting documentation.

Distribution of the online questionnaire started on December 5th, 2012. For DOTs who did not respond, periodic reminders were sent until January 10th, 2013. After two online reminders, calls were placed to the DOTs. Finally, a total of 24 responses were received from the 50 contacted State DOTs, yielding a response rate of approximately 47%. The following sections summarize the results obtained.

3.2 Implemented Value Extraction/Alternative Use of Highway ROW

This section details the data obtained from Question 1, "Has your state implemented any value extraction strategy/alternative use of the highway ROW to generate revenue or offset expenditures?" 12 out of 24 of the DOTs (50%) that participated in the survey answered “Yes” to this question. Moreover, two of the DOTs who answered “No” expressed that they use land leasing as a source of revenue, but do not consider it alternative revenue. Table 1 shows the percentage of "Yes" and "No" responses.

Table 1: Percentage of DOTs who have implemented or are currently implementing value extraction/alternative use of highway ROW

Answer	Bar	Response	Distribution
Yes		12	50%
No		12	50%
Total		**24**	

In the subsection for this response, DOTs who answered “Yes” to Question 1 are asked to briefly describe their project(s). Table 2 presents this information followed by a summary of the responses given by the participating State DOTs.

Table 2: Value extraction strategies implemented by state DOTs

Strategy	Implementing State
Solar Photovoltaic	Oregon
Airspace leasing	California, Washington, California
Land leasing	Colorado, Alaska, New Jersey, Wisconsin, New York
Accommodating pipeline, utility, and communication infrastructure (Cellular towers)	New Jersey, Colorado, Virginia, Connecticut, Arizona, Wisconsin, Oregon
Advertising and sponsorship	Connecticut, Michigan, Pennsylvania, New Jersey
Mineral lease	Colorado
Sales of coal excavated	Virginia
Oil and gas leasing	Ohio
Natural resource extraction	Idaho (No fee)

The first respondent to the survey, Ohio DOT, provided little detail but mentioned oil and gas leasing as formations under the ROW. Next, the respondent from Alaska DOT indicated that most of their highway ROWs are held as an easement interest as opposed to a fee. Use of these easements is limited to those uses that are within the scope of a highway easement. However, for those situations in which they owed an excess ROW fee, they leased or sold the parcels to generate revenue. The third respondent, Oregon DOT, is the only DOT among respondents that licenses use of land for renewable energy projects (solar arrays). They also lease land for cell towers.

California DOT (Caltrans) provided further explanation as they have several different highway ROW programs. The airspace leasing program allows the following types of construction development and use: parking, commercial vehicle parking/storage, mini storage, wireless cell sites, commercial buildings (such as retail, motel, and office developments), park facilities, nature trails, boat ramp and marina storage, oil and gas extraction, and homeless kitchens and shelters. Caltrans had about 670 active lease agreements with a total value over $25,000,000 during FY 2011/2012. 5,900 parcels have been sold since 1995 for amount of $450,000,000. Property Management (land held for new projects) had 3,800 parcels under management during FY 2011/2012, for the amount of $12,400,000. All of this revenue is allocated to the State Highway Account, and then transferred to the Public Transportation Account.

Wisconsin DOT charges utilities an occupation fee or obtains dark fiber for the longitudinal use of controlled-access highway ROW (interstates, freeways, and freeway/expressway mixes). This includes cellular towers installed anywhere on the ROW. Additional details are provided in their Utility Accommodation Policy 09-15-40. According to Wisconsin's Highway Maintenance Manual, longitudinal utility installations on controlled-access highways are limited to communications and electric transmission facilities only. Cellular antennas and their associated equipment are included as longitudinal occupations. Other types of utility facilities may be allowed to longitudinally occupy controlled-access highways in rare circumstances. A utility may be charged a fee or provide WisDOT with communication services (typically dark fiber), or a combination of fees and services, for the right to locate its facilities longitudinally on controlled-access highways. Similarly, Arizona DOT has a cellular site leasing program that at present contains an inventory of about one hundred sites statewide. The leases for these sites are maintained in the ADOT Right of Way Property Management Section. The majority of these sites are within ADOT operating ROW.

New York is a special case, as it should be noted that although New York's DOT answered "No" to this question; they have both an active surplus property program and a use and occupancy permit/leasing program. However, they consider these programs to be routine program area activities and responsibilities. The respondent mentioned that these are not specifically a value extraction strategy/alternative use of the highway ROW initiative or program, and therefore responded "No."

Connecticut DOT administers the state’s effective control of off-premise advertising by regulation and adherence to statutes. With the exception of a limited number of grandfathered locations, Executive Order of the Governor No. 18 prohibits the use of state controlled property ROW for the purpose of advertising (billboards) for profit. While opponents of this measure seek its repeal, they are unaware of any formal strategic initiatives to the contrary. Idaho DOT allows farmers to cut and bale areas of ROW to help reduce weeds and to improve the appearance of a property. The DOT provides this free of charge and the farmers do not pay for the grass hay they receive. Idaho State has six (6) District Offices and one property management personnel in each District to take care of surplus property. Each District provides auction information on its website when property is to be put up for sale. Virginia DOT (VDOT) utilizes ROW to lease cellular tower sites and collect monthly rental fees for those located on the site. VDOT also received compensation for the sale of coal excavated from the ROW on a project. In addition, they generate revenue by permitting the sponsorship of certain structures and facilities by outside entities.

Pennsylvania DOT utilizes two highway sponsorship programs. The first litter pick-up program allows private sponsorship signs along the roadway and generates $20,000 per month. The second is public adopt-a-highway program for litter pick-up that is worth $32M in redirected resources. They can save $500,000 per year by Turnpike sponsors freeway service patrol vehicles.

Colorado DOT has over 100 land leases and over 150 mineral rights leases throughout the state. They also have approximately 20 cell tower leases. Similarly, Washington State DOT (WSDOT) currently has approximately 945 leases statewide, with yearly revenues of approximately $4-5M. WSDOT's leasing program is ongoing and has various types of leases, for example, airspace, commercial, displace, and ground. New Jersey DOT stated that the sale of surplus land or rentals to adjoining land owners may be needed in the future. They have a statutory cap on the number of billboards that can be on their ROW. They have consolidated the total square footage into larger signs at favorable locations. Moreover, they have a consultant helping to manage the auctions for those sites. They also license cellular tower sites on ROW at a set fee to users.

3.3 Value Extraction/Alternative Use of Highway ROW being Explored/Considered for Future Implementation

This section reviews the data collected from Question 2, "Is your state currently **exploring/considering** the implementation of any value extraction strategy/alternative use of the highway ROW to generate revenue or offset expenditures?" As shown in Table 3, a total of 23 state DOTs answered this question, with 14 respondents (61%) answering “Yes.” If the respondents answered "Yes," they were asked to briefly describe the strategies they were considering. Arizona, Colorado, Virginia and Indiana DOTs mentioned “Solar Photovoltaic” as a strategy that is under consideration in their states. Arizona DOT is exploring “Wind” as well. The Virginia and South Carolina DOTs are investigating using “Airspace Leasing” as a revenue generating source. Iowa, Connecticut, and Idaho DOTs are working on “Cellular Tower” leasing on highway ROW. The responses of different DOTs with further detail are described in the following paragraphs.

Table 3: Percentage of DOTs who are currently exploring/considering value extraction/alternative use of highway ROW

Answer	Bar	Response	Distribution
Yes		14	58.3%
No		9	37.5%
Blank		1	4.2%
Total		**24**	100%

Arizona DOT (ADOT) is considering implementation of a process to incorporate broadband providers longitudinally within operating ROWs pursuant to the Digital Arizona Highways Act of 2012 recently enacted by the state legislature. ADOT is also investigating the possibility of allowing installation of solar or wind energy generating facilities at appropriate locations within the state. These alternative energy sites could be located either on ADOT excess land (outside of operating ROWs) or could be located within operating ROWs. Ohio DOT pointed out that they have a P3 group which is looking at a number of possible revenue-generating strategies; however, it did not indicate the strategies considered. Iowa DOT did not provide details, but is also discussing the sponsorship of rest areas and possible cellular tower sites.

As one of the most implemented strategies to generate revenue in highway ROW, California DOT (Caltrans) has hired a consultant to explore operating the R/W property, such as Park and Ride facilities, vista points, maintenance stations, etc., available under the Airspace program. An additional program being considered is the commercialization of existing Changeable Message Sign (CMS) under long-term lease for commercial billboard development. The CMS program has approximately 1,200 installations and is located within the operating R/W. A draft of this study has been submitted by the consultant and is currently under review. This study will not be released unless it is approved by Caltrans Management. Furthermore, Solar Development RFI was deployed for those sites deemed appropriate by Caltrans staff for long-term solar development. However, no long-term contracts have resulted from the RFI. Other aspects under consideration are Caltrans' expectation of fair market returns, safety concerns, financing/developers' rights, and whether to end a program if it is not profitable or creates safety problems (early termination clause). Developer difficulties in securing appropriate agreements between local utilities and the end users of the power produced is also being considered in existing roadblocks.

Minnesota DOT is researching state and federal requirements and limitations. It has also had a meeting with companies that assist or manage agency real estate assets to leverage funds in order to fact-find and determine opportunities. Connecticut DOT has created a master agreement for cell tower lease agreements. To date, they have not contracted any leases within the highway ROW. At this time, leases utilizing the railroad ROW are in the works. Idaho DOT indicated that they were approached by a California service who asked whether they had excess property they would like to make money from. The service proposed generating revenue in the form of cell tower leases, which California would operate for them and pay to lease. This option is currently being investigated. There are also many properties that cannot be sold because those properties are landlocked or have not generated interest. Idaho DOT is trying to determine methods for generating revenue from this surplus property.

Among the DOTs participating in this survey, three (3) states are currently investigating Solar Power generation in their ROW (airspace leasing). In Virginia, VDOT negotiations about utilizing applicable ROW for the solar power generation airspace are underway in their NOVA area outside of Washington, D.C. Colorado DOT is also currently in the beginning phases of partnering with alternative solar energy providers in the ROW. Similarly, Indiana DOT is investigating rest area sponsorship and leasing ROW for the placement of solar panels. In addition, South Carolina DOT is currently considering airspace leases for parking. Finally, Pennsylvania DOT, since the passing of a P3 law, is moving all sponsorships into a bundled P3 package. PennDOT obtained legislative board approval on January 9th, 2013 to solicit proposals from private industry. They are modeling their program after VDOT's. This includes 511 and traffic information; traffic management centers; video sharing; rest areas and welcome centers; freeway service patrol vehicles; and roadway weather information systems (RWIS).

3.4 Value Extraction/Alternative Use of Highway ROW Considered but not Implemented

This section discusses the responses to Question 3, "Has your state explored/considered the implementation of any value extraction strategy/alternative use of the highway ROW to generate revenue or offset expenditures in the past, but decided not to proceed?" As shown in Table 4, 12 out of 22 respondents (a majority of 55%) had past experience in exploring and considering value extraction strategy/alternative use of the highway ROW but ultimately decided not to proceed with implementation.

Table 4: Percentage of DOTs who have explored/considered value extraction from highway ROW, but decided not to proceed

Answer	Bar	Response	Distribution
Yes		12	50%
No		10	41.7%
Blank		2	8.3%
Total		**24**	100%

Alaska DOT indicated that they considered strategies, but that the reason for rejection is that they anticipated little return for such programs. They not, however, identify what program they considered. Iowa DOT also considered strategies, but rejected them due to political reasons, as there is a strong objection to the government use of obtained property for revenue gain. Simply put, the public view this type of funding as a tax that should be avoided.

The respondent from Oregon DOT mentioned that current activities are being investigated and/or performed within existing state and federal guidelines. Since guidelines have changed over the years, there may have been some programs implemented in the past, but she did not know about them.

California DOT (Caltrans) responded that it is not allowing (which is not quite correct, as it is not prohibiting but only discouraging) private commercial buildings to be constructed under flyways. The reason for this position is that Caltrans has been compelled to re-acquire certain land rights in order to reconstruct highway structures that were damaged during earthquakes. Again, it is not prohibiting all new construction, but Caltrans retains the right to return to the property and reconstruct the damaged highway structure at no additional cost. This position has limited financing to parties interested in constructing large (expensive) structures underneath California highway facilities flyways. It also had company offer to construct 1,000 wireless sites through state. Proposed developer sought significant discount on existing pricing structure and sought many lease terms and conditions that staff deemed untenable.

Wisconsin DOT considered the implementation of application fees for utility, driveway, and general work on highway ROW permits. However, it was felt at the time that imposing fees would be a hidden tax upon their customers. The issue has not been revisited in over five years. Arizona DOT provided little detail, mentioning only that installation of fiber optics, etc. within longitudinal easements along operational ROW had been considered in the past. It is not clear why these programs were rejected. Idaho DOT indicated that whenever they wanted to use any unsalable property for something like cellular towers, they meet public resistance claiming that the agency is in business against them. Any ideas regarding how to address this would be welcome at Idaho DOT. Finally, Alabama DOT (ALDOT) looked at implementing fiber optic lines in the ROW, but any funds generated would have gone to the state general fund budget and not necessarily to ALDOT. The potential funds were not deemed to be worth the management costs, so it was not pursued. They have also harvested timber in the median of a bifurcated interstate. That proved to be much less beneficial than thought and they will not pursue that effort again.

New York State DOT (NYSDOT) conducted a study of the potential use of airspace several years ago. The study focused on a limited number of sites all located within the City of New York where it was believed there was the best opportunity for a return due to property values and potential development opportunities. While the study made specific recommendations, a combination of resource issues and the Department's lack of experience in property development led the Department to decide not to pursue site-specific development. It was believed that there were and are more appropriate government entities, both state and local, to facilitate such development. NYSDOT's role was and is to focus on the acquisition and use of properties for transportation purposes.

Virginia DOT worked on wind turbine energy production, but they did not mention the reason for rejection of the program. Pennsylvania DOT responded that they were going to do each area separately, but are bundling everything under one package in hopes of generating more revenue. Michigan DOT stated that they looked at various items, but had not pursued any strategies. As for Washington State, while there have been certain leases that the agency staff determined should not be allowed, they continue their leasing program, which has been in effect for decades.

New Jersey has been approached about the use of solar energy along a corridor, and also about charging fees for utility use within their corridor. The rental of a corridor for solar power did not go forward due to safety concerns, legal issues, and lack of statutory authority to address such a unique use. Generally, their ROW does not contain a significant amount of "extra" width due to the density of New Jersey's population. This means that there are few opportunities for such sites. The fee for utilities within the ROW did not move forward because New Jersey statutes require the DOT to accommodate public utilities, so a fee system is not practical.

4. SOLAR PHOTOVOLTAIC (PV) TECHNOLOGY PRIMER

4.1 Definition and Terminology

Solar photovoltaic (PV) panels are a distributed, electricity-generating technology using solid-state semiconductors to convert direct and indirect sunlight into direct current (DC) electricity. Generated electricity can be used on-site or be fed into the utility grid.

PV Technology Components

Solar PV equipment is generally divided into two parts: the PV array and "balance-of-system" components (Figure 1). The descriptions below illustrate the distinct elements necessary for a PV system.

- **Solar PV array**: Solar cells are the basic unit of a solar PV system and are generally made of crystalline silicon. Solar cells are placed together to form a photovoltaic module, and a series of modules form a PV array. PV systems are engineered for a useful life of 20-30 years, and most manufacturers will warranty systems for 25 years. PV arrays can be sized accordingly to meet onsite electrical needs, and the site context.
- **Balance-of-system**: A PV system includes a number of other essential components, including electrical connections, mounting structures, inverters, and any other ancillary equipment needed such as security cameras and fencing, etc. An inverter converts direct current (DC) to alternating current (AC), at a voltage compatible with onsite or utility systems.

Solar Potential

Site context and location is a key consideration because the amount of energy a panel produces depends on sunlight levels, weather conditions, and tilt of the array. PV Watts Calculator is a Web resource that provides an approximate value of solar energy potential depending on geographic location. The solar developer and state DOT engineers can take this initial estimate and develop a more accurate estimate once a site location has been identified.

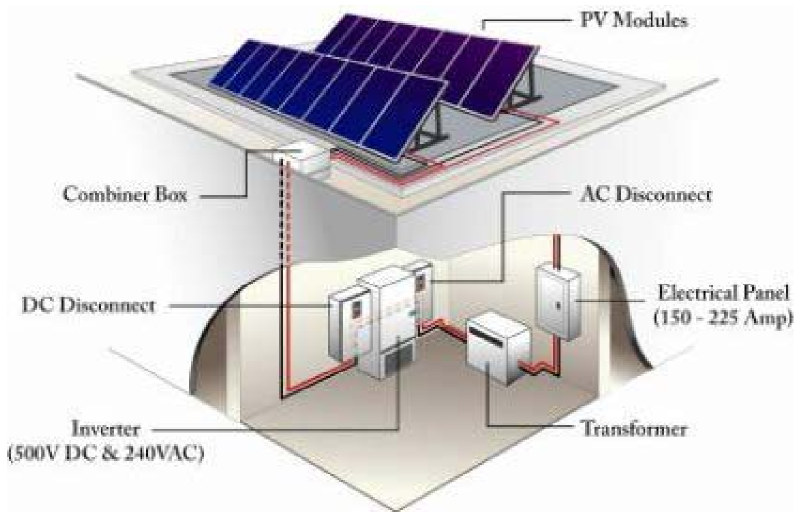


Figure 1: Major Components of Grid-connected PV System

Installation Locations: Ground Mounted vs. Rooftop, Fixed Tilt vs. Axis Tracking

PV arrays are installed on rooftops or ground surfaces and can either be mounted as fixed tilt (at a specific angle/tilt) or axis tracking (follows or tracks the sun's movement). State DOTs can install solar on the following right-of-way locations: highway shoulder (ground mount), maintenance or district office buildings (rooftop), interchanges or cloverleafs (ground mount), and rest areas (ground mount or rooftop). Rooftop solar may be attached with nonpenetrating anchors if the roof has a membrane product, may be ballasted with concrete blocks if the roof can support the load or may be mounted on penetrating anchors. Ground mount racks can be built on a driven or a poured pier, an attached rack to a concrete slab or ballasted on eco-blocks.

Interconnection

Interconnection refers to the connection of a PV system to the electric grid. Most electric utilities require that a grid-tied photovoltaic system meet specific interconnection standards.

4.2 Common Business Models

At the outset of project development it is critical to choose a viable business model that ensures project financing and proper management over the life of the project. Entity owned and third party ownership are the two main pathways to solar PV project development.

- **Entity owned:** refers to ownership and management by the agency, in this case, the state DOT. This model requires that the state DOT finances the project internally and may include incentives and funding sources that are publicly available such as loans or grants. Some of the more common versions of this type include net metering agreements, feed-in tariffs and utility accommodation. Crowdsourcing has recently emerged as an innovative financing mechanism.
- **3rd party ownership**: this model allows a public entity to partner with a private entity in order to finance and manage the solar project. The state agency generally benefits through property lease payments for property and generally is given a favorable electricity rate over retail electricity rates for on-site electricity demand (e.g., lighting, rest area or building energy load). Typical sub-types of this business model include airspace leases, third-party power purchase agreements and solar lease agreements.

State DOT Ownership

Net Metering

Net metering allows a small-scale nonutility electricity producer to tie to the electricity grid and distribute electricity to be paid at a retail rate by the utility. In Florida, net metering laws require that no system can provide more than 2 MW of electricity to the grid. A customer's net excess generation (NEG) or the remainder of electricity produced and put onto the grid can be carried forward at the utility's retail rate (i.e., as a kilowatt-hour credit) to a customer's next bill for up to 12 months. After 12 months, the utility pays the customer for any remaining NEG at the utility's avoided-cost rate. Net metering laws in Florida only apply to investor-owned utilities and not cooperatives and municipal utilities (DSIRE, 2012).

Utility accommodation

Please see the section on regulatory and policy landscape. Additional information for utility accommodation can be found in the Oregon DOT Solar Highway Manual (www.oregon.gov/ODOT/hwy/oipp/docs/solarmanual.pdf).

Third-Party Ownership

Airspace Lease

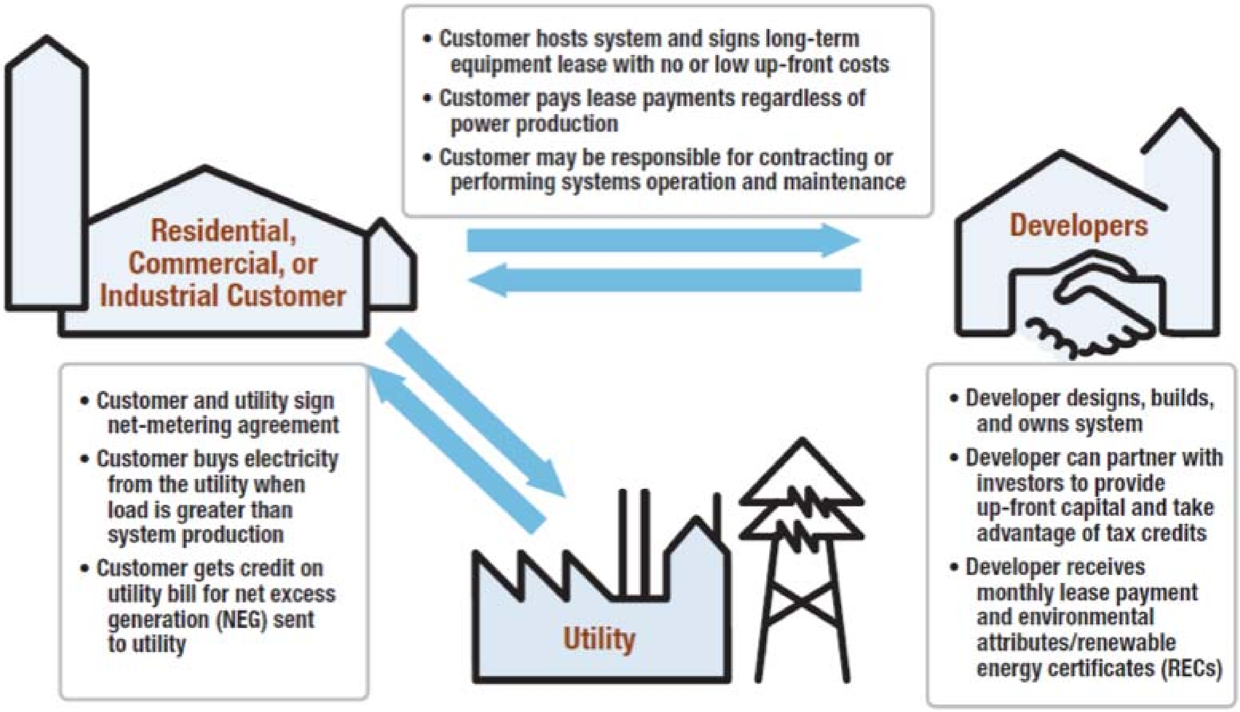
Please see the section on regulatory and policy landscape. Additional information for utility accommodation can be found in the Oregon DOT Solar Highway Manual (www.oregon.gov/ODOT/hwy/oipp/docs/solarmanual.pdf).

Power Purchase Agreement (PPA)

A PPA is one of the most common vehicles for developing a third-party agreement for solar PV installations. A PPA commits the solar developer to finance and build the system on the partnering "Host" organization's site (e.g., state DOT) and to enter into a long-term agreement (e.g., 10-30 years) to purchase the electricity produced. A PPA transfers all upfront capital costs to the developer in addition to responsibility for maintenance and operational logistics over the life of the contract. In return, the contract allows the developer to receive a steady stream of income and therefore have a reliable method of repayment. Additionally, third party private developers are able to obtain financing incentives that public agencies are not able to apply for. For example, a state agency does not have tax burden and therefore is not able to take advantage of renewable energy tax credits but a private entity partner is able to use the tax credits as long as they have tax liability to offset.

Solar Services Agreement or Solar Lease Agreement

A solar services agreement is a similar model to the PPA in that it also generally requires the third-party developer to provide the initial investment. A solar services agreement differs because the contract does not use a price of electricity but effectively using a substitute cost that covers equipment, maintenance and electricity use. The utility and electricity customer (e.g., state DOT) develop a net metering agreement that allows the customer to feed unused onsite electricity to the grid and establishes that the customer purchases electricity. Figure 2 below illustrates the relationship between the customer, developer and utility.



Source: NREL (Kollins, et al., 2010)

Figure 2: Major Components of Solar Services Agreement

4.3 Financing Sources and Incentives

Public Agency Access to Incentives

Financial incentives for solar energy systems are generally directed toward private sector incentives. Even solar ROW projects that access public funds from such sources as the U.S. Department of Energy (USDOE) are required to contract a private developer for the use of those funds. It is generally more difficult for public entities to launch solar projects than private firms due to significant upfront investment and incentivizes are largely targeted to private entities.

Federal Solar Incentives

Investment Tax Credit

The Federal Investment Tax Credit (ITC) is a business energy investment tax credit of 30% the initial cost of the solar equipment. First, this type of incentive is not available to public agencies because they do not have tax liability. Therefore, a solar developer or third-party investor is required that has a tax liability equivalent or higher than 30% of the cost of the solar equipment, in order to fully benefit from this solar incentives.

Modified Accelerated Cost Recovery System

Modified Accelerated Cost Recovery System (MACRS) is a private sector incentive allowing for the accelerated depreciation of renewable energy systems. Currently, the federal government treats solar PV systems as an asset that can be depreciated over a five-year timeframe. This shorter period for depreciation allows for the project cost to be recouped faster than it would otherwise be treated.

Other Federal Incentives

Department of Energy, US Treasury and USDA each have offered other financial incentives or loan programs for renewable energy projects including solar PV projects. These sources vary significantly over time and should be assessed at the frontend of a project as they can fill the funding or profitability gap.

State Incentives

From a state policy perspective, Florida is not a state that strongly incentives solar despite the state’s considerable solar resource. The only solar financial incentive the state of Florida currently offers is a sales tax exemption on the purchase of solar equipment. This exemption has been available since 1997 under Florida Statue §212.08.

A number of states offer incentives independent of federally accessible funding. For instance, Massachusetts has implemented a Renewable Portfolio Standards (RPS) requiring renewable energy production to meet a certain annual percentage of electricity generation. This effort requires utilities to meet certain thresholds for the percentage of electricity generated by renewable sources and therefore the utility purchases

Renewable Energy Certificates (RECs), and in this case Solar Renewable Energy Certificates (SRECs) to meet those thresholds. SRECs do not have an established price. Instead prices are dictated by a RECs market, which is ultimately based on the supply and demand of RECs. A certified solar facility that produces 1,000 kilowatts of solar produced electricity is awarded one SREC. Currently the state of Florida does not have an established RPS or REC trading but it is possible this policy change could take effect in the future.

Utility Sponsored Incentives

Performance incentives and energy rebates are two main classes of incentives utilities offer for commercial solar projects. Performance incentive options are generated for the per unit energy production from renewable sources.

Performance Incentives

Gainesville Regional Utilities (GRU) and Orlando Utility Commission (OUC) both offer a per kilowatt-hour (kWh) incentive. GRU is by far the best financial solar incentive in the state offering a feed in tariff (FIT). A FIT accelerates solar adoption by offering solar developers a guaranteed price that is above market rate for the duration of the agreement. GRU offers a twenty-year term and offers either $0.18 or $0.15 per kWh depending on the solar array nameplate capacity. This incentive reduces the time to pay back the initial capital cost of the equipment and reduces the solar developer's risk. In contrast, OUC offers a $0.05 kWh production incentive as well as net metering but currently does not issue standard offer wholesale solar contracts; therefore the OUC incentive is not nearly as beneficial as GRU's feed-in tariff.

Energy Rebate

The second type of solar incentive is an energy rebate program. Both Progress Energy and Florida Power and Light (FPL) offer the most notable energy rebates. A public entity can receive energy rebates if it owns the solar equipment. Florida Turnpike Enterprise's Turkey Lake Service Plaza was able to collect a $150,000 in rebates from Progress Energy. Progress has allocated $1.3 million on an annual basis for commercial solar projects according to the array size and funding availability.

Alternative Financing: Crowdfunding

One of the more innovative mechanisms for project financing is “crowdfunding.” This novel approach to raising funds from nontraditional sources generally uses a Web platform that offers a project menu that people can choose to invest in. Unlike traditional investments that often require an investor to be certified, anyone is capable of participating as an investor. Mosaic is another form of a third-party investor with a large number of individual investors pooling their funding to finance a project. As the solar project generates energy and the customer pays for the electricity produced, the investors are paid back their investment with interest.

Mosaic, one of the most recent platforms to launch, targets solar projects in California. Launched in January 2013 and within four days funded three small-scale solar projects with hundreds of investors contributing $313,325. In the following two months, Mosaic offered another 8 projects, ranging in size from 9-102 kW, totaling $1.1 million in investment. Oregon DOT has hired Five Stars International to assess the possibility of a developing a crowdsourcing platform, one that might use donations (*not investments*) to fund the gap in financing that often occurs in solar project development. Oregon DOT was able to leverage financial incentives for the first two solar projects, such as the Oregon Business Energy Tax Credit (BETC), but those financial incentives no longer exist as is common in the dynamic world of solar incentives. Mr. Frank of Five Stars envisions a “buy a brick” model where an individual or business buys a solar module as part of the larger array and that investor could track in real-time the panel’s energy generation.

Table 5: Solar Incentives in Florida

Incentive Programs	Type of Incentive	Incentive	Source
Gainesville Regional Utility (GRU)	Feed-in-tariff (FIT) - performance based incentive	$0.18/kWh > 10kW to 25kw (ground mounted solar) $0.15/kWh > 25 kW to 1,000 kW	https://www.gru.com/Pdf/SolarFIT/solar-fit-program-guideline.pdf
Progress Energy (Duke Energy)	Utility rebate program	$2.00/watt – For the first 10 kW $1.50/watt – 10 kW – 50 kW $1.00/watt – 50 kW – 100 kW Rebates offered up $130,000	https://www.progress-energy.com/florida/business/save-energy-money/sunsense/commercial-solar-pv-program.page?
Florida Power and Light (FPL)	Utility rebate program	$2.00/watt – For the first 10 kW $1.50/watt – 10 kW – 25 kW Rebates cap of $50,000	http://www.fpl.com/landing/solar_rebate/business_pv.shtml
Orlando Utility Commission	Solar performance based incentive	PV (Commercial and Residential): $0.05/kWh	http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=FL60F
Gulf Power	Utility rebate program	$2 per watt Rebates offered up to $10,000	http://www.gulfpower.com/renewable/solarElectricity.asp
Florida Department of Revenue	Sales tax exemption	No limit to incentive although solar equipment must be certified by Florida Solar Energy Center (FSEC)	http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=FL01F&re=1&ee=0
U.S. Federal Government	Investment tax credit (ITC)	Tax credit available up to 30% of the cost of solar equipment; no maximum credit; requires tax liability	http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US02F
Florida State Energy Office	Incentives are not currently being offered	N/A	http://www.freshfromflorida.com/offices/energy/

4.4 Further Resources to Review

- NCHRP– Renewable Energy Guide for Highway Maintenance Facilities (http://www.trb.org/Main/Blurbs/169047.aspx)
- Oregon Department of Transportation Solar Highway Manual (http://www.oregon.gov/ODOT/hwy/oipp/docs/solarmanual.pdf)
- Turkey Lake Service Plaza Feasibility Study (http://www.cce.ufl.edu/wp-content/uploads/2012/08/Final%20Report%20Print%20Version-1.pdf)
- NREL – PV Watts Grid Data Calculator (Version 2): (http://www.nrel.gov/rredc/pvwatts/grid.html)
- NREL – Levelized Cost Calculator (http://www.nrel.gov/analysis/tech_lcoe.html)
- NREL – Distributed Generation Energy Technology Capital Costs (http://www.nrel.gov/analysis/tech_cost_dg.html)
- Colorado Department of Transportation – Assessment of Colorado Department of Transportation Rest Areas for Sustainability Improvements and Highway Corridors and Facilities for Alternative Energy Source Use (http://www.coloradodot.info/programs/research/pdfs/2011/restareas)

Arthur Hirsch, a consultant with TerraLogic, and one of the principal investigators for the CDOT study assessing Colorado rest areas referenced above is currently conducting a rest area assessment along the I-4 corridor between Orlando and Lakeland. One specific component of Mr. Hirsch's work is to provide a sustainability toolkit able to assess rest area opportunities in terms of renewable energy potential, water efficiency, as well as LED solid-state lighting, among other possibilities. It is recommended to contact Mr. Hirsch to learn more about his current rest area evaluation and the lessons it might have for other Florida rest area locations.

5. CASE STUDIES: *SOLAR ENERGY IN THE HIGHWAY RIGHT-OF-WAY*

5.1 Solar PV in State DOT Context

In Florida, solar right-of-way (ROW) projects are not currently at the stage of widespread adoption because at present they cannot generate required revenues and profits to make projects viable for all stakeholders. Nationwide, all current solar ROW installations received substantial financial incentives and shepherding in order to come to fruition. The current status of solar in ROW should not dissuade FDOT from exploring solar as a ROW project in the coming years as market conditions for the price of solar will certainly change. Greater adoption of solar projects in the right-of-way will depend largely on market forces, funding sources, a project champion, state and local political landscape, and cooperation with local agencies and developers. All in all, these high level takeaways are a snapshot in time, as potential barriers or necessities for projects evolve at a constant rate.

Nationally, large-scale adoption of right-of-way solar has not occurred, in part due to a lack of financial incentives and, in some cases, outdated policies that create additional obstacles. Solar ROW installations continue to increase but mostly in locations such as California where there is both solar access and financial incentives to make all parties and stakeholders benefit. Even in the California context, which is at the forefront of solar installations nationally, there have been significant obstacles to project development for the state DOT. Technological feasibility is proven and not a barrier. Solar does represent an opportunity that should be assessed as market and political factors adjust.

5.2 Lessons Learned

<u>Consider:</u>

- **Small Financial Impact for State DOT:** Currently, solar ROW projects do not contribute effectively to agency budgets. California raises more than $30 million in highway ROW projects with approximately $24 million from airspace leases (e.g., parking lots above highway properties) and $6 million in cell tower lease revenues.

Caltrans plans on charging nominal fees for solar land leases. For example, Caltrans only requested a $1,200 annual land lease and MassDOT charges the Town of Carver $880 per year for the land lease.

- **Scale:** Projects need to shift into the megawatt (MW) range in order to make a more significant impact to the share of renewable energy in addition to having a larger impact on both the organizational carbon footprint of the DOT. Rooftop solar at maintenance yards and state DOT district offices could also contribute to transitioning to renewable sources.
- **Project Development Shift:** If projects originate with the communities, as is the current experience at MassDOT, development pressure for FDOT will be reduced.
- **Partnerships:** Progress Energy and FPL do not currently partner with private or public agencies to build solar projects but there is potential in the future that the utility could develop solar projects in the highway ROW.

Motivations

State DOTs are motivated largely by greenhouse gas and cost reductions as well as public education and awareness, although benefits of a solar project in the ROW include:

- Adding value to existing land use
- Developing an alternative revenue source for the state DOT
- Climate change mitigation
- Agency sustainability metrics and efforts
- Increase energy price stability
- Supporting a green economy and local jobs
- Increasing public education and awareness
- Public recognition of DOT’s participation

Key Stakeholders

Solar ROW projects have relied heavily on leadership, both at the top of the organization to the project manager and players within the state DOT, in order to successfully install projects. A state DOT project champion is essential to ensuring that the project continues momentum at each stage of the process, particularly given the number of challenges presented by these projects.

A number of players participate in bringing a solar array project to completion but the main two roles for solar projects are one of agency director and that of project champion. As mentioned in the prior section, interviewees indicated that a project was initiated with a leader emerging as a protagonist to share either a vision or methods of incorporating new practices into department operations.

- DOT or Turnpike Authority leadership and project manager
- Solar developer
- Electric utility
- Local or regional government entity (city, county officials)
- Nearby communities and neighborhoods
- State environmental entity (e.g., Florida Department of Environmental Protection)

Policy Landscape

Supportive Policies:

- Net Metering

Policy Challenges:

- Power Purchase Agreement (PPA)
- Federal Highways Administration
- Virtual Net Metering

Business Model

All existing ROW solar highway installations have received substantial financial support beyond typically available incentives in order to be financially feasible. A third party power purchase agreement (PPA) is not possible given the current policy landscape, therefore, the most reasonable model for FDOT is to lease land to solar developers using a solar services lease option.

Many of currently installed solar ROW projects benefited from one-time ARRA grants. Current solar incentives in Florida at both the state and local level are limited in comparison to other parts of the country. Gainesville, through the Gainesville Regional Utility (GRU) does offer a feed-in-tariff for both commercial and residential projects. The Orlando Utility Commission offers a nominal incentive as well and other utilities such as Progress Energy and Florida Power and Light (FPL) offer energy rebates for solar projects. Shifts in the state and federal policy landscape, including third-party PPAs, could also play a role in increasing the opportunity and scale of solar projects for a state DOT. In Florida, it does remain a possibility that Florida will follow suit behind a number of other states that have created Renewable Portfolio Standards (RPS).

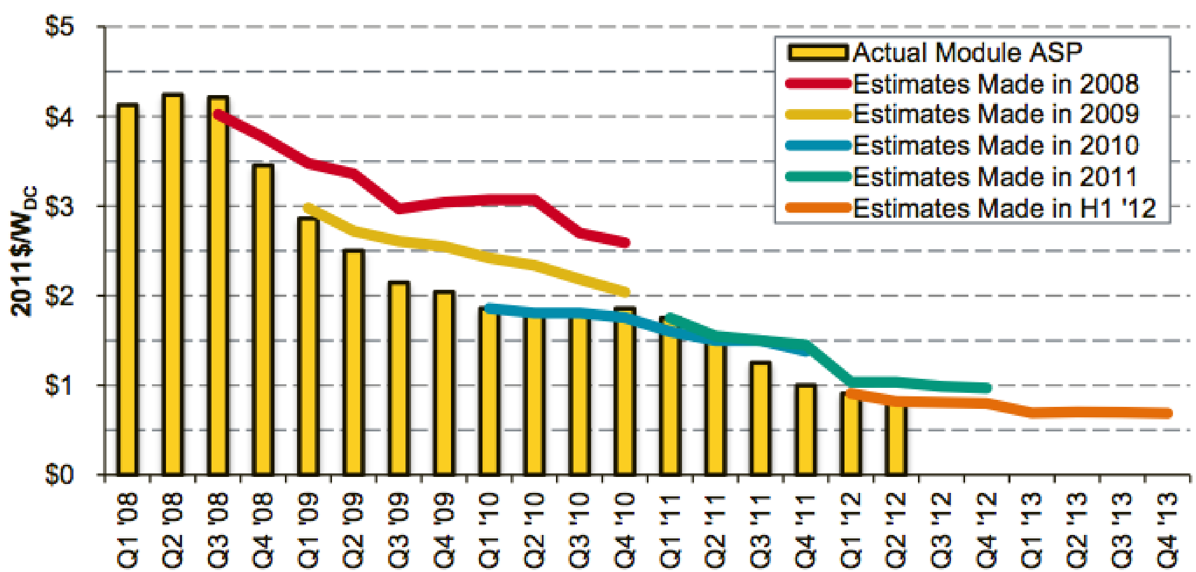
States are attempting to develop mechanisms that allow for greater renewable energy generation. One example that the Orlando Utility Commission (OUC) is considering implementing reverse auctions for distributed generation in the future. A reverse auction, utilized in other states such as California, requests solar developers to establish the lowest price that they are willing to accept to develop a solar project. This mechanism ensures that the utility gets the best deal on behalf of ratepayers and is not overcharged but it does expose the risk of having the solar developer not be able to meet the conditions due to a low initial bid (SEIA, 2013).

Financial Analysis

Solar might not be an income generator or cost reduction option for FDOT in the right-of-way context at this moment yet market and policy forces will change over time. Grid parity, or *the ability of solar to generate electricity at the same levelized cost as other energy sources*, will fundamentally change the decision as to whether to install solar or not. This dynamic set of forces will surely change in the coming years due in large part to decreasing solar prices.

Figure below illustrates the parallel between the predicted decline of solar prices and the actual decline of solar prices since 2008. Solar prices have largely followed solar price estimates. It is important to recognize that even with solar panel price reductions, the balance-of-system (BOS) costs have decreased but not at the same rate and there will undoubtedly be a floor to BOS related decline. Therefore, BOS costs are an important factor and therefore siting must identify locations that reduce BOS costs; for example, security equipment such as fences.

Most currently installed projects are demonstration projects rather than full-scale efforts by state DOTs, therefore projects to date have not scaled to a generation capacity that plays a measurable role in cost reductions and renewable energy generation. However, ROW solar projects in Massachusetts and Oregon are on the path to shift from small scale PV systems to much larger systems that are capable of offsetting DOT electricity generation and contributing more effectively to more renewable energy sources.



Source: (Feldman et al., 2012) **graph provides price per watt ($/watt) for panels and does not include balance-of-system costs*

Figure 3: Estimated vs. Actual Solar Prices

State DOT Solar Right-of-Way Projects

Nationwide, DOTs have installed solar in the highway right-of-way. While most of these installations could be best characterized as demonstration projects, this may be starting to change. For example, Massachusetts has set goals to install 10 megawatts (MW) of solar in the highway and rail right-of-way by 2014. In addition to the following list of DOTs, Arizona, Indiana, Rhode Island DOTs were contacted to learn more about their solar project efforts but currently have not moved solar ROW projects forward due to challenges in the initial project development phases.

Table 6: Solar Projects by State

Organization	Contact/Role	Project and Stage of Process	Business Model or Obstacles to Business Model
Oregon DOT	Allison Hamilton Oregon Solar Highway Program Manager Office of Innovative Partnerships 503-551-9471 allison.m.hamilton@odot.state.or.us www.oregonsolarhighway.com	1.75 MW and 104 kW solar array projects installed; currently in development of West Linn project	3rd party PPA with utility, state and federal incentives
Florida Turnpike Enterprise (FTE)	Tom Percival Environmental Management Florida's Turnpike Enterprise (407) 264-3013 tom.percival@dot.state.fl.us	Turkey Lake Service Plaza milemarker 263 on Florida's Turnpike (State Road 91) installed a 112 kW solar array	DOT research grant funded
MassDOT	Steve Miller Supervisor of Environmental Management Systems and Sustainability steven.j.miller@dot.state.ma.us (617) 973-8248	- 3 MW facility on Route 90 in property adjacent to ROW currently being negotiated with nearby town and solar developer - 67 kW installation in project development at MassDOT district office	3rd party PPA with utility Solar Renewable Energy Credits (SRECs), Renewable Portfolio Standards (RPS) influencing utilities
Town of Carver, Massachusetts	Jack Hunter Town Planner, Carver Massachusetts (508) 866-3450	115 kW system on highway ROW (non-federal aid highway), adjacent to wastewater treatment plant	3rd party PPA with utility Solar Renewable Energy Credits (SRECs), Renewable Portfolio Standards (RPS) influencing utilities
Caltrans	Brent Green Division Chief Right of Way and Land Surveys (916) 654-5075	- The Republic Solar Highways project has been in negotiation of PPA agreement for last 1.5 years. - A second Caltrans project with a utility partnership did not receive an successful bid	3rd party PPA with utility
Michigan DOT	Paul Arends P.E., Operations Engineer (616)451-2663 arendsp@michigan.gov	-100 kW ROW installation on rooftop of Park and Ride carpool lot - Two 20 kW installation in rest area properties	US Department of Energy ARRA funded grant for all three projects - covered all equipment and construction costs

5.3 Motivations

The impetus for developing state DOT solar array projects in the right-of-way is multi-faceted.

State DOT: Evolving Role in Energy, Climate Change, and Public Awareness

The main reason highlighted by interviews for starting down the path of a solar highways project is the establishment of a changing approach to energy generation and transportation. In most circumstances state or internal organization benchmarking became a strong motivation and many interviewees shared the story of how an individual, often the organization's director, had a vision of how the DOT or public organization could fundamentally participate in the changing face of the transportation sector whether that related to: developing an alternative revenue source for the state DOT, climate change mitigation, agency sustainability metrics and efforts, increase energy price stability

Opportunity: Highway ROW Untapped Resource – Adding Value to Existing Land Use

Property within the highway ROW represents a considerable amount of land, *and if utilized* could provide additional benefit to existing uses. Large renewable energy projects, particularly solar, can require large tracts of land and in most cases compete for other land uses. Over 3.4 million acres of unpaved federal highway ROW areas represent a largely untapped resource. State DOTs such as Colorado Department of Transportation (CDOT) have quantified the solar energy production available in Colorado ROWs (Kreminski et al., 2011).

State Goals and Sustainability Metrics: Oregon Department of Transportation (Oregon DOT) Example

For example, Oregon Department of Transportation (Oregon DOT) referenced the importance of internal goals, one of which tied directly to sustainability metrics and efforts) as well as contributing to the state's green technology cluster. Ultimately, building a solar project in the ROW serves to increase the public's awareness of alternative energy and the transportation sector's involvement. Oregon DOT developed the first solar ROW project in the nation and by doing so has been lauded for its participation and has been recognized formally by the U.S. DOT and AASHTO, and will receive another award in May 2013. This type of recognition and public awareness maintains the department's efforts as it demonstrates a commitment to sustainability and being at the front edge of a unique field.

5.4 Key Stakeholders

Developing a solar project is a multifaceted effort requiring both leadership and active project management. All of DOT project managers interviewed demonstrated a concerted effort to bring a project to fruition in spite of bureaucratic complexities or setbacks that are common in developing an innovative project. Leadership and management within DOT are essential but there are a host of other players needed to bring a successful project to bear. The following is a list of the organizations or stakeholders needed.

Key project partners:

- DOT or Turnpike Authority leadership and project manager
- Solar developer
- Electric utility
- Local or regional government entity (city, county officials)
- Nearby communities and neighborhoods
- State environmental entity (e.g., Florida Department of Environmental Protection)

Additional resources and potential partners:

- Florida Solar Energy Center (FSEC)
- State Office of Energy
- Department of Justice – for legal pathway.
- Solar energy organizations (e.g., solar advocacy groups - FSEIA)

- Nonprofit entities (e.g., Energy Trust of Oregon) which can provide technical or financial assistance
- Other DOTs – many DOTs communicated with DOTs with prior solar ROW experience before and during project development

Example: Florida Turnpike Enterprise

In the case of Florida, James Ely, the Executive Director and CEO of the Florida Turnpike Enterprise (FTE) put forth a concept of FTE taking part in the transition to a more sustainable transportation infrastructure. That message set in motion, Tom Percival, the Turnpike Authority's Environmental Management Office Manager, to find a way to develop the state's first solar ROW project. Mr. Percival developed a DOT research grant, which he submitted to the state office in Tallahassee.

Stakeholder Challenges

Challenges with stakeholders are driven by the project context. In some cases, utilities served to be obstacles but in other situations the project would not have materialized without their ardent participation. Additionally, neighboring communities represent a role of both challenge and opportunity. In some cases, neighboring communities are vocal in their disfavor of projects. A "not in my backyard" (NIMBY) type response can be common for renewable energy projects and this type of opposition generally surfaces once a project site is announced. Common concerns (founded or not) will be the aesthetic and health implications of the solar arrays. While Oregon DOT's Allison Hamilton mentioned the importance of involving public stakeholders throughout the process to gain community buy-in. However, communities might not oppose but rather encourage solar projects. Oregon DOT has shared publically via its website, tours and phone, their experience with engaging public stakeholders effectively. In Massachusetts, towns are currently the main driver for new solar ROW projects. Towns, with solar developer partnerships, are approaching MassDOT with potential site locations in the highway ROW or adjacent DOT property (these projects are currently being negotiated and cannot be identified). Oregon DOT's Allison Hamilton mentioned that community stakeholders are generally very interested in prioritizing brownfield or unattractive sites for solar projects.

Opportunity: Include Nontraditional Stakeholders

Given the novelty and associated complexity with navigating legal structures and business models there may be the need to involve stakeholders that otherwise would not be part of a traditional DOT construction project. For instance, in Oregon the Department of Justice (DOJ) helped Oregon DOT developed both the site license and power purchase agreement as well as developing guidelines for procurement that allowed Oregon DOT to make purchases within the state. DOJ's partnership and work on behalf of Oregon DOT is highlighted in their recruiting materials. Additionally, Oregon worked carefully with Oregon Department of Energy (ODOE) on procurement guidelines. These guidelines are a resource that continued to be used today and have been requested by a number of organizations seeking to include local economic development initiatives in their requests for proposals.

5.5 Policy Landscape

Supportive Policy: Net Metering

The State of Florida, as previously mentioned in the Technology Primer, allows net metering on site for a solar PV system up to 2MW. This policy mechanism allows the state DOT to produce electricity onsite and feed the grid electricity that is not using onsite as long as the system capacity is no greater than 2MW of nameplate capacity.

Current Policy Challenge: Power Purchase Agreement (PPA)

The main regulatory obstacle in the Florida context for a solar highway project is the inability to establish a PPA between a utility and a third-party solar developer (PUC Decision: Docket 860725-EU; Order 17009). Only six states, including Florida, Georgia, North Carolina, Oklahoma, Kentucky and Iowa do not permit this type of agreement. A PPA serves two important functions. First, it allows the DOT to finance the solar project via external funding sources, using a solar developer to finance the project. Many DOTs do not have the initial investment required to develop solar projects so this source of capital is important. Second, a PPA in part is an agreement that negotiates the electricity rates to be paid by the utility to the solar developer. Many PPAs will give the energy user, in this case the DOT, a preferred electricity price over the course of the contract and this can further contribute to cost savings.

FTE's Turkey Lake Service Plaza solar project avoided a problem with a PPA because it purchased the solar arrays via grant funding and therefore did not engage a third party developer. A PPA was avoided for financing but it also used all of the solar electricity generation on-site and therefore did not need to create a power purchase agreement to sell electricity. In contrast, Oregon and Massachusetts have relied heavily on third-party PPAs to both finance and develop projects in the highway ROW.

Current Policy Challenge: Federal Highways Administration (FHWA)

FHWA determines approach to specific design guidelines on a district level although it receives guidance from the national office. Therefore, it is possible for a district level FHWA office to rule differently than other district offices. This is the case with solar in the right-of-way. Oregon DOT worked closely with the district FHWA office that was supportive of the innovative nature of the solar highway project. Similar support for innovation has not occurred in California, where the district FHWA office turned out to be the main obstacle to developing a solar highway project. California has been able to install other solar projects albeit not on in the right-of-way. The main hurdle is that the district FHWA office has more stringent guidance on highway interchange use. According to Brent Green, Deputy Director of Right of Way Land and Surveys for Caltrans, highway interchanges are some of the most conducive locations offering minimum appropriately sized parcels for solar, and therefore, this obstacle at the regional district level has stalled current projects and sets a difficult precedent for similar projects. It is important to involve the district FHWA office in conversations at the beginning of project development to ensure that the project is feasible based on its location and context and avoid potential hurdles later.

Current Policy Challenge: Virtual Net Metering

Many highway ROW locations do not use a considerable amount of electricity (e.g., highway lighting). Virtual net metering, which is currently not allowed in Florida, allows a utility customer to allocate net electricity generation (i.e., electricity not used onsite) to other accounts that are not physically tied to that source of generation. Virtual net metering would allow a state DOT to site solar in the right-of-way and allocate that energy usage to other DOT locations that use more energy such as a district office. This arrangement would allow a DOT to offset its energy production mix and reduce its carbon footprint. California allows this practice currently and other states such as Massachusetts are assessing the possibility of neighborhood or community net metering (DSIRE, 2013).

5.6 Business Model and Financial Viability

The PPA model is generally considered the most advantageous option for a state agency advance a solar project; however, there are other options available to a DOT both in the selection of a practical business model and financial incentives.

- State DOT owned
- Solar Services Agreement
- Turnpike Partnership (private enterprise)
- Public entity creates private enterprise

State DOT Ownership

Perhaps the most straightforward option available to a state DOT is to self-finance a solar project in the highway ROW. The limiting factor on this option is the amount of capital available in the budget to purchase a solar system without external financing. Due to this limitation, all state DOTs have either sought outside grant funding or partnerships to finance projects.

Solar Services Agreement

Although a PPA business model is not a viable model in the Florida context, an alternative model exists. In conversations with staff at both Progress Energy and the Public Services Commissions (PSC), they indicated the possibility of bypassing the PPA rule by setting up a lease arrangement that instead uses net metering as the conduit for creating the business model. Similar to the PPA model, the DOT would not assume responsibility for the upfront investment capital necessary for the purchase of the solar equipment nor its maintenance. Instead of arranging a PPA agreement with the utility, the third party developer would negotiate a contract with the DOT for the purchase of electricity demand for the immediate area of the meter. A similar approach has been proposed by solar developers for municipal government in Florida (Smith and Shah, 2010).

This structure undoubtedly creates challenges, particularly in the legal structuring and documentation. One of the staple components of a PPA, is an agreement for a site host to purchase electricity from the system at a predetermined negotiated price of electricity over the course of the contract, often time 20-25 years in duration. This electricity price generally increases over the duration of the contract but at a known interval, giving certainty to both the buyer and seller.

In the case of a leasing arrangement, a specific electricity price could not be referred to because that would break the PSC's 1980 ruling on PPAs. However, a proxy could be used for electricity price and could be negotiated between the electricity purchaser (e.g., DOT) and energy producer (solar developer) that would essentially meet the parameters to make the project viable for both parties. The solar lease model may allow third-party participation but there is greater possibility for complication and potentially the inability to qualify for certain financial incentives (Kollins et al., 2010).

Walter Clemence of the Florida Public Services Commission (PSC) and David Gammon, Cogeneration Manager at Progress Energy explained the model and mentioned that they have heard that it is working in other locations but could not offer specific examples. Mr. Clemence and Mr. Gammon are well versed in power purchase agreements, but this solar leasing structure is not one that they routinely manage. They both expressed the need to ensure that the legalities of the structure be well vetted with a lawyer at the early stages in order to avoid potential stumbling blocks later in the process. Neither Mr. Clemence nor Mr. Gammon could provide an example of a solar lease structure in Florida because technically these entities would not need to announce that business model to the PSC or a utility. Given the strength of the PPA exclusion in Florida, it is Mr. Gammon's estimation that these entities would have nothing to gain by sharing this model publically but it could serve as a risk to developing policies to exclude lease structures on the same basis as PPAs. The National Renewable Energy Laboratory (NREL) is a good resource for public agencies seeking specific information related to legal structures.

Turnpike Partnership

Florida's Turnpike Enterprise (FTE) is a private entity and therefore it could partner with FDOT to develop solar PV right-of-way projects. Given the motivational interest of both groups to reduce costs and greenhouse gases, each could garner benefits from the partnership. FTE could benefit from the ITC and other private tax benefits that FDOT would not be able to assume. Project financing would remain an issue that the two groups would need to assess.

Public Entity Creates Private Company

Charles Kibert, University of Florida professor and co-author of the Turkey Lake Service Plaza feasibility study identified the possibility of a public entity creating a private entity with the expressed interest of developing ROW solar projects. While this model would allow a public organization to take advantage of private incentives it would add several layers of complexity in the formation of a new entity. Mr. Kibert mentioned his personal experience of this model. The school board of Meadowbrook Elementary School, a Green Globes school, did not have the upfront capital investment available to fund a solar array and therefore they are currently in the process of developing a public-private model. (Kibert et al., 2010)

Challenge: Business Contract Complexity

A number of DOT representatives indicated contractual or business model issues that fundamentally changed the project feasibility regardless of the business model employed. These types of contractual agreements are complex and there are a number of tradeoffs between risk and reward. For example, the Indiana DOT (INDOT) encountered a request from the utility (beyond general PPA requirements) to accept full liability for any disruption to the power grid resulting from the installation. The scenario in Indiana illustrates that a utility may not be as interested in project success as the state DOT. This additional liability proved to be too large an obstacle and therefore INDOT did not pursue the project or the PPA further (E. Pollack, Indiana DOT, personal communication, 2013). This type of issue is generally managed in the interconnection standards and highlights the importance of the persistent project champion that can work through these types of hurdles with stakeholders. In certain circumstances, it is the DOT that can propose difficult requirements of the solar developer. In the case of

Massachusetts, MassDOT initially requested that the town of Carver be responsible for maintaining the grounds of the right-of-way surrounding the solar installation. Many other DOTs require language in the easement or lease that obligates the developer to dismantle the solar equipment if that location is deemed necessary for DOT use. While this poses a threat to solar developers, many indicated that this was not a fatal condition.

Challenge: Solar Developer Partnership

Finding a solar developer that is capable of managing the unique nature of a highway solar ROW project can be a difficult task. The town of Carver, Massachusetts provides one of the best examples of perseverance in identifying a solar developer. Carver publically announced a request for proposal (RFP) for a 115 kW system in May 2010 and received an initial bid by a developer in November 2010. Between November and May 2011, the town and solar developer negotiated a contract. Carver encountered another developer and proceeded to negotiate and sign a PPA in October 2011. The day after the PPA was signed, Solar Renewable Energy Credits (SRECs) prices declined in the state's auction and the second solar developer backed out. According to the developer the small project scale, grid connection tie and site access made the project unreasonable. In December 2011 once again opened the bidding process but there was no response (J. Hunter, Town of Carver, MA, personal communication, 2013).

Oregon's local utility contracted with a prime contractor that predominantly operates as a DOT contractor and the solar developer served as the subcontractor. This combination provided the knowledge for the ROW work, but also the necessary solar expertise. This model is easy to use but may need to be altered with solar contractor as the prime contractor.

Challenge: Financial Viability for Third-Party Developer

As another example, Caltrans has been unable to install a right-of-way project to date in large part due the inability to find a solar developer that can bring the project to culmination. For the first project, Caltrans partnered with a utility to establish a solar highway project on a ROW parcel that was adjacent to a utility property, which seemed to be a worthwhile partnership given the greater expertise of the utility with respect to energy generation projects. The partnership publicly announced a RFP but the only interested solar developer needed five times the amount the utility was offering.

Challenge: Patent Issue with ROW Solar

The U.S. Patent Office granted Gein Fein and Edward Merritt patent US7495351 titled "System and method for creating a networked infrastructure distribution platform of solar energy gathering devices." The patent gives the holders the expressed right to the idea of solar energy in the highway right of way. There has been considerable controversy over the legitimacy of the patent and a number of states and countries have not acknowledged the validity of the patent. A state DOT should consult with legal counsel prior to engaging a solar right-of-way project and assess state precedents or whether this patent is still valid.

5.7 Financial Analysis

Financial analysis is one of the main facets of the Feasibility Screening Tool (Task 7) and is fundamental to determining project viability. In most scenarios, a state DOT will be developing a project with a third-party project developer. Typically a project developer needs to perform the financial modeling to determine project viability. However, a state DOT can facilitate the feasibility assessment by completing a financial analysis prior to consulting just to understand the conditions for a successful project early on. This process educates the DOT regarding expected project revenues and costs, which aids in the negotiation process and serves as an initial litmus test as to whether a project is worth pursuing. Given that solar projects do not work in a number of current contexts, basic financial analysis also helps determine viability as market and policy conditions change.

The following sections outline costs, revenues, incentives, project scale and provide a few examples of different project incentives and contexts and the metrics to develop the analysis.

Costs

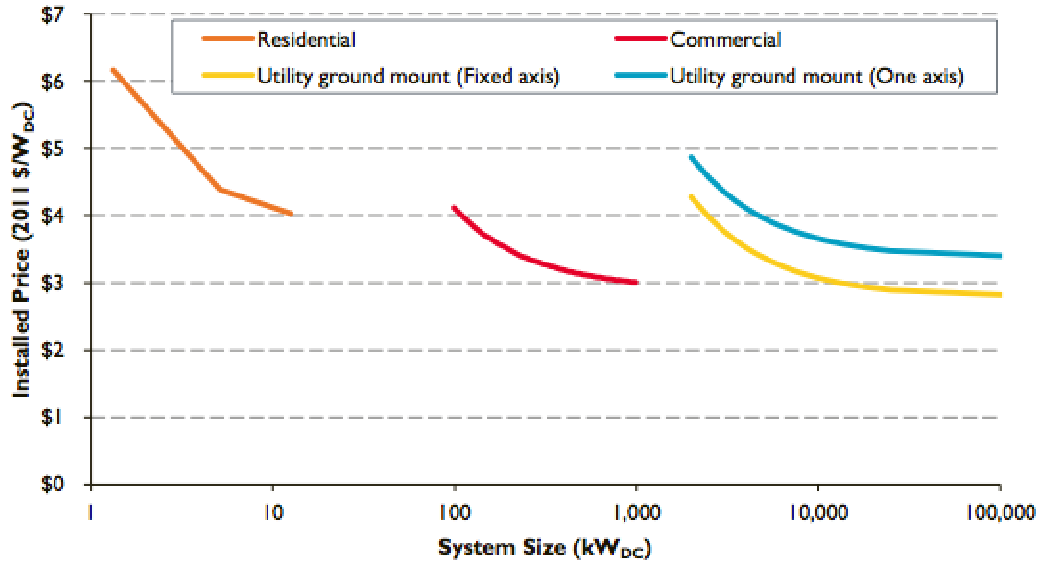
- Solar PV equipment
- Balance-of-system: installation, ground mounting, utility connection, permitting, security fence/cameras
- Operations and maintenance: ensure inverter functionality, panel cleaning, visual inspection for defects, maintaining site grounds/landscaping
- Legal: legal entity creation, vetting liability, contracts

Revenues and Incentives

- Contract with state DOT to supply electricity (i.e., in Florida part of site license agreement due to third-party PPA regulations)
- Net metering agreement or feed-in tariff agreement
- Federal Investment Tax Credit (ITC) – if applicable
- Utility energy rebate – if applicable

Scale

To date, most installed solar ROW projects have been between 75-150 kW in production nameplate capacity; however, a number of more recent projects have been in excess of 1.5MW or more. Bigger projects offer economies of scale that make them more attractive to project developers. The graph below distinguishes the difference in pricing between differently sized PV systems. Commercial scale PV projects can be either ground mount or rooftop installations. Larger systems tend to be ground mounted and the Oregon DOT projects have both been ground mounted PV installations. For the purpose of this paper, ground mounted installations will be the focal installation method.



Source: (Feldman et al., 2012)

Figure 4: Installed Solar Prices by System Size and Class

Scenarios and Assumptions

Base Assumptions:

- **System Size** – Compared a 300 kW system versus a 1 MW system (1,000 kW)
- **System Costs** – Current installed system PV costs ($3.00-3.75 per watt) in addition to estimated future solar pricing ($2.50 per watt)(Feldman et al., 2012)
- **Annual Output** – 1,319 annual kWh of electricity generated per kW of PV (Gainesville zip code)(NREL, 2013)
- **Type of Installation** – Ground mounted fixed axis system
- **Electricity Pricing** – $0.0956 per kWh (U.S. Energy Information Administration, 2013)

Scenario 1: Baseline solar PV in Florida without financial incentives

This scenario provides a basic baseline case for solar in order to compare with other financial and incentive project contexts.

Table 7: Scenario 1: Baseline solar PV in Florida without financial incentives

	$3.75/watt	$3.00/watt	$2.50/watt
System Costs 1 MW system (w/ ITC)	$3,750,000	$3,000,000	$2,500,000
Annual O&M Costs (0.17% of total installed cost)	$6,375	$5,100	$4,250
Annual Output (kWh)	1,319,000		
Electricity Cost ($/kWh)	$0.0956		
Annual Energy Value (Production less O&M, in dollars)	**$126,096**		
Simple Payback (in years)	29.7	23.8	19.8

Scenario 2: Investment Tax Credit (ITC)

This scenario assumes a 30% tax credit, which is only available to a private entity, therefore this scenarios implies a partnership between the state DOT and a private entity (e.g., Turnpike, solar developer)

Table 8: Scenario 2: Investment Tax Credit (ITC)

	$3.75/watt	$3.00/watt	$2.50/watt
System Costs 1 MW system (w/ ITC)	$2,625,000	$2,100,000	$1,750,000
Annual O&M Costs (0.17% of total installed cost)	$4,463	$3,570	$2,975
Annual Output (kWh)	1,319,000		
Electricity Cost ($/kWh)	$0.0956		
Annual Energy Value (Production less O&M, in dollars)	**$121,634**		
Simple Payback (in years)	21.6	17.3	14.4

Scenario 3: Energy Rebate in Progress Energy Service Area

This scenario demonstrates the full use of a $130,000 energy rebate, the highest rebate provided within the state of Florida.

Table 9: Scenario 3: Energy Rebate in Progress Energy Service Area

	$3.75/watt	$3.00/watt	$2.50/watt
System Costs 1 MW system (w/ sales tax exemption)	$2,625,000	$2,100,000	$1,750,000
Energy Rebate	$130,000	$130,000	$130,000
Total System Cost	**$2,495,000**	**$1,970,000**	**$1,620,000**
Operations and Maintenance Costs $0.005/kWh	$4,242	$3,349	$2,754
Annual Output (kWh)	1,319,000		
Electricity Cost	$0.0956		
Annual Energy Value (in dollars)	**$126,096**		
Payback (in years)	19.8	15.6	12.8

Scenario 4: Feed-in Tariff with Gainesville Regional Utility (GRU)

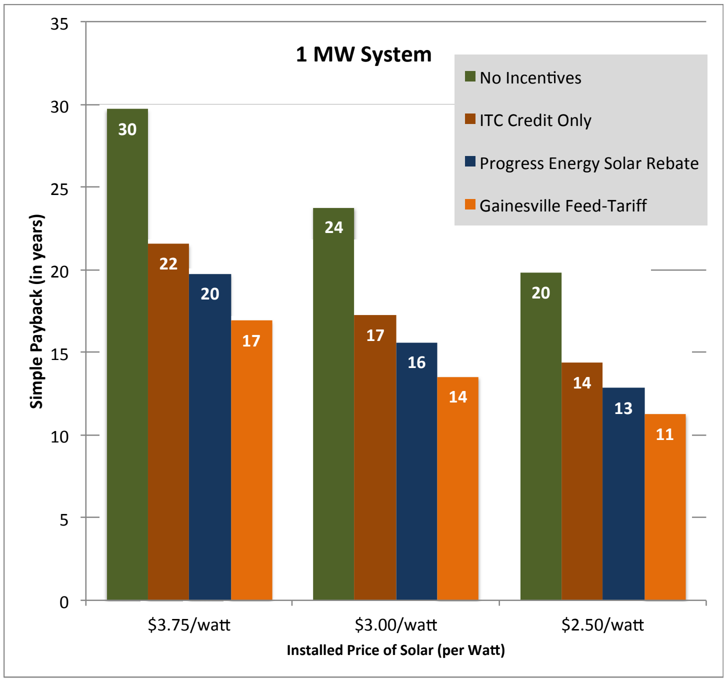
This scenario utilizes a maximum feed-in tariff contribution of 300 kW because under current payments a 300 kW system is the largest system participating in the FIT program.

Table 10: Scenario 4: Feed-in Tariff with Gainesville Regional Utility (GRU)

	$3.75/watt	$3.00/watt	$2.50/watt
System Costs 1 MW system (w/ 30% ITC)	$2,625,000	$2,100,000	$1,750,000
Annual O&M Costs (0.17% of total installed cost)	$4,463	$3,570	$2,975
Annual Output (kWh)	1,319,000		
Electricity Cost ($/kWh)	$0.0956		
Total Annual Energy Value	**$155,031**		
(Production less O&M, in dollars)	$88,267		
Feed-in Tariff Contribution	$71,226		
Simple Payback (in years)	16.9	13.5	11.3

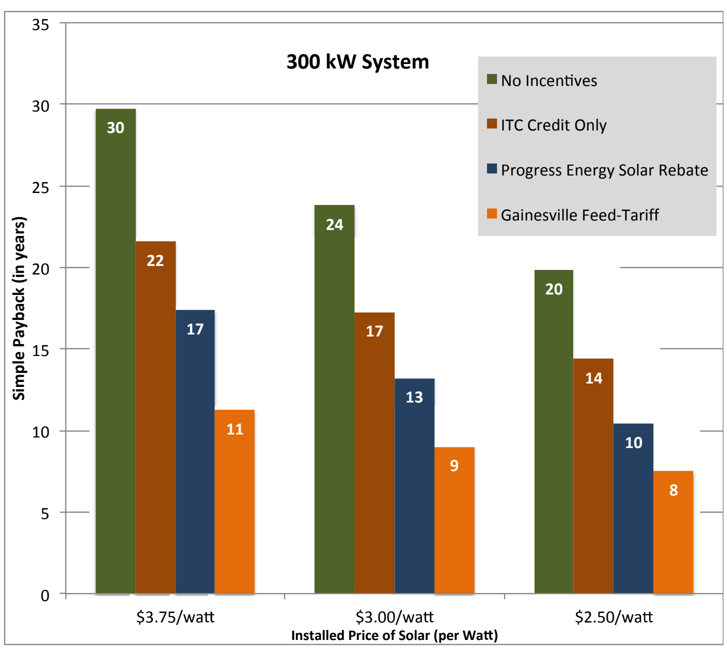
Utilizing Financial Incentives

Given the variety of financial incentives, it is important to understand funding availability, funding limitations and functions, as well as how they can ultimately impact the viability of a project. When comparing financial incentives it is important to piece together available incentives when possible and to gauge where to site solar PV projects given the unique nature of geographic incentives (e.g., Gainesville, Orlando). As the following two graphs demonstrate, a solar feed-in tariff is most effective, followed by a solar rebate and ITC federal credit.



Source: Authors Analysis

Figure 5: Simple Payback of 1 MW System

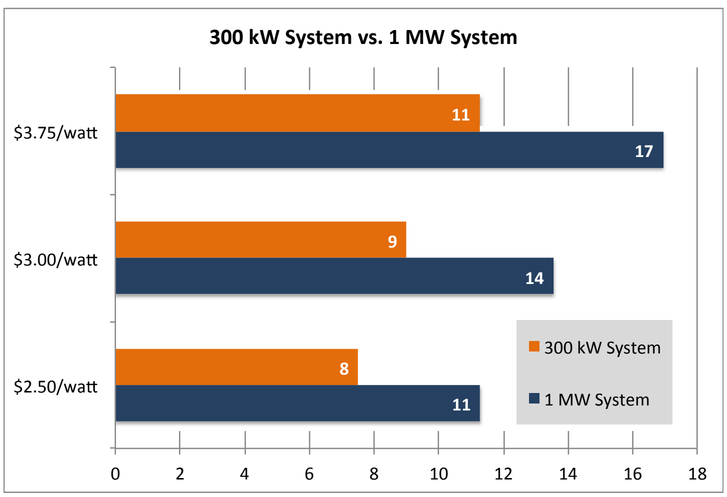


Source: Authors Analysis

Figure 6: Simple Payback of 300 kW System

Sizing a PV System Appropriately

As mentioned in the previous section, the size of a system determines its financial feasibility, particularly to the solar developer. However, given Florida's current incentives, it is important to note that a smaller system of approximately 300kW is perhaps the most effective system, given the current ceiling for financial incentives of 300 kW for both solar rebates and the GRU's FIT program. System sizing and impact on payback is a critical part of the analysis. These financial incentives are subject to change and it is possible that certain incentive programs may attempt to target larger scale projects. Evaluating incentives, as well as well project scale, are important components of a solar PV system financial analysis.



Source: Authors Analysis

Figure 7: Simple Payback of 300 kW System vs. 1 MW system

6. SOLAR ENERGY – FEASIBILITY SCREENING TOOL

Note: As of project delivery June 2013, meeting some of these criteria and project considerations may not be possible given current regulations and geographic context (e.g. third-party power purchase agreements) but these items are subject to change and should be reviewed during initial project evaluation.

		Checklist	Comments/Notes
Motivation	**Project Rationale: Clear guiding policy or directive from leadership AND/OR compelling financial and environmental benefits**	**Define project motivations:** ☐ Specific direction from agency head or governor ☐ Cost avoidance ☐ GHG emissions ☐ Public education	**Describe policies, mandates, leadership directives, financial and environmental benefits:** *(e.g., GHG emissions reductions targets in state DOT charter)*
	Key Stakeholders: Support and Opposition	**Identify participant and stakeholders in the process and whether they support or oppose the project:** **Support Oppose** *DOT personnel:* ☐ ☐ State DOT leadership ☐ ☐ DOT personnel *Solar technology and financing:* ☐ ☐ 3rd party developer ☐ ☐ PV manufacturer *Utility* ☐ ☐ Electric utility *Government agencies:* ☐ ☐ Local or regional government ☐ ☐ State environmental agency ☐ ☐ State of Office of Energy ☐ ☐ Other state DOTs *Community stakeholders:* ☐ ☐ Community residents ☐ ☐ Local environmental advocates ☐ ☐ Anti-electromagnetic field advocates *Nonprofits:* ☐ ☐ Florida Solar Energy Center (FSEC) ☐ ☐ Solar energy organizations (e.g. SEIA)	**Names, titles and contributions of each supporting stakeholder:** *(e.g., state DOT personnel including maintenance, environmental and business office staff)* **Strategies for building support and managing opposition:** *(e.g., Hold public meetings/charettes to share site selection process and benefits of solar ROW project)*

Policy and Regulatory	**Review Status of Policies and Regulations**	**Review applicable policies and regulations for solar ROW projects:** **Utility - look for existing contract pathways that the utility has set up** ☐ Net metering *(up to 2 MW with large load onsite*) and virtual net metering ☐ Feed-in tariff (FIT) ☐ Third-Party Power Purchase Agreement (PPA) ☐ Renewable Portfolio Standard (RPS) - solar carve out/premium provided by utility **State DOT - look for appropriate legal pathway or definition to engage solar** ☐ State DOT Charter - legal review ☐ Utility contracts ☐ Airspace lease and other site license agreements **Federal Highways Administration (FHWA)** ☐ *Title 23 Commercialization of Right-of-Way (Bruce Bradley - FHWA Office of Realty)*	**Describe policies and regulations in their current form and applicability to the project:** *(e.g., state regulations changed in 2014 to allow third-party power purchase agreements)*
Business Structure and Financial Return	**Business Model**	**Choose the following business model options to consider:** ☐ Solar services agreement (third-party) - site license agreement for equivalent value of energy production ☐ Public-private partnership (e.g. Florida Turnpike Enterprise) ☐ Utility owned and operated PV array on state DOT right-of-way ☐ Third-party power purchase agreement (PPA) - if possible	**Analysis of potential business models and their advantages:** *(e.g., third-party model allows the opportunity for project to use tax credit or other state/federal incentives)* **Business model disadvantages:**

Business Structure and Financial Return	**Financing Incentives**	**Federal and state programs - federal or state incentives only available to a third party (non-government) partner:** ☐ Federal tax credits ☐ State tax credits ☐ Federal rebate ☐ State rebate ☐ Federal tax exemption ☐ State tax exemption **Utility Incentives (available to both private and government entities):** ☐ Feed-in tariffs (FIT) ☐ Utility rebates	**List and provide comments for relevant state, federal and utility incentives:** *(e.g. Federal Investment Tax Credit (ITC) - 30% of PV costs; federal income tax benefit, can only be used by third-party)*
	Financial Analysis	**Develop basic financial analysis to ascertain financial feasiblity for partnering developer, paying particular attention to:** ☐ Scale of PV system (e.g. 350 kW nameplate capacity) ☐ Current solar pricing (prices are declining significantly on an annual basis) ☐ Solar PV installer's understanding of nuances of ROW installations including access for installation/maintenance, vandalism ☐ Balance of system (BoS) costs associated with site specific context (e.g., utility connection, legal costs) ☐ Solar potential (see site selection criterion below)	**Perform basic financial analysis calculating simple back or return on investment to determine whether project is financially feasible for solar developer:** *(e.g. project has a simple payback of 11 years with a 9% return on investment for the PV developer based on an installed cost of $3.68 per watt)*
	Legal Contract	**Identify legal costs and needs to be addressed:** ☐ Define and create business model and electricity purchase from developer ☐ Address net metering with utility (ensure that site is qualified based on generation and what amount of electricity is anticipated to be fed to the grid) ☐ Site license agreement ☐ Airspace lease or land lease agreement ☐ State expectations for project decommissiong and site	**Describe legal issues:** *(e.g., need agency lawyer to draft site license agreement with third party developer to address liability issues and payment terms)*

Site Selection Criteria	**Safety**	**Ensure site analysis addresses criteria and permits related to:** ☐ Outside the highway clear zone and meets DOT engineers guidelines/expertise on appropriate siting ☐ Solar panels cannot shade the roadway due to potential safety issues (e.g frost patches) ☐ Check fire	**Assessment from state DOT safety engineers:**
	Solar Potential - energy performance analysis	☐ Good southern exposure and without topographic, vegetative or future structure shading ☐ Confirm with solar developer that the site meets the following criteria for solar access/resource, acreage, slope, mounting options, soil conditions (if ground-mounted) and obstructions	**Assessment from solar PV developer and state DOT engineers:**
	Current and Long-Term Site Usage	☐ Screen site for current and future conflicting uses ☐ Focus on sites ≤ 5 acres such as wayside information centers and rest areas, interchanges, inactive or abandoned weigh stations, rest areas or maintenance yards. ☐ The best sites will have minimal slope (less than 5%) and feature cohesive soils and avoid natural hazard zones, flood and landslide areas.	**Assessment from state DOT planning office and engineers:**
	Grid Connection	☐ Locate near existing utility connection that can handle electricity load ☐ Focus on sites within 1/2 mile of an electric distribution grid that can accommodate a three-phase interconnection.	**Assessment from local/regional utility and state DOT engineers:**

Site Selection Criteria	**Assessibility for O&M**	☐ Safe location for initial construction and ongoing maintenance access	**Assessment from state DOT safety engineers:**
	Environmental Impact Analysis	☐ Environmental permitting ☐ Biodiversity and habitat (e.g., wetlands and critical habitat sites) ☐ Water resources ☐ Hazardous materials ☐ Local land use ☐ Noise ☐ Geology ☐ Historical and cultural resources ☐ Parks ☐ Scenic and visual resources	**Assessment from state environmental agencies and state DOT engineers:**
	Adherence to Required Permitting	☐ Construction stormwater permit ☐ Local jurisdiction land use, electrical and construction permits ☐ Airspace lease or utility accomodation	**Assessment from state environmental agencies, government officials and state DOT engineers:**
	Protection Against Theft and Vandalism	☐ Fencing and/or other mechanisms to protect solar arrays from theft and vandalism, concern for electrocution	**Assessment from solar PV developer and state DOT engineers:**
Screening for Potential Projects and Candidate Sites	**Community Acceptance**	☐ Engage community stakeholders in the site selection process ☐ Adjacent neighbors ☐ Local agency politicians ☐ Local agency managers ☐ Pro solar advocates	**Assessment from state DOT planning office and engineers:**

Site Selection Criteria

Many considerations need to be accounted for when determining which site is most conducive to a solar array. This section outlines the broad set of criteria to consider when assessing potential site locations. Highway ROW locations are the subject of this study but it is important to mention that many other state DOTs have sited solar in other locations other than the highway shoulder or cloverleaf. Rest areas, turnpike service plazas, DOT district offices, DOT maintenance, carpool or park and ride lots have each been the located for solar ROW projects. Solar exposure and appropriate size of site are basic concerns.

Summary of Essential Site Criteria

- Good southern exposure and without topographic or vegetative shading
- Confirm with solar developer that the site meets the following criteria for solar access/resource, acreage, slope, mounting options, soil conditions (if ground-mounted) and obstructions
- Outside the highway clear zone and meets DOT engineers guidelines/expertise on appropriate siting
- Screen site for current and future conflicting uses
- Locate near existing utility connection that can handle electricity load
- Fencing and/or other mechanisms to protect solar arrays from theft and vandalism
- Avoid sensitive environmental resources or cultural resources
- Safe location for initial construction and ongoing maintenance access
- Engage community stakeholders in the site selection process
- Assess need for additional permits (e.g., encroachment, grading, etc.)

Safety

Safety is of the utmost priority for a state DOT exploring a solar ROW project. Completed projects have focused on this element and have ensured both the DOT and public that site locations are sited outside of the highway clear zone. Even with a proper buffer, questions will certainly surface from DOT personnel as to the safety of siting solar in the ROW including the possibility of increased vehicle fatality. Currently, principal investigator Bryan Roeder from Colorado DOT (CDOT) and his research team is completing an assessment on behalf of the Transportation Research Board (TRB) to determine the potential impacts of solar arrays on highway safety and operations. This research effort is currently underway and once complete will undoubtedly be a valuable resource for DOTs exploring solar ROW projects.

Solar Access

It is important that solar panels are not shaded because a shaded panel, even just partially shaded will dissipate power rather than produce it. Assessing a site for solar access and unimpeded solar collection starts with good southern exposure and without topographic or vegetative shading. It is important to involve the solar developer and state DOT engineers in the process of assessing solar potential and that it meets the necessary characteristics including proper slope, and mounting options.

Long-Term Access

Given the long lifetime of solar PV systems, it is important that a site is assessed for its current and future used and it is screened for conflicting uses.

Local Electric Grid Interconnection

In the Florida context, given third-party PPA limitations, a solar lease business model would require net metering. In Florida, net metering laws require that no system can provide more than 2 MW of electricity. Additionally, solar projects cannot feed the full production but must offset with onsite usage whether that is highway lighting, rest areas, maintenance or district office. Therefore, a system needs to be sized appropriately in order to not exceed the limits of the net metering rules.

Another interconnection consideration is the physical location of the utility meter relative to the array. In most states a PV installation needs to be located near a utility meter that is capable of handling the energy load. In both Michigan and Oregon, the utility requested that the solar array not plug into the nearest meter but rather one located on the other side of the highway. Costs associated with boring underneath the highway and connecting to the other meter raises costs and may make a project at a given site impractical. As mentioned previously, balance-of-system costs are associated with everything beyond the capital cost of the solar PV system equipment, including wiring, meters, switches, inverters and any site preparation or legal fees. These costs are important because, as solar equipment prices continue to decrease, balance-of-system costs do not decline proportionally and therefore become more of a focus for cost management.

Accessibility for Safe, Initial Installation and Ongoing Maintenance

If the site selected will be true immediately adjacent property (e.g., highway shoulder or cloverleaf rather than a turnpike, maintenance or district office parcel), accessibility to the site is an important consideration. In the experience of Carver, Massachusetts, discussions with one solar developer terminated because the solar developer planned on needing daily access to the site during the construction phase. This request would have required a state trooper to be present to ensure safety, which signified a substantial contribution, one that the project could not bear. A subsequent developer identified a solution, and only required access to the highway site for two days, once to drop off all materials and then again to pick up any leftover equipment. During the construction phase, the developer accessed the site via an adjacent water treatment plant rather than limited access high traffic option. Choosing a site that already has construction and maintenance access via existing infrastructure will llimit complications because adding permanent access on federal aid highways requires FHWA approval. Even changing the pattern of access requires approval which occurred at the Oregon DOT demonstration site.

Protection Against Theft and Vandalism

Within one month of SolarAir's solar array installation in Carver, Massachusetts, five of the panels were stolen. Subsequently in the following three weeks additional panels were taken and vandalized. The solar developer fortified the fence, locked the panels to the brackets and installed motion detectors. Oregon DOT's project with Portland General Electric (PGE) avoided initial safety concerns by installing fences, video cameras and panel trackers. Upfront management of this issue is fundamental.

Community Buy-In

Solar PV projects should involve the public including nearby communities and municipal governments to ensure that communities understand a project's intent and site considerations.

Environmental and Cultural Resources

The best sites for solar will be those that avoid certain sensitive cultural or ecological sites and flood, landslide and other natural hazard zones. The state DOT can play a key role in providing the necessary assistance in moving the environmental permitting processes (e.g., NEPA) forward given organizational familiarity with internal policies in documenting potential environmental issues and state requirements. DOT personnel can help navigate the nuanced path of categorical exclusion versus environmental assessment or environmental impact statements. Additionally site permits might be required including permits for encroachment and grading.

According to Brent Green, Caltrans's Deputy Director of Right of Way Land and Surveys, and Arthur Hirsch, Terra Logic Sustainable Solutions consultant, generally ROW sites have been pre-approved during the initial highway construction and therefore are less likely to incur environmental permitting than greenfield sties. One area that will most likely need greater consideration is storm water permitting. For Caltrans ROW projects the two main required environmental permits are a National Pollutant Discharge Elimination System (NPDES) stormwater permit and a Storm Water Pollution Prevention Plan (SWPPP).

Part of stormwater mitigation can be the installation of swales as part of a landscape plan. Vegetation can also help mitigate stormwater and can in many ways improve a site's baseline conditions for stormwater management.

Given Florida's natural landscape, wetlands are perhaps one of the most important environmental considerations. In order to avoid costly environmental studies and project delays, selected sites should generally avoid delineated wetlands. Where otherwise ideal site conditions prevail and sensitive habitats or species exist there are ways to still project work. For example, the Town of Carver in cooperation with the U.S. Army Corps of Engineers (USACE) identified wetlands between the ROW site and the nearby wastewater treatment plant that offered the closest grid connection. The town worked closely with a local conservation group to ensure that the least amount of impact. A conduit for the solar array to the utility meter used a directional drill that went underneath the wetlands, serving as a “remarkable mitigation”, and resulting in no disturbance to the wetlands.

The Carver site also discovered a historic and important cultural Native American trail that traversed the site and needed to be protected. Carver’s planning staff worked with local organizations and community members by limiting access and potential impacts to the site and ultimately safeguarding the historical pathway.

Forest resources and wildlife corridors are additional considerations. Heavily forested sites are certainly not ideal for siting but in certain contexts, thinning or cutting down a handful of trees in order to site a project could be considered appropriate, particularly given the effective carbon savings potential of the solar array. Migratory patterns and wildlife corridors should also be evaluated in the site selection process. In most cases, solar arrays represent a minimal amount of impact to wildlife corridors.

7. LIGHT EMITTING DIODE (LED) TECHNOLOGY PRIMER

7.1 Definition and Terminology

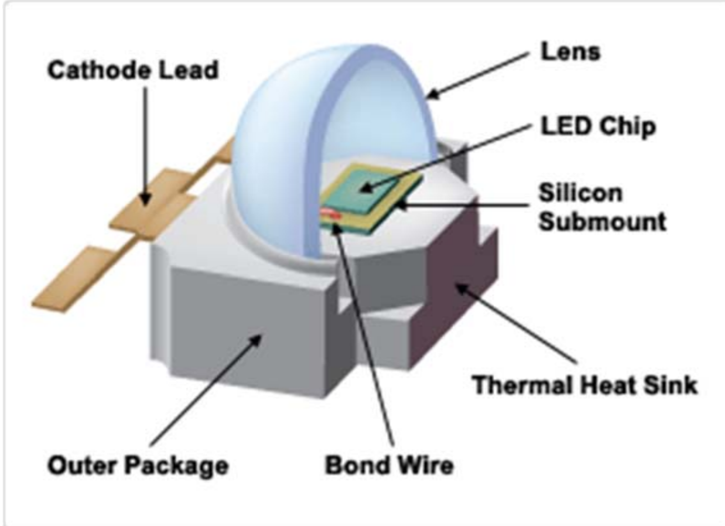
Light Emitting Diodes (LEDs), also referred to as solid-state lighting (SSL), are semiconductor lighting devices that produce light without the use of vacuum or gas tubes. Solid-state refers to light produced by solid-state electroluminescence or the direct passage of electricity through a semiconductor. A luminaire refers to the housing that holds a lamp but in commercial applications, such as roadway lighting it is the lighting fixture.

LEDs are playing a fundamental role in the shift of conventional lighting for commercial and residential building lighting due to significant long-term energy savings while providing high-quality lighting. Recently lighting applications in municipal and roadway lighting are becoming better defined (National Research Council, 2013; Tsao, 2002).

LED Technology Components

LED lights differ in design dependent upon the manufacturer; however, the basic components for a light emitting diode are:

- LED chip
- LED module or package
- Thermal heat sink
- Lens or optics
- Control circuit
- Power supply or driver



Source: Energy Star

Figure 8: LED Parts

LED Chip

The LED chip is comprised of semiconductor layers. These layers produce light when voltage is run through them. Operating ranges, such as luminous flux (lighting power) or the number of lumens, vary depending the number of semiconductor layers (Avrenil, et al., 2012).

LED Module or Package

To function, a LED chip must be enclosed in a LED package that is composed of epoxy, a heat sink, metallic leads and a light reflector. LED modules are the building block of a LED lighting system where multiple LED packages can be combined to produce the desired light.

Thermal Heat Sink

A heat sink allows a LED to remove heat from the module to its immediate surroundings. This prevents the LED module from prematurely burning out. A heat sink is sized accordingly to the properties of the material and the amount of heat that needs to be dissipated. Heat dissipates through conduction (heat transfer from one material to another), convection (heat transfer from a solid to fluid – in this case air) or radiation (heat transfer from two bodies of different surface). Conduction serves as approximately 90% of the heat removal.

Lens or Optics

The LED lens is used to shape the lighting pattern and can be accomplished by lenses or reflectors that channel the light in a specific direction. Also, different lenses can be used to achieve a specific light pattern. A LED module may also include secondary optics to improve focus or intensify light depending on the lighting application.

Control Circuit

The control circuit regulates the flow of current and therefore adjusts the amount of light emitted.

Power Supply or Driver

High-power LEDs cannot be subjected to reverse voltage otherwise they will fail. LEDs therefore should be protected from reverse voltage and should be surge protected for the regulation of current. LEDs require a power supply or driver to convert alternating current power (typical for electrical service) to the appropriate direct current voltage.

Lighting Technology Types

A wide array of lighting technologies exists beyond LEDs and each is used according to the desired lighting application. High intensity discharge (HID) light sources are common in roadway lighting contexts and they include high pressure sodium (HPS) and metal halide (MH) lights. HPS lamps are known for their high lumen ratings and yellowish tint. MH lamps produce fewer lumens than HPS and have a whiter appearance (Avrenil, et al., 2012).

The following is a list of lighting technologies: High-Pressure Sodium (HPS)

- Metal Halide (MH)
- Fluorescent
- LiFi Plasma
- Mercury Vapor

- Incandescent
- Halogen Quartz
- Induction

LED Lighting Advantages and Disadvantages

While the savings of LEDs are important, the challenges of LED lighting are also important to assess before purchasing them. The following table from a FHWA report developed by the Illinois Center for Transportation outlines the positive and negative considerations of a LED luminaire (Avrenil, et al., 2012).

Table 11: Advantages and Disadvantages of LED Luminaires

Advantages	Disadvantages
Energy Efficiency Less energy usage than conventional lighting by as much as 80%	**Luminous Efficacy (amount of light to energy provided)** In some cases LEDs are less than or equal to luminous efficacy in comparison to HID lighting
Longer Lamp Life LED luminaires last longer than alternative option i.e. lumen decline occurs on a longer time frame	**Heat Conversion Rate** Thermal management of LEDs can be a challenge as heat is primarily lost through conduction
Color Quality LED light renders a color temperature that leads to greater accuracy of an object's actual color	**Labor Installation Cost** LEDS cost from $500 to $1000 to initally install each versus $100 to $250 per HPS lighting fixture
Better Visibility by Human Eye Color spectrum of LEDs may allow the human eye to visually see the light more clearly	**Issues in Obtaining White Light** LEDs require manipulation (via manufacturer or buyer) to obtain white light through conversion methods unlike incandescent lighting
Lack of Warm-Up Time Conventional lights require time reach full brightness, which is not the case with LEDs	**Use of LED Module Arrays** Generally a number of LED chips need to integrated into one lighting package to meet requirements
Compact Size LEDs are smaller in size to their counterparts allowing for flexiblity in form and design	
Directional Light - Reduced Light Pollution LEDs offer greater directional control of light thereby meeting regulations and avoiding light trespass (light loss, pollution)	
Environmental Benefits LEDs are free of mercury, lead and also contribute to a reduction in GHG emissions	
Dimming Capabilities LEDs can be dimmed to save energy during timeframes of low road usage. Dimming can be programmed remotely from a state DOT office	
Breakage and Vibration Resistance LEDs do not have fragile components such as filament, arc tube or glass that are more susceptible to breakage	

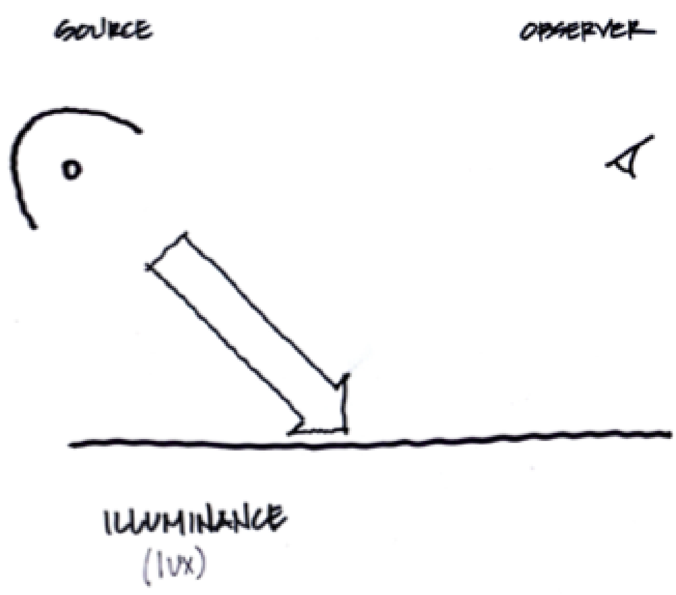
Source: Avrenil, et al., 2012

Lighting Terminology

Illuminance and luminance are the two principal forms of designing and measuring light in the roadway lighting context. The AASHTO Roadway Lighting Design Guide permits either the illuminance technique or the luminance technique to be used for highway lighting design. FDOT chooses to use illuminance technique for lighting designs (Chester Henson, Florida DOT, personal communication 2013).

Illuminance for Design

Illuminance is the measure of concentrated light incidence on a surface (e.g., pavement). Illuminance is measured in lux (lx) and indicates the number of lumens per square meter and lumens per square foot are referred to as footcandles (fc) (National Research Council, 2013). For example, FDOT's design standards, for conventional lighting luminance are 1-2.5 horizontal footcandles (HFC) depending on the roadway classification (e.g., interstate, bicycle lane). The following diagram illustrates the perspective of measuring lux on the lighting surface.

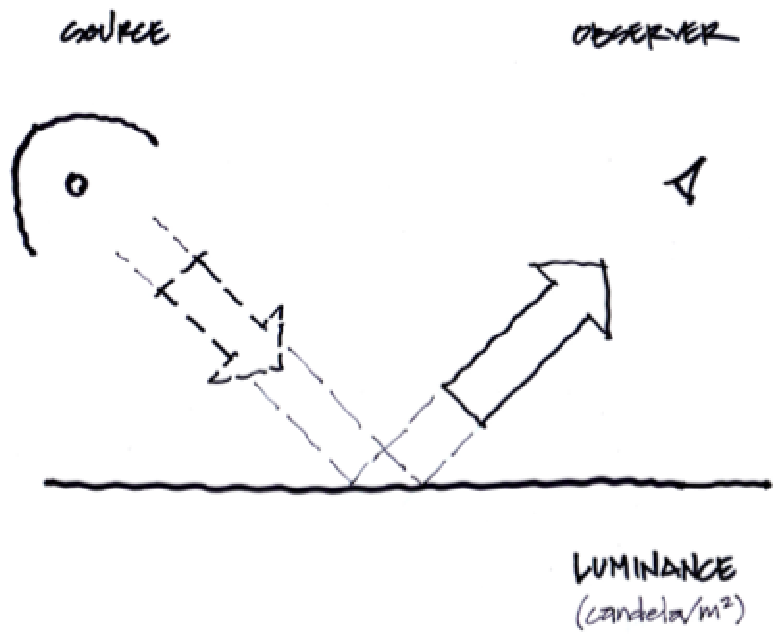


Source: Clanton, 2012

Figure 9: Illuminance Diagram

Luminance for Measurement

Luminance is the measure of reflected light from the pavement surface that is visible to the human eye. This measurement technique is more complex and requires knowledge of the reflective characteristics of the surface including how those reflective characteristics of the pavement change over time and vary with weather conditions. As a result, FDOT chooses not to use this design measurement standard. The following diagram illustrates the perspective of the observer and the light reflected off of the lighting surface.



Source: Clanton, 2012

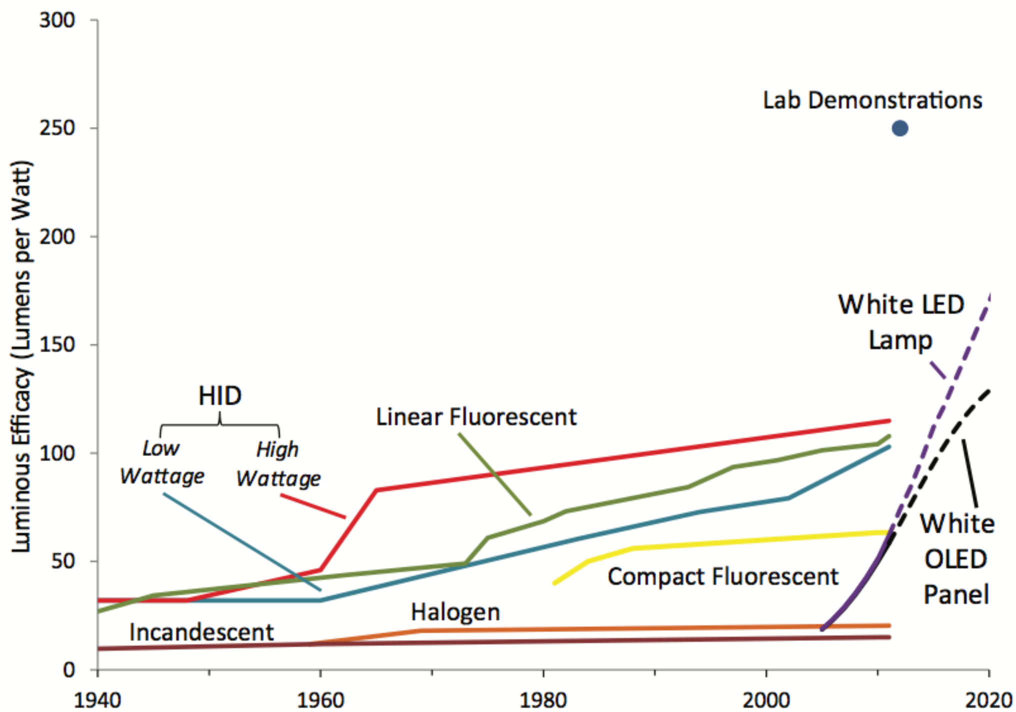
Figure 10: Luminance Diagram

Luminous Efficacy Comparison

Luminous Efficacy

Luminous efficacy is essentially the amount of light a light source produces given a certain amount of energy. In order to calculate luminous efficacy, divide total luminous flux of the lighting technology (e.g., LED) by the lamp wattage (in lumens per watt).

The following graph illustrates different lighting technologies and their technological advancements in luminous efficacy from 1940 to forecasted technological advancements in 2020. Luminous efficacy is ability to deliver the same amount of light using less electricity and is the main factor in LEDs starting to outpace rival technologies. Continued advancements in LED technology will only improve efficacy rates.



Source: National Research Council, 2013

Figure 11: Lighting Efficacy by Lighting Technology

7.2 LED Roadway Applications

The highway right-of-way is just one of the sites where state DOTs are installing LED luminaires. Rest area buildings, parking lots, maintenance and district offices are also upgrading to interior and exterior LED lighting. It is important to match LED lighting technology with the correct application and ensure that the replacing LED lighting technology meets technical criteria as well as viable energy savings and relamping prioritization.

Three main lighting applications exist within the highway ROW including:

- Conventional lighting (high pressure sodium)
- High mast lighting (high pressure sodium)
- Sign lighting (induction)

Conventional Lighting

Conventional lighting most commonly includes lighting poles between 30 to 50 feet tall with a luminaire and bracket arm. The arm generally places the light directly over the travel lane. Conventional lighting installation and maintenance generally require a shoulder closure and in some cases a lane closure (Texas DOT, 2003).

High Mast Lighting

High mast lighting is used principally where continuous lighting is desirable, such as:

- Interchange lighting,
- Lighting of toll plazas,
- Rest areas and parking areas,
- General area lighting,
- Continuous lighting on highways having wide cross-sections and a large number of traffic lanes.

LED high mast lighting is beginning to demonstrate the technical robustness necessary for more broad application. Both Maine and Idaho have installed high mast LED lighting at interstate interchanges. LED high mast lighting initially seemed unlikely because HPS lighting is capable of greater luminance from taller fixtures. High mast lighting fixtures are generally 60 to 100 feet in height and in some cases 250 feet. Energy savings were a key driver of implementation but took second place to meeting the technical requirements. Both Maine and Idaho have demonstrated that the LED lights are functional and meet design and safety standards and this will undoubtedly lead to more state DOTs using high mast lighting at interchange locations.

Some state DOTs are deciding to use high mast lighting in place of conventional lighting particularly in high traffic areas. Maintaining conventional lighting installations require the use of a bucket truck and often times require extensive traffic control, including lane closures. For many high mast lighting locations maintenance often only requires one or two people and a pickup truck as the light assembly can be lowered to be serviced. This reduces risks involved with having personnel working near high-speed traffic.

Induction Lighting

Induction lighting is used primarily for sign illumination. One of the main benefits of induction lighting is that it has a long-life, reducing the need for maintenance. Some state DOTs have relamped signs but strongly advise that the lights (which are more efficient than HPS) be replaced at the end of their useful life (Bowen, 2013).

7.3 Common Business Models and Incentives

Business Models

State DOT Funded

To date, most LED replacements or new lighting construction has been funded internally within state DOT budgets. This pathway is easier in terms of resources and time involved in financial acquisition and the number of parties needed to engage; however it is limited by the current state DOT budget.

Partnerships

In the case of shared ROW, state DOTs partner with local municipalities or utilities that fund the lighting infrastructure, installations and maintenance. This funding route allows state DOTs to effectively install more lights in roadway contexts without spending internal state DOT budgets.

Energy Services Performance Contract

An energy savings performance contract (ESPC) is an agreement between a state DOT and an energy services company (ESCO). An ESCO provides the up-front financing necessary for the project and receives payment for its contribution with regular payments based on the resulting energy savings. An ESPC agreement negotiates which party is responsible for lighting maintenance over the term of the agreement. ESPCs have an established record of being used in the federal sector for energy efficiency projects.

Financial Incentives

Financial incentives for lighting energy efficiency projects in the highway roadway are limited. Most rebate and grant programs target commercial building upgrades and generally interior lighting projects. Local utilities do offer programs but these publicized opportunities generally do not reference state agencies.

The following three resources provide updated information on energy grants by state:

- U.S. Department of Energy: Federal Energy Management Program http://www1.eere.energy.gov/femp/financing/eip_fl.html
- U.S. Department of Energy – grants database http://energy.gov/savings
- Database of State Incentives for Renewables and Efficiency (DSIRE) http://www.dsireusa.org/incentives/index.cfm?re=0andee=0andspv=0andst=0andsrp=1andstate=FL

7.4 Further Documents to Review

Ongoing Research

- Federal Highway Administration: "Evaluation of Adaptive Lighting on Roadways", expected end date August 28, 2013. Research lead: Craig Thor, 202-493-3338, craig.thor@dot.gov http://www.fhwa.dot.gov/research/tfhrc/projects/projectsdb/projectdetails.cfm?projectid=FHWA-PROJ-11-0059
- NCHRP 20-07/Task 305: "Analysis of New Highway Lighting Technologies", expected delivery June 2013, Principal Investigator: John D. Bullough http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3069

Lighting Report

- Avrenli, K., Benekohal, R., and Medina, J. 2012. LED Roadway Lighting, Volume 1: Background Information. Illinois Center for Transportation: Urbana, IL. Available at http://ict.illinois.edu/publications/report%20files/FHWA-ICT-12-012.pdf.
- Avrenli, K., Benekohal, R., and Medina, J. 2012. LED Roadway Lighting Volume 2: Field Evaluations and Software Comparisons. Illinois Center for Transportation: Urbana, IL. Available at http://ict.illinois.edu/publications/report%20files/FHWA-ICT-12-013.pdf.
- Kinzey, B.R. and Myer, M.A. 2009. Demonstration Assessment of Light-Emitting Diode (LED) Roadway Lighting at the I-35W Bridge, Minneapolis, MN. Pacific Northwest National Laboratory for the U.S. Department of Transportation: Washington, D.C. Available at http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/gateway_i-35w-bridge.pdf.

Lighting Specifications

- Minnesota DOT. 2013. MN/DOT Specification Light Emitting Diode (LED) Luminaire For Roadway Lighting at a Mounting Height of 40 feet. Available at http://www.dot.state.mn.us/products/roadwaylighting/pdf/40%20Foot%20LED%20Spec03202013.pdf.

- Minnesota DOT. 2013. MN/DOT Specification Light Emitting Diode (LED) Luminaire For Roadway Lighting at a Mounting Height of 49 Feet. Available at http://www.dot.state.mn.us/products/roadwaylighting/pdf/49%20Foot%20LED%20Spec%2003202013.pdf.

Additional ESCO Context in Florida

- Energy Services Coalition: *http://www.energyservicescoalition.org/chapters/FL/resources.htm*
- Florida Department of Management Services

  http://www.dms.myflorida.com/business_operations/real_estate_development_management/facilities_management/sustainable_buildings_and_energy_initiatives

8. CASE STUDIES: *LIGHT EMITTING DIODE (LED) – SOLID STATE LIGHTING IN THE HIGHWAY RIGHT-OF-WAY*

8.1 LEDs in State DOT Context

FDOT is poised to implement LED roadway lighting as a common practice on Florida's highways and roadway. Similar to other state Departments of Transportation (DOTs), Florida faces funding concerns with decreasing federal and state highway revenues, and increasing costs of expanding, maintaining, and operating an aging, often congested, highway system. Roadway lighting represents a significant contribution to overall energy usage and agency costs. To mitigate the impacts of decreased funding and increased demands and costs, LED lighting offers a straightforward opportunity to reduce energy costs. Several state DOTs already have demonstrated and implemented LED lighting to replace traditional High Intensity Discharge (HID) lighting (typically metal halide or high pressure sodium). The principal reasons for this shift to LEDs are a longer product life and reduced energy consumption in comparison to traditional HID lights. Even with higher initial equipment and installation costs, LED lights offer substantial savings and relatively short payback periods.

8.2 Lessons Learned

LEDs are in their infancy in the highway ROW application. LEDs in this context, however, are ready to follow a similar trajectory as the municipal lighting scale and will likely be adopted widely. State DOTs recognize the benefits of energy savings and expect LED technology to continue to improve both in functionality and cost. Two case study state DOTs purchased LED lighting from Cooper Lighting and Philip Color Kinetics. These LED manufacturers among others will continue to improve their product offerings for roadway application. All state DOTs generally believe that there are little or no downside safety risks to using LED lighting and a newly created AASHTO committee will be updating the Roadway lighting Design Guide and LEDs are expected to be included specifically. State DOTs have much to learn from their peers that are embarking on similar projects to learn about the design applications but also in choosing the manufacturer that can match the appropriate LED option for the lighting context. LEDs are continuing to undergo significant improvements implying the need for reviewing the most current product offerings.

In summary, LED lighting in the highway ROW can largely offer the same amount of light using less electricity, less maintenance and can offer a number of unique applications such as dimming that can both positively impact state DOT budgets and lighting for all users.

Consider

- **Precedence/Mature Technology –** FDOT is not alone in its implementation and evaluation of LED roadway lighting as tens of state DOTs are involved in the same process. Significant adoption of street lighting in cities and towns across the country also provides extensive demonstration of the technology.
- **Fewer Implementation Obstacles –** Unlike other alternative income streams or cost savings projects, LEDs represent a process with fewer stakeholders, steps involved in the process, and overall barriers to implementation.
- **Custom and Adaptive Technology –** LED technology has developed and continues to develop niche lighting capabilities for the roadway context (e.g., high mast lighting) as well as adaptive technology (e.g., dimming) that can save even more costs and bring additional benefits/features.

Motivations

LED lighting implementation is driven by a number of considerations including the following influencing factors:

- **Financially Viable –** LEDs demonstrate variable cost savings over existing lighting, but generally payback initial upfront costs within 5 to 7 years. LED useful life (depending on the number of hours used daily) generally last longer ten years in traditional lighting situations. Many LED manufacturers offer retrofit kits, which allow the state DOT to simply replace the light rather than the housing, poles, etc. avoiding an additional cost of fixture replacement.

- **Improved Safety for Maintenance Staff and the Public -–** LEDs last longer thereby reducing incidents of lighting outages and maintenance costs associated with relamping. Less maintenance and replacement results in safer conditions for maintenance staff and drivers. Adaptive technology functionality allows real-time management allowing for state DOTs to monitor equipment resulting in fewer lighting complications.
- **Environmental Impact –** LED roadway lighting can lead to significant reductions in electricity consumption and associated greenhouse gas emissions and therefore represents a measurable, effective environmental performance improvement.

Key Stakeholders

Usually, a state DOT has all of the technical expertise internally to develop a LED lighting project. The following are potential roles and stakeholders involved depending on the context of the project:

- DOT lighting specialists and district design engineer
- DOT maintenance personnel
- DOT agency director
- DOT finance and budgeting department
- LED manufacturers
- Local government partners
- Local utilities
- Energy Services Companies (ESCOs)
- Communities

State DOT personnel in design, engineering, maintenance as well as the agency director and budget department are essential contributors. For FDOT, Chester Henson, State Traffic Standards Engineer, is the lead for LED lighting projects and standards and serves a critical project role. Depending on the business model and funding strategy, a state DOT may choose to involve a local government entity (e.g., municipality), utility or ESCO in project development.

Product Functionality and Regulations

State DOTs have developed individualized technical specifications for LED lighting dependent upon lighting application (e.g., conventional, high mast). FDOT's Chester Henson has facilitated the design specifications for LEDs in the absence of AASHTO design standards. It is expected that AASHTO will provide these standards in time as they have formed a committee to address this specification.

Business Model

State DOTs can choose from three primary options for business and funding models including:

- State DOT owned – funded through internal state DOT budget
- Partnership – utility or local government entity partners with state DOT and provides initial project capital
- Energy Services Performance Contract (ESPC) – The ESCO covers upfront costs and is paid back through monthly or annual energy savings

Choosing an appropriate business model is largely a consequence of the specific context of the project (e.g., site location, project type). Funding availability internally within the state DOT and potential partners is also a key driver to business model selection.

Financial Analysis

Financial viability of the project, particularly agency cost reductions, is a primary rationale for replacing traditional lights with LEDs. Financial analysis should be tailored to the lighting application accounting for specific design guidelines, equipment and maintenance costs, as well as factors that might imply higher costs (e.g., additional light pole installations). This analysis can be completed internally with the assistance of state DOT staff and information provided by LED manufacturers.

LED State DOT Projects

LED installations are a viable option for state DOTs to pursue. Indeed FDOT has already implemented its first roadway LED project in the City of Gulf Stream in partnership with the local electric utility Gulf Power. The following table shares some highlights of the experience of other state DOT that have implemented LED projects. In addition to those listed here, Illinois, North Carolina, Massachusetts, Colorado and Minnesota Department of Energy have developed or are implementing LEDs into the highway right-of-way.

Table 12: LED State DOT Projects

Organization	Contact/Role	Project	Business Model
FDOT	Chester Henson, P.E. State Traffic Standards Engineer 850-414-4117 chester.henson@dot.state.fl.us	- City of Gulf Breeze - replacement of 4,000 feet of lightings on U.S. 98; expected to increase uniformity of light and ultimately reduce pedestrian and bicyclist mortalities	- FDOT partnership with utility and City of Gulf Stream
WSDOT	Keith Calais HQ Traffic Design 360-705-6986 CalaisK@wsdot.wa.gov	- Olympia US -101 - replacement of 88 lights; 15 year lifespan; dimming controls technology; reduce energy usage by 1.7 million kilowatt-hours of electricity and save more than $75,000	- Internal state DOT funded project
Michigan DOT	Brian Baratono, P.E., LEED,AP Statewide Electrical Engineer 517-373-0733 BaratonoB@michigan.gov	- Interstate 696 - replacement of 350 400-watt high pressure sodium lights with Electro-Matic AP Series Solid State LED luminaries	- Internal state DOT funded project (maintenance and construction budget) - Contracted out installation
Maine DOT	Ron Cote Electrical Supervisor 207–624–3602 / 446-2305 ron.cote@maine.gov	I-295 project - high mast demonstration project of Global Tech luminaires - LED uses 600W in comparison to 1200 W HPS fixture and would save $315 per light annually.	- Internal state DOT funded project; state credits

Source: Author Research and Phone Interviews

8.3 Motivations

Replacement of roadway lighting Implementation of LED lighting by state DOTs is driven by a combination of factors including

- Cost and energy savings
- Improved safety

- Environmental performance
- Technology maturation and precedents

Cost and Energy Savings

Cost and energy savings are the advantages most widely cited by interviewees. Past and current U.S. Department of Energy (US-DOE) and Federal Highway Administration (FHWA) research assessed the comparable energy savings in comparison to traditional technologies and found that LEDs are viable at present and will only improve their savings potential as this breakthrough technology continues to evolve. As an example, Philips announced in April 2013 that it is has recently discovered how to double the luminous efficacy of household LED lights (200 lumens/watt) in comparison to 100 lumen/watt fluorescent light technology. Lighting technology improvements from conventional household and commercial technology applications will certainly change the roadway lighting practices (Hower, 2013).

Improved Safety

LED lighting not only uses less energy than conventional lighting technologies but also have substantially longer product lifespans. As a result, LED lighting has several safety advantages over conventional lighting. Since LED lights are less likely to fail drivers are less likely to encounter dark areas that are usually lit, even for short periods of time, reducing the potential of vehicle accidents. Lighting replacement and maintenance can involve lane restrictions or closures, impacting traffic flow and requiring drivers to take action to accommodate the restrictions or closures. Also replacing lights requires elevated work for maintenance workers and exposure to traffic hazards– even with proper safety controls. While procedures are in place to make the work safe, reducing the amount of higher risk maintenance work is safer. Maintenance intervals differ product to product. On average a LED light will last between 50,000-100,000 hours while mercury, metal halide and HPS street lamps last approximately 10,000, 22,000 and 24,000 hours, respectively (Avrenil, et al., 2012).

Environmental Performance

Few interviewees mentioned environmental performance directly as a primary benefit. Communicating the switch to LEDs is an opportunity to message the importance of energy savings as an environmental benefit as much as it is a cost saving measure. Energy efficiency is often overlooked for its role in mitigating and reducing an organization's carbon footprint. The US DOE completed a life-cycle assessment of LED lighting and its role in reducing environmental contamination (e.g., mercury, lead and greenhouse gas emissions) as well as reducing environmental impacts through its energy savings features and can be referred to for public or internal communications (Navigant Consulting, 2012).

Technology Maturation and Precedence

One of the main reasons for the widespread state DOT movement to LEDs is due to previous efforts of municipalities across the country. Cities throughout the U.S. have installed hundreds of thousands of LED lights, a practice that will likely continue for years to come as the legacy lighting system is upgraded. Seattle, Los Angeles and New York are notable examples. Demonstrating the technology on a large scale has allowed the technology to be vetted and continue the process of improvement needed to fit in the highway ROW context. Not only have state DOTs learned from municipalities but also they are paying attention to other state DOT experiences to guide their decision making process.

FDOT Example: Gulf Power

Finding a solution to the high pedestrian and bicyclist fatality rate along one section of US 98 drove FDOT's initial foray into a LED highway ROW project. FDOT began work on a design in collaboration with Gulf Power, the local electricity provider, and during that process a preference for LED luminaires emerged. Further stakeholder discussion resulted in LED lighting being chosen for its higher density light pattern providing a more uniform light thereby enhancing safety.

8.4 Key Stakeholders

Highway LED replacement will generally involve fewer stakeholders than many other alternative income stream ROW projects, such as revenue generating projects. LED installation or retrofit projects can be completed within the state DOT without having to undergo significant project development time and complications such as public process.

That said, advance communication of the change is recommended to support a more comfortable transition to the new nighttime driving experience.

Key project partners:

- DOT lighting specialists and district design engineer
- Maintenance office personnel
- DOT finance and budgeting department
- LED manufacturers
- Local utilities
- Energy Services Companies (ESCOs)
- Communities

Internal State DOT Personnel

Internal capacity to complete the project relies heavily on lighting specialists and design engineers. Chester Henson, FDOT's State Traffic Standards Engineer, is leading the LED effort at FDOT and has extensive knowledge of the technology, design standards and ongoing efforts in other states through his participation in the Municipal Solid-State Street Lighting Consortium (MSSLC).

In-house personnel at a state DOT are essential in determining phasing of lighting replacement, location prioritization and funding mechanisms. The state DOT budgeting office plays a role in defining how best to approach lighting replacement, the scale of replacements possible and the phasing of that work.

Utility and Local Government

In some circumstances, it may be the utility or local government that collaborates to determine a financing structure, as was the case Gulf Breeze project. LED manufacturers are also very interested in continuing to improve highway lighting applications because they provide a significant market for their products.

Additional resources and potential partners:

- Other state DOTs
- U.S. Department of Energy (USDOE)
- Pacific Northwest National Laboratories (PNNL)

Other state DOTs might be one of the best sources for information with respect to design specifications, vendor selection, functionality and financing mechanisms. The U.S. Department of Energy (USDOE) has played a similar, crucial role by bringing municipal stakeholders together to develop both the necessary technical understanding but also to develop a national community of municipalities that can share best practices and lessons. Pacific Northwest National Laboratories (PNNL) is a federally funded research agency that has done considerable work in understanding both the technology and market dynamics for LED solid-state lighting and their specialists can provide important context for certain design applications. These stakeholders are not necessary to develop a project but they can provide essential insights that can lead to greater success. A list of program officers at PNNL is included in the Appendix.

8.5 Product Standards and Regulations

Design Manuals and Lighting Spectrum

Highway and bridge lighting is largely guided by American Association of Highway and State Transportation officials (AASHTO) standards. Lighting guidance is contained in the AASHTO Road Design Guide (Green Book), AASHTO Roadside Design Guide, and AASHTO Roadway Lighting Design Guide. To date, none of these manuals has included specifications for LED lighting; rather these guides set standards for illuminance and luminance – regardless of the light source.

Lighting Regulations

Less efficient lighting is being phased out of the consumer sector by regulation. The Energy Independence and Security Act (EISA) of 2007 required a 65% reduction in energy use by 2020. This act did not deny the use of incandescent bulbs but instead required an efficiency threshold that incandescent bulbs could not achieve. To date, no regulations in the U.S. require that municipalities or government agencies choose LED technology over traditional options. However, given state and community energy efficiency targets, regulation may be instituted to require certain efficiency thresholds to be met in the lighting sector.

FDOT Lighting Specifications

In Florida, highway lighting specifications are outlined in the Plans Preparation Manual in Volume I in chapters 2 and 7 with horizontal clearance described for lighting poles in chapter 2 and lighting design criteria in chapter 7. Design criteria for conventional, high-mast and sign lighting are listed in the tables below.

Table 13: Conventional Lighting Design Criteria

Roadway Classifications	Illumination Level - Average Initial Horizontal Foot Candle (H.F.C.)	Uniformity Ratios		Veiling Luminance Ratio
		L avg./L min	L max./L min	Lv max/L avg.
Interstate, Expressway, Freeway & Major Arterials	1.5	4:1 or less	10:1 or less	0.3:1 or less
All Other Roadways	1	4:1 or less	10:1 or less	0.3:1 or less
Pedestrian and Bicycle Lanes	2.5	4:1 or less	10:1 or less	--

Source: Henson, 2012.

Table 14: High-Mast Lighting Design Criteria

Roadway Classifications	Illumination Level - Average Initial Horizontal Foot Candle	Uniformity Ratios	
		L avg./L min	L max./L min
Interstate, Expressway, Freeway & Major Arterials	0.8 to 1.0	4:1 or less	10:1 or less
All Other Roadways	0.8 to 1.0	4:1 or less	10:1 or less

Source: Henson, 2012.

Table 15: Sign Lighting Design Criteria

Ambient Luminance	Illumination Level - Average Initial Horizontal Foot Candle (H.F.C.)	Uniformity Ratios
		Max./Min.
Low	15-20	6:1
Medium and High	25-35	6:1

Source: Henson, 2012.

Other State DOT LED Lighting Specifications

Minnesota DOT (MnDOT) has published conventional LED luminaire specifications for 40 and 49 feet (Minnesota DOT, 2013a, 2013b). The specifications cover listing requirements, lighting housing, lighting requirements, LED performance requirements, optical requirement, luminaire performance, warranty and minimum required submittals and state DOT acceptance testing. For example, a LED replacement of a 250W HPS luminaire at 40 ft. installation would need to meet the following requirements:

- Use ANSI/IES RP8-00, American National Standard Practice for Roadway Lighting
- Be mounted on one side of the roadway in order to light two 12 foot wide lanes and maintain a 23 foot setback from fog line (i.e., right edge of driving lane)
- Mounted on a davit extending 9 feet from the pole towards the roadway and mounted on poles spaced at 250 feet
- Light from luminaires placed on the opposite side of the roadway will not be included in any light level calculations.

Table 16: MnDOT LED Approved Manufacturers for 40-Foot Installation

LED Luminaires For Roadway Use Mounted at 40 Feet 250 Watt HPS Replacement Operating Voltage Range of 120 through 277 Volts AC or 120 through 240 Volts AC			
Product	**Manufacturer**	**Manufacturer Address**	**Approval Date**
Autobahn Series ATB2 LED Roadway: ATB2 60BLEDE10 MVOLT R3 NL NR	American Electric Lighting	P.O. Box A Conyers, GA 30012	10/31/2012 Light Loss Factor = .77
NAVION NVN: NVN AA 04 E U SL2 10K U AP MNDOT	Cooper Lighting	1121Highway 74 South Peachtree City,GA 30269	03/11/2013 Light Loss Factor = .86
Satellite Series SAT-M: SAT 96M 0 S T2 600 GY 3 A UL	http://www.ledroadwaylighting.com/	115 Chain Lake Drive Halifax, Nova Scotia Canada B3S 1B3	01/16/2013 Light Loss Factor = .75
Roadview LED Series RVM: RVM 190W112LED4K R LE2 UNIV API GY3	http://www.usa.lighting.philips.com/	3000 Minuteman Road M/S 109 Andover, MA 01810	03/06/2013 Light Loss Factor = .82

Source: Minnesota DOT, http://www.dot.state.mn.us/products/roadwaylighting/ledroadway.html

Table 17: MnDOT LED Approved Manufacturers for 49-Foot Installation

LED Luminaires For Roadway Use Mounted at 49 Feet 400 Watt HPS Replacement Operating Voltage Range of 120 through 277 Volts AC or 120 through 240 Volts AC			
Product	**Manufacturer**	**Manufacturer Address**	**Approval Date**
Autobahn Series ATB2 LED Roadway: ATB2 80BLEDE10 MVOLT R3 NL NR	American Electric Lighting	P.O. Box A Conyers, GA 30012	03/15/2013 Light Loss Factor = .77
NAVION NVN: NVN AA 06 E U SL2 10K U AP MNDOT	Cooper Lighting	1121Highway 74 South Peachtree City,GA 30269	03/15/2013 Light Loss Factor = .86
Roadview LED Series RVM: RVM 215W128LED4K R LE2 UNIV API GY3	http://www.usa.lighting.philips.com/	3000 Minuteman Road M/S 109 Andover, MA 01810	04/19/2013 Light Loss Factor = .81

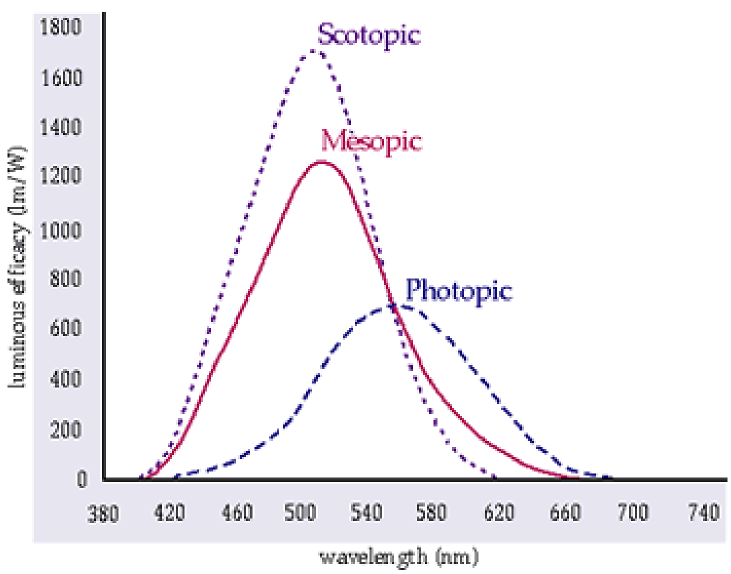
Source: Minnesota DOT, http://www.dot.state.mn.us/products/roadwaylighting/ledroadway.html

LEDs Conducive to Human Vision

LEDs offer the potential for improved lighting for drivers. Although still in the research phase, efforts are underway to better understand how the human eye sees in low light conditions and how LED technology may be able to provide a particular spectrum (4,000 to 6,000 Kelvin) that is more conducive to the human eye. At night or in low light conditions, the human eye switches to scotopic vision, and the human eye may respond better to the LED spectrum (Chester Henson, Florida DOT, personal communication, 2013).

Phototopic, mesopic and scotopic vision are three wavelengths of the human eye based on different ranges of luminous efficacy.

- Photopic is the human eye's vision in well-lit conditions
- Scotopic is human eye's vision under low light conditions
- Mesopic is the human eye's vision in conditions that are low lit but not quite dark



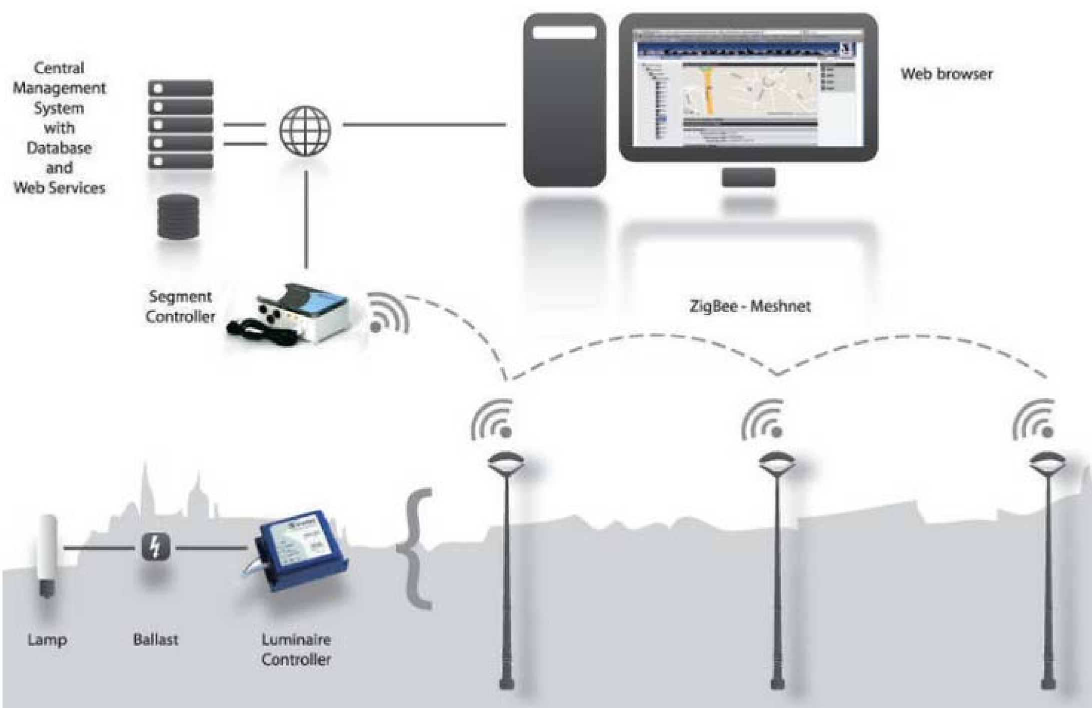
Source: Lighting Research Center, http://www.lrc.rpi.edu/programs/Futures/LF-auto/roadway.asp

Figure 12: Wavelengths and Luminous Efficacy of Phototopic, Mesopic and Scotopic Vision

Opportunities and Challenges

Opportunity: Adaptive Technology

LED luminaires offer additional characteristics beyond lighting superiority. LEDs can be combined with other technologies (e.g., wireless networking) to increase savings and performance and lighting manufacturers continue to develop additional functionality and value added features. Wireless networking is one beneficial feature that connects LED lights to a network allowing the maintenance office to manage lights in real-time (e.g., monitor functionality). Additionally, this connectivity permits operators to dim or turn off lighting, which could be helpful during certain times of the day when less lighting is required. WSDOT is using this adaptive system by adjusting conventional lighting levels during low traffic periods. WSDOT has also used adaptive technology to program multiple LED signs remotely rather than having to program each sign in person. Camera and audio recognition technology, another embedded feature being developed by LED manufacturers, allows site monitoring that may improve emergency response time (e.g., higher vehicle crash sites).



Source: ThomasNet News, *http://news.thomasnet.com/fullstory/Wireless-Lighting-Controls-suit-urban-outdoor-environments-578314*

Figure 13: Diagram of Adaptive Technology Functionality

Challenge and Response: Hidden costs and need for design variances - City of Gulf Stream

The City of Gulf Stream project on US 98 required reducing the height of the lighting fixtures and arms from the typical 40 to 50 foot elevation to 30 feet to accommodate lighting uniformity. FDOT engineers prioritized uniformity in order to increase safety. In addition to reducing the height of lighting fixtures, auxiliary poles were also required for additional lights. A design variance was required because the 1.0 ft-cd luminescence was below the Florida specification of 1.5 ft-cd for new installations but due to FDOT's focus on light uniformity they were willing to accept lower light levels in exchange for more uniform light.

Challenge and Response: Avoiding Inferior Products

A significant number of LED manufacturers exist and are positioning themselves to sell LEDs to municipalities and government agencies. Not all of these manufacturers maintain the same level of quality. Therefore, one challenge is determining how best to develop a request for proposal that ensures that quality requirements are met. Minnesota Department of Transportation (MnDOT) has developed a LED lighting specification and noted strict criteria on housing, grounding, surge suppression and other technical issues necessary to prevent inferior quality products from being used in LED lighting projects (see Appendix for lighting specifications and links).

8.6 Business Structure

LED lighting does represent a higher upfront cost than traditional lighting options, but the extended life of LEDs allows those costs to be recouped over time and the saving realized. Many state DOTs that have initiated LED projects have funded LED lighting projects from traditional construction and maintenance funds. However, budget constraints do not always allow DOTs to overcome the higher upfront costs and realize the long-term savings. In these circumstances alternative funding options are appropriate.

Conventional Funding

Washington State Example

Washington State DOT relamped a section of highway US 101 west of Olympia using conventional LED lights, replacing High Pressure Sodium (HPS). The project cost $105,000 and was funded entirely with maintenance funds. The project return is anticipated to be a simple payback of less than 5 years with the new LED's life expectancy of more than 10 years. The LEDs did require an additional installation cost in addition to lighting infrastructure. WSDOT's use of the LED's adaptive technology and dimming controls is estimated to save more than $75,000 in maintenance and operations costs and reducing energy usage by more than 1.7 million kilowatt-hours of electricity over the life of the equipment (WSDOT, 2013).

Alternative Funding

Florida Example

In Florida, Gulf Power, a utility company, is providing the upfront financial investment for the lights and billing the City of Gulf Stream (local agency that is responsible with maintaining the particular roadway) a monthly fee. Such a funding structure is already used for other types of lighting. In Florida, a number of cities are charged highway maintenance for roadways in their geographic boundaries. Cities and municipalities could contribute monthly, partially or in full to the initial purchase and installation of the LED lights.

Challenges and Opportunities

Challenge: Upfront Costs of Initial Conversion is 3-5 Times the Cost of Existing Lights

Although some state DOTs have been able to convert to LED lighting projects, other states have been unable to cover the higher, upfront costs required. For example, Arizona DOT (AZDOT) recently considered a LED installation project but deemed that the budget did not allow for the expense – while acknowledging the higher life-cycle costs. DOTs therefore need to be tactical in approach to selecting sites and potentially finding funding sources outside of the state DOT office. State DOTs are generally installing LEDs when existing lighting requires replacement (relamp) or as part of construction projects that would replace or install new lighting and doing so with maintenance funds.

Opportunity: Partnerships

Florida has two unique partnerships that it is already utilizing. In the City of Gulf Stream, FDOT worked with the local utility and community to finance the project. This type of partnership removes the upfront financial cost for the state DOT and allows the local communities to actively participate in these projects. This partnership cannot be used to replace every right-of-way light but an analysis of highway sections where this strategy could be employed would be beneficial. This idea will be developed further in the Feasibility Tool section.

Opportunity: Performance Contracting

Energy Service Companies (ESCOs) are entities that provide the initial capital requirements to make the purchases. ESCOs receive payment (reimbursement) for their upfront capital contribution by taking a monthly portion of energy savings. No state DOT interviewed mentioned using an ESCO. Some utilities offer a similar model that reduces the upfront capital contribution by the customer.

Opportunity: Group Purchasing

The USDOE municipal program (MSSLC) Gateway Program that has brought together municipalities from across the country together to engage them in participating in lighting projects that bring greater energy efficiency and financing savings. MSSLC has been influential in its support of municipalities and in developing more widespread adoption of LED technology and part of that process has been to create group purchasing programs to reduce initial equipment costs. FDOT could benefit from group purchasing internally but the opportunity to combine LED purchases with other state DOTs or maybe municipalities could be an important cost savings driver.

8.7 Financial Analysis

Financial analysis is a key step in the project development process and ascertaining whether a project is feasible. As mentioned previously, there are three main lighting types but there are a wide variety of lighting applications. Lighting technology needs to be matched appropriately from a technical perspective but thorough examination of the financial implications of lighting changes needs to be fully understood in order to perform proper financial analysis. This exercise is more straightforward in other lighting applications, such as interior lighting at rest areas, but conventional or high-mast lighting invite other considerations and associated costs.

Project Costs

Particularly with LED projects, it is important to collect all of the pertinent data and information prior to beginning the financial analysis. LEDs garner significant energy savings attention, and rightly so, but it is important to include all project costs in the analysis, otherwise seemingly small costs can add up quickly when scaled to a large number of lighting fixtures. For instance, initial installation costs need to be appropriately accounted for. Conventional LEDs do require more time in the bucket truck than HPS or MH lights and therefore that additional cost needs to be included. Also time in the ROW and the traffic controls add significant costs to the installation that may not be an issue in other locations.

The following lists project costs that should be included if applicable to the project:

- LED modules
- Lighting fixtures
- Lighting pole retrofit (e.g., lower height) and/or new lighting pole installation
- Initial installation costs of luminaires – maintenance staff or contracted installation
- Ongoing operations and maintenance costs
- Adaptive lighting features – accounting for dimming, wireless monitoring, or initial programming which costs more upfront, but will yield savings over the life of the fixture.

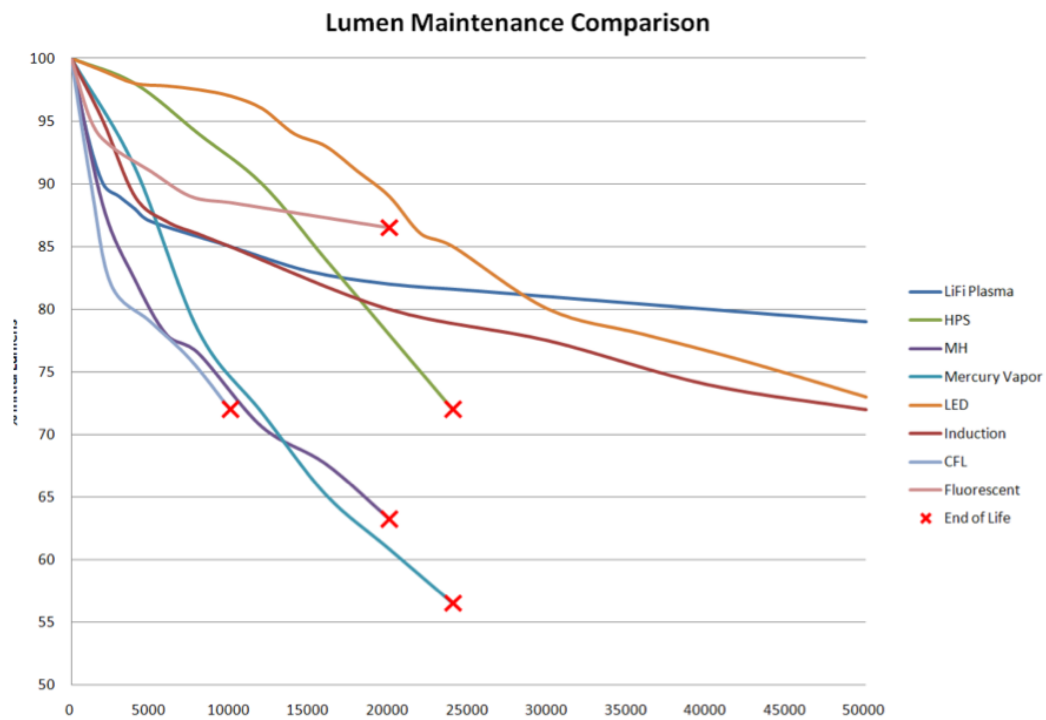
Sources of Cost Savings

LEDs have the potential to scale to a level that translates into significant budget and greenhouse gas emissions savings.

- Energy savings
- Maintenance savings with fewer lighting replacements trips and traffic controls
- Utility rebates

Maintenance Savings

One of the main benefits of LED lighting applications is their longer life in comparison to MH and HPS alternatives. The graph below diagrams the number of hours a lighting technology lasts over time and the functional decline in lumens over that period. LED maintains a longer lumen than its counterpart technologies. LiFi plasma and induction have similar lifespans and lumen depreciation. The longer LED life ensures few replacements thereby reducing lighting maintenance and installation costs, particularly useful in high traffic areas.



Source: Henson, 2012

Figure 14: Comparison of Lighting Technology Lifespan and Maintenance Implications

Financial Modeling Tools

Due to the variety of contexts and technology applications, financial analysis should be tailored to the specific conditions of a site location and not be too formulaic. The analysis itself is not extremely complicated, the complication is ensuring that all information is collected and included. Perhaps one of the best open source, user-friendly lighting resources is the USDOE's retrofit financial analysis tool developed by the DOE's Municipal Solid-State Street Lighting Consortium available at:

http://www1.eere.energy.gov/buildings/ssl/financial-tool.html.

The Illinois Center for Transportation has also published a lighting research report that includes guidance on economic analysis and calculation methods for initial costs, maintenance costs, energy costs, and salvage value (Avrenil, et al., 2012).

Financial Analysis Examples

A number of LED financial analyses can be found in the public domain, yet many of these examples are useful only in their effort to identify and highlight the categories and cost factors required for project. Defining an accurate LED price and attributing realistic maintenance costs are two main considerations for performing an effective analysis. Also it is important consider the number of daily or annual hours that a lighting fixture may use. WSDOT and Maine DOT have performed financial analysis for their respective projects and could provide guidance or lessons learned.

For the purposes of this research, a Pacific Northwest National Laboratory (PNNL) study is used to provide the baseline (Royer, et al. 2012b). As mentioned, in the referenced report, the financial analysis is limited by defining a reasonable LED price, in part because LED prices continue to decline but also this demonstration project purchased a small number of lights and therefore was unable to acquire lights at a competitive price. Secondly, maintenance costs were assumed to be the same as Ceramic Metal Halide (CMH) even though this is most likely a conservative estimate given the longer life of LED lights.

In this case study, the City of Portland, Oregon a simple payback period of 10 years is the threshold the city has developed internally for energy efficiency projects. The PNNL report demonstrated that the project was not feasible under the conditions presented however altering price and maintenance costs changes the financial viability of the project. The following analysis should help to demonstrate the importance of using the most appropriate and relevant cost information in order to correctly calculate the investment and cost reduction potential of a LED project.

Scenarios and Assumptions

Base Assumptions:

- **Lighting** – Compared LEDs with induction, ceramic metal halide (CMH) and high pressure sodium (HPS) lights. Wattages for each lighting technology are referenced in Table 18.
- **Initial Lighting Costs** – Initial lighting costs were based on PNNL study and those costs are provided in Table 18.
- **Annual Energy Cost** – Annual energy costs were referenced from the PNNL study and use established electricity prices (transmission, distribution and energy charges)
- **Maintenance Costs** – Monthly/annual costs of maintenance were referenced from PNNL study, using the utility's monthly established cost for CMH lighting

Scenarios:

- **Scenario 1** – Baseline from PNNL Study
- **Scenario 2** – Lower Maintenance Costs
- **Scenario 3** – Lower LED Prices
- **Scenario 4** – Lower Maintenance Costs and LED Prices

Scenario 1 – Baseline from PNNL Study

Scenario 1 outlines the demonstration project from Cully Boulevard in Portland, Oregon

Table 18: Scenario 1 – Baseline from PNNL Study

Lighting Technology	LED Option #1	LED Option #2	LED Option #3	Induction	CMH	HPS
Initial Luminaire Cost ($)	$604	$679	$619	$625	$632	$137
Total Annual Energy Cost	**$29.36**	**$29.12**	**$25.12**	**$37.29**	**$25.46**	**$46.60**
Measured Input Power (W)	*79*	*79*	*68*	*101*	*69*	*142*
Annual Use (hours)	*4,100*	*4,100*	*4,100*	*4,100*	*4,100*	*4,100*
Energy Use Rate ($/kWh)	*$0.0903*	*$0.0903*	*$0.0903*	*$0.0903*	*$0.0903*	*$0.0903*
Total Annual Maintenance Cost ($)	24.6	24.6	24.6	24.6	24.6	31.0
Annual Cost Savings ($)	23.6	23.8	27.8	15.7	27.5	-
Simple Payback (years)	**19.8**	**22.7**	**17.3**	**31.1**	**18.0**	-

Source: Royer, et al. 2012b

Scenario 2 – Lower Maintenance Costs

Scenario 2 reduces the monthly maintenance costs for LED fixtures from $2.05 per fixture to $1.25 per fixture.

Table 19: Scenario 2 – Lower Maintenance Costs

Lighting Technology	LED Option #1	LED Option #2	LED Option #3	Induction	CMH	HPS
Initial Luminaire Cost ($)	$604	$679	$619	$625	$632	$137
Total Annual Energy Cost	**$29.36**	**$29.12**	**$25.12**	**$37.29**	**$25.46**	**$46.60**
Total Annual Maintenance Cost ($)	15.0	15.0	15.0	24.6	24.6	31.0
Annual Cost Savings ($)	33.2	33.4	37.4	15.7	27.5	-
Simple Payback (years)	**18.2**	**20.3**	**16.5**	**39.9**	**23.0**	-

Source: Royer, et al. 2012b and Analysis by Authors

Scenario 3 – Lower LED Prices

Scenario 3 reduces the initial LED luminaire cost from $604 per unit to $275 based on group purchasing and decreases in LED prices.

Table 20: Scenario 3 – Lower LED Prices

Lighting Technology	LED Option #1	LED Option #2	LED Option #3	Induction	CMH	HPS
Initial Luminaire Cost ($)	$275	$275	$275	$625	$632	$137
Total Annual Energy Cost	**$29.36**	**$29.12**	**$25.12**	**$37.29**	**$25.46**	**$46.60**
Measured Input Power (W)	*79*	*79*	*68*	*101*	*69*	*142*
Annual Use (hours)	*4,100*	*4,100*	*4,100*	*4,100*	*4,100*	*4,100*
Energy Use Rate ($/kWh)	*$0.0903*	*$0.0903*	*$0.0903*	*$0.0903*	*$0.0903*	*$0.0903*
Total Annual Maintenance Cost ($)	24.6	24.6	24.6	24.6	24.6	31.0
Annual Cost Savings ($)	23.6	23.8	27.8	15.7	27.5	-
Simple Payback (years)	**11.7**	**11.5**	**9.9**	**39.9**	**23.0**	-

Source: Royer, et al. 2012b and Analysis by Authors

Scenario 4 – Lower Maintenance Costs and LED Prices

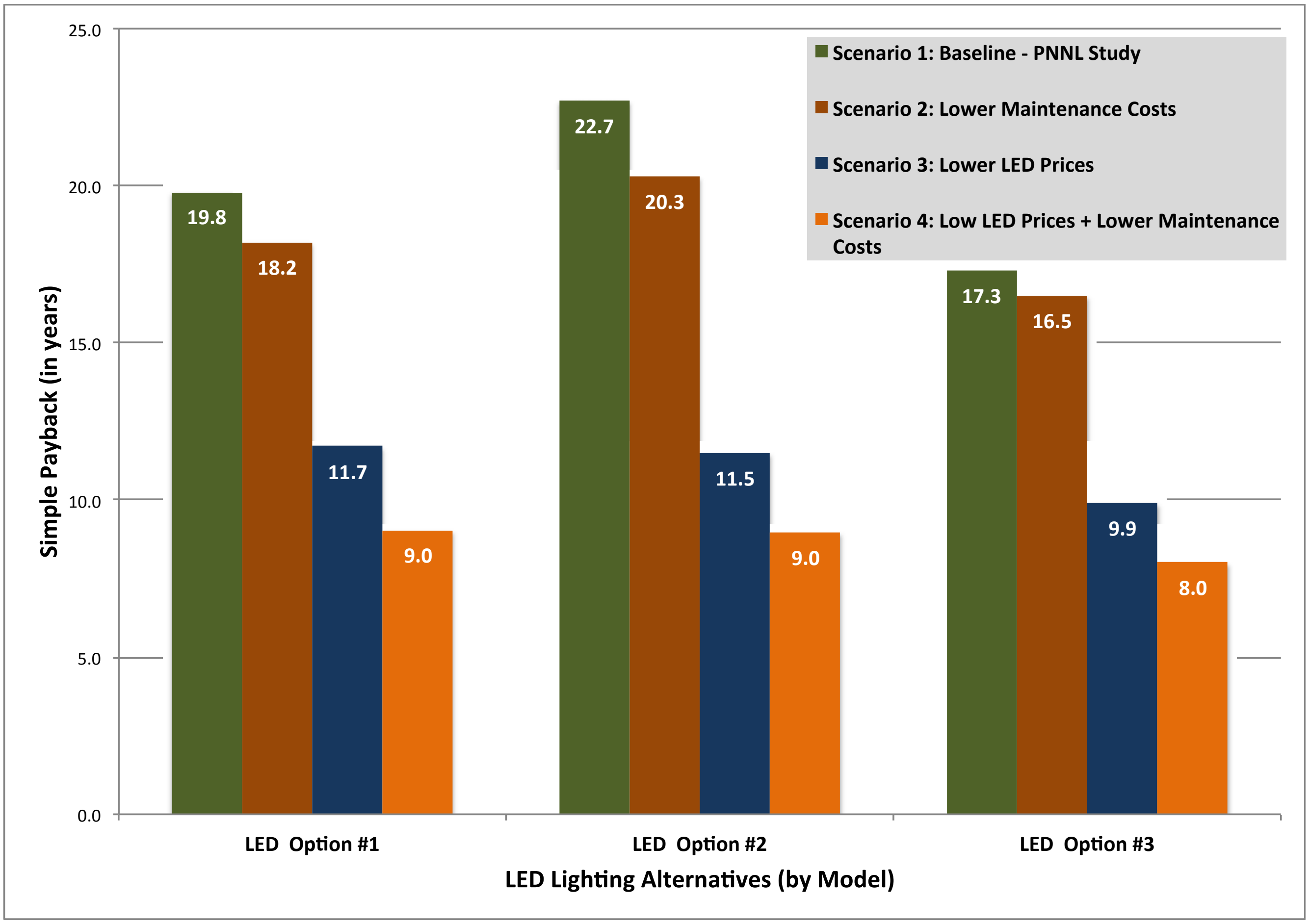
Scenario 4 reduces both monthly maintenance costs and the initial LED luminaire costs.

Table 21: Scenario 4 – Lower Maintenance Costs and LED Prices

Lighting Technology	LED Option #1	LED Option #2	LED Option #3	Induction	CMH	HPS
Initial Luminaire Cost ($)	$300	$300	$300	$625	$632	$137
Total Annual Energy Cost	**$29.36**	**$29.12**	**$25.12**	**$37.29**	**$25.46**	**$46.60**
Total Annual Maintenance Cost ($)	15.0	15.0	15.0	24.6	24.6	31.0
Annual Cost Savings ($)	33.2	33.4	37.4	15.7	27.5	-
Simple Payback (years)	**9.0**	**9.0**	**8.0**	**39.9**	**23.0**	-

Source: Royer, et al. 2012b and Analysis by Authors

The graph below outlines the relative differences in simply payback based upon lower LED prices as well as lower maintenance costs. Based on the PNNL demonstration study a LED project does not make sense at a small scale given relatively high prices. Nor is a LED project as viable if does not provide maintenance savings but the main driver is going to be upfront lighting costs.



Source: Royer, et al. 2012b and Analysis by Authors

Figure 15: Comparison of Scenarios and Simple Payback

9. LED – FEASIBILITY SCREENING TOOL

Note: As of project delivery in June 2013, meeting some of these criteria and project considerations may not be possible given current regulations, design guidelines and geographic context (e.g. AASHTO lighting design guidelines) but these items are subject to change and should be reviewed during initial project evaluation.

		Checklist	Comments/Notes
Motivation	**Project Rationale: Compelling financial and environmental benefits AND/OR Clear guiding policy or directive from leadership**	**Define project motivations:** • Financial savings - Energy savings and decreased frequency of maintenance after re-lamping • Improved safety • Improved illumination and color quality • Use of LED adaptive technologies (e.g., dimming) • Meets agency or state's energy efficiency or GHG emissions goals	**Describe policies, mandates, leadership directives, financial and environmental benefits:** *(e.g., GHG emissions reductions targets in state DOT charter)*
	Key Stakeholders: Supporters and Antagonists	**Identify participant and stakeholders in the process and whether they support or oppose the project:** **Support Oppose** *DOT personnel:* ☐ ☐ State DOT lighting specialists/district design engineer ☐ ☐ State DOT maintenance office personnel ☐ ☐ State DOT finance and budgeting department ☐ ☐ State DOT leadership and project manager *Government agencies - technical support:* ☐ ☐ U.S. Department of Energy (USDOE) ☐ ☐ Pacific Northwest National Laboratories (PNNL) ☐ ☐ Other state DOTs *LED technology and financing:* ☐ ☐ LED manufacturers ☐ Electric utility ☐ ☐ Local or regional government (lamp hosts) Community ☐ Neighbors for light quality/color and changes ☐ Wildlife advocates - some light spectrums need to be adjusted for land creatures (e.g., loggerhead turtles)	**Names, titles and contributions of each supporting stakeholder:** *(e.g., state DOT personnel including maintenance, environmental and business office staff)* **Strategies for managing opposition:** *(e.g., hold public meetings/charettes to share site selection process and benefits of LED lighting project. Light trespass will be reduced in certain circumstances so this may build allies)*

Policy and Regulatory	**Review Status of Policies and Regulations**	**Review applicable policies and regulations for LED projects:** ☐ Review state design lighting standards ☐ Check status/changes to AASHTO's Road Design and Roadway Lighting Design Guide ☐ Check municipal, state or federal level lighting policies for newly created regulations and opportunities to install LEDs	**Describe policies and regulations in their current form and applicability to the project:** *(e.g., AASHTO design guidelines changed in 2014 to specify LED lighting in certain applications)*
Business Structure and Financial Return	**Business Model**	**Choose which of the following business model options to consider:** ☐ State DOT funded through maintenance or other relevant budget item ☐ Obtain funding from utility, municipality, and/or county partners ☐ Energy Services Company (ESCO) invests initial project capital in lighting, state DOT realizes monthly energy savings and pays portion of savings to pay initial ESCO investment	**Analysis of potential business models and their advantages:** *(e.g., partnership model allows the opportunity for project to leverage financial incentives)* **Business model disadvantages:**

Business Structure and Financial Return	**Financing Incentives**	**Assess *current* financial incentives:** **Federal, state or municipal programs:** ☐ Federal rebate ☐ State rebate ☐ Federal grant program ☐ State grant program ☐ Municipal incentive programs **Utility Incentives** ☐ Utility rebates	**List and provide comments for relevant state, federal and utility incentives:** *(e.g. utility rebate program)*
	Financial Analysis	**Develop basic financial analysis to ascertain financial feasiblity and payback of initial investment, paying particular attention to:** ☐ Number and type of lights to be replaced ☐ Comparing useful life of current lighting vs. LED upgrades (in hours or years) ☐ Reduced maintenance fees (LEDs generally require fewer maintenance trips than current lighting systems) ☐ Additional costs (if required, lighting poles may need to be lowered or additional lighting poles may need to be installed to provide proper luminence and uniformity)	**Perform basic financial analysis calculating simple back or retunr on investment to determine whether project is financially feasible for solar developer:** *(e.g. project has a simple payback of 5 years based on a total project cost of $135,000)*
	Purchasing Contract	**Identify purchasing contract components to be addressed:** ☐ Contact other state DOTs to learn about their experiences and worthy LED manufacturers ☐ Consult manufacturers on possibilities for retrofit options versus full lighting replacement ☐ Vet LED manufacturer quality (do not purchase simply on price). ☐ Ensure LED manufacturer offers an adequate warranty ex. 5 years ☐ Assess possibility of group/coordinated purchasing with other agencies/organizations to reduce costs	**Describe contract considerations/challenges:** *(e.g., need agency lawyer to draft contract language to ensure five-year warranty of lights)*

Site Selection Criteria	**Safety**	**Ensure site analysis addresses criteria and permits related to:** ☐ Lighting meets DOT engineers guidelines/expertise on appropriate specifications	**Assessment from state DOT maintenance personnel and state DOT safety engineers:**
	Match Lighting Application to Site Requirements	☐ High mast lighting (high pressure sodium), conventional lighting (high pressure sodium) and sign lighting (induction)	**Assessment from LED manufacturer and state DOT engineers:**
	Long-Term Site Usage	☐ Screen site for current and future conflicting uses. LEDs last longer than conventional lighting options - so you should consider ROW changes over the life of the new fixture.	**Assessment from state DOT planning office and engineers:**
	Environmental Impact Analysis	☐ Address and avoid or tune light color to sites with issues related to lighting and impact to wildlife (e.g., loggerhead turtles and lighting spectrum impact in coastal zones)	**Assessment from state environmental agencies and state DOT engineers:**
Screening for Potential Projects and Candidate Sites	**Priority Site Locations**	☐ High kWh price ☐ New construction projects ☐ Lighting scheduled to be relamped or closer to the end of lifespan ☐ Partnership opportunities on highway or roadway sections where local utilities and cities/towns can participate	**Assessment from state DOT engineers, state DOT maintenance personnel, state DOT planning office:**

Site Selection Criteria

While conventional lighting may be more straightforward than its counterpart LED applications in high mast, luminaire, and sign lighting, LED lighting can offer significant energy savings and reduced maintenance effort after taking into account two main considerations. The LED lighting pattern is different than that of HPS and therefore in some cases in order to maintain uniformity and the desired light level, the lighting engineer may choose to add more poles or reduce lighting fixture pole height, as was the case in Michigan. These amendments and upgrades have associated costs that need to be factored into an initial cost analysis.

The USDOE has been supportive of LED demonstration projects in the highway ROW. The GATEWAY program has launched LED projects primarily on bridges and interchanges. These sites have been useful because they are concentrated locations that serve to highlight LED retrofits or installations without relamping an entire highway right-of-way. Many state DOTs have chosen to follow a similar model using bridges and interchanges to highlight their efforts. In December 2012, Massachusetts DOT installed a $150,000 LED project on the Leonard Zakim Bunker Hill Bridge that is expected to reduce electricity usage by 80%.

Retrofit Versus Full Installation

Some LED lighting manufacturers are offering retrofit LED light options. Rather than having to replace the entire fixture, retrofit kits allow the LED light to use the existing fixture (e.g., cobrahead), which ultimately saves a significant amount of investment both in the cost of the fixtures but also saving installation time.

Challenge: Sea Turtles

LEDs are environmentally benign in comparison to a number of highway ROW alternatives. In one case an environmental consideration was sea turtles in coastal areas that may be negatively affected by the spectrum of light. In the city of Bradenton Beach, Florida the city installed turtle-friendly LED and HPS lighting. Amber LED lights, still visible to the human eye, are not visible by turtles and therefore reduce the impact to loggerhead turtles. Beacon Products and Sea Turtle Lighting both offer turtle-friendly lighting options.

Summary of Priority Installations

Priority should be given to installations that maximize energy savings, and finance a greater number of projects. These four conditions will achieve one or both of those goals:

- High kWh price
- New construction projects
- Lights that are scheduled to be relamped or are closer to the end of their lifespan
- Partnership opportunities on highway or roadway sections where local utilities and cities/towns can participate

10. HAYING OR PLANTING IN THE HIGHWAY RIGHT-OF-WAY

10.1 Introduction

This chapter discusses the opportunity to utilize highway rights of way to generate revenue or offset maintenance costs from growing and harvesting agricultural crops. Specifically it discusses the opportunity to i) harvest existing grassy vegetation for use as hay and ii) intentionally plant and harvest nursery stock. The chapter is divided into two parts: the first part reviews some general considerations about the utilization of highway rights for such purposes and the second part provides additional considerations about the two specific potential project types.

10.2 General Considerations

Several state DOTs already allow or are investigating the use of highway ROWs for growing and harvesting agricultural crops. Some activities, such as permitted haying, have been in place for some time while others and have well established protocols and procedures, while other activities, such as growing oilseed crops for bioenergy production, are more recent and are best characterized as research and demonstration projects. While no direct precedent for utilizing highways ROWs to grow nursery stock was identified such a project could still be informed by some of the general learning of these other projects.

10.3 Motorist Safety

The safety of the traveling public is of paramount importance in evaluating the feasibility of growing and harvesting an agricultural crop in the ROW. The discussion below reviews some of the safety issues that should be considered.

Clear Zone

Beyond the shoulder of the roadway lies what is commonly referenced as the “clear zone”—the area adjacent to the roadway clear of fixed obstacles that would otherwise prevent an errant vehicle from safely stopping or returning to the roadway. While vegetation in this zone is permissible it is generally limited to low-growing grasses, forbs and shrubs. These types of plants are preferred because they do not pose a substantial collision risk to errant vehicles. Small trees, generally less than a few inches in diameter, can also be accommodated in the clear zone in certain contexts.

In Florida, the accommodation of trees in the clear zone is determined by FDOT's Design Standards and specifically section 700 "Roadside Offsets." According to the Design Standards, trees not expected to exceed 4 inches in diameter measured 6 inches above the ground are permitted in the clear zone so long as they conform to applicable sight distance standards. While in certain urban contexts trees expected to exceed 4 inches in diameter measured 6 inches above the ground are permitted within the clear, they are not permitted in the clear zone of most limited access highways. Where guardrails and other safety barriers along the roadway, larger trees are allowed.

The Design Standards also specify the width of the clear zone based on the design speed of the subject roadway. Minimum width ranges from 10 feet for auxiliary lanes and single lane ramps with design speeds less than 45 miles per hour up to 36 feet for travel lanes and multiple lane ramps with design speeds in excess of 55 miles per hour.

The zone beyond the clear zone up to the right of way boundary is generally managed as a natural zone where native vegetation is allowed to regenerate. This zone can also be found where sufficient widths occur in medians, at grade separations and at interchange infields. There are generally few restriction on the type vegetation acceptable in this zone with the exception of noxious or invasive plants and those that might present a hazard to the roadway (e.g., overhanging limbs).

Sightlines

Clear lines of sight allow motorist to see roadway conditions, signs, other motorists and the shape of the road and make adjustments accordingly. Accordingly, limits are placed on the placement of vegetation in order to avoid visual obstructions with special emphasis given to intersections, horizontal and vertical curves, and roadway signs.

In Florida, these limits are articulated in FDOT's Design Standards and specifically section 546 "Sight Distance at Intersections." These standards specify how to determine the areas adjacent to the roadway though which clear lines of site must be maintained and the parameters for vegetation height and spacing within that zone. These parameters vary by design speed and roadway geometry.

Access Control

Access to and from the roadway is managed to limit and separate traffic conflict points in order to promote the safe and efficient flow of traffic. In addition to regulating interchange additions and modifications, driveways and median openings, access management also involves the permitting more limited access breaks such as locked gates used to access utility and other facilities located in the right-of-way.

In general, access to and from the roadway along limited- and controlled-access facilities such as interstate highways, turnpikes, and other divided highways is tightly restricted. In the case of interstate highways, new or revised access, even for locked gates, requires approval from FHWA.

In approving locked gate access points, FHWA guidance calls for the access point to have appropriate sight distances to allow safe ingress and egress and to be constructed so to discourage unauthorized use. In general, access to and from a service road or adjacent property is preferred over access to and from the traveled roadway. Notably, even gated access from an adjacent property requires FHWA approval.

Wildlife Collision

Highways inevitably cross through wildlife habitat and disrupt migration paths posing a risk for both humans and animals from wildlife vehicle collisions. Utilizing highway rights-of-way to grow and harvest certain agricultural crops could increase the attractiveness of these areas to wildlife by providing enhanced food and shelter. Agricultural crops may be are more palatable or nutritional than those plant species than otherwise might be present. The presence of agricultural crops may also provide enhanced cover and habitat.

10.4 Utility Installation Considerations

Like most DOTs, Florida allows utilities to be on highway ROW. Mowing activities on existing vegetation (haying) need to ensure that they are done in a manner that doesn't damage permitted utility installations. Similarly, planting and maintenance of native plants on highway ROW would have to conducted in a way that doesn't damage permitted utility installations.

10.5 Public-Private Partnerships

DOTs that have sought to utilize highway rights of way to grow and harvest agricultural crops have largely partnered with external parties in those endeavors.

Where those endeavors involved the intentional cultivation of a particular crop, those partners most often have been faculty from land-grant universities with specific agronomic expertise and research budgets though in some cases the DOT has partnered directly with an interested farmer. The state of Texas for example allows adjacent landowners to cultivate unfenced portions of state highway right-of-way outside of the clear zone. In the case of haying existing vegetation, those partners are generally private individuals.

10.6 Federal Policy Issues

The uses and management of rights-of-way where federal funds were used are governed by applicable federal rules and policies. The over-arching purpose of the federal policy framework is to ensure that the safety of the public and the current and future operation of the transportation facility are not impaired by any non-transportation uses of the rights-of-way. There are also specific provisions related to vegetation management.

Specifically, 23 CFR 752.4 specifies that landscape development, which includes landscaping projects and other highway planting programs, within the right-of-way of all federally funded highways or on adjoining scenic lands should include the opportunity for natural regeneration of native growth and shall include the planting of native wildflower seeds or seedlings or both, unless a waiver is granted by FHWA. 23 CFR 752.11(b)(3) provides that a waiver can be granted if the planting is used for agricultural purposes.

Most of the efforts to date to utilize highway rights of way for agricultural crop production have not required formal approval or review by FHWA because those efforts have been limited to small-scale demonstration plantings conducted under the sponsorship of the state DOT and its authority to manage and maintain roadside vegetation.

It is expected that a more programmatic effort to utilize federal-aid rights-of-way for agricultural production would require formal consent and approval. This is particularly true if the program was implemented through a formal airspace agreement. Such agreements, as noted at 23 CFR 710, must charge a fair market value lease rate for the use of the property and are subject to FHWA approval.

10.7 Potential Business Models

There are three basic business models a DOT could pursue to utilize the right-of-way to grow and harvest agricultural crops— a self-service model, a contract for services model, and a private entity leasing model. Each model has its advantages and disadvantages as discussed below

<u>Self-Service Model</u>

Under this approach, the DOT would grow, harvest and market the agricultural crop itself relying on its own expertise, equipment and budget.

The primary advantage of this approach is that DOT maintenance staff is already familiar with the real world operation of suitable equipment under similar circumstances in the ROW. For example, DOT staff has experience with planting and maintaining roadside wildflower plantings. Moreover, DOTs have broad latitude in determining the appropriate methods for managing roadside vegetation including discretion in the selection of the type of plantings and generally do not need to seek FHWA approvals to change that management regime.

The downside of this approach is that DOT staff may not have the agronomic expertise necessary to implement a particular production system or find suitable markets for harvested materials. Additionally, the private sector might balk at the prospect of a DOT directly engaging in such an enterprise.

Contract for Service Model

Under this approach, the DOT would contract with a private party to grow, harvest and market the agricultural crops. The private party would provide all necessary labor, equipment and material inputs while the DOT would make available the land at no cost. Ideally, this model would utilize a "positive bid" contract where the successful bidder makes payment to the DOT in exchange for performing the vegetation management service. In lieu of a cash payment it might also be possible to structure the agreement so that the successful bidder make an in-kind payment such as nursery stock to be used in a DOT landscaping project.

Some precedent for such an agreement exists for clearing and grubbing contracts, where it is expected that the salvage value of the materials to be removed is expected to exceed the actual cost of removal.

The primary advantage of this approach is the DOT would not be directly responsible for the establishment, harvest, and marketing of the agricultural crop and could instead rely on the expertise of qualified bidders.

Additionally, since the bidder would be acting as an agent of DOT it this approach would avoid federal restrictions on accessing the right-of way from the established grade of the highway. As is the case with contracted construction, contractors performing vegetation management services are working under the direction and control of the DOT. As such they are an in essence an extension of the DOT, and can, as long as permitted in the contract language, access areas to be maintained in the same manner that a DOT would access the area. If the activity increased the number of incursions over those occurring under current practice FHWA would likely want to be involved.

The disadvantage of this approach is that the DOT would not have direct control over the implementation of a particular production system, though presumably some of this risk could be mitigated through the development of a well-crafted procurement process that sets some minimum qualification and performance standards.

Private Entity Leasing Model

Under this approach, the DOT would enter into an airspace lease with a private entity that would then use the leased land to grow and harvest the agricultural crop. Similar to the contract for service model, the private party would provide the necessary equipment and inputs while the DOT would make the land available. In addition to the airspace lease, a permit from the DOT would likely be required in order to delineate the specific details and any requirements of the use.

The primary advantage of this approach is that it relies on a proven pathway for developing non-highway uses of the right-of-way. FDOT has established procedures for developing and executing right-of-way property leases described in detail in the FDOT Right of Way Manual at Section 10.6. Like the contract for service model, this approach would also rely on the expertise and resources of the private entity rather than the DOT.

The disadvantage of this approach is that the process for awarding lease agreement can be cumbersome and carry with it other restrictions that make it difficult to implement a project. Specifically, where the property was acquired as a part of a federal aid project it must comply with applicable federal rules including 23 CFR 710. Among other things these rules requires the DOT charge a fair market rent, a requirement that likely defeats the purpose of making these lands available for agricultural production since there would then be no economic advantage to a prospective grower who could otherwise lease farmland elsewhere and avoid the other complications of operating in the ROW.

Additionally, federal rules specifically prohibit airspace agreements from allowing access to the leased land adjacent to the Interstate directly from the roadway. While this this prohibition does not extend to non-interstate federal aid highways, FHWA will likely be concerned if the use substantially increases incursions from the highway.

10.8 Specific Considerations - *Haying*

Several states have developed specific permits to allow private parties to mow and collecting grassy biomass (i.e., hay) from highway rights-of-way. The practice seems concentrated in the Midwest, though at least one southern state, Tennessee has an established permitting procedure.

In general, it does not appear that states that allow haying in the ROW do so as a means to generate revenue. Only two states could be identified as charging a fee to obtain necessary permits. Colorado charges a fee of $100 per mile for a five-year right to harvest material. Missouri recently began issuing permits to in response to a competitive bidding process however no information was available about the results.

While haying permits may not generate discrete revenues, they may offer a means to reduce a DOT's own maintenance activities and the associated costs.

Some of the common features of haying program include:

Safety and Performance Standards

Most states require the posting of traffic safety signage (e.g., "Farm Machinery-One Mile") in accordance with FHWA's *Manual on Uniform Traffic Control Devices* to alert motorists of the presence of equipment. Some states also specify that persons operating the equipment must wear high-visibility safety apparel. Additionally, equipment is not permitted to be left unattended (Kansas DOT, 2010). Most states set minimum mowing heights and require that the operation be uniform and continuous, except for restricted areas. Generally harvested materials must be removed from the right of way within ten days (Kansas DOT, 2010, FHWA HEPR, 2013).

Permit Recipient Eligibility

Several of the state's that allow haying of the right-of-way either restrict eligibility or give preference to adjacent landowners.

Access Control

In most states, access to the ROW is only allowed through gates in the ROW fence. All states explicitly prohibit access from the traveled roadway (Kansas DOT, 2010; Michigan DOT, 2013; Missouri DOT, 2012; South Dakota DOT, 2010). Where not explicitly addressed, federal regulations will control access from interstate highways.

Location

Haying is typically permitted only in areas outside of the clear zone, and commonly limited just to areas on the outer edges of the right of way along the fence line. Some states also include restrictions on sloped grades and sensitive areas such as wildlife and wildflower areas. Another common restriction is to limit haying to areas with well-established vegetation (i.e., no haying is allowed in recently seeded areas) (Kansas DOT, 2010; Michigan DOT, 2013; Missouri DOT, 2012; South Dakota DOT, 2010).

Insurance and Liability Releases

A number of states require permit recipients to have liability insurance for both personal injury and property damage with coverage minimums ranging up to $600,000. Additionally most permits assign liability for accidents, claims, or damages to the permitee (Kansas DOT, 2010; Michigan DOT, 2013; Missouri DOT, 2012; South Dakota DOT, 2010).

Timing and Frequency

Haying is often limited to specific times of the year, week and day (Kansas DOT, 2010; Michigan DOT, 2013; Missouri DOT, 2012; South Dakota DOT, 2010). Seasonal restrictions generally to correspond to the late summer apparently in order to avoid interference with nesting birds. This restriction to the late summer effectively limits the frequency to once per year. Some states prohibit haying the same section in consecutive years.

Most states also restrict the days of the week during which haying is allowed, generally prohibiting mowing on weekends and holidays. Activities are also typically restricted to daytime hours (Kansas DOT, 2010; Michigan DOT, 2013; Missouri DOT, 2012; South Dakota DOT, 2010).

Improvements

Only one state, Missouri, explicitly allows permit holders to make improvements to increase the quality and yield of hay harvested from the right of way. Those improvements are limited to over seeding, fertilization and herbicide spraying (Missouri DOT, 2012). No states allow plowing or cultivation.

Contaminants

Most states include a disclosure in the permit application that the harvested area may have been treated with herbicides that may be toxic to livestock (Kansas DOT, 2010; Michigan DOT, 2013; Missouri DOT, 2012; South Dakota DOT, 2010)..

10.9 Specific Considerations - *Nursery Stock*

No precedent for growing nursery stock in the highway right of way could be identified. What follows is a summary of the issues typically associated with developing a wholesale field or container nursery as identified in the literature and a discussion of how those issues might be influenced by the restrictions of operating in the highway right of way.

Container versus Field Production

There are two primary modes of nursery stock production: field and container. Field nurseries primarily produce trees and woody shrubs grown directly in the ground in open fields. Field production is the preferred system for larger caliper landscape and shade trees. Container nurseries produce a range of plants including ornamental trees and shrubs, fruit trees and flowing and herbaceous perennial plants gown above-ground in containers.

Minimum Area Requirements

While nurseries vary greatly in size-- from just a few acres to more than a thousand acres—it has been suggest that the minimal area required for a profitable field nursery is on the order of 200 acres (University of Kentucky Cooperative Extension Service, 2013) and for container nursery is on the order of 20 acres (Halcomb and Fare, 2009). Smaller scale nurseries (ie., less than 5 acres in container production or less than 15 acres in field production), can still be profitable but tend to do so by catering to niche markets by producing crops since they generally cannot compete with larger nurseries on production costs (Diver and Greer, 2001).

These minimum areas requirements suggest that most parcels in the ROW will not be suitable for large-scale nursery production.

Layout and Design Considerations

Field nurseries are typically planted in blocks separated by 10-12 foot wide aisles between block to facilitate equipment access for planting, maintenance and harvesting. The width and number of rows within a block is based on the type of crop (both species and desired size of the harvested plant) being grown and performance specifications of equipment (e.g., air blast sprayers) (LeBude and Bilderback, 2008).

Container nurseries are typically designed around a central propagation area featuring a combination of permanent greenhouse and outdoor planting beds where seedlings are started from seed or cutting and then transplanted into larger containers. These containers are then set out in various production areas, large fields covered with gravel or woven landscape fabric, where the plants are set out in rows and grown out to maturity. Like field nurseries, wide aisles are placed between production areas to facilitate equipment access (Yeager and Ingram, 2010).

Both production systems also require a staging area large enough to accommodate a tractor-trailer to prepare and load harvested material for shipping and to receive equipment and supplies. Most nurseries are also design to accommodate on-site storage of chemicals, fertilizers, and other equipment and supplies) (LeBude and Bilderback, 2008; Yeager and Ingram, 2010).

These layout and design requirements raise questions about the capacity of ROW parcels to host a nursery production operation. Of note is the common practice of co-locating ancillary services such as propagation, shipping and receiving, and equipment and material storage with actual production area. This practice presumably is in place to maximize production efficiencies and it is unclear how decentralizing these services would affect enterprise profitability.

Site Selection Considerations

Soil conditions are of paramount interest in the selection of an appropriate site for a field nursery. Soils should be high in organic matter, rock free and well-drained. The soil must also be cohesive enough to remain around the roots of harvested plants. Other important considerations is slope, a slope of 2-5% promotes air circulation and drainage. Flood-prone and wetland sites should be avoided (University of Kentucky Cooperative Extension Service, 2013).

Site selection is less important for container nurseries, since plants are usually grown in soilless potting mix. However the site must still provide adequate drainage. This can be achieved by locating the production area on a natural or graded slope or by building up the bed with gravel (Yeager and Ingram, 2010).

Site selection criteria do not seem to be an insurmountable consideration for a prospective nursery in the ROW. However, altering existing site conditions through grading or the building up gravel pads may be problematic. At a minimum consideration should be given at the outset to site remediation upon project termination.

Irrigation

Both production systems generally rely on some level of supplemental irrigation. In field production supplemental irrigation is primarily during establishment, the first few years during which the plant develops a healthy root system capable of tapping ground water resource. Once established, supplemental irrigation may still be required during periods of drought to ensure survival and optimal growth (University of Kentucky Cooperative Extension Service, 2013).

Container systems rely on supplemental irrigation throughout the production lifecycle. Ongoing irrigation for container crops is required since the plant root systems do not tap ground water resources (Halcomb and Fare, 2009).

Irrigation can be provided by either overhead spraying or by a drip or trickle system. Overhead irrigation uses more water than drip systems, because of higher evaporative losses. However, drip systems have higher upfront capital and ongoing maintenance costs. Both irrigation system can utilize either surface or ground water resources but both require pumps to provide adequate water pressure. Irrigation pumps can be either gasoline/diesel or electric powered (Diver and Greer, 2001).

The requirement for irrigation seems to be a significant issue in potentially accommodating nursery production in the ROW since the most likely water source would appear to be a groundwater well. Obtaining necessary permits for a new irrigation well and drilling the well itself, are fairly straightforward processes. Less straightforward are answers to questions about risks, liability and responsibility. Would FDOT be the permit holder or would the nursery operator? Who would pay for the costs for obtaining the permit and drilling the well? What about maintenance? What if the well did not perform in a period of drought? What happens if the well becomes contaminated? What about the long-term fate of the well?

Beyond these issues is the question of providing/allowing the infrastructure necessary support the irrigation system including electricity service or on-site fuel storage.

Fertilizers, Herbicide and Pesticide Use and Water Quality

Both production systems nurseries rely on synthetic chemical to manage weeds, pests and diseases and synthetic fertilizers to supplement plant nutrients. While alternative and low-input methods can reduce the quantities of chemicals used, nutrient and pesticide runoff can be a concern that may requires on-site mitigation measures like detention basins and water recycling systems (Sharma, et al. 2008).

Potential of runoff issues seems to be a significant issue in potentially accommodating nursery production in the ROW. Before proceeding with a potential project, care should taken to understand these potential risks and the potential liability to FDOT. Of particular concern are questions about how a potential facility would be accommodated under the agency’s Stormwater Management Plan.

Soil Loss

Most field nurseries are managed for "balled and burlapped" production where the tree is dug up with the soil intact around the root system and wrapped in burlap fabric. While, the size of the root ball and the amount of soil removed will vary according to the size of the harvested tree it has been estimated that field nurseries loose between 200 and 2500 tons of soil per acre at each harvest (Diver and Greer, 2001). While these types of nurseries seek to mitigate this soil loss by applying compost and mulches after harvest, this practice can deplete soil resources over the long term.

While not an insurmountable consideration, the issue of soil loss should be proactively addressed in the design and implementation of a potential project.

11. LEGAL REVIEW

11.1 Federal Review

This section provides a synopsis of the current federal rules regarding the use and management of the highway ROW as contained in 23 Code of Federal Regulations (CFR) Part 1 – General: Section 1.23, 23 CFR 710, and 23 CFR$ 645 Subpart B.

Acquisition of ROW: 23 CFR Part 1 – General: Section 1.23

23 CFR Part I Section 1.23 Rights-of-Way stipulates the purposes whereby ROW can be acquired for federal aid highway projects. The interest that shall be acquired under Section 1.23 (a) shall be of such nature and extent *as are adequate for the construction, operation and maintenance* of a project. The use for which ROW is acquired is for *highway purposes*.

Paragraph (b) states that except as provided under paragraph (c) of this section, all real property, *including air space*, within the ROW boundaries of a project shall be *devoted exclusively* to *public highway purposes*. Paragraph (b) also notes that state highway departments are responsible for preserving such ROW free of all public and private installations, facilities or encroachments, *except for those approved under paragraph (c)* and those that the Administrator approves as constituting a part of a highway or as necessary for its operation, use or maintenance for public highway purposes such as, information sites established and maintained under §1.35 of the regulations.

The exception in §1.23(c) allows for temporary or permanent occupancy *or use* of the ROW approved by the Administrator as either being in the *public interest* and will not *impair* the highway or *interfere with free and safe flow* of traffic thereon. The Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) has had a long-standing policy of utility accommodation within, across, and adjacent to ROW. Utility accommodation has historically been viewed as *beneficial for the public good.*

Real Property Control: 23 CFR Sub-chapter H – Right of Way and Environment: Part 710 Right of Way and Real Estate: Section 710.401

This subpart describes the acquiring agency's responsibilities to control the use of real property required for a project in which Federal funds participated in any phase of the project. Prior to allowing any change in access control or other use or occupancy of acquired property along the Interstate, the DOT shall secure an approval from the FHWA for such change or use. The DOT shall specify in the ROW operations manual, procedures for the rental, leasing, maintenance, and disposal of real property acquired with money under 23 CFR. The DOT shall assure that local agencies follow the State's approved procedures, or the local agencies own procedures if approved for use by the DOT.

Real Property Management: 23 CFR Sub-chapter H – Right of Way and Environment: Part 710 Right of Way and Real Estate: Section 710.402

Under Section 710.403 (a) the DOT has to assure that all properties within the boundaries of the federally-aided facility are devoted *exclusively* to the purposes of that facility and is preserved free of all other public or private alternative uses, unless these have been permitted by regulation or FHWA. The *alternative use must be consistent* with the continued operation, maintenance, and safety of the facility and the use *shall* not result in the exposure of the facility's users or others to hazards. Under 710.403 (b) The DOT is required to comply with specific procedures in their ROW manual for determining when the real property interests is no longer needed. This includes provision for coordination among DOT divisions (including, maintenance, safety, design, ROW, environment and traffic operations).

The DOT under sub-section (c) *shall* evaluate the environmental effects of disposing or leasing property and must obtain FHWA approval under 23 CFR Part 771. DOTs are required to charge current fair market value or rent for the use or disposal of these property interests, including access control, if the properties were obtained with Title 23 United States Code (U.S.C) funding. An exception to this is provided under 710.403 (d) (1) through (5) of this section:

(1) With FHWA approval, when the DOT clearly shows that an exception is in the overall public interest for social, environmental, or economic purposes;

nonproprietary governmental use; or uses under 23 U.S.C. 142(f), Public Transportation.

(2) Use by public utilities in accordance with 23 CFR Part 645.

(3) Use by Railroads in accordance with 23 CFR Part 646.

(4) Use for Bikeways and pedestrian walkways in accordance with 23 CFR Part 652.

(5) Use for transportation projects eligible for assistance under 23 U.S.C, provided that a concession agreement, as defined in section 710.703, shall not constitute a transportation project.

Under §710.403 (e) the Federal share of net income from the sale or lease of excess real property shall be used by the DOT for activities eligible for funding under title 23 U.S.C. Under this provision, the project income derived from this sale does not create a federally-aided project.

Leasing of Property: 23 CFR Sub-chapter H – Right of Way and Environment: Part 710 Right of Way and Real Estate: Section 710.407

Under 710.407 (a) the leasing of real property acquired with 23 CFR funds, shall be covered by an agreement between the DOT and lessee which must contain provisions to insure the *safety and integrity* of the federally funded facility. It shall also include provisions governing lease revocation, removal of improvements *at no cost* to the FHWA, adequate insurance to hold the State and the FHWA harmless, nondiscrimination, and access by the State Transportation Department (STD) and FHWA for inspection, maintenance, and reconstruction of the facility. Section 710.407 (b) provides that where the proposed use requires changes in the existing transportation facility, such changes shall be provided without Federal funds unless otherwise specifically agreed to by the DOT and the FHWA. Section 710.407 (c) requires that any proposed uses of the ROW shall conform to the current design standards and safety criteria of the FHWA for the functional classification of the highway facility in which the property is located.

<u>Sale of ROW: 23 CFR Sub-chapter H – Right of Way and Environment: Part 710 Right of Way and Real Estate: Section §710.409</u>

23 CFR §710.409 deals with the disposal of real property interest that is deemed in excess to transportation needs. §710.409 (c) allows the DOT to retain excess property to restore, preserve, or improve the scenic beauty, and environmental quality adjacent to the transportation facility.

Federal Statute: Utility Guidance

Guidance on the accommodation of utilities in ROW can be found in federal codes. At the federal level, 23 CFR governs utility accommodation policy in Sub-chapter G Engineering and Traffic Operations at Part 645 Utilities, and also in 23 CFR Sub-chapter H Right of Way and Environment at Part 710.

<u>Utility Accommodation: 23 CFR Part 645B</u>

23 CFR Sub-chapter G Engineering and Traffic Operations Part 645 outlines policies for accommodating utility facilities and private lines in the ROW of federal aid or direct federal highway projects. Section 645.203 applies to new utility installations. Section 645.205 (a) notes that it is in the *public interest* for utility facilities to be accommodated in the ROW of federal highways as long as such use and occupancy of the ROW *does not adversely affect highway or traffic safety or its aesthetic quality*. Section 645.205 (b) notes that by tradition and practice highway and utility facilities have frequently coexisted within common ROW or along the same corridors and that it *is essential* that these public service facilities be *compatibly designed and operated*. In the design of new highway facilities consideration should be given to the utility service needs of the area traversed if the service is provided by utility facilities on or near the highway. Joint highway and utility planning is encouraged for federal highway projects.

However, the section also provides in §645.209 (3) that states are not precluded from adopting more restrictive policies with regard to longitudinal utility installations along ROW. Regarding the provision of private lines under §645.209 (e), state DOTs are required to establish uniform policies for controlling such permitted use. Longitudinal installations must conform with 23 CFR §1.23(c). For scenic areas, new utility installations are not permitted in highway ROW or on other lands except in a few circumstances, which include:

- aerial installations where placement underground is not technically feasible,
- other locations are not available, or are unusually difficult or costly, or are less desirable from the standpoint of aesthetic quality, and
- the proposed installation will be made at a location, and will employ suitable designs and materials, which give the greatest weight to the aesthetic qualities of the area being traversed.

Section 645.211 lays out the accommodation policies and requires that consideration shall be given to the effect of utility installations on *safety, aesthetic quality, and costs or difficulty of highway and utility construction and maintenance.* Section 645.211 (c) outlines standards for regulating use and occupancy of ROW. Sub-section (5) allows a DOT to deny a utility's request to occupy ROW based on state law, regulation, local ordinances or the DOT's utility policy. However, where these provisions are cited as the basis for disapproving a utility's request to use and occupy ROW, measures *must be provided to evaluate the direct and indirect environmental and economic effects of any loss of productive agricultural land or any impairment of the productivity of any agricultural land that would result from the disapproval*. The environmental and economic effects on productive agricultural land together with the possible interference with or impairment of the use of the highway and the effect on highway safety must thus be considered in the decision to disapprove any proposal by a utility to use such highway ROW.

Section 645.211 (e) requires DOTs to include in their utility accommodation plan, the detailed procedures, criteria, and standards it will use to evaluate and approve individual applications for utilities on freeways under the provisions of §645.209(c) of this part. DOTs may develop such procedures, criteria, and standards by class of utility. In defining utility classes, consideration may be given to distinguishing utility services by type, nature or function, and their potential impact on the highway and its user. Section 645.211 (f) notes that the means and authority for enforcing the control of access restrictions applicable to utility use of controlled access highway facilities should be clearly set forth in the DOTs utility accommodation plan.

Under Section 645.215 (a) states are required to submit a statement to FHWA on (a) the authority of utilities to use and occupy ROW; (b) the department's power to regulate this use and identification of any areas on the federal aid highways where the DOT is without legal authority to regulate use by utilities, and (c) any policies and procedures that the DOT employs to facilitate accommodation of utilities within the ROW of federal aid highways. Once FHWA determines that the DOT's policies meet the requirements and satisfies provisions of 23 CFR §1.23 and §1.27. it can then approve their use on Federal-aid highway projects in that State.

FHWA 2009 Utility Accommodation Longitudinal Guidance

In 2009 FHWA released guidance on longitudinal accommodation of utilities in the interstate system ROW (FHWA 2009). This was as a consequence of the emerging interest in the production and distribution of renewable energy and proposals that were coming into the states to locate such facilities in highway ROW. The guidance describes steps to determine whether the accommodation should be conducted under 23 CFR Part 645 Subpart B or 23 CFR Part 710.

The guidance encouraged states to review their accommodation policies and make updates and modifications to consider renewable energy and other items outlined in the memo. The guidance is intended to complement FHWA's 6th Edition of the Program Guide: Utility Relocation and Accommodation on Federal-Aid Highway Projects released in January 2003 (FHWA, 2003), but notes that much of the discussion contained in the document is *considered applicable to other freeways and similar transportation facilities.* The guidance provides steps to determine whether the facility serves the public and meets the definition of utility and can thus be accommodated under 23 CFR 645 Subpart B.

The guidance in reviewing other longitudinal accommodation considerations, notes that other federal policies, laws, regulations, and standards may come into play in the decision making process. One area that is discussed is planning. Noting that U.S.C 134, 135, and 23 CFR 450 established FHWA requirements for statewide and metropolitan transportation planning, the guidance goes on to say that while utility interests are not explicitly addressed in the regulations, it is nevertheless *appropriate to include a utility element in the undertaking of a multimodal, systems-level corridor or subarea planning study or in the development of the long-range statewide and* *or/metropolitan transportation plan*. Discussions in these documents, the memo concedes would supplement, rather than supplant, the information contained in utility accommodation policies. FHWA encourages coordination with utility interests in a strategic planning process that identifies roles and responsibilities of the DOT in the accommodation of longitudinal utility facilities within the ROW of the interstate system. Specific proposals for longitudinal installation along the interstate system could then be evaluated for compatibility with applicable metropolitan or statewide long-range transportation plans.

FHWA *encourages* DOT's in this memo to include in their policy discussion of how utility accommodation can be *better integrated into their transportation planning process at the state, regional, and corridor levels*. This focus would place states in a better position to handle accommodation questions systematically rather than on a case-by-case basis. The memo also encourages FHWA Division staff to:

- work with DOTs to integrate consideration of utility facilities in statewide strategic plans, highway system metropolitan transportation plans and corridor transportation plans.
- work with their DOTs to conduct a review and assessment of the DOT's utility accommodation plan to ensure it adequately meets current needs.

11.2 Florida Review

This section provides a review of the current legal and/or regulatory framework in Florida related to the potential use of three value extraction project in the State's rights-of-way:

1. Solar/Photovoltaic
2. Solid State Lighting Technology (LED lighting)
3. Hay Production/Nursery Stock/Crops

Solar/Photovoltaic

A review of Florida Statutes (F.S.) did not find specific language related to the airspace leasing or utility accommodation as it relates to Solar P/V as a value extraction application in State rights-of-way.

Title 26, Public Transportation, Chapter 337, "Contracting; Acquisition, Disposal, and Use of Property" of the Florida Statutes and specifically Section 337.401, *Use of right-of-way for utilities subject to regulation; permit, fees* is silent regarding solar photovoltaic placement in state rights-of-way property. The only reference to utilizing solar photovoltaic power in the Florida Statutes requested the Public Service Commission to investigate the potential for using off-grid solar photovoltaic power as a source of electricity for electric vehicle charging stations:

Title 27, Railroads and Other Regulated Utilities, Chapter 366, Public Utilities

366.94 Electric vehicle charging stations.—

…

(4) The Public Service Commission is directed to conduct a study of the potential effects of public charging stations and privately owned electric vehicle charging on both energy consumption and the impact on the electric grid in the state. The Public Service Commission shall also investigate the feasibility of using off-grid solar photovoltaic power as a source of electricity for the electric vehicle charging stations. The commission shall submit the results of the study to the President of the Senate, the Speaker of the House of Representatives, and the Executive Office of the Governor by December 31, 2012.

However, Title 26 F.S. Chapter 337.251, *Lease of property for joint public-private development and areas above or below department property* does allow for the use of department property and airspace leasing, including rights-of-way to further economic development and generate revenue for transportation.

337.251 Lease of property for joint public-private development and areas above or below department property.—

(1) The department may lease to public agencies or private entities, for a term not to exceed 99 years, the use of department property, including rights-of-way, for joint public-private transportation purposes to further economic development in this state and *generate revenue for transportation*. *The department may also lease the use of areas*

above or below state highways or other transportation facilities for commercial purposes (emphasis added). Leases under this section are subject to any reservations, restrictions, or conditions necessary to ensure adequate protection for the safe and efficient operation and maintenance of all transportation and utility facilities, the adequacy of traffic flow, and the full use of existing and future state transportation facilities…

The Florida Administrative Code (F.A.C.) rule related to F.S. Ch. 337.251 was repealed on November 11, 2007. Specifically, and as part of the entire section: Chapter 14-109.0011*, Joint Public/Private Development of Right of Way*, Rule Chapter 14-109, F.A.C., is being repealed as unnecessary to Department operations. The Department process can be addressed in procedures. Repeal of this rule chapter is part of the Department's overall goal to review existing rules and to repeal nay rules that are considered to be obsolete or unnecessary.

A review of the Florida Department of Transportation *2010 Utility Accommodation Manual* did not reveal specific FDOT policy references to airspace leasing and utility accommodation as related to placement of any of the three specific value extraction applications (solar/PV; LED lighting; nursery stock/crops production) within the state rights-of-way. The manual does refer the utility agency/owner (UAO), while on FDOT right-of-way, to comply with the manual specifications:

1.5 APPLICATION OF STANDARD DRAWINGS AND SPECIFICATIONS

When an agreement exists between the UAO and FDOT, the UAO's work shall conform to the requirements of the agreement. Otherwise, while on the FDOT R/W or within FDOT projects, the UAO's work shall comply with the requirements of the UAM and the standard drawings and specifications listed in UAM Sections 1.5.1andUAM Sections 1.5.2, or the UAO may elect to use the most current version of these standard drawings and specifications.

In addition, the FDOT *Right of Way Manual* was accessed and reviewed to determine whether airspace lease of state rights-of-way referenced the three value extraction applications identified above. The rules regarding right-of-way property leases and related sections, including guidance documents, did not specifically address these value extractions applications.

Regarding toll/turnpike facilities and airspace lease/utility accommodation on the Florida Turnpike, the Florida Statutes reference contracts with the Department for provision of services on the turnpike system, but did not specifically mention airspace leasing or value extraction applications. Florida Statutes chapters 338.234 and 338.235 allow the Department to enter into contracts with persons and/or business opportunities that benefit the traveling public, i.e., concessions, or *provide additional revenue to the turnpike system* (emphasis added); however, specific value extractions applications such as LED lighting, solar photovoltaic implementation, and production of nursery stock/crops were not referenced.

A search of *Florida Attorney General Opinions* regarding state rights-of-way and the three value extraction applications referenced herein was unproductive. Many opinions relate to eminent domain issues and rights-of-way, but not regarding these particular applications.

While examining related articles, a research/feasibility study for a PV system to be installed on the Florida Turnpike was reviewed. A University of Florida research team collaborated with Florida Turnpike Enterprise and Florida Department of Transportation staff to examine contemporary solar technologies, particularly solar photovoltaic (PV) systems, for their potential to meet the energy needs of the Turkey Lake Service Plaza. The Florida Turnpike Enterprise (FTE) selected the Turkey Lake Service Plaza on the Florida Turnpike for a case study to explore the potential shift to renewable energy sources. In addition to addressing the potential for renewable energy for the Turkey Lake Service Plaza, (site of the headquarters of both the FTE and the Florida Highway Patrol's turnpike operations) the research provided a template for the large scale adoption of solar energy technologies for other Florida Turnpike plazas as well as for Florida Department of Transportation facilities and activities.

The report did not reference specific FDOT rules or Florida Statutes and/or Administrative Code addressing the use of Florida Turnpike Enterprise rights-of-way for this specific value extraction application. The authors, while not addressing whether any legal and/or regulatory constraints existed at that time (2010), did conclude that:

"…if a private developer, defined as a utility or other company engaged in providing solar photovoltaic systems, partnered with FTE to install a Solar Photovoltaic system, it would be feasible for a system to be installed at no cost to the FTE, provided agreements regarding power purchase and other issues are successfully addressed."

Solid State Lighting Technology (LED lighting)

As expected, a review through Florida state statues and administrative code regarding the above-referenced technology and value extraction application was unsuccessful. No relevant laws or rules were found to be related to its use on state rights-of-way in such capacity.

In addition, no direct references for use of this as a value extraction application were found throughout FDOT policies or available manuals.

Hay Production/Nursery Stock/Crops

A search through Florida state statues and administrative code regarding the above-referenced value extraction applications were unsuccessful. No relevant laws or rules were found to be related to its use on state rights-of-way.

A review of the *AASHTO Guidelines for Vegetation Management* manual did not reveal any specific references regarding use of state rights-of-way in the capacity of this value extraction application. The guidelines apply to state DOT vegetation management programs and practices of state rights-of-way as needed for maintenance and planning purposes.

Similarly, the *Florida Highway Landscape Guide* relates to highway vegetation management systems and maintenance, and does not directly address use of state rights-of-ways for any value extraction applications related to vegetation production.

12. CONCLUSIONS

12.1 Summary

This research was conducted in two phases, i.e., Phase 1 and Phase 2. In Phase-1, the research team established the state-of-the-practice of value extraction projects and initiatives in highway rights-of-way and provided FDOT with a complete set of choices related to the nontraditional use of highway rights-of-way. This was achieved through (i) a literature search which supplemented the extensive literature review that the members of the research team conducted during past sponsored research projects by reviewing published consultancy reports, documented research, and other publicly available information sources and (ii) an online survey of State DOTs which requested information on nontraditional uses of highway rights-of-way.

Upon completion of the literature search and the State DOT survey, the research team discussed the findings during an internal team meeting and identified the most relevant and credible projects and programs for further evaluation. From this internal meeting the research team delivered a draft memo of findings and accompanying bibliography to FDOT. The draft memo contained an inventory of viable value extraction projects, which provided FDOT with a complete set of choices related to the nontraditional use of highway rights-of-way. In the next step, the research team held a meeting with FDOT via phone conference to discuss the list of viable value extraction projects and develop a shortlist of “high-priority” projects for an in-depth analysis in Phase 2 of the project. This effort led to a shortlist with three project types including (i) solar photovoltaic, (ii) LED lighting, and (iii) haying or planting in highway rights-of-way.

In Phase 2, the research team conducted the required analyses and developed the tools to be used by FDOT as decision support in implementing the high-priority value extraction projects identified in Phase 1. In this phase, our team analyzed the legal framework affecting implementation of value extraction projects, conducted case studies to collect additional data, and developed a tool for feasibility screening of the three value extraction projects chosen by FDOT.

12.2 Recommendations for Future Research

This research laid the foundation for a pilot project in Florida to design, implement, and evaluate the value extraction projects discussed in this report.

REFERENCES

Alternative Energy Institute. 2013. “TXDOT.” Retrieved from http://www.windenergy.org/projects/txdot.html.

American Association of State Highway and Transportation Officials (AASHTO). 2012. Roadway Lighting Design Guide. Washington, D.C.

Avrenli, K., Benekohal, R., and Medina, J. 2012. LED Roadway Lighting, Volume 1: Background Information. Illinois Center for Transportation: Urbana.

Blanco, S. 2011. “Pennsylvania turnpike plazas will all get DC fast charging stations for EVs.” Retrieved from http://green.autoblog.com/2011/12/19/pennsylvania-turnpike-plazas-will-all-get-dc-fast-charging-stati/.

Bomford, M., Sluss, T., Hansford, S., and Bates, K. Potential of Kentucky Freeway Rights of Way to Displace Fossil Fuel Consumption through Production of Prairie Switchgrass. Kentucky State University: Frankfort.

Bowen, D. 2013. “Colorado DOT taps LED rail crossing safety signs.” Retrieved from http://www.railwayage.com/index.php/safety/colorado-dot-taps-led-rail-crossing-safety-signs.html.

Campbell, B. 2004. Creating Sustainable Air Rights Development Over Highway Corridors: Lessons from the Massachusetts Turnpike in Boston. Thesis. Massachusetts Institute of Technology: Cambridge.

Chapman, P. and Wiczkowski, P. 2009. Wind-Powered Electrical Systems - Highway Rest Areas, Weigh Stations, and Team Section Buildings. Illinois Center for Transportation: Springfield.

Clanton, N. 2012. “Traveling Down the Lighted Street.” Presentation at Municipal Solid-State Lighting Symposium. March 6. Seattle, WA.

CTC and Associates LLC. 2010. Roadside Management Strategies to Reduce Greenhouse Gases. California Department of Transportation (Caltrans), Division of Research and Innovation: Sacramento.

Database of State Incentives for Renewables and Efficiency (DSIRE). 2012. “Florida Incentives/Policies for Renewables & Efficiency. Net Metering.” Retrieved from http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=FL19R.

Database of State Incentives for Renewables and Efficiency (DSIRE). 2013. “Net Metering.” Retrieved from http://www.dsireusa.org/solar/solarpolicyguide/?id=17.

Denholm, P., and Margolis, R. 2007. The Regional Per-Capita Solar Electric Footprint for the United States. U.S. Department of Energy, National Renewable Energy Lab: Golden, CO.

Derr, Jamie. 2011. Wisconsin Ditchmass: A 2010 Road Shoulder Biomass Energy Harvesting Pilot Project. Wisconsin Department of Transportation and Wisconsin Office of Energy Independence: Madison.

Diver, S. and Greer, L. 2001. Sustainable Small-Scale Nursery Production. Appropriate Technology Transfer for Rural Areas: Butte, MT.

DKS Associates. 2009. LED Streetlight Application Assessment Project. Seattle City Light: WA.

Energy Plus Roadways (2009.) “Overview and Outcomes.” Retrieved from http://energyplusroadways.unl.edu/info.php?section=overview.

Feldman, D., Barbose, G., Margolis, R., Wiser, R., Darghouth, N., and Goodrich, A. 2012. Photovoltaic (PV) Pricing Trends: Historical Recent, and Near-Term Projections. U.S. Department of Energy, National Renewable Energy Laboratory: Golden, CO.

Halcomb, M. and Fare, D. 2009. Conventional Container Production. University of Tennessee Extension.

Harper, S. 2010. “Electric-car charging station opens in Virginia Beach.” Retrieved from http://hamptonroads.com/2010/12/electriccar-charging-station-opens-virginia-beach.

Henson, C. 2012. “Introduction to Lighting.” Presentation at 2012 Design Training Expo.

Hower, M. 2013. “Philips TLED Prototype Doubles LED Energy Efficiency.” April. Sustainable Brands. Retrieved from http://www.sustainablebrands.com/news_and_views/design_innovation/philips-prototype-doubles-led-lamp-energy-efficiency.

Jarman, Josh. 2010 “Money-making pitch: biofuel crops along I-70.” Retrieved from http://www.dispatch.com/content/stories/local/2010/12/09/money-making-pitch-biofuel-crops-along-i-70.html.

John A. Volpe National Transportation Systems Center (Volpe Center). 2010. Estimated Land Available for Carbon Sequestration in the National Highway System. U.S. Department of Transportation, Federal Highway Administration: Washington, D.C.

John A. Volpe National Transportation Systems Center (Volpe Center). 2012. Alternative Uses of Highway Right-of-Way. U.S. Department of Transportation, Federal Highway Administration: Washington, D.C.

Kalbli, S. 2009. “Carbon Sequestration and the Florida Department of Transportation: An Investigation into the Feasibility of Providing Carbon Credits Through Revised Vegetation Management Practices.” Newsletter Article. Wood + Partners Energy Environmental Design Solutions (WEEDS), Volume 1, Issue 6.

Kansas Department of Transportation (Kansas DOT). 2010. Harvesting Hay on Highway Right of Way Permit.

Kibert, C., Sherif, S. A., Ries, R., Minchin, E., Walters, R., and Hertel, L. 2010. A Comprehensive Solar Energy Power System for the Turkey Lake Service Plaza. University of Florida: Gainesville.

Kollins, K., Speer, B., and Cory, K. 2010. Solar PV Project Financing: Regulatory and Legislative Challenges for Third-Party PPA System Owners. U.S. Department of Energy, National Renewable Energy Laboratory: Golden, CO.

Kossy, A., and Guigon, P. 2012. State and Trends of the Carbon Market 2012. World Bank: Washington, D.C.

Kreminski, R., Hirsch, A., and Boand, J. 2011. Assessment of Colorado Department of Transportation Rest Areas for Sustainability Improvements and Highway Corridors and Facilities for Alternative Energy Source Use. Colorado Department of Transportation: Denver.

LeBude, A. and Bilderback, T. 2008. Field Production of Nursery Stock: Field Preparation, Planting, and Density. North Carolina Cooperative Extension: Raleigh.

Markham, K. 2009. “Airspace Alchemy: Turning Unused Space into Revenue!” Inside 7 – District Employee Newsletter. California Department of Transportation. Retrieved from http://www.dot.ca.gov/dist07/Publications/Inside7/story.php?id=430.

Michigan Department of Transportation (Michigan DOT). 2013. “Guidelines for Harvesting Hay.” Retrieved from http://www.michigan.gov/mdot/0,4616,7-151-9623_26662_26679_27267_48606-278184--,00.html.

Minnesota Department of Transportation (Minnesota DOT). (2013a). MN/DOT Specification Light Emitting Diode (LED) Luminaire For Roadway Lighting at a Mounting Height of 40 feet.

Minnesota Department of Transportation (Minnesota DOT). (2013b). MN/DOT Specification Light Emitting Diode (LED) Luminaire For Roadway Lighting at a Mounting Height of 49 Feet.

Missouri Department of Transportation (Missouri DOT). 2012. “Hay and Other Crops on the Right of Way - Engineering Policy Guide.” Retrieved from http://epg.modot.org/index.php?title=822.7_Hay_and_Other_Crops_on_the_Right_of_Way.

National Research Council. 2013. Assessment of Advanced Solid State Lighting. The National Academies Press: Washington, D.C.

Navigant Consulting. 2012. Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products. Part I: Review of the Life-Cycle Energy Consumption of Incandescent, Compact Fluorescent, and LED Lamps. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy: Washington, D.C.

North Carolina State University, College of Agriculture & Life Sciences (NCSU CALS). 2011. “BAE partners with DOT to grow bioenergy crops on highway rights-of-way.” Retrieved from http://www.cals.ncsu.edu/agcomm/news-center/perspectives/bae-partners-with-dot-to-grow-bioenergy-crops-on-highway-rights-of-way.

Ohio Department of Transportation (Ohio DOT). “Veterans' Glass City Skyway.” Retrieved from http://www.dot.state.oh.us/districts/D02/Pages/VGCS.aspx

Oregon Department of Transportation (Oregon DOT). “Innovative Partnerships Program: Electric Vehicle and Infrastructure Program.” Retrieved from http://www.oregon.gov/ODOT/HWY/OIPP/pages/inn_charging_stations.aspx

Oregon Department of Transportation (Oregon DOT). 2011. "Innovative Partnerships Program: All About the Oregon Solar Highway.” Retrieved from http://www.oregon.gov/ODOT/HWY/OIPP/Pages/inn_solarhighway.aspx.

Parsons Brinckerhoff Quade & Douglas. 2001. Inventory of Comparative Decking Projects. City of Sacramento, CA.

Pennington, D., Gould, M. C., Seamon, M., Knudson, W., Gross, P., and McLean, T. 2012. Expanding Bioenergy Crops to Non-traditional Lands in Michigan. Michigan State University Extension: East Lansing

Ponder, D., Proudfoot, J., and Luftig, S. 2011. Solar Highway Program: From Concept to Reality. Oregon Department of Transportation: Salem.

Prozzi, J., Paes, T., Lisa Loftus-Otway, L., Caldas, C. 2012. Guidance on Extracting Value from TxDOT's Land Holdings. Center for Transportation Research at the University of Texas at Austin.

Robbins, James. Starting a Wholesale Nursery – Part I. University of Arkansas Cooperative Extension Service.

Royer, M.P., Tuenge, J.R., and Poplawski, M.E. 2012a. Demonstration Assessment of LED Roadway Lighting. Host Site: Philadelphia, PA. Pacific Northwest National Laboratory and U.S. Department of Energy.

Royer, M.P., Tuenge, J.R., and Poplawski, M.E. 2012b. Demonstration Assessment of LED Roadway Lighting. Host Site: NE Cully Boulevard, Portland, OR. Pacific Northwest National Laboratory and U.S. Department of Energy.

Sharma, J., Wilson, P.C., and Yaeger, T. 2008. Remediation of Runoff: Options for Container Plant Nurseries. University of Florida Institute of Food and Agriculture Sciences Extension.

Sinha, K., Johnson, K. D., Cherney, J. H., Petritz, D., and Hu, K. 1984. Feasibility of Harvesting Hay on Highway Right-of- Way: Yield, Quality, and Load Content of Forage along Indiana Highway. Joint Highway Research Project, Indiana Department of Transportation and Purdue University: West Lafayette, Indiana.

Smith, D.A.L. and Shah, J. 2010. Proposal & Solar Financing Options: Florida Municipal Governments in Palm Beach County. SunEdison. Retrieved from http://wpb.org/wp-content/uploads/sites/21/2009/11/West-Palm-Beach-City-Center-Solar-Proposal-05-07-09.pdf.

Solar Energy Industries Association (SEIA). 2013. "Reverse Auction Mechanism." Retrieved from http://www.seia.org/policy/renewable-energy-deployment/reverse-auction-mechanism.

South Dakota Department of Transportation (South Dakota DOT). 2010. Interstate Highway Right of Way Mowing Permit.

Texas Department of Transportation (Texas DOT). 2003. "Highway Illumination Manual." Retrieved from http://onlinemanuals.txdot.gov/txdotmanuals/hwi/conventional_vs_high_mast_lighting.htm.

Thrive! Morgan Hill. 2012. "Solar Highways Pilot Project." Retrieved from http://www.thrivemorganhill.org/solar-highways-pilot-project.php.

Tsao, J. (ed.). 2002. Light Emitting Diodes (LEDs) for General Illumination. Optoelectronics Industry Development Association: Washington, DC.

U.S. Department of Energy, National Renewable Energy Laboratory (NREL). 2013. "PVWatts Viewer." Retrieved from http://gisatnrel.nrel.gov/PVWatts_Viewer/index.html.

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (EERE) 2013. "DOE Municipal Solid-State Street Lighting Consortium." Retrieved from http://www1.eere.energy.gov/buildings/ssl/consortium.html.

U.S. Department of Transportation, Federal Highway Administration (FHWA). 2003. Utility Relocation and Accommodation on Federal-Aid Highway Projects, Sixth Edition. Washington, D.C.

U.S. Department of Transportation, Federal Highway Administration, Office of Real Estate Services (FHWA HEPR). 2009. Longitudinal Accommodation of Utilities in the Interstate System Right-of-Way. Washington, D.C.

U.S. Department of Transportation, Federal Highway Administration, Office of Real Estate Services (FHWA HEPR). 2012. "A Case Study in Early PEV Implementation: West Coast Green Highway Program." Office of Real Estate Services Newsletter. June, 4(3), 10–11.

U.S. Department of Transportation, Federal Highway Administration, Office of Real Estate Services (FHWA HEPR). 2013. "Right-of-Way Corridor Management. Colorado DOT Handbook on Haying in Rights-Of-Way." Retrieved October 22, 2012, from http://www.fhwa.dot.gov/realestate/rowharvesthay.htm.

U.S. Department of Transportation, Federal Highway Administration and John A. Volpe National Transportation Systems Center (FHWA and Volpe Center). 2009. Carbon Sequestration Pilot Program: Implementation and Next Steps. Washington D.C.

U.S. Energy Information Administration. 2013. Electric Power Monthly with Data for June 2013. U.S. Department of Energy: Washington, D.C.

University of Kentucky Cooperative Extension Service. 2013. Field Nursery Production.

Washington Department of Transportation (WSDOT). 2013. "Adaptive Light-Emitting Diode Lighting System on State Highways." Retrieved from http://www.wsdot.wa.gov/Design/Traffic/Electrical/LEDPilotProject.

Washington State Auditors Office. 2010. Citizen Hotline Report: Department of Transportation, Report No. 1003499.

Whitesides, R. and Hanks, D. 2011. Freeway to Fuel: A Baseline Study of Biofuel Feedstock Growth on Non Traditional Agronomic Lands in Utah. Utah State University, Department of Agriculture Science: Logan, UT.

Windspire Energy Inc. 2010. “Missouri DOT Offsets Traffic Carbon with Wind Power at Welcome Centers.” Retrieved from http://www.windspireenergy.com/case-studies/missouri-department-of-transportation.

Yeager, T. and Ingram, D. 2010. Layout and Design Considerations for a Wholesale Container Nursery. University of Florida Institute of Food and Agriculture Sciences Extension.

APPENDIX: LED Lighting

Lighting Specifications
Minnesota State Department of Transportation (MnDOT)

40-Foot Specification
http://www.dot.state.mn.us/products/roadwaylighting/pdf/40%20Foot%20LED%20Spec03202013.pdf

49-Foot Specification
http://www.dot.state.mn.us/products/roadwaylighting/pdf/49%20Foot%20LED%20Spec%2003202013.pdf

FDOT Materials

FDOT Highway Lighting Intro presented by Chester Henson, P.E.
http://www.dot.state.fl.us/structures/designExpo2012/Presentations/HighwayLightingIntro.pdf
"Florida Greenbook" - Manual Of Uniform Minimum Standards For Design, Construction And Maintenance For Streets And Highways
http://www.dot.state.fl.us/rddesign/FloridaGreenbook/2013-DRAFT-FGB.pdf

Florida FDOT Lighting Contacts:

Chester Henson, P.E., State Traffic Standards Engineer, (850) 414-4117, Chester.Henson@dot.state.fl.us

Christopher Lewis, P.E. (850) 414-4339, Christopher.Lewis@dot.state.fl.us

Bernie Masing, P.E. District Design Engineer FDOT - District 1 801 North Broadway Street Bartow, Florida 33830-1249 (863) 519-2543 FAX (863) 519-2892 bernie.masing@dot.state.fl.us

Jimmy Pitman, P.E. District Design Engineer FDOT - District 2 1901 South Marion Street Lake City, Florida 32025-5814 (386) 961-7583 FAX (386) 961-7809 jimmy.pitman@dot.state.fl.us

Scott Golden, P.E. District Design Engineer FDOT - District 3 Post Office Box 607 Chipley, Florida 32428 (850) 638-0250 FAX (850) 638-6148 john.golden@dot.state.fl.us

Howard Webb, P.E. District Design Engineer FDOT - District 4 3400 West Commercial Blvd Ft. Lauderdale, Florida 33309 (954) 777-4439 FAX (954) 777-4482 howard.webb@dot.state.fl.us

Annette Brennan, P.E. District Design Engineer FDOT - District 5 719 South Woodland Boulevard Deland, Florida 32720 (386) 943-5543 FAX (386) 736-5302 annette.brennan@dot.state.fl.us

Chris Tavella, P.E. District Design Engineer FDOT - District 6 1000 NW 111th Avenue Miami, Florida 33172 (305) 470-5250 FAX (305) 470 5338 chris.tavella@dot.state.fl.us

Ronald A. Chin, P.E. District Design Engineer FDOT - District 7 11201 N. McKinley Drive Tampa, Florida 33612 (813) 975-6030 FAX (813) 975-6150 ronald.chin@dot.state.fl.us

Pacific Northwest National Laboratory Contacts

Michael Royer, PhD
michael.royer@pnnl.gov
http://tpd.pnnl.gov/staff/staff_info.asp?staff_num=2349

Bruce Kinzey (GATEWAY program lead)
bruce.kinzey@pnnl.gov
http://tpd.pnnl.gov/staff/staff_info.asp?staff_num=1325
Kinzey BR, and M Myer. 2009. Demonstration Assessment of Light-Emitting Diode (LED) Roadway Lighting at the I-35W Bridge, Minneapolis, MN. PNNL-18687, Pacific Northwest National Laboratory, Richland, WA.

Jason Tuenge, LC, LEED AP Pacific Northwest National Laboratory
http://tpd.pnnl.gov/staff/staff_info.asp?staff_num=1779
tuenge@pnnl.gov

Michigan Department of Transportation: Lighting Specification for Roadway Luminaire

MICHIGAN
DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
FOR
LUMINAIRE - ROADWAY

a. Description. This work consists of furnishing all materials, equipment, and labor necessary to install luminaires as shown in the contract. All work must be completed in accordance with the standard specifications, the National Electric Code (NEC), and as specified herein.

b. Materials. Provide luminaire assemblies meeting all ANSI/NEMA/UL/IES applicable codes, including the following requirements:

Luminaire housing must be (IEC IP66 rated) die-cast aluminum construction with stainless steel or zinc plated steel fastening hardware. The fixture must be a grey or silver powder-coat finish unless otherwise shown in the contract. Provide a mast arm horizontal tenon mounting provision with ±5 degree leveling adjustment capable of mounting on a 2 inch (2⅜ inch O.D.) pipe arm (if required). Ensure the fixture has passive heat sink cooling (no fans, pumps, etc.) with self-cleaning ability and designed to operate within a -40 degree C to 40 degree C ambient temperature environment.

Provide the luminaire optical assembly with a color temperature between 4000K and 6000K, with a CRI of 70 or greater and with an IES photometric distribution as specified in the contract. Ensure the luminaires' driver/ballast is solid state type (ANSI/NEMA/American Nation Standard Lighting Group {ANSLG} C78.377) with built-in overload and voltage surge protection. Ensure the driver/ballast has a 90 percent or greater power factor with less than 20 percent Total Harmonic Distortion at full load and input voltage as shown in the contract. Ensure the drivers/ballasts have a minimum rated useful life of 100,000 hours and comply with FCC 47 CFR part 15 nonconsumer rules and regulations.

Provide luminaires with a minimum 10Kv/5Ka replaceable internal surge suppression module meeting UL 1449/ANSI C62.41.2 Category C, high exposure requirements. Ensure the luminaire power supply, driver/ballast, optical assembly, and surge suppression module is field serviceable and upgradable by means of modular electrical connections and easy access mounting hardware. Install luminaire busman fusing inside pole base handhole as shown on detail sheet.

Luminaire must conform with ANSI C136.31/37 for 3G rating of vibration for bridge and overpass applications, ASTM B 117 for Salt Spray (Fog) testing (Minimum 3000 hours) and IES TM-15 for Backlight, Uplight and Glare (BUG) ratings, without resorting to additional shields being attached to luminaire housing.

Ensure the luminaire delivers 90 percent or greater initial delivered lumens after 50,000 hours of operation and has a 70 percent or greater lumen maintenance after a minimum of 100,000 hours rated life. Provide the Engineer the luminaire life expectancy rating

(L70), Manufacturer's documentation and photometric data per IES-LM-80 calculated at an ambient temperature of 25 degrees C., by a third party independent test lab recognized by the Department of Energy as qualified to conduct photometric testing per IES LM-79.

Luminaire must have a minimum 10 year manufacturer's written warranty covering luminaire assembly, electrical components, driver, mechanical components and paint finish.

The Engineer reserves the right to request standard production model fixture samples for inspection and to require such tests as deemed necessary to ensure complete compliance with the specifications. Luminaires that do not meet these tests or those luminaires with improper or inadequate light distribution are subject to rejection. All costs associated with submitting and testing of replacement luminaires or lamps due to rejection of submitted luminaires must be paid by the Contractor.

c. Construction. All new installations must have luminaires provided as shown in the contract. Examine all luminaires delivered to the jobsite prior to installation to ensure all specification requirements and Shop Drawing comments have been incorporated by the Manufacturer. Ensure luminaires are individually packed for shipment in such a way as to ensure arrival at their destination in an undamaged condition.

Provide Shop Drawings showing luminaire type, and driver/ballast specification sheets.

All luminaire assemblies must be provided by one manufacturer. Any proposed luminaire must achieve the photometric levels and uniformity ratios per IES LM-79 for the fixture spacing as shown in the contract, and must be submitted with project specific point by point lighting footcandle calculations by an independent third party testing lab, meeting the following design criteria:

Candle power distribution must be in accordance with the 2005 AASHTO Roadway Lighting Design Guide criteria as follows: Average maintained illumination level must not be less than 1.0 footcandles and minimum maintained illumination level must not be less than 0.2 footcandles with a uniformity ratio (Average/Minimum Footcandles) not exceeding 4:1.

Road surface classification must be "R3" unless otherwise noted, with the light loss factor determined by manufacturer's lumen maintenance depreciation calculated at 55,000 hours (~12 years dusk-to-dawn operation), lumen dirt depreciation of 0.90. (LLF=LM*0.90)

Luminaires must be oriented to provide optimum designed light level distribution on the roadway.

Clean the Luminaire reflector and glassware after installation is complete. Ensure cleaning is done in accordance with the luminaire manufacturer's recommendations.

Provide Manufacturers calculations and supporting test data indicating lumen maintenance life and product Warranty documentation to the Engineer. Final photometric calculations must be based on lumen photopic values, scotopic lumen values are not recognized.

d. Measurement and Payment. The completed work, as described, will be measured and paid for at the contract unit price using the following pay item:

Pay Item
Pay Unit

Luminaire, Roadway....................................Each

Luminaire, Roadway includes payment in full for furnishing and installing the complete Luminaire as specified.