Alternative Uses of Highway Right-of-Way

Accommodating Renewable Energy Technologies and Alternative Fuel Facilities

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Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ARRA	American Recovery and Reinvestment Act of 2009
Caltrans	California Department of Transportation
CDOT	Colorado Department of Transportation
CFR	Code of Federal Regulations
CPV	Concentrating photovoltaic
CTR	University of Texas at Austin's Center for Transportation Research
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOJ	Department of Justice in Oregon
DOT	State Department(s) of Transportation
EIA	Energy Information Administration
EMF	Electromagnetic field
EU	European Union
EV	Electric vehicle
FAA	Federal Aviation Administration
F2F	Freeways to Fuel Alliance
FHWA	Federal Highway Administration
FTC	Federal Trade Commission
FTE	Florida Turnpike Enterprise
GHG	Greenhouse gas
GIS	Geographic information system
HVAC	Heating, ventilation, and air conditioning
JPO	Joint Program Office
kW	Kilowatt
kWh	Kilowatt hour
LED	Light-emitting diode
LRTP	Long Rang Transportation Plan
MassDOT	Massachusetts Department of Transportation
MPH	Miles per hour
MW	Megawatt
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NJDOT	New Jersey Department of Transportation
NREL	National Renewable Energy Laboratory
ODOE	Oregon Department of Energy
ODOT	Oregon Department of Transportation
OSU	Ohio State University
PGE	Portland General Electric
PHEV	Plug-in hybrid electric vehicle
PPA	Power Purchase Agreement
PV	Photovoltaic
REC	Renewable Energy Credit
RFP	Request for Proposals
ROW	Right of Way
RPS	Renewable Portfolio Standard

SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Act: A Legacy for Users
SEP-15	New Special Experimental Project
SLA	Solar License Agreement
SMUD	Sacramento Municipal Utility District
STIP	Statewide Transportation Improvement Program
TIGER2	Transportation Investment Generating Economic Recovery 2
TIP	Transportation Improvement Program
TxDOT	Texas Department of Transportation
UAP	Utility Accommodation Policy
UDOT	Utah DOT
UK	United Kingdom
USC	United States Code
U.S. DOT	United States Department of Transportation
USU	Utah State University
Volpe Center	U.S. DOT John A. Volpe National Transportation Systems Center
WSDOT	Washington State Department of Transportation

Executive Summary

In recent years, the U.S. Department of Transportation (U.S. DOT) has sought to better understand global climate change and the transportation sector's effects on the issue, and vice versa. The Safe, Accountable, Flexible, Efficient Transportation Act: A Legacy for Users (SAFETEA-LU) transportation authorization bill provides opportunities for State and Federal agencies to conduct research on innovative practices that may reduce transportation-related greenhouse gas (GHG) emissions and, by extension, the transportation sector's contribution to climate change effects and impacts. As such, this research investigates the state of the practice in accommodating renewable energy technologies and alternative fuel facilities within highway right-of-way (ROW), both activities that might help curb climate change.

The development of renewable energy technologies and alternative fuel facilities is compatible with current national and U.S. DOT priorities. These applications promote energy security by helping diversify the means of energy generation and delivery, and reducing the reliance on imported petroleum. They contribute to lowering GHG and other pollutant emissions by being both less energy intensive to produce and more energy efficient when used. Such projects can also foster the creation of a local green job market while enhancing the economic growth, competiveness, and viability of the nation's renewable energy and alternative fuel technology industries.

From a highway ROW perspective, however, there are considerable economic, ecological, legal, and political uncertainties related to whether accommodating renewable energy technologies and alternative fuel facilities can be practical highway land management practices. This report is intended to provide transportation agencies with information that will better enable them to consider the implications and evaluate the feasibility of implementing renewable energy and fuel options in the ROW. The findings presented in this report are based on the review of the relevant literature and a series of interviews with stakeholders representing State highway ROW renewable energy and alternative fuel facility projects that are in varying stages of completion and that utilize, or are pursuing, a range of technologies. A peer exchange convened among the interviewees and additional stakeholders supplemented the information collected during the interviews. The lessons that early adopters have learned is intended to help inform others seeking to pursue similar projects.

Key observations and findings include:

- A supportive institutional environment is critical.
- Siting concerns and requirements for renewable energy projects in highway ROW are a principal issue.
- Projects can be implemented through a variety of public-private partnership models.
- Permitting processes vary based on project details, location, and state laws.
- Developing the lease agreements is a multifaceted process.
- DOTs may require outside assistance in developing complex contract agreements.
- Responsibility for environmental clearance varies by state and project type.
- State and Federal tax credits and grants are currently needed to make projects economically viable.
- Carbon offsets and Renewable Energy Credits (RECs) could be used to finance

renewable resource development on the highway system in the future.
- Patent issues may increase project costs and timeline.
- Renewable energy projects may require zoning changes at the local level.
- Renewable energy projects require effective public involvement.

Best practice opportunities for DOTs are:
- Consider revising State Utility Accommodation Policies to include renewable energy.
- Identify State statutory or regulatory constraints that preclude renewable resource development to foster such development.
- Identify appropriate renewable energy technologies and potential sites through a statewide or regional feasibility study.
- Review Long Range Transportation Plans (LRTP) to identify potential siting conflicts. Consider developing guidelines for how renewable energy and alternative fuel facility projects can be considered during the statewide transportation planning process and how their performance can be assessed.
- Develop an internal interdisciplinary team to address the unique issues renewable energy projects in the ROW present.
- Create partnerships with external stakeholders.
- Develop comprehensive value-based selection criteria (in addition to criteria based on technical characteristics and price) for renewable energy and alternative fuel facility projects in highway ROW.

FHWA can further help states achieve desired outcomes by removing existing obstacles and providing incentives to encourage DOTs and energy developers to produce alternative power along the highway ROW.

Opportunities and potential next steps for FHWA are:
- Clarify its endorsement of using highway ROW to accommodate renewable energy technologies and alternative fuel facilities.
- Consider the use of pilot projects to identify any needed revisions or policies that restrict a DOT's ability to construct and operate renewable energy technologies and alternative fuel facilities in highway ROW.
- Discuss potential patent issues for renewable energy projects in highway ROW with the American Association of State Highway and Transportation Officials (AASHTO) and other relevant partners.
- Coordinate early involvement with the U.S. Department of Energy to facilitate the development of renewable energy projects in the highway ROW.
- Evaluate the benefits of comprehensive value-based selection criteria for renewable energy and alternative fuel facility projects in highway ROW.
- Analyze effective DOT practices in administering ROW access on routes controlled under the Highway Beautification Program.
- Consider the benefits of sponsoring research to evaluate rest areas, excess lands, and other transportation ROW for renewable energy generation.
- Help build a community of practice that develops and provides training and technical assistance to ROW practitioners and other stakeholders on accommodating alternative energy technologies and alternative fuel facilities.

Introduction

The Federal Highway Administration (FHWA) sponsored this research to learn more about the current state of the practice, challenges State Departments of Transportation (DOTs) have faced, and lessons learned in accommodating alternative energy technologies and alternative fuel facilities in highway right-of-way (ROW). Dissemination of the information in the report should better enable State DOTs and local public agencies to evaluate the feasibility of accommodating renewable energy technologies and alternative fuel facilities in the ROW and to identify effective practices for implementing such projects.

1.1 Background

In recent years, there has been significant growth globally in the capacity, generation, and consumption of energy derived from renewable sources. In the United States in 2009, renewable energy provided 413 billion kilowatt hours (kWh) of electricity, or 10 percent of the Nation's total electricity consumed. This represents an approximately 8 percent increase from what was generated in 2008 and a roughly 14 percent increase from 2005. Renewable energy consumption relative to total energy produced has shown similar increases over the same time period.[1]

The growth in renewable energy production is due in part to an increasing understanding of the anthropogenic aspects of climate change. Few other sectors present as many opportunities to manage greenhouse gas (GHG) emissions and the subsequent effects of climate change as renewable energy.[2] While there is debate, some people view a prompt transition from fossil fuels to renewable sources as a critical component to a stable climate and sustainable society.[3] Others see renewable energy production as a way to promote energy security, economic growth, and the viability of the nation's green energy industries. As a result, national and state policy initiatives to increase renewable energy production and reduce GHG emissions are emerging. For example, President Obama issued Executive Order 13514 to "establish an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions a priority for Federal agencies." Correspondingly, FHWA and its Sustainable Transport and Climate Change Team are undertaking a variety of activities to promote the incorporation of climate change considerations into transportation decision-making, including looking for ways to improve system and operational efficiencies, reduce the growth of vehicle miles traveled, transition to lower GHG-emitting fuels, and improve vehicle technologies.[4]

Traditionally, efforts to increase renewable energy production have focused on developing large,

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[1] U.S. Energy Information Administration (EIA). August 2010. Electricity Net Generation from Renewable Energy by Energy Use Sector and Energy Source. www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table3.html

[2] See TRB's Transportation Research Record, No. 2191, Energy and Global Climate Change 2010.

[3] Pimentel, David, et al. September 1994. Renewable Energy: Economic and Environmental Issues. BioScience, Vol. 44, No. 8.

[4] Two FHWA climate change-related publications of note are *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I* (www.climatescience.gov/Library/sap/sap4-7/final-report/) and *Regional Climate Change Effects: Useful Information for Transportation Agencies* (www.fhwa.dot.gov/hep/climate/climate_effects/index.cfm).

central-station renewable energy generators. Providing the renewable energy produced from such facilities to the grid often requires building new transmission and distribution power lines (or energy storage devices), which can entail expensive and lengthy processes. Aiming to increase renewable energy production in the near term, state and local transportation agencies recently have expressed a growing interest in installing decentralized renewable energy technologies on spaces not traditionally considered for electricity generation. Decentralized production, also called distributed generation, refers to electricity produced onsite or close to the load center and is interconnected to the utility distribution system. Decentralized renewable energy generation provides a near-term and feasible means to produce renewable energy on a broad scale without reliance on long-distance transmission lines.[5] Producing power close to the load center also improves cost effectiveness and efficiency by minimizing transmission and distribution losses.

Internationally, many transportation agencies have demonstrated the viability of utilizing the highway ROW for decentralized renewable energy production. Following these leads, several DOTs in the U.S. are exploring similar prospects given that the ample lands they manage are in proximity to power loads and, in some cases, have already been disturbed or are no longer held for the environmental attributes. With over 8 million lane miles of public roadways under state DOT supervision,[6] the properties that DOTs manage are presumably locations with the potential to generate significant amounts of renewable energy (e.g., via sun, wind, arable land, etc.). In addition, these areas could be important places from which alternative fuels might be distributed.

1.2 Methodology

This report is based on phone discussions with stakeholders representing highway ROW renewable energy and alternative fuel facility projects that are in varying stages of completion and that utilize or are pursuing a range of technologies (see Table 1).[7] A March 2011 peer exchange among the interviewees and additional stakeholders enhanced the information collected during the phone discussions. Additional information was gathered from an extensive literature review, as well as documentation that stakeholders provided throughout the research process. The project team then synthesized the literature, supplemental documentation, and phone discussion and peer exchange notes to identify the challenges, lessons, and recommendations presented in this report.

[5] Elkind (2009).
[6] The FHWA and U.S. DOT/Volpe Center (2010) have estimated that the National Highway System encompasses approximately 5 million acres of land and nearly 550,000 lane miles.
[7] A list of stakeholders that the project team interviewed is included in Appendix A. The calls followed the discussion guide included in Appendix B. The project team tailored the discussion guide to each stakeholder, as appropriate.

Table 1: Case Study Initiatives Included in this Research

Initiative	Case Study
Renewable Energy in the ROW Feasibility Research	Colorado DOT Ohio DOT Texas DOT Massachusetts DOT
Solar Energy Projects	Oregon DOT's Solar Highway Projects California's Proposed Highway 50 Solar Energy Projects Carver, Massachusetts' Proposed Route 44 Solar Energy Project Ohio DOT's Veterans' Glass City Skyway Bridge Solar Array Project
Wind Energy Projects	Massachusetts DOT's Proposed Wind Energy Project along the Massachusetts Turnpike Ohio DOT's Wind Turbine Project
Bioenergy Projects	Utah DOT's and Utah State University's Freeways to Fuel Pilot Project North Carolina DOT's Bioenergy Pilot Project
Electric Vehicle Charging Stations	Florida Turnpike Enterprise

1.3 Report Contents

Section 2, *Governance of Utilities in Highway ROW*, provides an overview of the Federal and state regulations governing the use of highway ROW related to utilities.

Section 3, *Renewable Energy Technologies in the ROW*, provides an overview of the various renewable energy technologies and alternative fuel facilities that can be accommodated in highway ROW. Summaries of each of the initiatives listed in Table 1 above are included while detailed case studies for each are included in Appendix C.

Section 4, *Observations and Findings*, describes the key insights that interviewed stakeholders have come away with based on their experiences implementing highway renewable energy and alternative fuels projects. The section provides information on the issues that may arise and the topics that need to be considered when designing, developing, and implementing these projects.

Section 5, *Conclusions and Recommendations*, offers best practice ideas for how DOTs can work with other stakeholders to capitalize on the opportunities to develop sustainable energy resources that utilizing unused ROW land can present. The section also suggests next steps for how FHWA can help states remove existing obstacles, overcome barriers, and encourage successful outcomes.

The appendices provide information on the stakeholders interviewed, the questions used to guide interview discussions, detailed case studies, the questionnaire sent to FHWA's Division Offices, example leases, requests for proposals, and other resources the stakeholders provided. They also include an annotated literature review.

2 Governance of Utilities in Highway ROW

The following section provides an overview of the Federal and state regulations governing the use of highway ROW related to utilities and, by extension, renewable energy technologies and alternative fuel facilities.

2.1 Federal Regulations

Prior to 1988, FHWA prohibited the installation of utilities within interstate ROW, and many states adopted the same policy for state highways. In 1988, that policy changed to allow each state to decide whether to permit utilities within interstate ROW and to specify the conditions for approval, or continue to adhere to the stricter AASHTO policies. The 1988 FHWA policy also stated that public utilities (i.e., utility service available for public use) that were "in the public interest" could be allowed in interstate ROW under the DOT's approved Utility Accommodation Policy (UAP) Manual or Plan as long as they are accommodated in ways that are safe for the traveling public and do not interfere with the operation of the facility. The emergence of opportunities for locating renewable energy technologies and alternative fuel facilities within highway ROW has caused FHWA and the states to reexamine the existing definition for "utility."

At present, a number of Federal statutes and regulations govern the use and management of the highway ROW. The Federal statutes and regulations most applicable to accommodating renewable energy generating technologies and alternative fuel infrastructure in the ROW are:

- 49 Code of Federal Regulations (CFR) 18.31(b) (Real Property)
- 23 United States Code (USC) 111 (Use and Access to ROW)
- 23 CFR 645 Subpart B (Accommodation of Utilities)
- 23 CFR 710 (ROW and Real Estate)
- 23 CFR 752.5 (Safety Rest Areas)

Some current Federal restrictions on highway real property use and commercialization may limit state DOTs' abilities to construct renewable energy technologies or alternative fuel facilities along the highway ROW. The use of highway real property is limited by 49 CFR 18.31(b), which states that except as otherwise provided by Federal statutes, real property will be used for the originally authorized purposes as long as the property is needed for those purposes. Commercialization along the interstate highway system is also restricted. Specifically, 23 USC 111 requires states, as a condition of receiving Interstate funding, to prohibit automotive service stations or other commercial establishments for serving motor vehicle users to be constructed or located on the ROW of the Interstate System. Federal regulations further prohibit states from charging the public for goods and services at safety rest areas except for telephone and vending machines (23 CFR 752.5).

A provision of SAFETEA-LU amended 23 USC 111 by adding subsection (d), permitting idling reduction facilities to be installed at safety rest areas on the Interstate for commercial vehicle use; subsection (d) permitted the charging of a fee for the use of those facilities. However, three

years later, this provision was repealed. The Administrator can still approve under 23 CFR 1.23 any noncommercial uses on the ROW if they are in the public interest and will not interfere with the free and safe flow of traffic.

Additional regulations govern the use of the Interstate ROW for utilities (23 USC 109(l) and 23 CFR 645). A utility is determined to be "public" by how a state defines the term under its own laws and regulations as well as whether it meets the Federal definition.[8] As defined in Federal regulation, a utility is a "privately, publically, or cooperatively owned line, facility or system for producing, transmitting, or distributing communications, cable television, power, electricity, light, heat, gas, oil, crude products, water, steam, waste, storm water not connected with highway draining, or any other similar commodity, including any fire or police signal system or street lightening system, which directly or indirectly serves the public" (23 CFR 645.207). DOTs can accommodate public and private utility facilities within the ROW when such facilities serve the public interest under their approved Utility Accommodation Policy (UAP) Manual or Plan (per 23 CFR 645 Subpart B). The UAP describes practices and procedures for regulating and accommodating utility facilities along, across, or on highway ROW and other transportation facilities under their respective jurisdictions. AASHTO's "Guide for Accommodating Utilities within the Right-of-Way"[9] establishes guidelines for states' UAPs, which FHWA ultimately reviews and approves.[10]

The use of highway ROW to accommodate facilities that will serve private or proprietary interests may also be accommodated; however, it is necessary for them to be approved under the airspace leasing requirements of 23 CFR 710 Subpart D. The right to use the ROW for interim non-highway use may be granted in airspace leases as long as such uses will not interfere with the construction, operation or maintenance of the facility; anticipated future transportation needs; or the safety and security of the facility for both highway and non-highway users.[11] The DOT shall charge current fair market value or rent for the use of the land; the income received from airspace leases shall be used for transportation purposes (as specified is 23 CFR 710.403(e)). Federal regulations do provide an exception to charging fair market rent if the DOT shows and the FHWA approves, that such an exception is in the overall public interest for social, environmental, or economic purposes. This exception may be appropriate for activities that address climate change mitigation and adaptation or contribute to improvements in air quality. The FHWA has final approval on leases of airspace on Interstate systems.

On March 27, 2009, FHWA's Office of Real Estate Services and Office of Program Administration jointly issued guidance on the longitudinal accommodation of utilities in the

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[8] The FHWA's *Program Guide: Utility Relocation and Accommodation on Federal-aid Highway Projects* (6th Edition, January 2003) describes several factors that help determine whether the facility is deemed a "public" or a "private line." In the event that there are questions concerning whether a proponent is a public utility, a legal opinion from the State may be necessary to establish the status of the facility.

[9] American Association of State Highway and Transportation Officials. October 2005. *A Guide for Accommodating Utilities within Highway Right-of-Way*, 4th Edition.

[10] The FHWA Program Guide *Utility Relocation and Accommodation on Federal-Aid Highway Projects*, which is a resource on regulations dealing with matters of accommodating utility facilities and private transmission lines in federal-aid highway ROW, can be found at: www.fhwa.dot.gov/reports/utilguid/index.htm

[11] FHWA's *Airspace Guidelines to 23 CFR 710.405–710.407*, which was issued August 10, 2010, is available at: www.fhwa.dot.gov/realestate/airguide.htm.

Interstate System ROW.[12] The guidance provides an expanded discussion on how 23 CFR Part 645 and 23 CFR Part 710 apply to utility accommodation proposals based on the classification of the facility's intended use.

Whether accommodated under a DOT's approved UAP or through an airspace lease, use of the highway ROW requires some form of written agreement. The terms of the agreement define the responsibilities and authorities of the parties involved, typically the DOT and the utility company. Additionally, the agreement should include provisions governing lease revocation; removal of improvements; adequate liability insurance to hold the DOT and the FHWA harmless; requirements of the utility; and access by the transportation agency for inspection, maintenance, and reconstruction of the transportation facility. The DOT should also have the capacity, policies, and procedures in place to verify the desired operation is progressing as planned and not adversely affecting highway safety and traffic flow.

Finally, each action in the highway ROW that is classified as a major Federal action must comply with the National Environmental Policy Act (NEPA) and other relevant environmental regulations. Federal actions are projects that use Federal funding, require a Federal permit, or require a Federal agency's approval.[13] The appropriate NEPA class of action is determined by the significance of the environmental impact of the project under study. Actions in the highway ROW that do not individually or cumulatively have a significant effect on the environment, for example, may be covered under a Categorical Exclusion level document.

2.2 State Regulations

In 2003, AASHTO published the "Policy on Accommodation of Utilities within ROW" to encourage the use of a uniform policy under which public and private utilities could accommodate renewable energy technologies in the ROW. State DOT's may need to reexamine their respective policies on the definition of utilities when considering the accommodation of renewable energy technologies and alternative fuel. As such, DOTs have employed different approaches over time. The project team distributed a questionnaire to the 52 FHWA Division Offices to identify and better understand any state-specific policies or regulations governing the accommodation of renewable energy and alternative fuel facilities in highway ROW that may exist. The project team received 42 responses representing 39 Division Offices (including the District of Columbia and Puerto Rico).

According to the responses, 29 states allow for the use of highway ROW to accommodate public utility facilities as noted in FHWA's *Guidance on Utilization of Highway ROW*. Five other states allow for utilities in highway ROW when certain exceptions are made, such as allowing for telecommunications utilities only (Colorado), utilities on highways but not the Interstate (Nebraska), or the longitudinal placement of high-voltage transmission lines–potentially for compensation–when there is no other practical alternative (Florida).

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[12] FHWA's HEPR and Office of Program Administration March 27, 2009. Information: Guidance on Utilization of Highway Right-of-Way. Longitudinal Accommodation of Utilities in the Interstate System Right-of-Way. www.fhwa.dot.gov/realestate/guidutil.htm

[13] http://ceq.hss.doe.gov/nepa/regs/ceq/1508.htm#1508.18

However, most states (29) also indicated that their UAPs do not characterize renewable energy facilities as utilities in regard to accommodating them in highway ROW. In one state, the definition of the term "utility" refers to the lines used to distribute power, not the means to generate it. In other states, the UAPs do not make distinctions between renewable and non-renewable energy facilities. Some states noted that while renewable energy facilities are not specifically distinguished as utilities in their UAPs, the permissibility of those facilities would likely be open to legal interpretation.[14]

Nevertheless, fundamentally most states (36) do not have any laws or other requirements that either allow or prohibit the generation of renewable energy within highway ROW. No specific legal authorizations or proscriptions have been given in these states. Of the remaining three states for which responses were received, two have laws allowing for the accommodation of renewable energy facilities in highway ROW while the third has an encroachment policy that may discourage some types of renewable energy technologies, such as wind turbines, within the ROW.

[14] In Ohio, the DOT *does* differentiate between renewable energy facilities and other utilities in describing the former as "alternative energy utilities." Ohio DOT anticipates that the 2011 update to its Utilities Manual will directly address the topic of accommodating renewable energy facilities in the state's highway ROW.

3 Renewable Energy Technologies in the ROW

The following section provides an overview of the various renewable energy technologies and alternative fuel facilities that have been or have the potential to be accommodated in highway ROW.

3.1 Overview of Renewable Energy Activities

Renewable energy has been used in roadway applications for at least 60 years. In 1948, a portion of U.S. 97 was reconstructed to widen a bridge across a canal in Klamath Falls, Oregon. The bridge was connected to an intersection at a steep grade, presenting traffic safety issues during winter months. Transportation engineers incorporated a geothermal de-icing mechanism into the bridge design as an experiment. Based on results from the test, which observations substantiate to date, it has been estimated that the pavement would be sufficiently clear of snow and ice to provide free travel at a temperature as low as -10°F (-23°C).[15] The exploration of geothermal roadway applications continued in the early 1980s when the Colorado Department of Highways (now the Colorado DOT) conducted a feasibility study to incorporate geothermal heating systems at critical locations in a proposed interstate. Results indicated that snow-cover duration on the roadways with installed heat pipes was significantly reduced as compared to unheated control areas.[16] Since these early applications, geothermal systems, which are very site specific, have been installed in New Jersey, South Dakota, Wyoming, Virginia, Japan, Switzerland, and Argentina.[17,18]

By comparison, *generating* renewable energy within highway ROW is an emerging concept in the United States. Much of the political and legislative effort for increasing renewable energy generation and use to date has focused on large-scale, centralized wind and solar developments, usually located far from the majority of energy consumers.[19] Only recently has the focus turned to localized, small-scale applications, which can be sited near their end users. Currently, solar, wind, and biocrop growth/harvesting, or "bioenergy," technologies offer the most immediate opportunities for generating renewable energy in the ROW. Other renewable energy opportunities, such as waste-to-energy conversion; hydrogen fuel generation from wind, solar, biomass, and waste resources; or energy harvesting via wave-, tidal-, and vibration-capturing technologies may serve important roles in the future.

Several state DOTs, including Colorado, Massachusetts, Texas, Ohio and California are conducting comprehensive statewide renewable energy feasibility studies to identify promising renewable energy technologies and locations to implement them. In 2010, the Colorado DOT

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[15] Lienau, Paul, Gene Culver, and John Lund. 1989. *Klamath Falls Geothermal Field, Oregon: Case History of Assessment, Development and Utilization*. Geothermal Resources Council 1989 Annual Meeting.
[16] Nydahl, John, et al. 1982. *Geothermal Heating of Highway Structures*. Transportation Research Record 860: Snow Control, Traffic Effects on New Concrete, and Corrosion
[17] Lund, John W. 2000. *Pavement Snow Melting*. Geo-Heat Center, Oregon Institute of Technology. http://geoheat.oit.edu/pdf/tp108.pdf
[18] Strawn, Jon A. and Ivar A. Engen. February 1982. *Geothermal Applications for Highway Rest Areas*. EG&G Idaho, Inc. for USDOE.
[19] Elkind (2009).

(CDOT) evaluated the alternative energy source potential, including wind, solar, biocrop, geothermal, and hydropower, of its ROW, facility grounds, building rooftops, and other built features.[20] A previous study conducted by the Colorado Governor's Task Force on Renewable Energy Generation had identified areas of the state with strong renewable resource potential.[21] CDOT ROW maps were superimposed with geographic information system (GIS) data layers of each alternative energy type to calculate the total energy potential within usable CDOT ROW. CDOT classified "usable ROW" based on resource-specific criteria, including slope, ROW width and accessibility, proximity to existing electrical transmission, and potential for CDOT usage (see Figure 1).

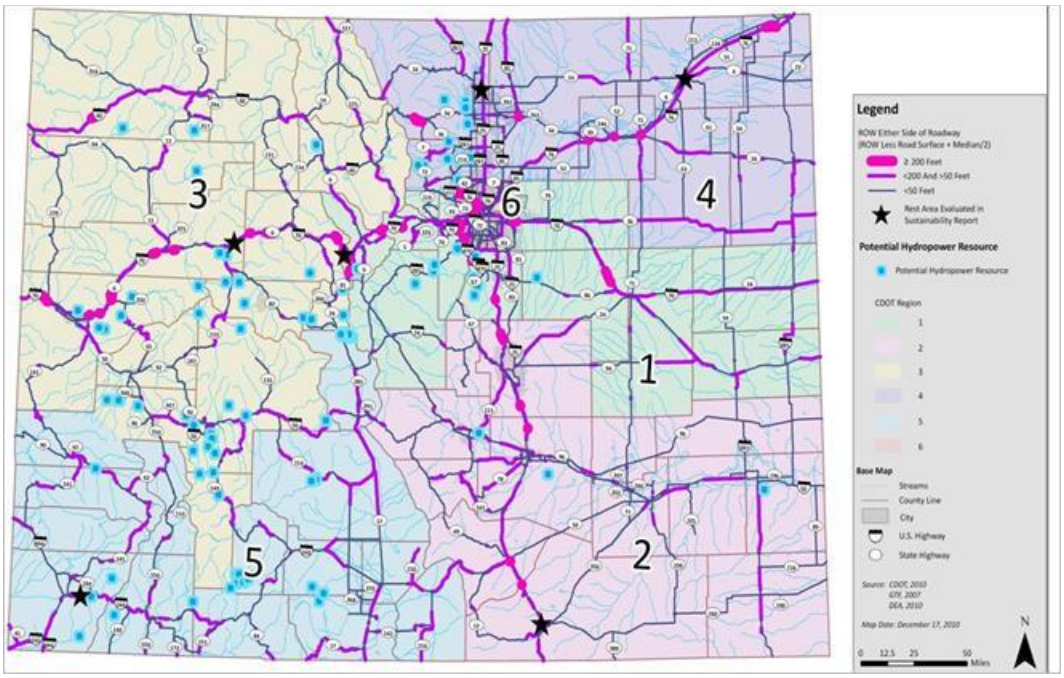

Figure 1: Map showing 91 potential hydropower sites in Colorado DOT ROW
Image source: Colorado DOT

The Massachusetts DOT (MassDOT) is currently conducting a similar statewide assessment of the Highway Division's real estate holdings, including buildings, structures, and ROW, to identify potential sites suitable for large- and small-scale wind and solar installations. To identify potential sites, GIS data on MassDOT facilities and other land holdings will be overlaid on solar and wind resource data, such as the National Renewable Energy Laboratory's (NREL's) 50-meter wind power data for Massachusetts. MassDOT holdings that are located in areas with quality wind and solar resources will be further assessed against a set of resource-specific suitability criteria, such as acreage, existence of environmental constraints, proximity to existing

[20] Colorado State University–Pueblo. March 2011. Assessment of Colorado Department of Transportation Rest Areas for Sustainability Improvements and Highway Corridors and Facilities for Alternative Energy. Source Use. Prepared for Colorado DOT. www.coloradodot.info/programs/research/pdfs/2011/restareas/at_download/file

[21] The Colorado Governor's Task Force on Renewable Resource Generation *"Connecting Colorado's Renewable Resources to the Markets"* mapped and evaluated Colorado's solar, wind, and hydroelectric power, as well as geothermal and biomass resources. The report is available at http://rechargecolorado.com/images/uploads/pdfs/redi_full%5B1%5D.pdf.

electrical transmission, and feasible construction access. Study results are expected in mid to late 2011. The Oregon Department of Transportation (ODOT) has also conducted a statewide GIS analysis of its operating and non-operating ROW for potential additional solar highway project sites. ODOT has identified over 600 additional sites and is in the process of applying additional criteria to narrow down an inventory of truly feasible sites. ODOT may further utilize this data and perform additional analysis in a future phase to search for sites for other types of renewable energy projects such as wind, biocrop, or public electric vehicle (EV) charging infrastructure. Similarly, the Ohio DOT is partnering with the Ohio State University to utilize GIS to identify opportunity zones for renewable energy and other revenue generating projects in the highway ROW. The research effort will utilize numerous GIS layers, including DOT assets and wind and solar resource maps, coupled with an economic analysis to identify priority locations, or "opportunity zones," for potentially implementing future renewable energy and alternative fuel projects.

The Texas Department of Transportation (TxDOT) is working with the University of Texas at Austin's Center for Transportation Research (CTR) to investigate opportunities to extract additional value for highway ROW and other DOT land holdings through various applications, including air right agreements, joint development initiatives, and implementing renewable energy technologies in the ROW. The CTR study will assess when, where, and under what circumstances to pursue specific applications. At the end of the assessment, which is scheduled for early 2012, CTR will develop guidance on when to pursue implementation of a value extraction application, including how to identify and involve key stakeholders.

At the national level, the National Cooperative Highway Research Program (NCHRP) 25/25 Task 64: *Feasibility Study of Using Solar or Wind Power for Transportation Infrastructure*,[22] completed March 2011, provides an overview of current and emerging technologies used in wind and solar applications. The report presents a general design approach for installations located near the roadway ROW and includes a tool for performing life-cycle cost analysis to determine the feasibility of potential transportation-related renewable energy installation projects. Similarly, NCHRP 20-85: *Renewable Energy Guide for Highway Maintenance Facilities*, to be completed in July 2012, will develop best practices for the planning, design, and operation of new and retrofitted highway maintenance facilities that are sustainable and energy efficient over their service lives through the effective use of energy capture technologies, including active, renewable energy sources and passive building and site modifications.

3.2 Solar Energy and Highway ROW

Solar energy technologies convert sunlight into usable energy. The amount of energy a particular solar technology can generate depends on how much of the sun's energy, both direct and diffused solar radiation, reaches the solar collectors. The primary technology used for generating solar power in the highway ROW is photovoltaic (PV) technology. PV cells, also known as solar cells, convert sunlight directly into electricity. Individual PV cells, which typically produce 1 to 2 watts of power, can be connected to form modules that, in turn, form solar arrays. There are

[22] Louis Berger Group, Inc (2011) Feasibility of Using Solar or Wind Power for Transportation Infrastructure. NCHRP Project 25-25, Task 64. http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP25-25(64)_FinalHandbook.pdf

two types of PV systems: traditional flat-plate PV systems and concentrating photovoltaic (CPV) systems. CPV systems use lenses or mirrors to concentrate sunlight onto high-efficiency solar cells. These solar cells are typically more expensive than conventional cells used for flat-plate photovoltaic systems. However, the concentration decreases the required cell area while also increasing the cell efficiency.

3.2.1 Solar Applications along the Roadway

The implementation of solar cell applications alongside travel lanes, versus in the road itself, has been most fully realized in Europe and, recently, Canada. The United Kingdom (UK), Netherlands, Switzerland, Austria, France, and Germany for example, have been installing various types of PV noise barriers along highways and railways[23,24] since the 1980s (see Figures 2 and 3). See Table 2 for example solar energy activities along highways globally.

Figure 2: PV sound barrier in Friesing, Germany (top) and PV system mounted on a noise barrier (bottom)

Photo source: www.asilin.org/2009/11/pv-soundless-world-record-along-highway.html(top), www.photovoltaik.eu/typo3temp/pics/92b3a2e7eb.jpg (bottom)

[23] Carder, D.R., L. Hawker and A.R. Parry. March 2007. Motorway Noise Barriers as Solar Power Generators. Proceedings of the Institution of Civil Engineers.

[24] Nordmann, T, A, et al. 2000. *The Potential of PV Noise Barrier Technology in Europe*. Presented at the 16th European Photovoltaic Solar Energy Conference and Exhibition, Glasgow, United Kingdom. www.pvdatabase.org/pdf/Mur_anti_bruit_ARRAS3.pdf

Figure 3: The German Unity Motorway Planning and Construction Company constructed a 2.8-megawatt (MW) solar array on the roof of a 2.7 km long noise-barrier tunnel on the A3 highway near Aschaffenburg, Germany.
Photo source: www.ralos.de

Several state DOTs throughout the United States are beginning to pursue similar projects encouraged by international activities, as well as directives to find ways to reduce statewide GHG emissions. The first solar highway project in the U.S. was developed in 2008 in Oregon. Partnering with Portland General Electric (PGE), ODOT developed the project, now commonly known as "Oregon's Solar Highway Demonstration Project," at the interchange of Interstate 5, a Federally designated "Corridor of the Future," and Interstate 205 in Tualatin, Oregon. It consists of a 594-panel, 104-kW_{dc} ground-mounted solar array system (see Figure 4) and has produced approximately 130,000 kWh annually since it first went online, or roughly enough electricity to supply a third of the energy needed to illuminate the interchange in that area. SunWay 1, a limited liability company managed by PGE, owns and operates the system. ODOT purchases the electricity the solar array produces from SunWay 1 at the same rate it pays for conventional power from the grid. ODOT and PGE plan to continue pursuing other solar energy projects in the highway ROW with the next project being located on approximately 7 acres adjacent to the Baldock Safety Rest Area on Interstate 5. The project will install a 1.75 megawatt (MW) direct current solar array, which includes approximately 6,994 250-watt panels. Construction began in August 2011 and is expected to be completed February 2012 (see Figure 5).[25]

[25] "Solar Highway Program: From Concept to Reality," which was prepared for the Oregon DOT and published in summer 2011, is a step-by-step guidebook intended to help DOTs develop solar PV systems on highway ROW. It is available at www.oregon.gov/ODOT/HWY/OIPP/docs/SolarManual.pdf.

Figure 4: Aerial view of Oregon DOT's Solar Highway Demonstration Project
Photo credit: Oregon DOT

Figure 5: Aerial view of Oregon DOT's Baldock Safety Rest Area Solar Highway Project
Photo credit: Gary Weber, Oregon DOT

ODOT is also installing a solar powered navigational lighting system on the Astoria-Megler Bridge, the coastal bridge on U.S. Highway 101 connecting Oregon and Washington. The 45-year old bridge still contains its original navigational lighting system, which the U.S. Coast Guard requires to be operational at all times. The existing electrical conduit for the navigational lighting system has deteriorated and is in need of replacement. ODOT, with approval from FHWA, will install new navigation lights, solar panels, and back up batteries (see Figure 6). In the first year of operation, ODOT will test the new solar powered lighting system in terms of light intensity, DC voltage output, charging current, and temperature. If the solar powered lighting system is deemed successful, ODOT plans to consider using similar systems on other bridges in coastal and remote areas.

Figure 6: Locations of the five different types of solar lights on the Astoria-Megler Bridge
Photo credit: ODOT

In the eastern U.S., Ohio DOT has partnered with the University of Toledo to deploy a solar array within the highway ROW to offset the electricity demand and operating costs associated with a 196-foot light-emitting diode (LED) lighted structure on the Veteran's Glass City Skyway bridge near Toledo, Ohio. The 100kW test array, which consists of both rigid and flexible solar panels (see Figure 7) made in Ohio, will be used to help Ohio DOT evaluate, select, and procure equipment for future permanent solar installations within the highway ROW, as well as to identify problems that are unique to alternative energy projects implemented in such a manner.

Figure 7: Rigid First Solar panels (left) and flexible Xunlight Corporation solar panels (right) installed along I-280 in Toledo, OH
Photo credit: Ohio DOT

Several other states have solar energy projects underway. MassDOT is coordinating with the Town of Carver, Massachusetts, to permit the installation of a solar array along Route 44, an east-west state highway in a southeastern part of the state. The Town of Carver, which has recently constructed a new water treatment facility in the North Carver Water District, is interested in installing a 112 kilowatt (kW) PV system to support the water system's energy needs. In November 2010, the town selected a preferred vendor, who will install, own, and operate the solar panels. The Town will purchase the renewable electricity from the vendor. The town anticipates construction of the solar facility to be completed in February 2012.

Beginning in 2008, the California Department of Transportation (Caltrans) and the Sacramento Municipal Utility District (SMUD) worked together in an effort to develop solar energy projects at two potential sites along Highway 50 in Sacramento County. The projects were expected to have a planned capacity of 1.4MW and utilize both traditional PV and CPV technologies. SMUD completed the environmental review[26] for the project in July 2011 and a conceptual draft airspace lease agreement that would have governed SMUD's use of the Caltrans ROW was approved in August 2011. SMUD then issued a Request for Offers to identify a partner to design, construct, and operate the solar systems. SMUD only received one bid for construction, which was priced higher than anticipated. As a result, SMUD determined that the solar highway project was not economically feasible at this time.

Caltrans also has also proposed to enter into a partnership agreement (airspace developmental lease and revenue share operations agreement) that would permit Republic Cloverleaf Solar, LLC (Republic) to install and maintain flat-plate solar panels within operating ROW at up to seven interchange locations throughout Santa Clara County. Republic would develop, finance, construct, own, operate, and maintain the PV systems, which combined would generate up to 15 MW of power to be sold directly to an investor or municipally owned utility. The airspace lease agreement would allow for the production of renewable power facilities on otherwise unleasable

[26] SMUD released the Revised Final Sacramento Solar Highway Initial Study and Mitigated Negative Declaration in July 2011. The document is available at www.smud.org/en/about/Documents/ceqa-pdfs/solar-highways-final-july11.pdf.

ROW, while establishing a new revenue source for the State. The draft environmental document for the project has been completed.[27]

Nationally, the "Adopt-A-Watt™ Program," which is based on the Adopt-A-Highway program, is seeking to promote energy conservation by giving sponsors community recognition for funding of clean energy, alternative fuel, and energy-efficiency projects. New Jersey DOT (NJDOT) is currently assessing the possibilities for constructing solar light poles and PV arrays at its rest areas as a part of the Adopt-A-Watt program. NJDOT's proposal has other precedents; all of the 19 rest areas that Wyoming DOT opened since 1980 use solar power to provide an estimated half of the rest areas' energy needs, a trend that is expected to continue. In August 2010, solar "flowers," or solar panels in the shape of flowers, began producing electricity at a rest area on Interstate 70 near Parachute, Wyoming (see Figure 8).

Figure 8I-70 rest area solar flowers in Parachute, WY
Photo credit: www.garfieldcleanenergy.org

Additionally, in April 2010, the FHWA entered into a cooperative agreement with the University of Nebraska-Lincoln to explore developing a Roadway Wind/Solar Hybrid Power Generation and Distribution System. The system would incorporate wind and solar hybrid energy harvesting systems with a "microgrid" that manages the energy produced with demand from surrounding infrastructure but that could interact with the overall power grid in the case that the microgrid needed additional energy, had excess energy to provide, or needed to isolate itself from disruptions in the larger power grid. The research effort will involve laboratory-scale testing and modeling of appropriate systems, followed by a full-scale installation and testing program.

3.2.2 Solar Power Applications in the Roadway

Transportation engineers have also sought ways to generate and/or use solar power directly from or in the roadway. A British company, for example, has developed a road stud that contains small solar panels and automatically emits LED light to illuminate roadways when it becomes dark outside. The solar panel road studs have been installed in over 120 roads in the UK and in locations in the Noord-Holland Province of The Netherlands.[28] Domestically, as of August 2010, the Washington State DOT (WSDOT) began a 5 year test of the same technology along a 2 mile

[27] Solar Highways Pilot Project: Initial Study with Proposed Mitigated Negative Declaration www.dot.ca.gov/dist4/documents/solar_highways_draft_is_mnd_110706_circulation.pdf
[28] Astucia Traffic Safety Systems. www.astucia.co.uk/Homepage

section of State Route 530 that has a history of run-off-the-road collisions.[29] The solar-powered road reflectors (see Figure 9) that WSDOT has installed contain an LED that will automatically light up under dark conditions to provide an estimated 10 times greater visibility for drivers than the traditional retro-reflective markers. Depending on the results of the tests and available funding, WSDOT will consider investing in additional test areas on other roadway surfaces or situations.

Figure 9WSDOT solar reflector
Photo credit: WSDOT, www.flickr.com/photos/wsdot/

The UK has also conducted successful trials of using inter-seasonal heat transfer systems that incorporate solar energy collectors in the road and shallow insulated heat stores in the ground.[30] Likewise, Worcester Polytechnic Institute researchers have found evidence suggesting that asphalt pavement solar collectors hold promise for energy recovery.[31] In more exploratory research, the Idaho-based company "Solar Roadways" has been awarded Small Business Innovation Research grants to develop 12-by-12-foot solar panels that could be embedded into roads to provide power into the electrical grid. It is estimated that each solar road panel, which would cost approximately $7,000 each, could generate roughly 7.6 kWh of power per day. Researchers are investigating whether the panels could feature LED road warnings and built-in heating elements that could prevent roads from freezing.

3.3 Wind Energy and Highway ROW

[29] Washington State DOT August 17, 2010 Press Release. www.rtands.com/newsflash/carmanah-trojan-battery-enter-into-strategic-partnership.html Last accessed February 14, 2011.
[30] Carder *et al* (2009).
[31] Worcester Polytechnic Institute. August 11, 2008 Press Release. www.wpi.edu/news/20089/asphaltnews.html

Wind can be used to generate electricity through the use of wind turbines. Wind turbines generate electricity through the following process, put simply: When wind blows over a turbine, it turns the turbine's blades, which are connected to a drive shaft. When the shaft turns, it spins a generator to produce electricity.

Wind turbine systems vary in size, application, and wind requirements. The system sizes generally available include small, mid-sized, and utility-scale systems (see Figure 10).

- Small wind turbines are typically used to supplement the power supply for small-scale users, such as individual homes and farms. They have a capacity rating of less than 100 kW. Small turbines, which have rotor blades with diameters around 8 meters (approximately 26 feet) mounted on towers of 40 meters or less, require an annual average wind speed greater than 9 miles per hour (mph). While the traditional pole mounted designs are normally ground mounted, some of these can be mounted on a building parapet or possibly on a high span bridge or other support structure.

- Mid-sized wind turbines are typically used for small commercial and community applications. Mid-sized turbines have a capacity rating of 100 kW to 1 MW.

- Utility-scale wind turbines are typically connected directly into the utility grid and used to provide electric power to utility customers. The majority of utility-scale turbines are horizontal axis wind turbines that are roughly 250–300 feet tall and have three long blades mounted on a tall tower. They typically need good exposure, available land (ideally already cleared), and have a capacity of 700 kW to 2.5 MW. Utility-scale turbines, which have rotor blades with diameters of 50 to 90 meters mounted on towers up to 90 meters tall, require an annual average wind speed of 11 to 13 mph. Multiple large wind turbines can be grouped together into wind farms.

Figure 10 Examples of small-, mid-, and utility-scale wind turbines
Photo credit: TxDOT (small- and mid-scale turbine images, left) and MassDOT (utility-scale turbine image, right)

Wind turbines can operate with naturally occurring wind, a resource consistently available in many parts of the U.S., or from less location-dependent "manufactured" wind resources, such as the air flow traveling vehicles produce. Past research has focused generally on improving the technology of mid-sized and utility-scale wind systems that capitalize on naturally occurring wind resources.

The relative size of highway ROW would likely make the accommodation of current mid-sized and utility-scale wind technologies impractical (although they are increasingly common along highways in Denmark, Germany, and the Netherlands). Instead, recent advances in smaller wind turbine technologies are providing the opportunity to explore possibilities for harnessing wind energy in many locations not previously possible, such as along roadways. For example, the Israel National Roads Company is initiating steps to install small turbines on lighting poles on the highway running along Israel's Mediterranean coastline to take advantage of sea winds; and in Taiwan, small-scale wind turbines are being installed in parking lots.

Developments are also being made in micro-wind turbine technology. The Department of Mechanical Engineering of the University of Hong Kong and MotorWave Limited have jointly developed and launched a new micro-wind turbine technology that enables wind turbines to start generating electricity at wind speeds as low as 2 meters per second. The micro-wind turbine can be arranged in an array of shapes and sizes, enabling them to be located where conventional

small wind turbines would not be allowed.[32] As an example, researchers are studying the practicality of using a modified version of the Jersey barrier, a concrete median, to harness wind that passing vehicles produce. The concept involves double-stacked Darrieus, or vertical axis, wind turbines within the structure that would capture the wind vehicles produce while passing the median in either direction.[33,34] Some critics debate that such turbines could only be placed on high volume roads and that they could reduce vehicle efficiency by imposing increased drag.

Figure 11: One of two, 1.2 kW wind turbines (one in each traveling direction) installed at Missouri DOT's Conway Missouri Welcome Center on I-44 . The wind turbines power the lights over the information counters.
Photo credit: Windspire Energy, Missouri DOT

To date, only a few state DOTs have examined the feasibility of installing wind turbines in highway ROW with most potential applications being at highway rest areas or on facilities. The Ohio DOT, for example, is installing a small 32 kW wind turbine at a maintenance facility in Northwood, Ohio. The maintenance facility is located adjacent to the highway ROW along I-68. The electricity produced by the turbine will be used on site, and Ohio DOT anticipates that it will help meet up to 65 percent of the electricity needs of the maintenance facility.

The former Massachusetts Turnpike Authority, now part of MassDOT, analyzed potential wind turbine sites along the Massachusetts Turnpike, a 138-mile highway extending across the state

[32] University of Hong Kong. March 15, 2007. HKU and Motorwave Limited Jointly Developed Micro-Wind Turbine Technology for Crowded Cities. Press Release. www.hku.hk/press/news_detail_5535.html
[33] Cavanaugh, Rebecca. January 10, 2007. The *New* Jersey Barrier: Mark Oberholzer explores the urban highway's potential for wind power. MetropolisMag.com. www.metropolismag.com/story/20070110/the-new-i-jersey-barrier
[34] Prok, Joshua. Spring 2008. Interstate Wind: Using New Technology to Enhance Transportation Fuel Investments. Transportation Law Journal. 35(67).

from east to west, in support of the state's Leading by Example Program that established GHG emissions reduction and renewable energy targets for all of the state's agencies. One of the sites the Turnpike Authority examined was a 68-acre property it owned in the western part of the state. The land holding is adjacent to the Blandford service area (see Figure 12). Over 13 months, the Turnpike Authority conducted a feasibility study, collecting wind speed and other site condition information.[35] It was ultimately determined that the site was suitable for wind power development, and in April 2009, the former Turnpike Authority issued a Request for Proposal (RFP) for a long-term lease for wind turbine development at the service area. Solaya Energy, LLC was selected to develop what was planned to be a nearly 400-foot tall, 1.5 MW wind turbine. However, in May 2011 registered voters at a Town of Blandford open town meeting defeated a wind power zoning bylaw that would have allowed the development of the proposed turbine, putting the future of this project in question.

Figure 12: Location of MassDOT's proposed Blandford rest area wind turbine
Image credit: MassDOT

In 2009, the University of Illinois at Urbana Champaign investigated use of wind for providing electrical power at Illinois DOT highway rest areas and weigh stations to determine the extent to which wind power could offset electricity costs and energy use and provide a reasonable return on investment.[36] The study, which identified several favorable sites where installing small wind turbines could be economically feasible, found that one of the most important determinants of return on investment and viability was the cost of the wind turbines—a variable consideration that depends on many factors. The team developed a spreadsheet that enables procurement

[35] Renewable Energy Research Laboratory. Wind Data Report Blandford Rest Area: December 2008 to February 2009. University of Massachusetts. www.umass.edu/windenergy/downloads/pdfs/Blan2_2009_QuarterlyReport_Winter.pdf
[36] Chapman and Wiczkowski 2009. *Wind-Powered Electrical Systems – Highway Rest Areas, Weigh Stations, and Team Section Buildings*. Illinois Center for Transportation. http://ict.illinois.edu/publications/report%20files/FHWA-ICT-09-034.pdf

agents to rigorously compare the prices and returns for given locations and turbine manufacturers. See Table 2 for example wind energy activities along highways globally.

3.4 Bioenergy and Highway ROW

Bioenergy is a form of renewable energy made from any organic material. Sources of bioenergy are called "biomass" and include agricultural and forestry residues, municipal solid wastes, industrial wastes, and terrestrial and aquatic crops grown solely for energy purposes. Many bioenergy proponents contend that the use of domestically produced biofuels will help reduce demand for imported oil, increase energy security, improve air quality, and lower GHG emissions. Advocates also assert that biomass production could enhance the visual quality of highway ROW, decrease weed species in the ROW, and stimulate the growth of a new domestic industry while helping support rural and agricultural economies. Today, biomass resources are used to generate electricity and power and to produce liquid transportation fuels, or biofuels, such as ethanol and biodiesel. It should be noted, however, that corn- and other feed-based ethanol have come under scrutiny with regards to inflating global grain prices as well as the life cycle GHG emissions associated with producing the fuel.

In the past decade, increased attention has been given to the development and use of biofuels as a substitute for transportation-sector petroleum consumption and a contributor to local air quality improvements. This has been due in large part to consistent Federal-level support for the development and use of domestically-produced biofuels as alternative transportation fuels. States and the Federal Government have provided incentives for the use of biofuels, particularly ethanol, several times since the 1970s. The convergence of recent record-high oil prices and a strengthening political will to address climate change effects through GHG reductions has resulted in Congress committing the Nation to goals that increase the amount of biofuels produced and used domestically in the transportation sector over the next 10 years. Increased biofuel use in the Nation's vehicle fleet is a primary strategy of the Energy Independence Security Act of 2007, which includes a Renewable Fuels Standard calling for annual incremental increases in delivered biofuel (reaching 36 billion gallons per year by 2022). It is expected that these requirements will help to reduce risk of long-term industry investment and create a long-lasting market demand for ethanol and biodiesel.[37]

Several agencies are beginning to explore the potential for bioenergy generation in highway ROW through the Freeways to Fuel (F2F) National Alliance. The F2F program investigates the use of non-traditional agronomic lands such as roadside ROW, military bases, and airports for the growth of biofuel feedstock crops across the country. Freeways to Fuel seeks to increase the production of biofuel without effecting food, fiber, feed, or flower production by targeting lands that are not currently in production It began in 2006 as a cooperative program between the Utah DOT (UDOT) and Utah State University (USU). UDOT was interested in learning whether it could use its ROW to produce alternative fuel feedstock and reduce maintenance costs. The two organizations decided to pilot test the planting and cultivation of safflower and canola in eight

[37] Biodiesel is a renewable fuel derived from plant and animal oils and fats that is used in diesel engines. At low concentrations, biodiesel blended with petroleum-based diesel can be used in existing diesel engines with little or no modifications. As concentrations of biodiesel increase, some manufacturers will not guarantee warranties for their diesel engines, or the engines may face compatibility issues.

20-foot by 8-foot plots in four different locations along the I-15 corridor. Ultimately, arid conditions and heavily compacted soil led the team to conclude that growing biocrops in Utah faces significant challenges that might not be manifested in other states. To address this issue, USU developed an aerator tool that could be attached to state DOTs' planting equipment. Based on lessons learned from the Utah pilot, USU developed a set of criteria by which the feasibility of a potential ROW biocrop program could be evaluated. The criteria included crop type, erosion, structural integrity of the road and ROW, habitat issues, line of sight issues, risk management issues, ecological impacts, and water quality issues.

Figure 13: NCDOT crews plant canola along I-40 in Raleigh.
Photo credit: NCDOT, www.flickr.com/photos/ncdot/

Since that time, the alliance has grown to include other State DOTs and land grant universities.[38] The North Carolina F2F project started in 2009 and is now largely regarded as one of the most promising programs in the Alliance. Its moist climate, fertile soils, and support from the State legislature have made North Carolina DOT's (NCDOT) biocrop growing efforts a national model. The North Carolina project began with four 1-acre plots of canola or sunflower crops (see Figure 13). The NCDOT, in coordination with North Carolina State University, selected crops that it believed would provide the greatest yield in the ROW. By working with seasonally rotated crops on the same plot, NCDOT has been able to meet or exceed national standards for crop production. In 2010, NCDOT extracted 3,000 lb of canola seed, which produced 100 gallons of virgin oil. This in turn created 150 gallons of B100, which was cut with conventional diesel to produce approximately 600 gallons of B20 product that NCDOT used to power its dump trucks, tractors, and other equipment. Media coverage and public feedback for the effort have been

[38] In addition to those discussed, Michigan DOT planted its first roadside plots during 2011, and five other states plan to plant plots in 2012 pending funding decisions.

overwhelmingly positive. As of August 2011, NCDOT has its fourth crop planted.

In Tennessee, its DOT and Genera Energy LLC recently planted several plots of switchgrass along Interstate corridors in the state (see Figure 14). The test plots are designed to demonstrate if switchgrass can help reduce maintenance costs by reducing the need for mowing, while having the added benefits of producing biocrops for cellulosic ethanol production and reducing erosion at highway interchanges. Likewise, there are other state DOTs, such as those in Oregon, Texas, and Washington (among others), that are working to identify potential ROW locations for biocrop plots. Similarly, Michigan DOT has identified 10,000 ROW acres for planting, which it plans to offer to bid in the near future. See Table 2 for example bioenergy activities on highway ROW.

Figure 14: Tennessee DOT highway switchgrass test plot
Photo source: Utah State University/Freeways to Fuel

3.5 Energy Harvesting and Highway ROW

Energy harvesting technologies could convert ambient energy of various forms (e.g., stress and strain, mechanical, vibrations and noise) into electrical energy. Some systems, such as wave or tidal power technologies, directly convert kinetic energy into electricity. Other technologies, such as piezoelectric materials, "scavenge" energy from ambient vibrations.

In the case of wave and tidal power, energy from the ocean can be converted into electricity or other useful forms of power with turbines placed underwater. Given that 78 percent of United States' electricity consumption occurs in a state bordering an ocean or a Great Lake,[39] wave and

[39] NREL (W. Musial). August 2008. Status of Wave and Tidal Power Technologies for the United States. www.nrel.gov/wind/pdfs/43240.pdf

water currents could be significant and virtually untapped renewable energy resources near or within highway ROW. This concept has been effectively demonstrated in Sweden, Scotland, and other European countries, such as France, where plans have been made to install eight turbines underneath bridges crossing the River Seine in Paris, France.[40] Wave energy applications in roadway settings are only beginning to emerge in the U.S. as compared to other renewable energy technologies. For example, in 2006, newspapers reported that city officials were considering submerging wave turbines at the Golden Gate Bridge to capitalize on the strong currents often measured there.[41] After several years of debate, the project was ultimately deemed too expensive to pursue. More recently, as reported in June 2010, Hawaii DOT is participating in early discussions for the accommodation of power lines in the ROW for wave energy transmission.

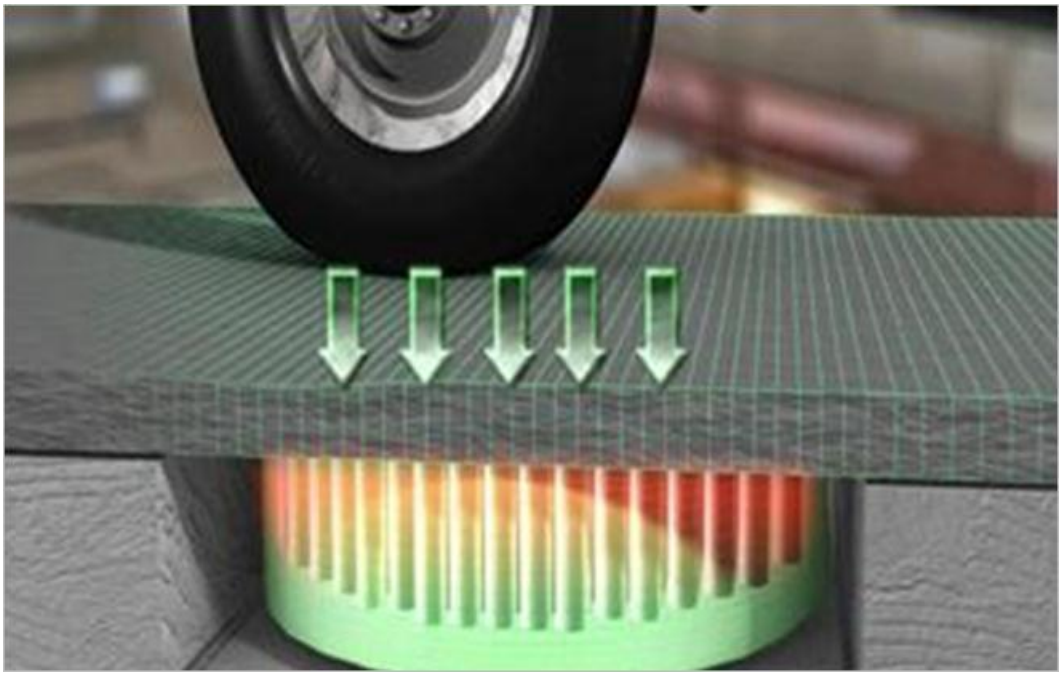

Figure 15: Example of roadway vibration capture technology
Image credit: Innowatech via TxDOT presentation at peer exchange

Using technologies that capture energy from roadway vibrations (see Figure 15) currently appears to be a more practical prospect for highway ROW renewable energy generation, though they are still comparatively unproven technologies when balanced against solar power, wind power, and bioenergy applications. For example, the Israeli company Innowattech is working with an Italian infrastructure and civil engineering contractor to use generators placed beneath the upper layer of asphalt on a highway to light road signs between Venice and Trieste, Italy. The generators will harvest the electrical charge that the vibrations of the moving vehicles

[40] Wilssher, Kim. June 28, 2010. Paris looks for power from turbines beneath the Seine. The Guardian. www.guardian.co.uk/world/2010/jun/28/paris-power-turbines-seine
[41] Vega, Cecilia. September 19, 2006. Tides around Golden Gate are potential energy source. The San Francisco Chronicle. www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2006/09/19/BAGKJL872O1.DTL

create.[42] Other companies are exploring opportunities to capture the energy lost in the process of a vehicle braking to generate electricity. The lost energy is captured via specially designed mats, which are installed on the road in places where vehicles slow down.[43]

Recently, FHWA has contracted with Virginia Tech University to investigate "energy independent" monitoring systems for bridges. The proposed systems would use piezoelectric materials to harvest electricity from the vibrations in the bridge that the vehicles crossing over it create.[44] Likewise, researchers at the University of Minnesota Duluth are developing a piezoresistive mixture of concrete with embedded electrodes in an effort to measure the change in electrical resistance that the stress of passing vehicles generates.[45,46]

3.6 Alternative Fuel Facilities in the ROW

Recent Federal energy polices have emphasized Federal agency adoption of strategies to reduce GHG emissions. In conjunction, compliance with Executive Order 13514 has prompted state DOTs to adopt various sustainability measures. In addition to using highway ROW for renewable energy generation, there is an opportunity for transportation agencies to distribute cleaner-burning, alternative fuels along roadways. Doing so could help accelerate the creation of a clean energy economy, promote energy security and offer state DOTs a new source of revenue generation, especially if petroleum prices continue to rise as expected. Finland has been at the forefront of fully exploring these opportunities. Proponents in the country are proposing to build a $1 billion carbon-neutral highway, the first of its kind in the world, from Helsinki to a city near the Russian border. The system would provide a mix of biofuels, EV charging infrastructure that obtains energy from solar and wind power technologies, and renewable energy generation technologies along the highway. The towns along the highway would be involved in the effort by growing biocrops for biofuel creation. The project is under the feasibility analysis stage and is projected to be completed by 2016 if approved.

The U.S. has established goals for alternative fuels and alternatively-fueled vehicles at both the national and state level. President Obama's Administration established targets to have one million plug-in hybrid electric vehicles (PHEV) on the highway by 2015 and to reduce oil use by approximately 3.5 million barrels per day in 10 years.[47],[48] Accordingly, unprecedented amounts

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[42] For more information, see www.greenprophet.com/2010/05/israel%E2%80%99s-innowattech-to-provide-renewable-energy-for-highway-signs-in-italy/ and http://spectrum.ieee.org/green-tech/mass-transit/startups-try-to-capture-road-traffics-excess-energy/?utm_source=techalert&utm_medium=email&utm_campaign=101410

[43] For example, the American company New Energy Technologies Inc. and the UK's Highway Energy Systems Ltd.

[44] Virginia Tech University. www.vtnews.vt.edu/articles/2009/02/2009-77.html

[45] ITS Institute. "Beyond the loop: Researchers develop the next generation of vehicle detectors." *The Sensor* Newsletter. Spring 2009. www.its.umn.edu/Publications/Sensor/2009/01/BeyondtheLoop.html

[46] As a part of its Technology Innovation Program, the National Institute of Standards and Technology sponsors research into new technologies that will enable an easily deployed, self-powered network of wireless sensors, together with analysis tools, to provide continuous monitoring of the structural integrity of bridges. For more information, see http://tipex.nist.gov/tippb/prjbriefs/prjbrief.cfm?ProjectNumber=080011

[47] January 2011 State of the Union Address

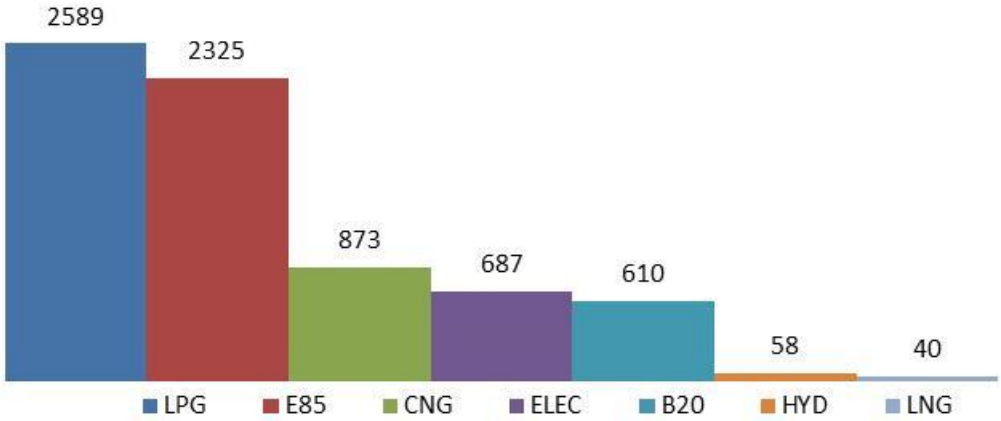
[48] In June 2011, a public comment seeking comments on whether FHWA should grant a waiver of the Buy

of funding under the US Energy Independence and Security Act of 2007 and the American Recovery and Reinvestment Act of 2009 (ARRA) are being put toward alternative fuels research and development.

If highway ROW were to distribute alternative fuels, stations that could deliver one or more of the following fuels would need to be installed:

- Electricity, preferably from renewable sources
- Biofuels, primarily ethanol and biodiesel
- Propane or natural gas
- Hydrogen

Figure 16: Fueling Stations Counts in the United States by Fuel Type, as of January 2011*
Data source: U.S. Department of Energy's Alternative Fuels and Advanced Vehicles Data Center



*As of January 2011, the most widely distributed high-level ethanol blend, E85 (85 percent ethanol/15 percent gasoline), was available at approximately 2,300 retail fueling stations in the United States. Although this figure indicates that E85 is available at less than two percent of all retail fueling stations in the country,[49] charging station technologies are even less prevalent. *LPG=liquefied petroleum gas; E85=85 percent ethanol/15 percent gasoline blend; CNG=compressed natural gas; ELEC=electric charging stations; B20=20 percent biodiesel/80 percent diesel blend; HYD=hydrogen; LNG=liquefied natural gas

The opportunities for accommodating EV and PHEV charging facilities within highway ROW are likely greater than for the other alternative fuels listed, especially when the electricity is generated on-site by renewable (e.g., solar and wind) sources. This is likely the case due to the fact that EV and PHEV technologies would require new supporting infrastructure, unlike biofuel distribution facilities that could use existing or modified pump and tank storage infrastructure already available at commercial service stations.[50] Thus, facilities within highway ROW, such as

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America requirements of 23 CFR 635.410 to permit the use of non-domestic 12 all-battery electric vehicles, 12 plug-in hybrid vehicles, and 5 neighborhood electric vehicles in the state of California ended. FHWA will publish a notice of finding after considering all comments received.

[49] According to the U.S. Census Bureau's 2007 Economic Census, there are nearly 119,000 gasoline stations in the United States.

[50] It should be noted that in California, planning to develop a California Hydrogen Highway Network is currently underway, and there has been some interest among private developers to support the establishment of hydrogen refueling stations on the East Coast as well. See www.hydrogenhighway.ca.gov/ and http://wheels.blogs.nytimes.com/2010/04/16/a-private-plan-for-a-hydrogen-highway/

visitor centers, recreational/natural resource rest areas, truck rest havens, and perhaps some scenic overlooks, may offer convenient locations for new EV and PHEV charging technology. DOTs could facilitate the development of a charging infrastructure network that supports interstate and regional travel, since routine charging will likely be provided by home- or work-based charging stations or other publically accessible locations.

The Florida Turnpike Enterprise (FTE), a separate business unit of the Florida DOT, for example, is currently trying to pilot test this concept as regulatory restrictions on commercial establishments along the transportation system do not apply to turnpike authorities. FTE was recently approved for six, 500-volt, high-current rapid charging stations that it plans on strategically placing along the Florida Turnpike in south Florida. These stations are in addition to 40 truck electrification stations installed on the turnpike that allow tractor trailer trucks to get heat, air, and electricity without having to idle. Similarly, MassDOT and the Massachusetts Executive Office of Environmental Affairs is working to identify prime locations for public charging infrastructure, particularly at public parking areas and in public-private partnership applications.

The Ohio DOT recently proposed a research project to evaluate the installation of a wind and solar-powered rest stop electrification system at two rest area facilities (see Figure 17). The project, which was ultimately cancelled due to changing priorities, would have involved installing 12 truck electrification stations (six at each rest area) that allow truck drivers to plug-in their vehicles and operate onboard devices such as heating, ventilation, and air conditioning (HVAC); computers; and appliances through a window unit or off-board 120-volt power pedestal. Commercial truck drivers would have used the system free of charge. A wind turbine and a ground mounted solar array system located at the rest area were proposed to power the electrification systems. FHWA granted conceptual approval of the research proposal, noting that as long as the Ohio DOT did not charge a fee for the use of the truck electrification systems, the activity would have been considered noncommercial, and since the use of the system would reduce fuel consumption and air pollution, the project would have been considered to be in the public interest.

Figure 17: Interstate I-90 Rest Area Facility Rendering
Image credit: Ohio DOT

In 2009 and 2010, the U.S. Department of Energy (DOE) awarded the company ECOtality a grant totaling $155 million to support the "EV Project," a pilot project to collect and analyze data to characterize vehicle use in diverse topographic and climatic conditions, evaluate the effectiveness of charging infrastructure, and conduct trials of various revenue systems for commercial and public charging infrastructures. The ultimate goal of the EV Project is to take the lessons learned from the deployment of the first 8,300 EVs, and the charging infrastructure supporting them, to enable the streamlined deployment of the next 5,000,000 EVs. The EV Project selected seven test markets to deploy EV vehicles and charging stations: California, Oregon, Washington, Arizona, Texas, Tennessee, and Washington, D.C. The DOE is also forming a partnership with Google Inc. and more than 80 EV stakeholders to help consumers find charging stations nationwide.

Three of the states participating in the EV project—Oregon, Washington, and California—have also partnered to form the West Coast Green Highway,[51] an initiative aimed at advancing the adoption and use of electric and alternative-fuel vehicles along the I-5 corridor. In October 2008, the three states jointly submitted a New Special Experimental Project (SEP-15) application for the I-5 Alternative Fuels Corridor Project. The project would allow limited commercialization of state-owned ROW or highway rest areas to promote the use of alternative fuels. USDOT determined that it would be better implemented through modification to the Interstate Oasis Program guidance.[52] The necessary change has not been initiated to date.

In June 2010, the Governor of Washington announced that WSDOT and the state's commerce

[51] West Coast Green Highway. Available at www.westcoastgreenhighway.com
[52] FHWA's Interstate Oasis Program: www.fhwa.dot.gov/safetealu/factsheets/iop.htm

department would partner to implement the Nation's first "electric highway," an initial network of public access EV charging locations along (but not within the ROW of) Interstate 5. Once implemented, Washington will have the first border-to-border highway to offer fast charge technology. In October 2010, ODOT received $2 million as part of the Transportation Investment Generating Economic Recovery 2 (TIGER2) Discretionary Grant program to help fund the installation of 22 DC fast-chargers in Northwest Oregon near major travel destinations and along heavily-traveled highway corridors at an interval of no more than 50 miles between each charging station (see Figure 18).[53] The Oregon Department of Energy (ODOE), with Recovery Act dollars through its State Energy Program, awarded ODOT $700,000 to extend the 3-phase, 480V-fast charge network along the corridor. The grant will fund eight DC fast-chargers from the southern end of the Willamette Valley in Oregon to the California border as part of a coordinated strategy between the EV Project installations and other West Coast states' installations.

Figure 18: Electric vehicle charging station in Portland, OR
Photo credit: Oregon DOT

[53] Oregon DOT. Electric Vehicle Charging Network. Available at www.oregon.gov/ODOT/HWY/OIPP/inn_ev-charging.shtml

Table 2: International and Domestic Examples of Renewable Energy and Alternative Fuel Facilities in Highway ROW

SOLAR ENERGY – DOMESTIC

California: Solar panels are being installed at carports across the state. Caltrans has also been installing solar power generating facilities on state-owned buildings (maintenance stations) and in safety roadside rest areas to offset the cost of the energy Caltrans uses. The facilities are sized so that the DOT does not generate more energy than it uses, thus avoiding being characterized as a utility. Additionally, a Swedish architect's "solar serpent highway" idea for Santa Monica, CA is in a conceptual phase.

District of Columbia: DDOT has installed solar powered parking meters. Solar lights are in use along the Metropolitan Branch Trail.

Florida: The Florida Turnpike Enterprise has plans to install a solar park at the Turkey Lake Service Plaza.

Hawaii: Hawaii DOT has installed PV power systems at seven DOT facilities, including five airport facilities, a DOT Highways Division baseyard, and a DOT administration building.

Massachusetts: MassDOT is working with the Town of Carver, Massachusetts to explore the installation of solar arrays on Route 44.

Missouri: MoDOT is using solar power to heat some bridge decks during inclement weather and to provide power to some traffic signals.

New Jersey: NJDOT is retrofitting over 200,000 utility poles with solar panels. It is also looking to install solar panels on the Carneys Rest Area on I-295 as a part of the national Adopt-A-Watt Program.

New York: NYSDOT is considering the installation of solar panels at highway rest areas.

Ohio: Ohio DOT, in partnership with the University of Toledo, created a solar highway along Interstate 280. The arrays were installed in the summer of 2010 and are used to offset electricity use at the Veterans' Glass City Skyway bridge.

Oregon: ODOT installed the Nation's first solar highway project in 2008. It is now working to develop other solar power projects along highway ROW.

Washington: WSDOT is considering potential solar installations along Interstates in the state.

Wyoming: Since 1980 WYDOT has opened 19 new rest areas. Solar heating provides nearly half of rest rooms' energy needs. In August 2010, solar "flowers," or solar panels shaped like flowers began operating at a rest area in Parachute, WY. www.garfieldcleanenergy.org/gov-solar-grand-opening-ParachuteRestArea.html

WIND ENERGY – DOMESTIC

District of Columbia: DDOT is considering self-contained turbine street lights but applied research is not underway at this time.

Illinois: Illinois DOT partnered with the University of Illinois to study the feasibility of using wind to provide electrical power at highway rest areas, weigh stations, and team section buildings.

Massachusetts: MassDOT is working to develop a proposed wind turbine project on land adjacent to a Massachusetts Turnpike rest area.

Minnesota: The Minnesota state legislature is currently assessing the benefits and costs of using state-owned land for wind energy generation systems.

Missouri: MoDOT has two, 1.2 kW wind turbines (one in each traveling direction) installed at a Welcome Center on I-44 in Conway, Missouri. The wind turbines power the lights over the information counters.

Ohio: Ohio DOT was advancing projects involving the installation of wind turbine electrical generators at two Interstate rest areas (I-90 in Ashtabula County and I-75 in Wood County) in order to provide power for these rest areas. The projects, which would have included the installation of Truck Electrification Systems for use at no cost, have been cancelled due to changing priorities.

Washington: WSDOT had been approached with the idea of installing wind turbines on the SR 16 Tacoma Narrows bridge and as part of the I-5 Columbia River Crossing bridge replacement project, but no specific proposals have been received.

Other: Some consulting firms have indicated intentions to install wind turbines along highway medians in several states. At this time, these claims could not be substantiated. (e.g., the Nebraska Department of Roads (NDOR) has been approached by a company to allow wind turbines in the highway ROW. NDOR is currently investigating whether this use would be permitted.

BIOENERY – DOMESTIC

Kentucky: Kentucky State University conducted a study to calculate the ethanol production potential of ROW along interstates and parkways in Kentucky.

Michigan: MDOT has planted a biocrops test plot along its ROW.

Missouri: MoDOT has signed an agreement to allow switch grass production on the ROW.

North Carolina: NCDOT is currently piloting the use of highway ROW to grow biocrops such as canola and sunflower.

Ohio: Members of the Etna Township Economic Development Committee have advocated for the planting of biocrops along I-70 in Ohio. www.dispatch.com/live/content/local_news/stories/2010/12/09/money-making-pitch-biofuel-crops-along-i-70.html?sid=101

Oregon: ODOT jointly submitted a New Special Experimental Project (SEP-15) application to USDOT with the DOTs in California and Washington for the I-5 Alternative Fuels Corridor Project. The application/project would allow limited commercialization of highway rest areas to promote the use of alternative fuels. USDOT determined that the concept would be better implemented through modification to the Interstate Oasis Program (www.fhwa.dot.gov/safetealu/factsheets/iop.htm) guidance. A rule change has not been initiated to date.

Tennessee: Tennessee DOT, in conjunction with Genera Energy LLC, a Knoxville-based renewable energy company, recently planted several test plots of switchgrass along interstate corridors in Tennessee. The plots are designed to assess whether switchgrass can help reduce maintenance costs by reducing the need for mowing and may also have the added benefit of producing biocrops for energy and reducing erosion at highway interchanges.

Utah: Utah State University, in conjunction with Utah DOT, has experimented with growing oil-seed crops in grassy highway medians and shoulders.

ELECTRIC VEHICLE CHARGING STATIONS – DOMESTIC

District of Columbia: The Sustainability Plan specifically addresses refueling and recharging infrastructure to encourage the use of alternative fuels and advanced vehicles. DDOT launched its Park and Charge Pilot program in November 2010. A recharging station is located in the 2000 block of 14th St., NW and additional stations are planned.

Florida: The Florida Turnpike Enterprise has plans to install recharging stations along the Florida Turnpike, beginning with several stations at the Turkey Lake Service Plaza.

Nevada: NDOT formed an EV task force to look at the potential for adding charging stations operated by a third party on the Interstate or other ROW

Oregon: Oregon is participating in the EV Project. Additionally, ODOT received a $2 million TIGER-2 grant to support the installation of 20 new EV charging stations along the I-5 corridor in the northwest part of the state.

Tennessee: TDOT is considering a proposal to place a charging station at a rest area.

Virginia: Has charging stations at rest areas, installed at no cost to the state. The first stations were installed at the New Kent Safety Rest Area on I-64.

Washington: WSDOT is currently working to install electric charging stations on I-5, as part of the West Coast Green Highway. Two rest areas have been identified for installations, one in northern WA and the other in southern WA.

WAVE ENERGY – DOMESTIC

Hawaii: Hawaii DOT is having early discussions regarding installation of a line in the ROW for wave energy transmission.

HYDROGEN – DOMESTIC

California: Caltrans is exploring legislation to allow charging stations at Park and Ride facilities, which the Vehicle Code currently prohibits. The California Hydrogen Highway Network was initiated in 2004 to support and catalyze a rapid transition to a clean, hydrogen transportation economy in California. California has recently awarded funding to develop nine hydrogen stations to support clusters in Los Angeles and San Francisco.

East Coast: Companies have announced plans to build 11 hydrogen fueling stations, each approximately 145 miles apart, from Florida to Maine.
South Carolina: Has public-private partnership to advance the commercialization of hydrogen fuel cell technologies in SC, including installing hydrogen fueling stations.

OTHER – DOMESTIC

Arizona: Considering testing the use of compressed air technology to store heated energy underground in order to produce electricity. The research site is located on excess ROW at I-10 and I-24 street bridges inside the City of Phoenix. The project has been in place for approximately 1 year.
Colorado: CDOT conducted a statewide feasibility study to identify potential renewable energy sites on the state's highways.
Massachusetts: MassDOT conducted a statewide feasibility study to identify potential renewable energy sites on the state's highways.
Minnesota: Minnesota DOT is considering options for sequestering carbon on highway ROW using native vegetation.
North Carolina: NCDOT is building sustainable rest areas that incorporate solar panel and wind turbine technologies in their designs.
Nebraska: In April 2010, FHWA entered into a cooperative agreement with the University of Nebraska-Lincoln to explore possibilities to incorporate wind and solar hybrid energy harvesting systems with a "microgrid" that manages energy produced with demand from surrounding infrastructure.
Nevada: NDOT is considering installation of a geothermal renewable energy transmission line within the ROW based on an NV Energy permit application.
New Mexico: New Mexico DOT is considering options for sequestering carbon on highway ROW using native vegetation.
Ohio: Ohio DOT had plans to develop green rest areas that are powered by renewable energy and that would include ethanol fueling stations and electric car recharging bays. These plans have been cancelled at present.
Texas: TxDOT and the University of Texas are conducting a research study to develop criteria for assessing ways to extract value from the ROW.

SOLAR ENERGY – INTERNATIONAL

Australia: Installed highway noise barriers made of PV panels.
Austria: Installed highway noise barriers made of PV panels.
Germany: Installed highway noise barriers made of PV panels; has several solar projects including solar arrays installed on highway close to Freiburg and 16,000 solar panels on the roof of a tunnel of A3 highway near Aschaffenburg.
Iraq: Installed solar panel and bulbs along roads to power streetlights.
Italy: Opened the world's first completely solar highway on January 1, 2011. The roadway situated between the cities of Catania and Syracuse, is 19 miles long and cost $81 million to construct. It integrates a series of PV panels along the entire distance of the roadway that generate enough electricity to power all of the highway's systems including the lighting and fans inside the tunnels and the highway lighting and emergency phones placed along the stretch of road. The solar panels will generate an estimated 12 million kW of solar power annually. www.energydigital.com/tags/a18-catania-siracusa/italians-race-solar-powered-highway
Japan: Plans to subsidize half the cost of installing solar power generation systems at public facilities, including highway rest areas.
United Kingdom: PV systems on highways provide electricity to power highway energy signs, lighting and equipment or into the national grid for more general use.
Spain: Has implemented solar car ports.
Switzerland: Installed highway noise barriers made of PV panels.

WIND ENERGY – INTERNATIONAL

France: An experimental wind turbine along the A6 between Paris and Lyon generates 1.5 kW of electricity, enough to power local road signs, speed detectors and video cameras.

Israel: Israel has planned to implement wind-powered lighting for coastal highways.
Netherlands: The Netherlands has implemented wind turbines along highways A12 and A20.

WAVE ENERGY – INTERNATIONAL

France: Paris authorities are exploring a proposal to install eight turbines underneath bridges to harness energy from currents of the river Seine.

ENERGY HARVESTING – INTERNATIONAL

Italy: Israel's Innowattech is working to provide renewable energy for highway signs in Italy. Generators are being placed beneath the highway's upper asphalt layer to capture the electrical charge created from moving vehicles on the road.
Netherlands: Ooms Avenhorn Holding BV has developed a way to siphon solar heat from asphalt road surfaces and use it to de-ice roads and help power nearby buildings.
South Korea: Researchers are currently designing induction strips and inverters that, when placed in the road, will help recharge passing electric vehicles. http://green.blogs.nytimes.com/2009/06/10/giving-new-meaning-to-electric-avenue/
United Kingdom: Experimenting with pavement heat transfer systems.

HYDROGEN – INTERNATIONAL

Canada: Planning to construct hydrogen highway in British Columbia with seven fueling stations.
European Union (EU): Members of the European Parliament have voted to develop the EU hydrogen highway network system in regard to technological and safety standards among the different countries. Denmark plans to link the Norway HyNor Project with the mainland European nations via its Hydrogen Link project. www.h2moves.eu/regions/sweden_western.html
Iceland: Icelandic Hydrogen is working towards the future hydrogen refueling infrastructure solutions focusing on small-scale hydrogen refueling stations.
Japan: Installing hydrogen stations along highway in Fukuoka Prefecture. Ten Japanese energy companies including automakers and gas suppliers have announced that they plan to install 100 hydrogen fueling stations in the country by 2015.
Norway: Hydrogen highway spanning nearly 375 miles between Oslo and Stavanger.
South Korea: Operating six hydrogen stations near highway, with others planned.

OTHER – INTERNATIONAL

Finland: Finland is proposing to build the world's first carbon-neutral highway. The highway would use a mix of biofuels, EV charging infrastructure, and renewable energy generation technologies. The highway would use EV charging points that obtain their power from solar and wind energy. The project is under the feasibility stage and is projected to be completed by 2016, if passed.

4 Observations and Findings

Several state transportation agencies are currently working to accommodate renewable energy technologies and alternative fuel facilities in highway ROW. The project team held a series of telephone interviews with staff from California, Ohio, Oregon, Massachusetts, and North Carolina DOTs and their partner organizations to learn more about the current state of the practice and discuss the challenges faced and lessons learned in doing so. The following section offers a summary of these states' experiences, focusing on their valuable insights into the issues that may arise and the topics that need to be considered when designing, developing, and implementing highway renewable energy and alternative fuels projects. The findings presented below are based on a synthesis and analysis of insights collected during the interviews and peer exchange convened March 30-31, 2011. Complete case studies are included in Appendix C.

A Supportive Institutional Environment is Critical

The approach to developing renewable energy technology and alternative fuel facility projects in highway ROW will differ from state to state based on the statutory, geographic, climatic, cultural, and political contexts. A supportive institutional environment is critical for the success of renewable energy projects in the ROW. Many of the projects analyzed in the case studies are located in states that have strong renewable energy generation and GHG emission reduction goals.[54] In the case study examples, state and state agency leadership were receptive to pursuing renewable energy projects in the ROW as a strategy to meeting the established target and goals.

However, even in agencies that are committed to generating renewable energy and reducing its carbon emissions, securing internal leadership support for these projects typically required a great deal of persistence from a project champion. Renewable energy projects are not typical to the DOTs' day-to-day activities; and over the course of the project, challenges and potential obstacles will inevitably arise. In the cases reviewed, a committed project champion was vital in working with the parties involved to overcome these potential barriers and keep the project moving forward.

Siting Concerns and Requirements for Renewable Energy Projects in Highway ROW are a Principal Issue

Transportation agencies must provide safe and efficient transportation systems for the public; any project in the ROW must not compromise a transportation agency's ability to meet this mission. As such, when siting renewable energy projects, project proponents must adequately address specific transportation issues and concerns, primarily safety, as well as reliability, durability, security, and avoidance of traffic flow disruptions.

Criteria that the DOTs and project partners have used to site solar and wind power projects include:

[54] For example, MassDOT's GreenDOT initiative aims to incorporate sustainability into all of its activities; from strategic planning to project design and construction to system operation. The initiative includes GHG reduction targets mandated under the Global Warming Solutions Act, signed by Governor Patrick in 2008. This law requires an 80 percent GHG reduction by 2050.

- **Height and set-back requirements**. Renewable energy systems in the ROW must be installed in locations that minimize impacts to the traveling public. Acceptable height and setback requirements based on existing constraints will need to be established. These requirements will typically be site specific, and may differ by technology type. Generally, DOTs require that any renewable energy facility in the ROW be located outside the clear zone and/or behind a barrier, such as a guardrail. Wind turbines will typically require larger set-backs to account for the risks of blade flicker,[55] falling fragments, or ice being thrown from rotors. CDOT used a 250-foot clear zone in its statewide assessment of potential wind turbine locations while MassDOT's proposed wind turbine would be set back 1500 feet from the roadway (a large parcel was available so the MassDOT decided to locate the turbine in the middle of the parcel). As a comparison, Caltrans required a 52-foot setback from the travel lanes and the on-ramp for the proposed solar projects in California. The solar panels in Carver, Massachusetts will be set back approximately 60 feet from the roadway, which is also the setback distance of the security fence surrounding ODOT's solar demonstration project.

- **Access**. Site access for construction, operations, and maintenance must be designed to avoid public safety and security issues. Ensuring safe access is a primary consideration when deciding on appropriate locations to site projects in the ROW. Some factors to consider include direct access from the highway versus local street access to the back of the ROW line; whether acceleration and deceleration lanes will be necessary, if access is from the highway; whether there will be restrictions to a site based on peak hour traffic, season, or other factors.

- **Proximity to electrical interconnection and transmission lines.** The electricity the renewable energy system(s) generates can feed into the utility grid or directly into a facility. The site must be in close proximity to the grid connection, transmission lines, and/or power user to minimize utility interconnection costs and ensure that the projects can be economically feasible. Unless it is utilized onsite, after electricity is generated it must travel on utility transmission lines to be used elsewhere. There are significant areas of land, particularly those in rural locations where renewable energy production potential may be high, with sparse transmission line coverage. Without transmission line access, production of renewable energy not consumed onsite may be infeasible or cost-prohibitive.

- **Minimum site acreage**. The site acreage must be able to accommodate a renewable energy facility that is large enough to make the project economically feasible. DOTs should consider developing criteria for what constitutes adequate acreage (based on the proposed project type). Experts in the renewable energy field may provide valuable insight into minimum site acreages.

  Site capacity for wind turbines is based on the turbine blade length and the height of the tower. If more than one turbine is planned, the site must be able to accommodate the necessary spacing between wind towers. In the case of solar projects, ODOT and PGE

[55] Blade flicker is the alternating light intensity that can occur as a turbine's moving rotors cast shadows on the ground and stationary objects.

determined from the demonstration project that at least 1 MW needs to be produced to make a solar highway project economically feasible in the state. The organizations have determined that currently about five acres are required to generate that amount of energy. The Ohio DOT also came to the same conclusion that 1 MW, which requires five acres of land, is needed for these projects to be economically viable. This metric will continue to evolve as new solar panels that are higher wattage are becoming available, allowing more energy generation on a smaller footprint.

- **Potential future use of the site**. A state DOT should evaluate potential sites against the metropolitan and statewide long-range transportation plan to ensure that the site will not be needed for another transportation purpose in the future. This would help avoid having to remove the renewable energy system before its operating life is over.

- **Proximity to aircraft navigation systems**. The form "7460-1 – Notice Of Proposed Construction or Alteration" must be filed with the Federal Aviation Administration (FAA) before construction of any structure over 200 feet (i.e., all utility-scale wind turbines). The FAA and the Department of Defense (DOD) review these filings for any potential obstruction or interference with air traffic, aircraft navigation/communication systems, military RADAR, or other systems. Most sites that are not within about 3–5 miles of a public or military airport are not considered a hazard to air traffic.

- **High visibility**. Many of the interviewed DOTs sought locations for their first renewable energy projects that were highly visible to the public. Locating initial renewable energy projects in high-visibility locations can help to raise public awareness of a DOT's sustainable energy efforts and the associated benefits.

- **Availability of natural resource to be used**. Maps that show natural resource availability (e.g., solar or wind potential) and/or that estimate the theoretical maximum electricity amounts possible can be helpful for State DOTs in determining locations potentially conducive for a renewable energy system. ROW maps and GIS data layers can be intersected for each renewable resource type (e.g., solar, wind, and biocrop) as a useful energy production estimating tool.

Producing biocrops in the highway ROW appears to raise fewer safety issues for transportation agencies as compared to solar and wind projects. Safety issues associated with growing biocrops in the ROW are generally the same as they would be for managing existing roadside vegetation. State DOTs would still need to locate areas of biocrop production in ways that minimize potential safety issues involved with harvesting the crops. NCDOT, for example, planted crops 10 feet from the road and included a grass buffer to further separate the crops from the roadway. By planting the crops at that distance from the road, it is not necessary for NCDOT to close a travel lane for a mobile operation of equipment when harvesting the biocrops.

Criteria that DOTs have used to assessing locations for bioenergy projects include:

- **Minimum site acreage and slope.** Plot sizes are typically 100-foot-wide crop area per mile. The slope of a potential highway ROW biocrop project would affect the ability of

roadside maintenance staff to cultivate any biocrops produced. As slopes increase, it may become more difficult for necessary equipment to reach the biocrop to be harvested (equipment can typically handle slopes of up to 35 percent). Steep slopes can also be less stable than lower sloped lands while presenting drainage and erosion challenges. Agencies can utilize GIS tools to analyze slope, width of ROW, and shoulder width sections to identify appropriate locations for biocrop production.

- **Regional climate.** Seasonal rainfall and temperatures play important roles in crop selection and resulting yields. For example, Utah's arid climate was one factor in low crop yields. In contrast, North Carolina's annual rainfall provided an ideal environment, which contributed to high yields.

- **Soil type**. Soil type plays an important role in crop yields. Soils that readily retain water, have high organic matter, and minimal clay content are generally more conducive for higher crop yields. However, soils near roadsides are often compacted to a higher degree than traditional farm soils (due to road construction, storage of vehicles and equipment, or other uses of heavy equipment), presenting a significant challenge for biocrop production in highway ROW. The soil needs to be loosened in a manner that does not impact the stability of the roadway. Research institutions and transportation agencies participating in the Freeways to Fuel program are currently exploring methods to best address soil compaction issues over the term of bioenergy projects.

- **Wildlife concerns**. When assessing potential highway ROW locations for biocrop projects, ROW practitioners should consider the species of crop to be planted and whether it might be expected to attract wildlife near the roadway. Many factors contribute to wildlife-vehicle collisions, and there is little conclusive evidence that addresses whether one single variable alone can effectively predict or correlate to wildlife-vehicle collisions. Vegetation management guidance has often focused on the removal of certain vegetation species that are attractive to wildlife within the ROW, thereby reducing or eliminating habitat and suggesting a correlation between vegetation and wildlife strikes.[56] On the other hand, some researchers have found that the presence of open land cover, believed by many to improve driver visibility or reaction time, could be correlated to increased presence of some wildlife species and, by extension, wildlife-vehicle collisions.[57]

Projects Can Be Implemented Through a Variety of Public-Private Partnership Models
Although DOTs can appropriate their own funds for developing alternative energy resources within the ROW, the availability of Federal tax credits and potential public-private partnerships can help to minimize capital and operating costs. Each of the renewable energy projects that the project team examined utilized a different business model, which, in turn, influenced the permitting process and contracting mechanism involved.

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[56] Lavsund, S. and F. Sandegren. Moose-Vehicle Relations in Sweden: A Review. Alces, Volume 27, 1991, pp. 118 to 126., and Jaren, V., *et al*. Moose-Train Collisions: The Effects of Vegetation Removal with a Cost-Benefit Analysis. Alces, Volume 27, 1991, pp. 93 to 99.
[57] Barnum, Sarah, *et al*. 2007. Habitat, Highway Features, and Animal-Vehicle Collision Locations as Indicators or Wildlife Crossing Hotspots.

Solar and Wind Business Models

Developing a "business model" requires innovation and will likely be unique to each project. The four business models used to date for solar and wind energy projects are:

- DOT purchases the renewable energy generated
- DOT does not purchase the renewable energy generated
- DOT acquires renewable energy credits (RECs) for the renewable energy generated
- DOT owns and operates the renewable energy facility

In the first model, the DOT allows a utility or private developer to install and operate a renewable energy facility in the ROW (through a utility permit, airspace lease, or special use permit); and the DOT purchases the electricity produced by the system. This business model involves two contractual agreements, a lease or license agreement, which allows the third-party developer to site the renewable energy facility on DOT land, and a Power Purchase Agreement (PPA). A PPA is a long-term contract between an energy provider and a customer (in this case a DOT) to purchase the renewable energy for a fixed price over the length of the agreement. Because the PPA clearly defines the revenue stream over the life of the contract, typically 20 to 25 years, it is a central document in helping the PPA provider secure financing for its project. Investors front the capital development costs for the system in exchange for state and/or Federal tax credits or other renewable energy development incentives, and the fixed-term power purchase contract with the customer. This model allows the investor to recoup costs along with a modest rate of return over the life of the tax credits (typically five to six years), and further provides a revenue stream from the energy for the project owner over the life of the project. ODOT's Solar Highway Demonstration Project followed this cost-neutral model; ODOT signed a solar license agreement (SLA) with SunWay 1, LLC to install, maintain, and operate a solar PV system and a PPA with the company to purchase the electrical energy generated by the PV system. Both contracts are for 20 years with options to renew for up to 35 years.

In other cases, DOTs might choose not to purchase the electricity that the renewable energy project generates. Instead, the public utility partner or another public agency could use the electricity generated. When the DOT is not using the electricity, the agency may utilize an airspace lease or a special use permit to permit the project. In this model, the DOT leases the site to the third-party and receives rent but would not enter into a PPA. MassDOT's proposed solar and wind power examples and Caltrans' proposed solar projects are each following this business model.

In a third business model being explored, the DOT could acquire the RECs associated with the renewable energy generated, but not the electricity. When a renewable energy facility operates, it creates two products: the electricity that is delivered into the grid and an REC, which represents the environmental attributes of the power produced. One REC is equivalent to 1 MW hour of electricity generated. The renewable electricity and the REC can be "unbundled" and sold separately. The REC product conveys the attributes and benefits of the renewable electricity, not the electricity itself; and the electricity that is unbundled from the REC is no longer considered renewable. The user of the renewable energy system's electrical output cannot make the claim that it is using renewable electricity unless the user also holds the RECs associated with the

electricity.[58,59]

There are two different market types in which RECs are purchased and sold: compliance and voluntary markets. Compliance markets are created when a state passes a Renewable Portfolio Standard (RPS) requiring that retail power suppliers obtain a percentage of the electricity it sells from renewable sources. Some states permit compliance with the RPS, in whole or in part, through the purchase of RECs. Voluntary markets allow public and private entities to purchase RECs to support renewable energy production. The price of an REC is typically higher on the compliance market than on the voluntary market. ODOT is currently working with PGE on a second solar highway project in which ODOT will receive a portion of the RECs the facility produces while PGE will retain the electricity. ODOT will enter into a site license agreement with the utility, but it will not be a party in the PPA.[60] ODOT will receive a token annual site license fee, with the idea of creating a framework for future projects with higher fees. By holding a portion of the RECs produced, ODOT will be able to claim them as contributing toward the agency's sustainability and carbon reduction goals as defined in the Oregon Transportation Plan and other state policy documents.

In the fourth business model, the DOT would not enter into a public-private partnership but would instead own and operate the system itself. The Ohio DOT followed this business model in its current solar array and maintenance facility wind turbine. However, the Ohio DOT has determined that owning the renewable energy facilities is not a sustainable business model, as the cost of alternative energy generating equipment is often high and prohibitive for DOTs. In future projects, Ohio DOT would advocate for a utility or private partner to own and operate the facilities with Ohio DOT purchasing the renewable energy through a PPA; the DOT plans to hire the services of an "energy broker" professional to help it buy energy in bulk, reducing the per kW rates. The lower rates could be achieved through tools such as reverse on-line auctions where suppliers bid on the right to supply energy to the DOT. The costs of developing renewable energy projects can also be lowered if private entities develop them, as they are able to take advantage of tax credits and other incentives, such as accelerated depreciation unavailable to the DOT. When the DOT fully capitalizes renewable energy projects, the costs can be higher; and the agency is less likely to experience a return of investment over the life of the project.

Bioenergy Business Models

Bioenergy projects also may utilize various business models. In NCDOT's current model, the DOT grows and cultivates the biocrop feedstock in the ROW and then pays a biorefinery to convert the feedstock grown into biofuel that the DOT later uses. It has been envisioned that a state DOT could also either sell the feedstock or sell permits to farmers to allow them to grow, harvest, and then use or sell the biocrops as they desired. Finally, USU evaluated another business model where the DOT performs both the farming and refining functions. It was

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[58] Center for Resource Solutions. 2010. Best Practices in Public Claims for Solar Photovoltaic Systems.

[59] The Federal Trade Commission (FTC) has issued guidelines for the use of environmental marketing claims: www.ftc.gov/bcp/grnrule/guides980427.htm. In October 2010, the FTC issued proposed updates to the environmental marketing claims guidance: www.ftc.gov/os/fedreg/2010/october/101006greenguidesfrn.pdf

[60] Additional information on state-driven approaches to financing clean energy projects is available from the National Governors Association Center for Best Practices. See: www.nga.org/Files/pdf/1101CLEANENERGYFINANCING.PDF

determined that this model was not economically viable since the DOT would have to purchase and operate refining equipment that may already be available and operated more efficiently locally.

Permitting Processes Vary Based on Project Details

Each of the solar and wind energy cases the project team reviewed utilized a different permitting process to approve the use of the highway ROW: the utility permitting process, an airspace lease, a special use permit, and an easement.

Oregon's I-5 solar highway demonstration project was approved under the DOT's UAP. ODOT, in consultation with the Oregon Department of Justice (DOJ) and the FHWA Division Office determined that since the project would supply electricity for ODOT's direct use (thereby a "public" use), the project would be permissible on ODOT's ROW through the utility permit process. The proposed Massachusetts projects will utilize airspace lease and easements. (California's proposed solar highway project would have also utilized an airspace lease). In these cases, the state DOT is not the end user of the electricity generated by the renewable energy project. Under Federal regulation (23 CFR 710.405), a state DOT may receive fair market income from airspace leases. MassDOT will require the developer of the wind turbine to pay an annual rental fee for use of the land. The rent will be tied to the total revenue generated by the facility with the rent equal to 3.5 percent of power sales with a minimum of $15,000 a year. Similarly, MassDOT is collecting fair market income at the rate of $880 a year from Carver for use of the 1.26 acres of highway ROW for its solar installation.

Developing the Lease Agreements is a Multifaceted Process

Whether a project is permitted through the utility permit process, airspace lease, or special use permit, the DOT and the project partner will enter in a written agreement that outlines the applicable terms and conditions for the use of the ROW. A DOT must ensure that the written agreement used to permit renewable energy facilities in the ROW is adequate to protect the transportation facility and clearly defines the responsibilities of the parties regardless of the permitting process used. An effective lease agreement must reflect legal, planning, environmental, design, construction, maintenance, insurance, safety, warranty, and security requirements. Developing a lease agreement that is acceptable to both the DOT and the lessee can be a complex, lengthy, and expensive process.

The interviewed DOTs identified the following items as some of the major issues that need to be considered in developing a lease agreement for solar and wind facilities:

- **Site Security**. Security of renewable energy technology and facility investments in highway ROW is a practical concern. To protect roadside equipment from theft or vandalism, project proponents are required to include specific procedures and measures in their plans to mitigate risks. Such measures may include, but are not limited to, security fencing, continuous security monitoring, surveillance cameras and communications equipment, hardening installation (such as the use of one-way screws), and embedding locator devices in equipment.

- **Maintenance**. Renewable energy facilities in the highway ROW require maintenance throughout the construction and operational phases, including the equipment itself as well

as the land on which the equipment resides. The agreement for ODOT's I-5 solar demonstration project assigned maintenance responsibility for the solar project to the licensee while ODOT retains responsibility for maintaining the ROW outside the project area. Similarly, the Town of Carver will be responsible for maintaining the immediate area around the solar power project while MassDOT will retain responsibility to maintain the ROW area beyond the project bounds. DOTs should also consider requiring vendors to provide the DOT with maintenance schedules and all warranty information available for the renewable energy installation and its components.

- **Liability**. Liability can be a contentious negotiation issue between the DOT and the lessee. The lessee should be required to maintain insurance covering injuries to persons or damages to property and the renewable energy system in order to minimize potential risk to the DOT. Additionally, the lease agreement should include indemnification provisions for both the DOT and the lessee. One such indemnification provision should pertain to patents and include language that the lessee must comply with any patents that may exist.

- **Vacating the site/removing equipment**. The lease agreement should outline responsibilities for removing the renewable energy technologies and associated equipment and restoring the site to its pre-installation condition upon expiration or termination of the agreement. DOTs may choose to include a clause providing them the opportunity to purchase the renewable energy system at the end of the contract term.

- **Termination**. The contracts should outline the process and conditions under which the agreement can be terminated. Reasons for DOTs to terminate a project include public safety or highway safety purposes; to comply with a transportation construction project adopted in an approved state transportation plan or changes in applicable laws requiring use of the licensed area. The contract should outline who is responsible for costs in the event of early termination.

- **Ownership of the Renewable Energy Credits**. The agreement should clearly state what entity retains ownership of the RECs the renewable energy facility generates.

DOTs May Require Outside Assistance in Developing Complex Contract Agreements
When a DOT purchases the renewable electricity generated, it typically does so through a PPA. PPAs are complex legal documents that DOTs may not be able to develop given current areas of in-house expertise. Therefore, the DOT may need to utilize outside legal counsel or consultants to help guide the development process of these agreements.

ODOT was the first Oregon state agency to enter into a solar site license agreement or a PPA. Legal staff at ODOT and the state's DOJ worked with an outside legal team to help draft the documents. The legal fees associated with developing these agreements constituted a large percentage of the overall project costs for the state. Similarly, the Town of Carver, Massachusetts is utilizing a $50,000 technical assistance grant it received from the Massachusetts Department of Energy Resources' Energy Efficiency and Conservation Block Grant program to retain consultants to support the town with developing its PPA.

Responsibility for Environmental Clearance Varies by State and Project Type
Renewable energy and alternative fuel facility projects in the highway ROW must meet all applicable Federal and state environmental regulations (e.g., NEPA, Endangered Species Act compliance, etc.). Each of the projects reviewed has conducted or is conducting detailed environmental analyses on common issues such as water quality, air quality, biological and cultural resources impacts, hazardous materials, and noise. However, responsibility for conducting such analysis varied across projects. In the Oregon demonstration project, ODOT was responsible for the environmental analysis and for the costs of mitigating or rehabilitating the impacts. In contrast, in both California and Massachusetts, the project proponents are responsible for complying with the state's environmental protection regulations.[61]

Each renewable energy technology also has its own set of unique environmental, health, and safety considerations. According to those interviewed, some of the primary considerations associated with solar energy projects in highway ROW to date have included:

- **Glint and glare**. DOTs may be concerned about the potential impacts of glint (increase in brightness) and glare (reflectivity) on traffic safety. Project proponents have addressed these concerns by describing how solar panels are designed to absorb sunlight and by citing related technical studies, such as the "Technical Guidance for Evaluating Selected Solar Technologies on Airports" that the FAA issued in November 2010.[62] The Ohio DOT is also using its solar field demonstration project to evaluate glint and glare impacts. Glint and glare have not presented issues for the projects accommodated to date in the ROW.[63] DOTs should still consider whether it is necessary to have a provision in the agreement that states the developer will mitigate glint and glare issues that may arise on the project in the future.

- **Electromagnetic field (EMF) environmental, safety, health, prevention, and control issues**. EMFs are electric and magnetic fields associated with electric potential, voltage, and currents. While the Federal Government has not established regulations governing exposure to power frequency magnetic fields, the International Commission on Non-Ionizing Radiation Protection has developed exposure guidelines in order to protect the general public and workers against potential adverse health effects. The Institute of Electrical and Electronics Engineers and the World Health Organization also have voluntary safety and health exposure limits. ODOT addressed citizen concerns about potential health effects of EMF by evaluating the sources and scale of the EMFs to be produced by its proposed solar projects. The review found that EMF levels of the proposed solar project do not approach the levels considered a risk to human health.[64] In

[61] The California Environmental Quality Act (CEQA) applies to all discretionary projects proposed to be conducted or approved by a California public agency. The Massachusetts Environmental Policy Act (MEPA) applies to projects that meet certain review thresholds and that require state agency action, i.e. a permit, financial assistance or land transfer from state agencies.
[62] FAA's Technical Guidance for Evaluating Selected Solar Technologies on Airports: www.faa.gov/airports/environmental/policy_guidance/media/airport_solar_guide_print.pdf
[63] More information on the potential glare impacts from one of ODOT's proposed solar highway projects is available at: www.oregon.gov/ODOT/HWY/OIPP/docs/Solar_GlarePotentialWL.pdf
[64] Good Company. Scaling Public Concerns of Electromagnetic Fields Produced by Solar Photovoltaic Arrays. www.oregon.gov/ODOT/HWY/OIPP/docs/EMFconcerns.pdf

addition, as part of the project review, NREL conducted a literature review on the topic. Their analysis showed that the magnitude of EMF exposure measured at the perimeter of PV installations has been shown to be indistinguishable from background EMF and is lower than that from many household appliances.[65]

- **Aesthetics**. Renewable energy projects should blend in with the highway and the surrounding natural environment and maintain a continuity of visual form without distracting interruptions. In designing the proposed Caltrans' solar projects, SMUD worked with a local architect firm to develop preliminary renderings of the installation. SMUD is also considering working with the local arts commission or having a design competition to generate ideas on how to design the project so that it fits into the community landscape.

Primary environmental considerations associated with wind energy projects in highway ROW are less apparent than for solar energy projects. DOT experience with wind power technologies in the ROW has not progressed far enough to have produced lessons learned. According to the literature, one of the primary environmental concerns in wind energy is the potential for bird and bat mortality; however, impacts vary widely by region and species[66]; and, overall, some studies have found no evidence of significant impacts on bird populations.[67] The Ohio DOT is working with the U.S. Fish and Wildlife Service to monitor the impacts to birds for its wind turbine project. Additional environmental concerns associated with proposed wind turbines include aesthetics and noise.[68]

Considerations in the physical environment associated with bioenergy projects in highway ROW are related chiefly to soil and seeding factors. According to those interviewed, environmental considerations associated with bioenergy projects in highway ROW include:

- **Over-cropping and soil health**. A DOT might set a threshold for what is an acceptable yield for biocrops planted in the ROW. In efforts to attain that yield, over-cropping and loss of soil nutrient health could become issues. Both the Utah and North Carolina projects searched for the appropriate till method to maximize yield without compromising soil health. In North Carolina, this involved examining outcomes from no-till, medium-till, and maximum-till approaches. Initially, NCDOT explored the concept of treating all weeds with herbicide and then performing one till; however, test results suggested that the no-till method may be the most effective environmentally and economically. NCDOT also avoided over-cropping and soil health issues by implementing a seasonal crop rotation practice.

- **Altered erosion patterns**. DOTs considering using highway ROW for biocrop plantings

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[65] Department of Energy. November 12, 2009. Health effects of electromagnetic fields from solar photovoltaic arrays. www.oregon.gov/ODOT/HWY/OIPP/docs/solar_USDOEmemo.pdf
[66] U.S. Government Accountability Office. September 2005. Wind Power: Impacts on Wildlife and Government Responsibilities for Regulating Development and Protecting Wildlife. www.gao.gov/new.items/d05906.pdf
[67] Committee on Environmental Impacts of Wind-Energy Projects, 2007. Environmental Impacts of Wind-Energy Projects.
[68] For additional information see www.awea.org/issues/siting/index.cfm.

should plant in ways that would not contribute to or exacerbate soil erosion or loss in the area.[69] Generally, crop rows would often need to be aligned perpendicular to present slopes.

- **Cross-pollination**. In some instances, the public has raised concerns regarding the potential for biocrops in highway ROW to affect agricultural crop activities and/or reduce yields on adjacent farm land. Cross-pollination is a particular concern in areas where seeds or flowers are being commercially propagated (i.e., seed purity is important) near proposed roadway biocrop projects.

State and Federal Tax Credits and Grants Are Currently Needed to Make Projects Economically Viable

Renewable projects in the ROW generally rely on public-private partnerships. As a public entity, state transportation agencies cannot benefit directly from Federal or state tax incentives because they are tax-exempt entities. However, the private partners in these projects can benefit greatly from state and Federal tax credits and grants to finance the renewable energy projects.

Renewable energy facilities require high upfront costs. Tax credits and grants help to make renewable energy cost competitive with fossil fuel-based energy. Due to the comparable costs of renewable energy, private partners would likely find renewable energy projects in highway ROW difficult to finance without the availability of Federal and state tax credits. DOTs and project partners indicated that without ARRA funding or available Federal and state tax credits, renewable energy projects in the ROW may not be feasible. Current information on Federal and state incentives for renewable energy can be found at: www.dsireusa.org/incentives/index.cfm?state=us&re=1&EE=1.

Carbon Offsets and RECs Could Be Used to Finance Renewable Resource Development on the Highway System

Carbon offsets enable an organization to reduce its GHG emissions by paying others to undertake activities that reduce, avoid, or sequester GHGs. In the U.S., the voluntary carbon offset market is large and diverse; over 600 organizations develop, market, or sell offsets, and the market involves a wide range of participants, prices, transaction types, and projects.[70] The carbon offset markets or the REC markets highlighted above could provide a possible source of funding for renewable energy projects in the ROW. However, involvement in such markets carries with it additional verification and monitoring requirements to ensure the credibility of the offset or REC. Additionally, once the offset or REC is sold, the owner of the renewable energy facility and the user of the associated electricity can no longer claim the renewable energy benefits associated with the project. See www1.eere.energy.gov/femp/pdfs/rec_webinar_062311.pdf for more information on RECs.

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[69] For example, see *Effective Planting Techniques to Minimize Erosion: Plug Planting, Sod Strips, Hydroseeding, Compost, Jute Netting* (2004) by the California Department of Transportation and the California Storm Water Management Program: http://trid.trb.org/view.aspx?id=771549

[70] GAO. August 2008. Carbon Offsets: The U.S. Voluntary Market is Growing but Quality Assurance Poses Challenges for Market Participants. www.gao.gov/new.items/d081048.pdf

Patent Issues May Increase Project Costs and Timeline
The systems that produce, collect, and transmit renewable energy are usually patented. Patent holders are entitled to collect license fees for use of the methodologies and techniques their patents cover.

There have been instances where a public entity paid for licenses for a renewable energy technology in the ROW when it was not clear that such licenses were required. This uncertainty, along with the fact that costs are being added to already expensive projects with little or no added value might, be a deterrent to a DOT considering the implementation of renewable energy projects in the ROW. Highway owners are encouraged to consult with a patent or intellectual properties attorney who can help determine the applicability of a particular patent given the legal complexities involved.

Renewable Energy Projects May Require Zoning Changes at the Local Level
Renewable energy projects in the ROW may be subject to local approval and, as a result, may require conditional or special use permits, variances, zoning changes, or waivers in order to meet regulatory or statutory requirements. For example, the town of Blandford, Massachusetts, in which MassDOT's proposed wind energy project would be located, does not currently have zoning standards for wind facilities. Before the proposed project could be approved, the Town first needed to adopt a wind power zoning by-law. In May 2011, registered voters at a Blandford open town meeting defeated the zoning bylaw that would have allowed the development of the proposed turbine, putting the future of this project in question. The Massachusetts Department of Energy Resources and Executive Office of Environmental Affairs have developed a model by-law[71] to assist cities and town in establishing reasonable standards for wind development and are currently working with the town of Blandford to help establish a similar by-law. Similarly, one of the solar projects currently under development in Oregon is located on land zoned exclusively for farm use; ODOT obtained the necessary conditional use permit from the local jurisdiction without any controversy or appeal.

Renewable Energy Projects Require Effective Public Involvement
Public support of renewable energy development in the ROW is a decisive factor to the success of these projects. Several of the renewable energy projects analyzed as part of this study conducted extensive public outreach efforts as part of the project development process. For example, as part of the scoping process for the environmental analysis, SMUD held four public workshops. SMUD had developed visualizations, including conceptual drawings, realistic photo renderings, and 3D animations, to help the public understand what the projects would entail. The visualizations were used during the public meetings to set the context for each project location and to help generate feedback from the public on the preliminary design. ODOT hired a local firm to manage the public involvement activities related to its solar demonstration project. The firm was able to conduct research describing when the solar highway would become "carbon positive," or beneficial to the atmosphere.[72] The research has been an effective public relations

[71] Massachusetts Department of Energy Resources. March 2009. Model As-of-Right Zoning Ordinance or Bylaw: Allowing Use of Wind Energy Facilities. www.mass.gov/Eoeea/docs/doer/gca/gc-model-wind-bylaw-mar-10-2009.pdf
[72] Good Company. August 2008. Avoided Carbon Emissions from Solar Panel Systems and Sequestered Carbon Emissions from Tree Growth www.oregon.gov/ODOT/HWY/OIPP/docs/treesvsolar.pdf

tool.

Several of the interviewed DOTs have continued their public involvement efforts after project implementation. PGE and ODOT have created a website where the public can get real-time information on the amount of electricity being produced at the I-5 demonstration site.[73] Ohio DOT maintains a similar project website that displays the total electricity production for its solar field demonstration project.[74] MassDOT would require the selected developer of its proposed wind project to install an information kiosk at the adjacent Blandford Service Area if the turbine is built. The kiosk would provide a written description of the wind turbine project and real-time information on its operation.

[73] See www.live.deckmonitoring.com/?id=solarhighway
[74] See www.buildingdashboard.com/clients/odot/

5 Conclusions and Recommendations

State DOTs are increasingly recognizing the threats climate change effects pose on transportation infrastructure, as well as the GHG mitigation potential that renewable energy and alternative fuel technologies present. Likewise, many utility companies have established renewable energy goals, often in response to state or regional GHG regulation. Together, DOTs and utility companies are beginning to capitalize on the opportunities that utilizing ROW presents to develop sustainable energy sources. Doing so not only reduces reliance on fossil fuels but can also promote energy security and conservation, and foster the creation of a local green job market. Such uses can also reduce highway maintenance and operational costs (in instances where a partner agency assumes maintenance responsibility) and generate additional revenue for transportation agencies. The following section describes best practices for both DOTs and FHWA to achieve desired outcomes in producing and distributing renewable energy and alternative fuels along the highway ROW, should a DOT decide to do so.

5.1 Best Practice Opportunities for DOTs

Use of the highway ROW to develop sustainable energy sources has only recently emerged as a viable solution to reduce the GHG emissions associated with transportation operations. The lessons that early adopters have learned and best practice recommendations presented below are intended to inform others seeking to pursue similar projects.

Consider revising state UAPs to include renewable energy.
DOTs interested in utilizing the ROW for renewable energy technologies or alternative fuel facilities should be proactive in their approaches to implementing these projects. State DOTs are encouraged to review their respective UAPs to ensure they are consistent with current needs and that the UAP definition of a utility includes or allows for renewable energy technologies.

Identify state statutory or regulatory constraints that preclude resource development and devise resolutions that would instead foster such development.
Attempts to accommodate renewable energy technologies and alternative fuel facilities in the ROW will likely expose legal constraints that limit opportunities for renewable resource development. A state's utility rules for net metering and feed-in tariffs, for example, may inadvertently and artificially restrict the most promising renewable energy sites on highway ROW. Some rules, such as those in Oregon, only allow consumers to offset load aggregated by meter and feeder across contiguously owned property and on the same rate schedule. Net metering may limit the amount of energy that a given site can generate. These restrictions could result in a greater number of smaller projects, a greater timeline to develop renewable energy resources (or a "solar highway" system), higher cost per kW installed, and/or decisions to pursue REC-based projects instead of those that would be net-metered.

According to some stakeholders interviewed, the development of an "administrative net metering" or feed-in tariff or process would greatly facilitate development of solar power projects in the ROW, ultimately resulting in lowered costs to the public. The tariff would allow an agency to offset its entire electricity load in a given utility's service area by utilizing the most

promising ROW locations to their full capacities. While a state DOT might not necessarily take the lead on this action, its involvement and partnership with other agencies will likely be important.

Identify appropriate renewable energy technologies and potential sites through a statewide or regional feasibility study.

A systematic review of the alternative energy potential of the ROW and real estate holdings can provide agencies with a clear picture of the quantity and quality of alternative energy resources under its management and can help a DOT prioritize which technologies to pursue. The following geospatial information is helpful in conducting feasibility studies: transportation real estate holdings; ROW information, including width, slope, and directional orientation; proximity to electricity transmission lines; underlying natural resource constraints, such as presence of wetlands or rare species and their habitats; and renewable energy resource maps. Transportation agencies should work collaboratively with partner agencies to collect and develop the geospatial data deemed appropriate. Additionally, transportation agencies should collaborate with utility companies and public utility boards to share data/maps on subsurface utility facilities for any new renewable energy installations. This would mitigate issues when new transportation projects come along and would help outline potential future utility conflicts.

Review long range transportation plans to identify potential siting conflicts or to develop guidelines for how renewable energy and alternative fuel facility projects might be included in statewide transportation planning.

A Transportation Improvement Program (TIP) is a multi-year capital improvement program of transportation projects. Each metropolitan planning area develops a TIP, which is then incorporated into the statewide transportation improvement program (STIP). Transportation agencies also develop Long Range Transportation Plans (LRTP) that outline the vision for the region's or state's transportation system and services.[75] In metropolitan areas, the LRTP indicates all of the transportation improvements scheduled for funding over the next 20 years. The Statewide LRTP may not be project specific, but will clearly detail the policy direction the State plans to take over the next 20 years.

The typical length of lease agreements (20 to 25 years) between the DOT and the utility/developer of the renewable energy project corresponds to the planning horizon of LRTPs. State DOTs should evaluate proposed renewable energy facilities for compatibility against metropolitan and statewide long range transportation plans and TIPs to determine whether proposed facilities conflict with future expansion of the transportation system or policy direction of the State or metropolitan region.

DOTs that are considering how renewable energy projects could be accommodated in highway ROW should integrate these considerations into the transportation planning processes at the state, regional, and corridor levels. This integration would enable states to address renewable energy projects in the ROW in a systematic process rather than on a case-by-case basis.

[75] For more information on the LRTP process, see www.planning.dot.gov/documents/briefingbook/bbook.htm

Develop an internal interdisciplinary team to address the unique issues renewable energy projects in the ROW present.

Renewable energy projects in the ROW differ from typical transportation projects in many ways. As such, these projects inevitably raise unique issues that standard operating procedures and policies may not address. Working through such issues requires a great deal of coordination and communication between departments within the DOT, including real estate services, maintenance, operations, safety, environment, planning and legal. It is important for representatives from each of the relevant departments to be involved early in the planning and decision-making process particularly for initial projects, when there is little to no precedent to rely upon. Developing a consistent internal message within the DOT is also an important factor in minimizing delays that can occur when different DOT offices have varying views or give conflicting direction to project partners. One DOT noted that having top management support that set a clear direction for all of the offices regarding the renewable energy project was "hugely beneficial" because it helped to eliminate any reluctance that may have existed. Furthermore, it is important for project sponsors to include a representative from the FHWA Division Office in these early to minimize the potential for delays.

Flexibility and creativity on the part of the DOT and its partners is necessary to devise solutions that meet the needs of all those involved. For example, DOTs might consider creating a full-time "energy manager" position when feasible. This person would serve as the primary lead and would be responsible for coordinating with the appropriate departments. Several DOTs that were interviewed indicated that the renewable energy learning curve for transportation agency staff is steep and that the dedicated attention of at least one staff member will contribute significantly to the DOT being able to implement a successful project, regardless of the success measure(s) chosen.

The approach to develop renewable energy projects in the ROW is largely dependent upon the specific context of the project, including the ownership and funding structure involved. At this time, there is no one definitive way to design and develop these projects. Similarly, the success of these projects can be defined in a number of ways including meeting policy objectives, having cost-neutral or positive return on investment, and level of public acceptance, among others. Even within a state, the model and approach followed may differ from project to project. A prototype model may emerge as DOTs' experiences in implementing renewable energy projects in the ROW evolve. Until then, however, DOTs and their partners will need to be flexible and creative when contemplating, implementing, and evaluating renewable energy and alternative fuel projects.

Create partnerships with external stakeholders.

It can be beneficial for DOTs to build partnerships with external stakeholders, such as utilities, public utility boards, banks, private energy developers, and alternative energy vendors. Building such relationships that avoid conflict of interest issues can be a valuable asset in educating the DOT and in facilitating issues that may arise later in project development and design. For example, Ohio DOT staff spoke with numerous stakeholders in the renewable energy field to learn about the technologies available and to ensure that the agency was obtaining the best value for its investments. The staff attended trade shows where they were able to network with representatives in the renewable energy industry.

State DOTs should also explore opportunities for public-private partnerships, especially in states where capital funding, and thus the means to undertake their own feasibility studies or renewable energy projects, is limited. Additionally, it is important to coordinate with the utility company early in the development of renewable energy projects where the local utility is not an active partner. This is particularly important if a proposed project does not have an identified customer for the electricity that will be produced.[76]

Specifically regarding wind energy project development, wind project proponents should first consult with the FAA, the Joint Program Office (JPO), and any local DOD installations about the siting of their project in order to avoid delays and unnecessary investigation expense. This should be a preliminary step in the development process. Early consultation with the FAA and JPO will allow project developers to evaluate whether their project site may potentially interfere with air defense radar and determine whether mitigation is necessary and possible.

Develop comprehensive value-based selection criteria for renewable energy and alternative fuel facility projects in highway ROW.
Renewable energy projects in the ROW can help agencies achieve their environmental and sustainability goals. When cost is the primary selection criteria used to award contracts, state-sponsored renewable energy projects could reward labor and environmental practices that are not in line with the overall sustainability and environmental goals that the project is intended to support. Outsourcing jobs and subsidizing such environmental practices may be unintended but foreseeable consequences of solely cost-based public investments. As a result, some states have utilized comprehensive value-based criteria to evaluate and award contracts for renewable energy projects. A state DOT may not necessarily take the lead on this action. Other agencies within a state may develop value-based selection criteria that the DOT could adapt to its needs.

When procuring the PV modules for its solar demonstration project, ODOT evaluated proposals using a set of value-based selection criteria (see Appendix E). In addition to corporate qualifications, technical characteristics of the proposed PV modules, and price, the selection criteria also included commitment to Oregon's Sustainability Policies, such as recycling of PV module materials after their useful life and the manufacturing locations of the PV modules. Careful consideration of the project's contribution to the state's overall public interests and values, not just direct costs, ensured that the demonstration project truly supported the state's sustainability goals.

5.2 Opportunities for FHWA

There are considerable economic, ecological, legal, and political uncertainties related to whether accommodating renewable energy technologies and alternative fuel facilities can be practical highway land management practices. FHWA is positioned to provide information and other assistance to DOTs that will better enable them to consider the implications and evaluate the feasibility of implementing renewable energy and fuel options in the ROW. Based on discussions

[76] Organizations such as the Electric Power Research Institute may be able to work with DOTs and FHWA Division Offices to identify utility partners to buy or distribute power.

with the stakeholders, FHWA will carefully consider the following next steps, although no commitments are made at this time:

Clarify its endorsement of using highway ROW to accommodate renewable energy technologies and alternative fuel facilities.
FHWA should make its position on accommodating renewable energy technologies and alternative fuel facilities in the ROW clear either in a policy, a directive, or a leadership statement. This activity would help establish continuity in decision-making when key personnel change. FHWA should also establish a point person within FHWA Headquarters whom Division Office staff can contact regarding alternative uses of the ROW.

Consider using pilot projects to identify any needed revisions or policies that restrict a DOT's ability to construct and operate renewable energy technologies and alternative fuel facilities in highway ROW.
Commercialization along the interstate highway system is restricted by Federal statute and regulation. States that receive Federal Interstate funding are prohibited from locating automotive service stations on the ROW of the Interstate System (23 USC 111). States are also prohibited from charging the public for goods and services at safety rest areas except for telephone and vending machines (23 CFR 752.5). Such restrictions limit the ability of the DOT to construct alternative fuel facilities in the highway ROW. FHWA should consider reviewing these regulations, perhaps in the context of a pilot project, to determine whether and how the regulations might be modified to better enable DOTs to accommodate alternative fuel facilities. FHWA should also ensure that new policies do not contradict existing policies and vice versa. Such activities would align with the January 2011 Executive Order to Improve Regulation and Regulatory Review, which encourages agencies to choose alternative regulatory approaches that maximize net benefits, including potential economic, environmental, public health and safety, and other benefits.

This action would likely be especially helpful for state DOTs considering highway ROW for siting EV and PHEV charging stations. Although most EV and PHEV owners will likely recharge their cars overnight at home, "range anxiety" among drivers is expected to remain a challenge until the connectivity of the charging network is improved. The ChargePoint America program, funded in part with a $15 million grant from the DOE, is working to address this issue to a degree through its plans to install 4,600 charging stations across the country. However, this and other similar and complementary efforts are necessary to help ensure the use of this potentially cleaner fuel source is maximized. Highway ROW may offer additional suitable locations, assuming regulatory barriers are addressed.

Finally, Federal regulations require that property purchased with Federal Highway funds must benefit the transportation system. This qualification may be an impediment to accommodating renewable energy and alternative fuel technologies in the ROW, particularly in situations where the DOT will not purchase the electricity generated by the renewable energy facility. FHWA should examine whether renewable energy activities within highway ROW could constitute a transportation use and, thus, be eligible for accommodation; the Agency should define or clarify how these activities are connected to the agency's responsibility to build and finance transportation infrastructure that supports the traveling public's needs. FHWA should also

reconsider its environmental guidelines and scope of ROW acquisition for future projects, if renewable energy actions are considered authorized transportation uses. This would enable DOTs to routinely analyze future projects regarding their potential for renewable energy activities. Accordingly, there may be justification to acquire additional ROW to accommodate the energy purposes along with the highway use. The proposed activity may require revision to Title 23 U.S.C. and Title 23 CFR.

Work with AASHTO and other relevant partners to address patent issues for renewable energy projects in highway ROW.

Some existing patents could be detrimental to advancing the practice of accommodating renewable energy systems on highway ROW. Since it is unlikely that all utility companies will have necessary licenses, the geographic extent in which DOTs might install projects could be limited. For example, if only one utility company has a required license, that state's DOT might be reluctant to consider other solar projects in places outside of the licensed utility's service area. Presumably, some of the "avoided" regions could have the state's prime solar, wind, or geothermal resources and/or available ROW. FHWA should coordinate with AASHTO and other relevant partners to discuss potential patent issues that may exist related to implementing renewable energy systems in the ROW.

Coordinate early involvement with the U.S. Department of Energy to facilitate the development of renewable energy projects in the highway ROW.

FHWA should facilitate national-level coordination with the DOE to coordinate initiatives and funding in order to maximize Federal support of these projects. Because of the dual energy and transportation aspects of siting renewable energy projects in the highway ROW, both DOE and FHWA may frequently be involved in the NEPA process. Because each agency has different processes for carrying out its NEPA responsibilities, determining which agency will serve as the lead agency for NEPA will have implications for projects.[77] For example, because ODOT received funding from the DOE for its Baldock project, the project was initially required to follow the DOE's NEPA regulations. However, lacking familiarity and experience with DOE's NEPA regulations, ODOT requested that it be allowed to follow FHWA's NEPA regulations. After a lengthy process, DOE allowed ODOT to follow FHWA NEPA regulations for research and development projects but did not extend the allowance to any potential future renewable energy projects. Similarly, the Ohio DOT essentially completed two NEPA processes, one for DOE and one for FHWA, for its wind project.

FHWA and DOE should coordinate to address the dual nature of these projects. Developing a memorandum of understanding or other agreement that clearly defines NEPA responsibility for renewable energy projects in the highway ROW would help to address DOTs' questions and concerns in this area. Additionally, because such projects support national energy and

[77] In 1978, the CEQ issued *Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act* (40 CFR §§ 1500–1508) to assist Federal agencies in effectively implementing the environmental policy and "action forcing" provisions of NEPA (42 U.S.C. 4321). To address the NEPA responsibilities that CEQ established, FHWA issued regulations (23 CFR § 771), *Environmental Impact and Related Procedures*. The FHWA guidance complementing the regulations was issued in the form of a Technical Advisory (T.6640.8a), *Guidance for Preparing and Processing Environmental and Section 4(f) Documents*. The Technical Advisory provides detailed information on the contents and processing of environmental documents. The DOE's NEPA implementing procedures are described in 10 CFR 1021.

transportation goals, the two agencies should work together to leverage funding. Coordinating programs that support climate change, renewable resource development, electric vehicles, smart grid technologies, and sustainable transportation could enhance the value of each.

Evaluate the benefits of comprehensive value-based selection criteria for renewable energy and alternative fuel facility projects in highway ROW.
Procurement policies focused only on cost-based principles may fail to achieve the values Federal and state leadership has established. FHWA should research effective value-based selection criteria that DOTs can utilize when awarding contracts for renewable energy and alternative fuel facilities. FHWA could solidify its position as a leader in promoting a more sustainable transportation infrastructure development practice by assisting DOTs in developing comprehensive value-based selection criteria for renewable energy projects in highway ROW.

Analyze effective DOT practices in administering ROW access on routes controlled under the Highway Beautification Program.
FHWA has issued policy regarding the clearance of vegetation within the ROW that may be impairing the view of outdoor advertising signs from the travelled way.[78] Some DOTs have had experience in allowing contractors ROW access on routes controlled under the Highway Beautification Program for this purpose. An analysis of experiences administering this type of program could relate to establishing and maintaining renewable energy or alternative fuel uses within highway ROW.

Consider the potential benefits of sponsoring research to evaluate rest areas and/or excess lands for renewable energy generation.
To date, there has been limited nationwide research on sustainable rest area design and operating practice or their environmental impact or carbon footprints. According to FHWA, the last exact count of rest areas occurred in 1972, when 1,214 rest areas were reported. A preliminary count made as a part of the research reported here indicates that there may be significantly more rest areas today. These facilities seem to offer some of the more immediate opportunities for accommodating renewable energy technologies and alternative fuel facilities in highway ROW given the facilities' potential sizes, setback from high-speed moving traffic, electricity needs, and potential electricity demands should EVs penetrate the fleet to a higher degree.

The proposed research should analyze available information for rest areas, such as square footage, date of construction, type of construction, use, and proximity to communications towers or other significant interferences and major electrical transmission lines that could provide convenient interconnections to the electricity grid. The analysis would result in development of a suitable site profile or guidance for different scales of renewable energy projects at rest areas. The site profile or guidance would be based upon a set of criteria that could include minimum requirements for natural resource availability; site acreage; distance from travel lanes, residences, and other development; construction access; and electrical interconnection points' as well as environmental and other pertinent constraints. The research would potentially help DOTs reduce life cycle cost for energy, conceptualize sustainable and renewable actions and features to rest areas, improve the visitor experience, and reduce GHG emissions.

[78] www.fhwa.dot.gov/realestate/oacprog.htm#VEGETATE

Furthermore, previous FHWA ROW acquisition policy encouraged excess ROW acquisition to extend to natural topographical barriers or whole block acquisitions to mitigate environmental impacts, areas that may be located within or outside the typical ROW limits. According to the questionnaire distributed to FHWA Division Offices as a part of this research, 23 of the 39 respondents indicated that their excess ROW could potentially be used for renewable energy facilities. Alluding to a gap in state DOT property management tracking that has been noted elsewhere,[79] Ohio and Oregon DOTs noted that they are undertaking GIS efforts to identify excess land parcels that are greater than five acres. The DOTs have found that at this time land parcels at least that size are needed to build renewable energy facilities at scales that make them economically feasible.

Other areas that may be suitable for renewable energy activities because of land use planning changes include scenic easements under the Highway Beautification program, state-owned borrow pits, waste areas, and banked mitigation lands. Such lands should also be inventoried and included in the assessment of DOT held property interests to help DOTs assess the magnitude of ROW they may have available for alternative uses.

Help build a community of practice that develops and provides training to ROW practitioners on accommodating alternative energy technologies and alternative fuel facilities in the ROW. Technology and information transfer will be critical to helping transportation audiences in the future with renewable energy and alternative fuel resource development efforts they may envision. As such, FHWA should work with relevant partners to help build a community of practice that would be able to develop and provide training on accommodating alternative energy technologies and alternative fuel facilities in the ROW. The proposed community of practice would offer forums (deployed via in-person training courses and/or webinar presentations) for transportation practitioners to share challenges and lessons learned, as well as to ask questions of other DOTs, utilities, universities, and related stakeholders that have more experience. By undertaking this activity, FHWA could also help respective state DOTs establish champions for pursuing renewable energy and alternative fuel projects in the ROW should the DOT desire to do so.

Some strategic training topics that the community of practice should address include:

- Structuring public-private partnerships to support renewable energy projects
- Developing effective lease agreements and PPAs
- Developing a research plan to facilitate the implementation of renewable energy and alternative fuel projects in the ROW.

Potential next steps for FHWA are:

- Present research results on a webinar, or series of webinars, within three months of finalizing the report
- Identify other Federal partners that provide renewable energy training or with whom training curricula on critical topics pertaining to the development of renewable energy

[79] FHWA. 2010. Estimated Land for Carbon Sequestration in the National Highway System. www.fhwa.dot.gov/hep/climate/carbon_sequestration/index.htm

and alternative fuel projects in highway ROW projects could be developed

- Develop a detailed action plan for moving forward, including coordination activities with DOE.

Appendix A. Stakeholder Contacts

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Appendix B. Phone Discussion Guide and Division Office Questionnaire

PHONE DISCUSSION GUIDE

Concept / Technology Identification

1. Provide a brief summary of the alternative fuel facility or renewable energy project.
2. Where did the idea for the project originate? What is the story and rationale behind pursuing it?
3. What stage is the project currently in? Could you rank the "Technology Readiness Level" – is this a demonstration of a new technology or a proven/sure bet?

Policy / Regulations

4. Are there enabling state regulations for the project?
5. Can you briefly describe your state permitting process for renewable energy facilities?
6. Were there any state/federal policies or regulations that were barriers to implementation?

Design / Siting

7. How did you know the selected location(s) was the right one? How would a DOT "know" it had a good location?
8. Was an environmental analysis necessary? What class of action? Was the class of action due to location sensitivity or size of the project? Describe.

Stakeholders and Public Involvement

9. Who are the stakeholders that have been involved?
10. Have public-private partnerships been necessary? Describe.
11. How could public opinion during the initial stages be characterized?

Installation

12. Who was responsible for installation?
13. What considerations had to be made for construction (e.g., season? Was it like other DOT construction projects?

Safety, Operations, and Maintenance

14. How much electricity does the project generate (monthly/annually)?
15. Have there been any unintended consequences of the project?
    a. Safety implications?
    b. Environmental management implications?
    c. Security implications?
    d. Maintenance/cleaning implications?

Funding

16. How were costs estimated?
17. From where did funding come?
18. Are economies of scale expected?

Best practice recommendations and lessons learned

19. What advice would you give other DOTs looking to implement a similar project?
20. What are future research needs in this area?
21. Does your agency have plans for additional alternative energy projects in the ROW?

Referrals
Can you provide the names of other people who were involved in this project – other DOT staff involved, utility company, etc.?

DIVISION OFFICE QUESTIONNAIRE
The Renewable Energy Technologies and the Use of Alternative Fuel Facilities in the Right-of-Way is a STEP research to develop information on accommodation of renewable energy technology and alternative fuel facilities. The Office of Real Estate Services would like to gather information about your States Right -of-Way and Utilities, laws and regulations to help identify where there may be opportunities or barriers to accommodating renewable energy technologies and alternative fuel facilities in the right-of-way.

1) Does your State laws allow for the use of highway rights-of-way to accommodate public utility facilities as noted in the "Guidance on Utilization of Highway Right-of-Way" available at www.fhwa.dot.gov/realestate/guidutil_a.htm?
   a) If so, is the accommodation of renewable/alternative energy facilities addressed in the State's Utility Accommodation Manual (UAM) or Plan?
   b) If not, are there plans to address alternative energy uses of the ROW with the UAM?
   c) Does your State characterize renewable energy facilities as utilities (i.e., in regards to the accommodation of utility facilities in the ROW)?
   d) When was the last update of the Utility Accommodation Policy?

2) Are there any State laws that either allow or prohibit the generation of renewable energy within the highway ROW? If so, please cite the law(s).

3) Does property interest in DOT-acquired ROW legally allow the application of renewable energy facilities if the following exist:
   a) Acquisition was of easement for highway use only? If so does underlying fee interest needs to be acquired or permission granted to allow construction of renewable energy facilities?
   b) Interest was condemned using eminent domain and does not grant legal authority to develop or use other than for highway use?
   c) Acquired interest has a reversionary right if not used for stated highway purpose?

4) Can States' excess ROW or potential excess ROW be used for renewable energy facilities?
   a) If so, under what circumstances?
      1. Acquire excess land to natural or logical physical barriers for mitigation of property damages or social economic environmental mitigation?
      2. Does the DOT have custodial authority for land banked rail corridors, consider using for this purpose?
   b) If not, what are the barriers, and are there any activities underway to address these barriers?
   c) Has your state received any request(s) to use the excess ROW for renewable energy or alternative fuel facilities?

5) Is your State pursuing or being encouraged to pursue any renewable energy projects in the ROW?
   a) Is there pending State legislation or executive orders from the Governors' office to develop more green/renewable energy resources?

Additional Comments:

Please provide an agency or contact names, and telephone numbers that can be used for follow-up.

Appendix C. Case Studies

Oregon DOT's Solar Highway Demonstration Projects

In 2007, Oregon's Governor Ted Kulongoski directed state agencies to meet 100 percent of their electricity needs with renewable energy by 2025. A year later, Oregon DOT, wanting to find a way to tangibly offset its carbon footprint and begin to meet the Governor's challenge, embarked on the effort to implement the solar highway project. The project, now commonly known as Oregon's Solar Highway Demonstration Project, is located at the interchange of Interstate 5 and Interstate 205, along the middle of a grassy island at the interchange. It consists of a 104 kW, 594-panel, ground-mounted solar array system positioned at 20-degrees to the horizon. The solar array has produced approximately 130,000 kWh annually since it first went online, or roughly enough electricity to supply a third of the energy needed to illuminate ODOT's high mast luminaries in the area. SunWay 1, a limited liability company that PGE manages, owns and operates the system.

Site Selection and Design

The primary criterion for selecting a location for the demonstration project was safety. The panels had to be located beyond the "clear zone," or the area where errant vehicles might travel off the edge of the pavement. ODOT's roadway design engineering section was consulted to determine appropriate clear zone boundaries. The system also had to be in an area that ODOT was not planning to improve in the foreseeable future, in this case, 20 years, to ensure that the panels would not have to be moved or removed. The system also had to be within PGE's service area in a location that could be connected to an existing ODOT electricity load to meet net-metering requirements. The site at the I-5 and I-205 interchange was attractive because there was available land outside of the clear zone that was south-facing, experienced little shading, and was in a highly visible area.[80]

Since the interchange otherwise had limited access, the site selected required that a small, gravel access road be built for system construction, operation, and maintenance access. Stipulations governing the access, ingress and egress of the site were incorporated into the Utility Permit, providing control over the times and conditions under which access would be allowed while mitigating risk to the traveling public.

Business Model and Financing

ODOT had to find an innovative way to finance and implement the project given that state statutes restrict the use of highway funds to activities related to construction, reconstruction, operation, and maintenance of the state transportation system. ODOT first released a request for information, which led to conversations between ODOT and Five Stars International. Five Stars International, Ltd. worked with ODOT to find a utility partner. PGE was the only provider who expressed interest in moving forward with a project.

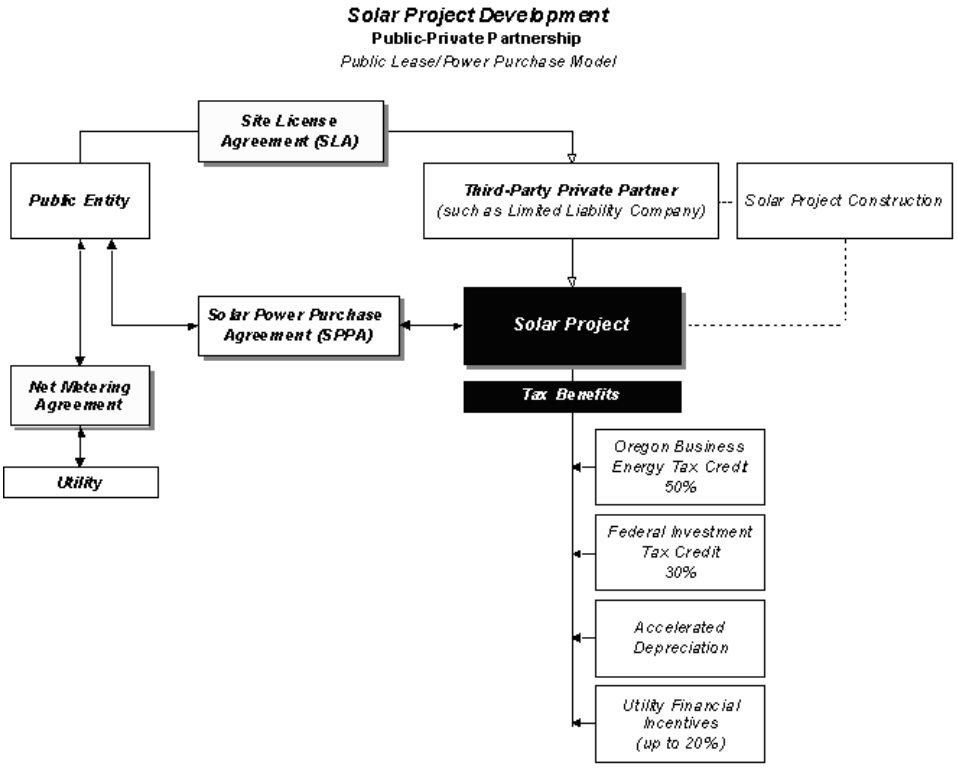
[80] ODOT believes that approximately 1.6 billion vehicles will pass by the demonstration project over its duration.

Ultimately, ODOT was able to finance the demonstration project through an innovative public-private partnership with PGE and other public and private entities. PGE partnered with U.S. Bank to form Sunway 1, LLC, which owns and operates the facility. ODOT then partnered with SolarWay to design, construct, and install the solar panels.

In order to take advantage of Federal and state tax incentives, which neither PGE nor ODOT could do because they do not have a tax liability, U.S. Bank was brought in as a tax equity investor (U.S. Bank has majority ownership of the project and leases the project back to SunWay 1, LLC at net cost). U.S. Bank utilized the state's Business Energy Tax Credit (BETC), which covered 50 percent of eligible costs, including equipment cost, engineering and design fees, materials, supplies and installation costs, and loan and permit fees. Additionally, U.S. Bank claimed the 30 percent federal Investment Tax Credit that the Energy Policy Act of 2005 (EPACT) created and the American Recovery and Reinvestment Act of 2009 (ARRA or Recovery Act) extended. The tax credits will be extracted over five years, after which the project will be fully capitalized. U.S. Bank can also utilize accelerated depreciation, which provides a way of deferring taxes by reducing taxable income in current years in exchange for increased taxable income in future years. PGE also contributed capital to the project. State regulation requires utilities to offset carbon emissions from coal-fired power plants. PGE valued the carbon offsets created by the solar energy project at $30 per metric ton.

ODOT entered into a Site License Agreement with Sunway 1 to allow the developer to site the solar PV system on ODOT land. ODOT also entered into a Solar Power Purchase Agreement (PPA) with Sunway 1 to purchase the electricity produced by the solar facility at the same rate the agency pays for electricity from other sources on the grid. The Site License agreement and the PPA, which both have initial terms of 20 years, allow ODOT to comply with constitutional constraints on the use of highway funds. Specifically, the PPA and Site License Agreements demonstrate that electricity the project produces will continue to be for ODOT's own use.

ODOT was the first Oregon state agency to enter into a solar site license agreement or a PPA. Legal staff at ODOT and the Oregon Department of Justice (DOJ) worked with an outside legal team to help draft the documents. The legal fees associated with developing these agreements constituted a large percentage of the overall project costs for the state.



Value-Based Procurement

ODOT and its project partners utilized value-based selection criteria to award contracts and procure components in order to ensure that the solar demonstration project met the state's sustainability goals. For example, when procuring the PV modules for the demonstration project, Oregon evaluated proposals using a set of value-based selection criteria. In addition to corporate qualifications, technical characteristics of the proposed PV modules, and price, the selection criteria also included commitment to Oregon's Sustainability Policies, such as no hazardous materials in the panels, recycling of PV module materials after their useful life, and disclosing the manufacturing locations of the PV modules (to assess shipping impacts, if any). By carefully considering the project's contribution to the state's overall public interests and values, not just direct costs, ensured that the demonstration project truly supported the state's sustainability goals.

Permitting

ODOT District offices issue and manage the permits as a normal course of business. ODOT, the Oregon DOJ, and the Oregon FHWA Division Office jointly determined that since the demonstration project was going to supply electricity for ODOT's direct use, the project would be permissible on ODOT ROW through the Oregon Administrative Rules Division 55 (OAR 734-055) Utility Permit process, which is usually used for utilities and which follows the Federal Utility Accommodation Plan (UAP). However, the parties involved agreed that while the Utility Permit Process would be followed for the initial three projects, future projects would reevaluate the appropriate permitting process to use. In addition, due to the pilot-testing nature of the solar installation, FHWA requested and completed review of the permit before it was issued. A traffic control plan was also submitted to the ODOT District office as a prerequisite to the Utility Permit.

Environmental Review

The Solar Demonstration Project followed the state environmental review process. Because the site location involved ODOT owned land that had been part of previous environmental analysis, the agency already had a wealth of information. ODOT retained responsibility for the analysis and obtaining environmental clearances, including issues related to hazardous materials, water quality, historic resources, and threatened or endangered species, and for the costs of mitigating or rehabilitating the impacts.

Additional issues that ODOT addressed in its environmental analyses for subsequent projects under study include noise, visual impacts, and electromagnetic frequencies.

Operations, Maintenance, and Security

As part of the site license agreement, PGE assumes liability for the I-5 solar system, including maintenance, operation, and security. The PV array and support equipment are located in a secure compound surrounded by a full height security fence, hardened with triple-strand barbed wire, razor wire coil, and 3-inch barbed security tape. An electronic security system monitors the perimeter fence and is capable of detecting when the fence is scaled, cut or damaged. Sensors monitor the opening and closing of the gate, and security cameras provide remote visual monitoring and motion detection within the compound. ODOT and PGE operations personnel will be immediately notified if any breach of security is detected. Under the security protocols established, ODOT will first notify State Police of site security issues, and then notify PGE. Additionally, PGE has implemented the use of Stop Theft technology, a proprietary theft deterrent product that PGE has used widely to safeguard, identify, and recover electronic equipment such as laptop computers, cameras and other moveable items. Placards are prominently displayed to further deter theft. Counter-sunk screws and tamper resistant bolts were used to make the removal of mounted hardware more difficult and time consuming. To date, the project has not experienced any security incidences.

In terms of maintenance, other than a cracked panel that the manufacturer had to replace, maintenance required has been minimal. Mowing has only been necessary a couple of times during the summer, as ODOT used a low-growing grass species that eliminates the need for regular mowing. Washing has never been necessary, as rain has successfully kept the panels clean. According to PGE, which has responsibility for maintenance, barring damage from external factors, the photovoltaic system should require very little maintenance during its service life.

Public Involvement

ODOT hired a local firm, Good Company, to manage the public involvement activities related to the project. Good Company conducted research describing when the solar highway would become "carbon positive," or beneficial to the atmosphere.[81] The research has been an effective public relations tool. In general, the public response to the projects has been extremely positive.

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[81] Good Company. August 2008. Avoided Carbon Emissions from Solar Panel Systems and Sequestered Carbon Emissions from Tree Growth www.oregon.gov/ODOT/HWY/OIPP/docs/treesvsolar.pdf.

However, ODOT and its project partners noted the importance of public outreach efforts to educate the public on renewable energy facilities and adequately address any concerns the public raises.

Patent Issue

Late in the project development process, a patent holder for several patents related to the development of alternative energy installations along roadways contacted the Oregon project partners. The patent holder was entitled to collect license fees for use of the methodologies and techniques covered by the patents. The parties involved chose to negotiate a licensing fee under a non-disclosure agreement in order to avoid the legal fees and project delays that might have resulted from a legal challenge.

Future Projects

Based on the I-5 solar highway experience, ODOT and PGE are currently working on developing additional solar energy projects in the highway ROW. The next project, the Baldock Solar Highway Project, is located on a seven acre site adjacent to the Baldock Safety Rest Area on Interstate 5. The project entails installing a 1.75MW direct current solar array, which includes approximately 6,994 250-watt panels. Construction activities began in August 2011 and are expected to conclude in February 2012. The third project will involve installing a 3 MW solar panel system on a terraced hillside above I-205 at an ODOT operation and maintenance staging site in West Linn, Oregon.

These next two projects will also be permitted through the Utility Permitting Process. However, after these three projects, which are considered research and development projects, additional projects may be permitted through airspace leases. Because ODOT received funding from the DOE for its Baldock project, the project will need to abide by the National Environmental Policy Act (NEPA); ODOT performs a NEPA-type environmental review regardless of federal funding or not. Since ODOT lacked familiarity and experience with DOE's NEPA regulations, the agency requested that it be allowed to follow FHWA's NEPA regulations. After a lengthy process, DOE allowed ODOT to follow FHWA NEPA regulations for its research and development projects, but this allowance does not currently extend to any potential future projects.

The Baldock project will also follow a different business model than the I-5 demonstration project. As with the I-5 demonstration project, ODOT will enter into a solar site license agreement with the third-party developer/utility to allow for use of the site. However, unlike the demonstration project where ODOT purchased the electricity the system generates, for future projects ODOT is considering receiving a portion of the "Renewable Energy Certificates" (RECs) that the projects create, not the electricity. When a renewable energy facility operates it creates electricity, which is delivered to a specific facility or the grid, along with an REC. The REC represents the environmental attributes and benefits (for example, emissions offset) of the renewable power produced. In these cases, the renewable electricity itself and its associated REC can be "unbundled" and sold separately. When this occurs, electricity that is unbundled from the REC is no long considered "renewable", and therefore, cannot be counted towards any renewable energy or carbon offset targets. The RECs ODOT would receive would be proportional to costs incurred related to project development activities, including staff and

consultant costs, legal costs, and environmental assessment costs. The RECs would be conveyed to ODOT through a site license agreement, and a PPA would not be needed. Because creating a PPA is a complex and lengthy process, ODOT views this business model as a preferred option.

Best Practices/Lessons Learned

Oregon DOT and its project partners learned many important lessons while implementing the nation's first solar highway project.

- A strong champion is critical to the overall success of innovative projects. Allison Hamilton, ODOT's Solar Highway Program Manager, was instrumental in ensuring that the project moved forward. Ms. Hamilton helped to secure support from ODOT leadership and strategic partners, and helped to facilitate communication and coordination between all the parties involved.

- Maintain flexibility. Implementing renewable energy projects in the highway ROW is an innovative concept. As such it is imperative that agencies be able to adapt process to address changing public policies. ODOT and its project partners continuously assess the success of its first demonstration project and are using lessons learned to inform development of future projects. For example, ODOT is pursuing a different business model, one that will rely on the ownership of RECs and an annual site license fee, for its next solar highway projects.

Additional information on Oregon's solar highways project is available at www.oregonsolarhighway.com.

Massachusetts DOT's Renewable Energy Feasibility, Solar Power, and Wind Power Projects

Statewide Renewable Energy Feasibility Study

The Massachusetts Department of Transportation (MassDOT) is conducting a statewide assessment of the Highway Division's real estate holdings, including buildings, structures, and rights-of-way, to identify potential sites suitable for wind and/ or solar power installations. The feasibility study is in response to several environmental directives and policies focused on reducing the environmental impacts of state government operations.

In 2007, Massachusetts' Governor Deval Patrick issued Executive Order 484, which established the state's Leading by Example (LBE) Program. The program established GHG emission reduction and renewable energy targets for all state agencies. In support of the LBE program and other related policies, MassDOT issued its GreenDOT policy directive in June 2010.[82] One of the three goals of GreenDOT is to reduce GHG emissions associated with the operation of the state's transportation system.

[82] MassDOT GreenDOT Policy: www.massdot.state.ma.us/greendot.aspx

MassDOT, in coordination with the consulting firm Epsilon Associates, Inc., is reviewing its real estate holdings to identify potential sites suitable for large- and small-scale wind and solar installations. To identify potential locations for wind and solar projects, the consultant will overlay geographic information system (GIS) data on MassDOT facilities and other land holdings with wind and solar resource data, such as the National Renewable Energy Laboratory's 50 meter wind power data for Massachusetts. MassDOT holdings that are located in areas with quality wind and solar resources will be further assessed against a set of suitability criteria. While MassDOT and its consultant are still developing the site suitability criteria, it is expected to include the following factors: minimum site acreage, minimum distance from travel lanes, construction access, proximity to utility interconnection, environmental constraints, and proximity to residences and other developments. The statewide assessment is expected to be complete by mid-2011.

MassDOT is also currently pursuing renewable energy generation projects within highway ROW that were initiated prior to the feasibility assessment. The two projects, one a wind power project and the other a solar power project, are highlighted below.

Wind Power at Blandford Service Area

Following creation of the LBE Program, the state sought to identify potential sites to support solar and wind facilities. The former Massachusetts Turnpike Authority, which is now part of MassDOT, analyzed potential wind turbine sites along the Massachusetts Turnpike, a 138-mile highway extending across the state from east to west. One of the areas examined was a 68-acre site adjacent to the Blandford service area, a Turnpike property located near the highest elevation on the Massachusetts Turnpike. After a 13-month feasibility study,[83] which collected wind speed and other site condition information, the Turnpike determined that the site was suitable for wind power development. In April 2009, the former Turnpike Authority issued a Request for Proposals (RFP) for a long-term lease for wind turbine development at the Blandford site. Solaya Energy, LLC was selected as the preferred developer. The developer proposes to build a 1.5MW turbine in the middle of the 68-acre site. The turbine will be set back approximately 1500 feet from the roadway.

<u>Development Agreement</u>

In September 2010, MassDOT and the Solaya Energy Corporation entered into a Development Agreement. The agreement requires the developer to develop preliminary and final development plans, design documents, and construction management plans, all of which MassDOT must approve. The developer must also obtain all necessary permits, secure financing, and enter into an Interconnection Agreement with a utility company before MassDOT will enter into a real estate lease.

The creation and final details of the Development Agreement differed from typical real estate agreements in a number of ways. These differences, as well as additional challenges and issues that the project faces include:

[83] Renewable Energy Research Laboratory (2009). Wind Data Report Blandford Rest Area: December 2008 to February 2009. www.umass.edu/windenergy/downloads/pdfs/Blan2_2009_QuarterlyReport_Winter.pdf

1. *Establishing Milestones.* Typical MassDOT real estate leases include specific milestones that the developer must meet in a specified amount of time. However, as this was the first renewable energy project for the agency, MassDOT was unsure of the appropriate milestones. Ultimately, the agreement included a general two-year timeframe in which the developer had to meet all its required conditions and commitments. The only milestone that was included, at the request of the developer, was that MassDOT had to approve the initial concept plan. MassDOT would not typically provide a developer with that long of a time frame to meet all of its obligations. However, since this was a first of its kind project, neither MassDOT nor the developer was certain on how long each step in the process would take.

   The agreement provides for opportunities to extend the two-year timeframe. For example, if the developer secures the necessary permits, but then a challenge is made, the developer will be granted an extension in order to address the challenge.

2. *Permitting.* The wind power project will be subject to local zoning regulations. The Town of Blandford, MA does not currently have zoning for wind power projects. Before the Town can permit the project, the applicable zoning bylaw needed to be developed. The Executive Office of Energy and Environmental Affairs worked with Blandford officials to do so. In May 2011, registered voters at a Town of Blandford open town meeting defeated the bylaw, putting the future of this project in question.

3. *Third Party Costs.* Under the Agreement, the developer is responsible for reimbursing MassDOT for all third party costs, such as consultants' and attorneys' fees, title, and engineering costs, associated with the project. However, since not all of the consultants that MassDOT is using are experienced with wind turbine projects, the developer has been allowed to approve a sub-set of vendors that the DOT may use. If MassDOT wants to utilize a vendor not included on the pre-approved list, it must first get the developer's approval.

4. *Due Diligence/Liability.* Because the return on investment associated with the wind project is expected to be low, the developer has been hesitant to accept the risks common to such projects. While utility scale developers have the experience and ability to absorb such risks, the smaller company has been more risk adverse. For example, the developer has been hesitant to accept liability for the project, because there is a concern that the liability will impact the developer's ability to secure financing. MassDOT made some allowances for this in the Development Agreement, allowing more latitude for the developer to get out of the project than is typical with such agreements.

5. *Power Sales.* The developer is having difficulty securing a customer for the renewable energy the wind power project is expected to produce. Due to the current economics of a power purchase agreement, the cost of the electricity the wind turbine would generate would be higher than competitive sources. Because MassDOT is already locked into a series of statewide power contracts, the DOT is not able to purchase the electricity. Potential customers include the vendors located at the adjacent service station. However, since the amount of electricity to be produced at the site exceeds the service station's

demand, the developer needs to find additional electricity customers. The developer's financing, and therefore, its lease with MassDOT, is contingent on securing a customer base for the wind energy produced.

Eventually, if and when the turbine is installed and operating, the operator will be required to pay rent to MassDOT for use of the land. The cost will be tied to the total revenue generated; with the rent equal to 3.5 percent of power sales, with a minimum of $15,000 a year.

Solar PV Array in Carver

The Town of Carver recently constructed a new water treatment facility in the North Carver Water District. The town was interested in utilizing renewable energy sources to support the water system's energy needs. Town officials initially analyzed the feasibility of installing wind turbines along Route 44, which runs adjacent to the water treatment facility. After the site assessment, it was determined that the location was better suited for a solar power project. Route 44 is an east-west state highway with an embankment at a 36-degree pitch, making it well suited for a solar array.

In February 2009, the Town of Carver approached the local MassDOT District Office about installing a 117 kW solar array along the highway ROW. The District Office was initially opposed to the concept. However, after several months of coordination with MassDOT and other state government leadership, the town secured support for the project as a demonstration.

Shortly thereafter, the Town was granted an easement from the MassDOT to construct the solar arrays along the highway ROW. The 117 kW system will be set back 65 feet from the roadway, and will be accessible through the water treatment facility property. The easement conditions require that the existing guardrail in the area be extended along the length of the solar array and includes language stating that if the DOT needs the land for expansion in the future, then the town will be required to remove the solar facility. As a requirement to obtaining the easement, the Town of Carver had to get an appraisal on the value of land, which was used to establish the annual rent owed to MassDOT. The town will pay $880 per year to MassDOT for use of the land.

In November 2010, the town selected a preferred vendor, who will install, own, and operate the solar panels. Shortly after the preferred developer was selected the town received a $50,000 technical assistance grant from the Massachusetts' Department of Energy Resources' Energy Efficiency and Conservation Block Grant (EECBG) Program, which is being used to support the Town with developing the power purchase agreement. The town was also awarded a $150,000 grant from the Federal Recovery Act, which will be used to underwrite the cost of the facility.

<u>Challenges</u>

While increasing reliance on renewable energy was a priority for the state, the Carver solar power project was one of the first in the state to pursue using the highway ROW for siting a renewable energy facility. Staff at the local MassDOT district level did not have experience with using ROW for such purposes and, thus, were initially hesitant about approving such a use. It took a great deal of lobbying on the town's behalf to move the project through the various levels of DOT approval. Securing support from the DOT leadership was critical to moving the project

forward at the local level.

Negotiations for the PPA have been lengthy and complicated, with the main issue being liability. The town is requiring the developer to accept complete liability for the project, while the developer is concerned with their ability to secure financing if their liability is too high.

California Highway 50 Solar Project

The Sacramento Municipal Utility District (SMUD) and the California Department of Transportation (Caltrans) had been coordinating to develop solar energy projects along Highway 50 in Sacramento County. The proposed 1.4 MW project would have been the first of its kind in the state. However, in November 2011, the project was canceled due to economic reasons, which are described below.

Background

Initially presented in summer 2007, the idea gained leadership support and the official go-ahead within about a year. Shortly thereafter, SMUD met with Caltrans and FHWA staff to discuss the project. With no precedent to rely upon, all of the involved parties have had to work through the issues together. For example, Caltrans and SMUD chose sites collaboratively through an iterative process focused on establishing the following siting criteria:

- Sites should have southern exposure to ensure maximum generation potential
- Workers should have the ability to access the sites from an entry point other than the roadway itself
- Caltrans height (8') and setback requirements (~52') for safety had to be met
- There could not be any competing commercial or private demand for the land
- The sites should be in close proximity to SMUD electrical facilities to minimize cost of interconnection
- The sites should be of sufficient size to ensure economic feasibility and the interest of private project developers.

SMUD used Google Earth as an initial screening tool to identify potential sites. Staff then conducted a field assessment of the locations found in the screening to see if the siting criteria could be met. Ultimately, two potential locations were selected:

East Sacramento –A section of the north slope of the roadway was chosen in part because it is located next to light rail tracks, which provide a non-highway access point, and it is a highly visible location near the center of the urban core. The solar installation at the East Sacramento location will consist of traditional flat-plate PV modules.

Rancho Cordova –A crescent-shaped parcel of land above the northern on-ramp to westbound Highway 50 and a short length of slope west of that onramp was selected as the second location (although the slope was later removed from the project scope when it was altered to accommodate an HOV lane expansion). The solar installation for this site will be

advanced, concentrator photovoltaic panels with dual-axis tracking systems enabling the installation to follow the sun. SolFocus, a solar panel developer and manufacturer from California and partner in developing the necessary Department of Energy grant application, will provide the technology for the installation.

Once the potential sites were identified, SMUD conducted a two-phase feasibility study. Phase I, completed in September of 2009, was a preliminary project evaluation that included a survey of the sites, preliminary PV system designs based on three different types of off-the-shelf flat-plate PV modules, an economic assessment of these designs and a preliminary identification of potential project barriers and challenges unique to deploying PV systems along the highway corridor. The Phase 1 study results found that the design utilizing poly-crystalline PV modules was the most cost effective PV system for installation along the highway. SMUD determined it to be attractive enough to initiate the Phase 2 analysis. IEC was contracted for Phase 2 to further evaluate the project cost and performance, fully examine the design parameters, barriers, mitigations, constraints, and project economics, and collect the findings required to gain approval from stakeholders and proceed to the environmental study and project bid phase.

In accordance with the California Environmental Quality Act (CEQA), SMUD released its Initial Study/Mitigated Negative Declaration and Mitigation Monitoring Plan in July 2011. Following the completion of the environmental document, Caltrans approved a conceptual draft airspace lease agreement for the project in August 2011. Subsequently, SMUD issued a Request for Offer (RFO) to identify a third-party to design, construct, and operate the solar installations. The developer would have owned and operated the solar arrays and would have sold the electricity produced to SMUD. SMUD's RFO received only one bid, which was higher than anticipated given estimated costs associated with similarly scaled projects. As a result, in November 2011, SMUD determined that it was not economically feasible to continue to pursue the solar highway project.

Issues and Challenges

Safety/Access. One of the primary considerations is to have access to the site from outside the travel lane. Caltrans did not have a related internal policy because private uses similar to solar installations in the ROW had not been previously encountered. Caltrans was also concerned about the appropriate distance to locate the solar panels from the highway. Establishing the setback and height requirements was a complicated process, requiring much discussion and coordination between Caltrans and SMUD. For this particular project Caltrans is requiring 52-foot horizontal and 8-foot vertical setbacks. The setback requirements apply to both the travel lane and the on-ramp areas.

Security. Full perimeter fencing is prohibited in the project area to minimize the number of objects and structures within the ROW. SMUD needed to identify appropriate, alternative security measures to address theft and vandalism concerns. The organization has experience securing other solar installations without perimeter fencing and will apply the lessons learned from those projects to this one. SMUD anticipates a number of features that will "harden" the design for protection in the urban environment, including anti-theft hardware, fully enclosed wiring, partial fencing to discourage casual access, and protective landscape features.

Additionally, the flat plate solar arrays will be mounted 18" from the ground to prevent the public from using them as shelter.

Glare. Caltrans expressed concern about the potential for the panels to create glare, which would present a safety hazard to motorists. SMUD addressed this concern in the environmental analysis via special studies examining the risk of glint and glare on motorists and residents. As other studies have demonstrated, solar panels are designed to absorb sunlight, rather than reflect it, minimizing potential impacts of glare. Additionally, the potential for glare is highest when viewing angles are acute, which occurs for only very limited periods of time in the morning and the evening from spring to late summer.

Aesthetics. SMUD worked with a local architect firm to develop preliminary conceptual designs of the Rancho Cordova installation. Design considerations are critical, as these project sites are highly visible and intended to be viewed as community assets. SMUD is also planning to incorporate design criteria into its Request for Offer (to select a project developer) and to involve the community in the evaluation of the proposed project designs. Post-construction, the developer will be required to maintain the surrounding landscaping and correct any graffiti or other disturbances at the project sites.

Legal. There is a patent holder with a patent covering the development of renewable energy projects on public ROW. SMUD considered it less costly to negotiate a license fee with the patent holder than to challenge the patent in court. However, SMUD is wary of setting a precedent for other utilities seeking to do similar projects. The patent issue is a national issue and will likely impact all projects that seek to install renewable energy projects in the highway ROW.

Public Outreach and Feedback

As part of the scoping process for the environmental analysis, SMUD held four public workshops in the September 2010. SMUD had developed visualizations, including conceptual drawings and realistic photo renderings to help the public understand what the projects would entail. The visualizations were used during the public meetings to set the context for each project location and to help generate feedback from the public on the preliminary design.

Best Practices/Lessons Learned

Although SMUD is no longer pursuing the projects, their efforts generated a number of lessons learned. Early on, gaining support for the solar installations required a great deal of persistence from the project champion at SMUD before the utility's leadership backed implementation of the concept. With leadership support, the project team has learned the following lessons over the last two years:

- Identify and address potential issues early. SMUD staff developed a risk matrix identifying all the issues that could potentially arise. When agency leadership asked questions or expressed concern in an area, staff thoroughly addressed the issues in detail. Producing quality work products early in the project enabled it to get past some of the early issues. This risk matrix has been updated as old issues have been resolved and new

ones arisen. It was also important to do basic groundwork early to ensure the project is feasible from design, permitting, and economic perspectives.

- Maximize internal and external communication. Working through issues has demanded a great deal of coordination and communication between Caltrans and SMUD. It has been important for each organization to present a consistent message internally. Topics such as safety, design, and permitting need to be discussed within the DOT before coordination with the other agencies can succeed. Having a consistent message is also necessary so that issues do not have to be readdressed with multiple parties.

- Plan for extra time. The process of installing PV technologies in the ROW could take longer than other locations since DOTs have limited experience doing so. Many new processes are being created or adapted to accommodate the Caltrans/SMUD pilot project, which can require more time and longer schedules than initially planned.

Ohio Department of Transportations' Renewable Energy Projects

In 2008, the Ohio Legislature established a renewable portfolio standard (RPS) that required utilities to provide 25 percent of their retail electricity supply from alternative energy resources by 2025. Shortly thereafter, the Ohio Department of Transportation (Ohio DOT) was granted the authority to lease their right of way for the deployment of alternative energy technologies in support of the newly established state RPS. Currently, Ohio DOT has several renewable energy projects underway in the highway right of way and on other department owned property.

Veterans' Glass City Skyway Bridge Solar Array Demonstration Project

In 2010, Ohio DOT, in coordination with the University of Toledo, installed a 100 kW grid connected solar array in the highway ROW off Interstate 280 and Greenbelt Parkway in Toledo, Ohio. Electricity developed by the solar array is used to offset the electricity demand of the Veterans' Glass City Skyway Bridge, which has a 196-foot lighted pylon containing 384 light emitting diode fixtures. The solar array is expected to meet 100 percent of the electricity demand for the bridge lighting. Ohio DOT funded the project through a Federal earmark and a use of state planning and research funds.

Ohio DOT implemented the solar array field demonstration project to evaluate the effectiveness of installing renewable energy technologies in the highway ROW. The project utilizes two types of solar panels, both of which are manufactured in state. The project includes 966 rigid solar panels manufactured by First Solar, and 198 flexible solar panels manufactured by Xunlight. Over the next year, the University of Toledo will conduct research to study the effectiveness of installing the solar array along the highway ROW in Ohio. The solar array is comprised of several sub-units. Each panel is attached to a monitoring system, which allows researchers to study how the solar arrays interact in a system. Ohio DOT will also use the field demonstration project to evaluate glint and glare impacts, and to identify additional issues that will need to be considered for future projects, such as the impact of snow melt and ice damming.

During the research phase, the University of Toledo, which installed the arrays, is responsible for operating and maintaining the system. At the end of the one year research effort, Ohio DOT will take over ownership and responsibility for the system. To date, a couple of panels needed to be replaced under the manufacturer's warranty.

Maintenance Facility Wind Turbine

In addition to the solar demonstration project, the Ohio DOT is also installing a small 32 kW wind turbine at an Ohio DOT maintenance facility in Northwood, OH along I-68. The wind turbine, which is approximately 100 feet tall, is located 140 feet from the roadway. As with the solar demonstration project, the Ohio DOT district will retain ownership and will be responsible for operating and maintaining the wind facility. The electricity produced by the turbine will be used on site, and Ohio DOT anticipates that it will help meet up to 65 percent of the electricity needs of the maintenance facility.

Environmental and Safety Considerations

Ohio's state resource and regulatory agencies did not have much experience with small scale wind projects. As such, the regulatory agencies did not have specific guidelines to follow in designing the wind facility. Ohio DOT worked closely with the agencies and the local municipality to address environmental and safety concerns such as ice throw, flickering of blades, fall radius, and bird deaths. Ohio DOT is also coordinating with the Fish and Wildlife Service to monitor the impact of the wind turbine on migratory bird populations.

For its wind project, the Ohio DOT received funding from the DOE. As a result, the agency was required to comply with both DOE's (10 CFR Part 1021) and FHWA's (23 CFR 771) NEPA regulations. The Ohio DOT chose to create two NEPA documents, one for FHWA and one for DOE, instead of trying to coordinate between the two agencies.

Statewide "Opportunity Zones" Assessment

In addition to the solar and wind projects currently underway, Ohio DOT is working with the Ohio State University to utilize geographic information systems (GIS) to identify opportunity zones for renewable energy and other revenue generating projects in the highway ROW. The research effort will utilize numerous GIS layers, including DOT assets and wind and solar resource maps, coupled with an economic analysis to identify priority locations to site future projects. In particular, Ohio DOT will identify excess agency-owned land parcels that are greater than five acres. These large land parcels are needed to build renewable energy facilities at a scale that make them economically feasible.

Lessons Learned

In developing its solar and wind projects Ohio DOT has identified several best practices and lessons learned.

- Ohio DOT ownership of renewable energy facilities is not a sustainable business model. In future projects, Ohio DOT would advocate for a utility or private partner to own and operate the facilities, with Ohio DOT purchasing the renewable energy through a power

purchase agreement. The costs of developing renewable energy projects would be lower if developed by private entities, as they are able to take advantage of tax credits and other incentives, such as accelerated depreciation. When projects are fully capitalized by the transportation agency the costs are higher and the agency is unlikely to experience an adequate return on investment over the life of the project.

- Developing renewable energy projects requires input from a cross-section of stakeholders. In their effort to develop the renewable energy projects, Ohio DOT staff spoke with numerous stakeholders in the field to learn about the technologies available and to ensure that Ohio DOT was getting a good value for its investments. The staff attended trade shows where they were able to network with industry representatives.

- Developing renewable energy projects requires a full time position. As the first renewable energy projects implemented by the Ohio DOT, both projects required an extensive amount of staff education on pertinent topics. The amount of work involved in developing these projects requires the full attention of at least one staff member. Ohio DOT recommends creating a full time position, such as an Energy Manager position, to centrally manage the energy needs and projects for the department.

- Educating DOT staff is integral to success. The staff working on developing the renewable energy projects spent a great deal of time educating other DOT staff on the project. Securing internal support from both leadership and the various departments and districts was an important element in the successful implementation of the projects.

Freeways to Fuel Program

Freeways to Fuel (F2F) is a national alliance designed to investigate the use of non-traditional agronomic lands such as roadside ROW, military bases, and airports for the growth of biofuel feedstock crops across the country.[84] The F2F program, which began in 2007 as a cooperative program between the Utah Department of Transportation (UDOT) and Utah State University (USU), seeks to increase the production of biofuel without affecting food, fiber, feed, or flower production by targeting lands that are not currently in production. The alliance has now grown to include other DOTs and land grant universities. As participants in the F2F program, these universities and DOTs collectively contribute to the research on whether uses of non-traditional lands are economically and environmentally feasible. To date, the F2F national alliance has tested safflower, canola, and flax crops.

Nearly all transportation agencies in the United States expend significant costs to maintain the highway ROW. For example, UDOT alone manages nearly 6,000 miles of highway roadsides, which incurred $300 per mile in maintenance costs in 2006. Transportation agencies can minimize maintenance requirements, as well as produce biofuel that can be used to replace traditional fuels, by planting and harvesting feedstocks in the highway ROW. This in turns helps

[84] Freeways to Fuel: http://freewaystofuel.org/htm/faq

transportation agencies reduce their GHG emissions. The F2F economic model shows that biodiesel produced from this method will be economically feasible given a petroleum diesel price of $2.50 per gallon.[85]

Utah Freeways to Fuel Pilot

In 2006, the USU research team partnered with UDOT to pilot the planting of crops in the highway ROW. This effort marked the first time that any group had attempted to grow biocrops for the purpose of creating a biofuel source in the highway ROW. While the production of biofuel was a key part of the Freeways to Fuel program, it was not the element that attracted UDOT; rather it was the potential cost savings that provided the greatest draw.

USU planted several test plots along the I-15 corridor, selecting 20-foot by 8-foot plots. The study team replicated these plots eight times in four locations. The team used a drill, commonly used for re-vegetating roadways to plant biocrops and seeded 15 feet off the pavement in the roadway shoulders. Initially, the crops did not produce a significant yield. The research team determined that there were soil compaction issues immediately adjacent the highway that impacted crop yield. In response, USU devised new planting techniques that would loosen the roadside soil without impacting the stability of the roadway. The USU team eventually developed an aerator tool that could be attached to planting equipment.

North Carolina Freeways to Fuel Program

The North Carolina Freeways to Fuel project, a cooperative effort between the North Carolina Department of Transportation's (NCDOT) and North Carolina State University (NCSU), started in 2009 and is now largely regarded as one of the most successful programs in the F2F alliance. Its moist climate, fertile soils, and support from the State legislature have made the biocrop growing efforts a national model.

As a first step in the project, NCDOT needed to identify areas in the highway ROW that were suitable and eligible for biocrop production. NCSU used GIS tools to look at slope, width of ROW, and shoulder width sections to determine the amount of acreage and mileage available for the biocrops program.

NCDOT, in collaboration with NCSU, selected four, one-acre plots to plant canola and sunflower crops. The canola is planted in the fall and harvested in June, and sunflower is planted in July and harvested in October. By working with seasonally rotated crops on the same plot, NCDOT has been able to significantly increase its yield over a model where only one crop was planted on a site. Other seasonal crops were ruled out based on their anticipated poorer growth performance in the harsh ROW conditions (as compared to conditions on a farm, for example). The plots are located more than 10 feet from the roadway, with a grass buffer area between crops and the road.

NCDOT has used its own equipment to manage the plantings, but also uses personnel from NCSU to supplement its own staff. Thus far, canola yields have either met or exceeded national standards. The sunflower crop harvest, while robust, was not as strong as the canola harvest.

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[85] Freeways to Fuel Economic Model: http://freewaystofuel.org/htm/economics

Drought was one issue that impacted the sunflower yield, and future sunflower harvests along the highway could produce more biocrops.

In designing and implementing its biocrop project, the NCDOT and NCSU addressed the following issues:

- *Tilling.* The North Carolina project searched for the appropriate till method to maximize yield. For North Carolina, this involved testing several tilling methods, including, no till, medium till and maximum till to see the outcome of each method. Initially the project team explored the concept of treating all weeds with herbicide then performing one till; however, testing indicates that the no till method may be the most effective. Less tilling is also the most economical method.

- *Safety:* Growing crops in the highway ROW creates similar safety issues as any roadside vegetation or mowing program. Biocrop production has not lead to any new safety issues for the Department. In addition, by planting the crops more than 10 feet from the road, NCDOT does not have to set up a mobile operation when working at the biocrops sites.

- *Compaction***.** Soil compaction is a significant issue in biocrop production, and general agricultural uses. Specifically in North Carolina, vehicles and equipment have been traditionally stored on the ROW of land now used for biocrop growth, which increased the compaction. NCSU and NCDOT are presently exploring methods to best deal with soil compaction issues over the term of the project.

Initial Outcomes and Next Steps

Once the canola and sunflower crops reach maturity, NCDOT harvests them and works with NCSU to convert the harvests to biofuel. In the past year, NCDOT extracted 3,000 pounds of canola seed, which produced 100 gallons of virgin oil. This in turn created 150 gallons of B100 (100 percent biodiesel). Using NCSU's portable production unit, the B100 was blended with conventional diesel to produce approximately 500 gallons of B20 (20 percent biodiesel and 80 percent conventional diesel). The program produced 500-800 gallons of B20 product, which NCDOT used to power its dump trucks and tractors, as well as other equipment.

NCDOT received positive feedback about this project, including a great deal of media coverage. Specifically the public indicated that it was pleased with the idea of using the ROW for biocrop growth, rather than general mowing. While the research effort between NCDOT and NCSU concluded in July 2011, NCDOT plans to continue research efforts with NCSU to grow biofuel crops in the highway ROW. The NCDOT is working on integrating biocrop growth into the broader vegetative management program.

Additional F2F Efforts

In addition to Utah and North Carolina, several other states are researching the effectiveness and efficiency of planning biocrops in the highway ROW. Additional efforts underway include:

- In 2010, Tennessee DOT planted switchgrass plots for use in cellulosic ethanol production.

- Michigan has identified 10,000 acres for growth, and is planning to bid on the plots soon.
- Oregon and Washington are working to identify plots for biocrop production. Researchers at Willamette University in Oregon are also working to understand the public private partnership aspect of growing biocrops in the ROW.
- Texas DOT is working to identify locations that it might establish biocrop plots. TxDOT currently mows 2 million acres of grass, which could translate to 0.5 billion gallons of biodiesel.
- Virginia DOT is working to identify a funding stream to support a biocrop program.

Appendix D. Questionnaire to FHWA Division Offices

TO THE ATTENTION OF: **Division Office Realty and Utility Staff**

The purpose of this message is to have the Realty staff participate in the survey below:

The Office of Real Estate Services, as part of a STEP 2009 Research project is collecting information on renewable Energy Technologies and the Use of Alternative Fuel Facilities within the highway Right-of-Way. Hopefully this information will help us identify where there may be opportunities or barriers for accommodating renewable energy technologies and alternative fuel facilities in the right-of-way. You may discuss the questions with the State DOT or other interested parties, but do not send the survey to the State and ask them to complete the survey.

1) Do the partners that you work with in the delivery of the program such as States DOTs, Indian Tribes and Federal agencies allow for the use of highway rights-of-way to accommodate public utility facilities as noted in the "Guidance on Utilization of Highway Right-of-Way" available at www.fhwa.dot.gov/realestate/guidutil_a.htm?

2) Do they characterize renewable energy facilities as utilities (i.e., in regards to the accommodation of utility facilities in the ROW)?

3) Are there any laws or other requirements that either allow or prohibit the generation of renewable energy within the highway ROW? If so, please cite the law(s).

4) Can excess ROW or potential excess ROW be used for renewable energy facilities?

5) Are they considering or carrying out research, development, or construction of renewable energy or alternative fuel facilities in the right-of-way, such as: wind, solar, bioenergy, electric charging stations, etc? If so, please describe.

(Please provide an agency or contact name, and telephone number we can use for follow-up.):

Please return the completed form to Bruce H. Bradley @ bruce.bradley@dot.gov or contact him directly at (202)493-0564 if you have any additional questions or need additional information.

Appendix E. Example Leases, Request for Proposals, and Other Resources*

I. Program Checklist for Alternative Uses of the ROW
II. Oregon's Solar Highway Initiative Solar License Agreement
III. Oregon's Solar Highway Initiative Power Purchase Agreement
IV. Oregon's Solar RFP Evaluation Criteria
V. MassDOT's Blandford Wind Turbine RFP
VI. MassDOT's Blandford Wind Turbine Development Agreement

**Items II through VI are only available in the online version of the report.*

Program Checklist for Alternative Uses of the ROW

The following checklist includes questions that DOTs might consider should they decide to assess whether a program to accommodate renewable energy or alternative fuel facilities in their state is viable. The checklist is not meant to communicate particular roles and responsibilities or imply that these are the only considerations necessary. Instead, it should help DOTs identify important components it already has in place versus those that might also be necessary to accommodate alternative uses of their ROW.

Yes? No?

1. **Does the DOT have leadership support to explore the accommodation of renewable energy technologies and/or alternative fuel facilities in the highway ROW?** _____
   In the case studies reviewed, a committed project champion within DOT leadership was vital in overcoming barriers and keeping projects on the paths forward.

2. **Are there state requirements or incentives for state agencies to acquire a certain percentage of their electricity from renewable sources? Are there state requirements or incentives for state agencies to reduce their GHG emissions?** _____
   The presence of such requirements or incentives can help DOTs "make the case" for pursuing alternative uses of highway ROW. If the answer to this question is no, accommodating alternative uses of the ROW could still be practicable; the justification would likely need to focus on economic or other environmental stewardship-related purposes.

3. **Does the DOT's UAP distinguish or include provision for renewable energy technologies?** _____
   DOTs interested in utilizing the ROW for renewable energy technologies or alternative fuel facilities should be proactive in their approaches to implementing these projects. DOTs are encouraged to review their respective UAP to ensure they are consistent with current needs.

4. **Does the DOT have an encroachment policy or other policy that might discourage some alternative uses of the ROW?** _____
   If so, the DOT should assess whether the policy pertains to all potential alternative uses and/or whether the policy still aligns with current priorities. A DOT might consider forming an ***interdisciplinary team*** *to identify and address the unique issues—including those related to design and construction—that alternative uses of the ROW present in that state.*

5. **Are the DOTs ROW property maps available electronically and/or geospatially-enabled format(s)?** _____
   Having electronically available ROW property maps would likely facilitate analyses of potential sites for accommodating alternative uses of the ROW.

6. **Does the DOT have staff qualified and available (likely GIS staff) to review data on natural resource location(s)? Does the state have natural resource data that the DOT can use/leverage?** _____
   If no, is the DOT in a position to hire a consultant to perform analyses of natural resource location data in relation to DOT property maps? For potential renewable energy projects, not all suitable locations from a transportation perspective will necessarily be in locations with suitable natural resource (e.g., solar, wind, or soil resources) availability.

7. **For renewable energy projects, has a utility company or private developer(s) that is willing to partner with the DOT been identified?** _____
   DOTs will need to find a location(s) of a sufficient size(s) to ensure the economic feasibility of the alternative use of the ROW being considered. Developing criteria for what constitutes adequate acreage (based on the proposed project type) would be a useful activity for DOTs to consider. For solar projects, for example, Oregon and Ohio DOT—in coordination with utility companies in their areas—have determined that at least 1 MW needs to be able to be produced to make a solar highway project economically feasible. Ohio DOT has concluded that requires approximately five acres of land. This metric will continue to evolve as new technologies that allow more energy to be generated on a smaller footprint become available.

8. **Does DOT legal staff have experience working with agreements related to renewable energy projects?** _____
   Renewable energy projects can involve complex legal documents that DOTs may not be able to develop given current areas of in-house expertise. Therefore, the DOT may need to utilize outside legal counsel or consultants to help guide the development process of these agreements.

Appendix F. Annotated Literature Review of Relevant Resources

SECTIONS

ROW, General
Renewable Energy, General
Solar Energy
Wind Energy
Solar and Wind Energy
Geothermal Energy
Alternative Fuels
News, Opinion, and Commentary

RIGHT-OF-WAY, GENERAL

Anspach, James. 2010. Utility Location and Highway Design. NHCRP Synthesis 405.
www.trb.org/resource.ashx?sn=nchrpsyn405

This study explores current practices in use by transportation agencies for consideration of utilities during the project development process, including where in the process the utility impacts are assessed and relocation decisions are made; what policies, regulations, manuals, and guidelines are used; and how design decisions are influenced by utilities.
Keywords: utilities; right of way

National Governors Association Center for Best Practices. Strengthening Our Infrastructure for a Sustainable Future. 2009.
www.nga.org/files/live/sites/NGA/files/pdf/0902INFRASTRUCTUREVISION.PDF;jsessionid=2647174082211BDE89FD0102508026EE

The scope of this report is to examine the role of the states in addressing infrastructure challenges, including challenges faced when considering the siting of electric transmission lines.
Keywords: utilities, electric transmission, right of way, infrastructure

U.S. Department of Transportation. Federal Highway Administration. April 1996. Shared Resources: Sharing Right-of-Way for Telecommunications Guidance on Legal and Institutional Issues.
http://ntl.bts.gov/lib/jpodocs/repts_te/1863.pdf

This study explores the nontechnical issues related to shared resource projects, i.e. sharing the public resource of highway right-of-way in exchange for private telecommunications expertise and capacity to further both public sector and private corporate objectives. The study outlines issues in four major categories: threshold legal and political issues, financial issues, project structure issues, and contract issues. The study findings note that while a number of issues must be addressed; there are options for each so that individual projects can be structured to suit particular circumstances. Shared resource partnering, however, is market driven and the window of opportunity for individual projects is limited, with the specific time frame depending on local circumstances.
Keywords: right of way; shared resource partnering

U.S. Department of Transportation. Federal Highway Administration. March 27, 2009. Guidance on Utilization of Highway Right-of-Way.
www.fhwa.dot.gov/realestate/guidutil.htm

The purpose of this memorandum is to provide guidance to Division Utility and Realty Professionals concerning the applicability of Federal laws and regulations to proposals for longitudinal accommodation, installation, operation and maintenance of public or private utilities, in particular renewable energy facilities, within the Interstate System ROW. The guidance identifies the existing laws, regulations, policies and guidance applicable to the longitudinal installation and accommodation of public and private utility facilities and clarifies their application on a case-by-case basis. Key points of the guidance include:

- The proper form of written agreement for a non-highway use other than a public utility is an airspace lease,

which should address applicable terms and conditions including but not limited to the rights and interests being conveyed, the terms of the conveyance, and the roles and responsibilities of the parties**.** 23 CFR 645 Subpart B and the DOTs' approved Utility Accommodation Manual or Plan regulate the use of Interstate air rights for facilities defined as public utilities. Accommodation of a facility as a public utility is determined by how a State views the facility under its own laws and regulations, as well as by that facility meeting the definition established in 23 CFR 645.207.

- The proper form of written agreement or permit for a public utility is established in the Utility Accommodation Manual or Plan and addresses the applicable terms and conditions including but not limited to the rights and interests being permitted, the terms of the agreement, and the roles and responsibilities of the parties. (See 23 CFR 1.23(c)). All actions in highway ROW that can be classified as a Federal action or have a Federal handle must comply with 23 CFR Part 771 (NEPA) and 23 CFR Part 774 (Section 4(f)).
  Keywords: right of way; guidance

RENEWABLE ENERGY, GENERAL

American Physical Society. November 2010. Integrating Renewal Energy on the Grid.
www.aps.org/policy/reports/popa-reports/upload/integratingelec.pdf

This report focuses on wind and solar energy and the three principal issues associated with integrating wind and solar resources with the grid: variability of generation addressed by forecasting, energy storage and transmission; remote location of wind and solar resources addressed by transmission; and how the incomplete business case undervalues key resources such as storage and transmission.
Keywords: renewable energy; grid

Elkind, Ethan. December 2009. In Our Backyard: How to Increase Renewable Energy Production on Big Buildings and Other Local Spaces. UCLA Environmental Law Center.

This policy paper is the second in a series of reports on how climate change will create opportunities for specific sectors of the business community in California and how policy makers can facilitate those opportunities. According to the researchers, the top four barriers to decentralized renewable energy production on big buildings and other local spaces are (1) lack of predictable and adequate financing; (2) uncertain government permitting and regulatory programs; (3) lack of education and outreach (i.e., public agencies often do not view capitalizing on their physical assets as part of their organizational mission); (4) landlord/tenant split incentives. One recommendation to California's state government was to "Instruct state agencies to utilize, when possible, public spaces and buildings, including schools, structures along rights-of-way, highways, aqueducts, and other large facilities, for renewable energy generation."
Keywords: renewable energy; highways; right of way

Energy Information Administration (EIA). April 2009. Renewable Energy Annual 2007.

This annual publication on renewable energy presents data on five areas:

1. Renewable Energy Trends in Consumption and Electricity – including biomass; geothermal; wind; solar; and conventional hydropower.
2. Solar Thermal Collector Manufacturing Activities
3. Solar Photovoltaic Cell/Module Manufacturing Activities
4. Geothermal Heat Pump Manufacturing Activities
5. Green Pricing and Net Metering Programs

Keywords: renewable energy; statistics; energy consumption

EIA. August 2010. Electricity Net Generation From Renewable Energy by Energy Use Sector and Energy Source. www.eia.doe.gov/cneaf/alternate/page/renew_energy_consump/table3.html

Fairley, Peter. June 2009. Building an Interstate Highway System for Energy. Discover Magazine.
http://discovermagazine.com/2009/jun/10-building-interstate-highway-system-for-energy

This article describes Oregon DOT's experience in establishing the nation's first "solar highway." According to the author, the system, which is located in the interchange of Interstate 205 and Interstate 5, is producing 30 percent of the energy needed to light the interchange at night.

Keywords: solar energy; solar highway; transportation; Oregon DOT; right of way

National Governors Association Center for Best Practices. January 2011.
www.nga.org/cms/center
This report examines state-driven approaches to financing clean energy projects. It looks at the sources of capital available to states, describes the leading mechanisms currently being used, and identifies important implementation issues. Most of the mechanisms described relate to energy efficiency and small-scale, renewable energy applications. These are the technologies most in need of, and most amenable to, state financing interventions. Other, larger-scale clean energy projects, such as grid-connected renewable energy and biofuels, are already covered by the commercial financing sector.
Keywords: renewable energy, financing

NCHRP 20-85. Expected 2012. Renewable Energy Guide for Highway Maintenance Facilities.
http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2731
The objective of the research is to develop best practices for the planning, design, and operation of new and retrofitted highway maintenance facilities that are sustainable and energy efficient over their service lives through the effective use of energy capture technologies, including active, renewable energy sources, and passive (such as solar-thermal) building and site modifications. The best practices will be presented in the form of a guide providing regional- and facility function-specific information that is suitable for possible adoption by AASHTO. The guide also will include case studies of the planning, design, and operation of typical, new, and retrofitted state DOT maintenance facilities of different sizes, functions, ages, and energy usage and found in a variety of geographic and climatic regions in the United States.
Keywords: renewable energy; maintenance facilities

Pimentel, David, *et al*. September 1994. Renewable Energy: Economic and Environmental Issues. BioScience, Vol. 44, No. 8.
This article describes findings from an analysis of the potential of various renewable or solar energy technologies to supply the United States with its future energy needs. Diverse renewable technologies are assessed in terms of their land requirements, environmental benefits and risks, economic costs, and a comparison of their advantages. In addition, the researchers make a projection of the amount of energy that could be supplied by solar energy subject to the constraints of maintaining the food and forest production required by society.
Keywords: renewable energy potential

Science Applications International Corporation. 2012 *expected*. Renewable Energy Guide for Highway Maintenance Facilities. NCHRP 20-85. http://144.171.11.40/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2731
The objective of this research is to develop best practices for the planning, design, and operation of new and retrofitted highway maintenance facilities that are sustainable and energy efficient over their service lives through the effective use of energy capture technologies. The best practices shall be presented in the form of a guide that provides regional- and facility function-specific information and is suitable for possible adoption by AASHTO.
Keywords: renewable energy; highway maintenance facilities

TRB. Transportation Research Record: Journal of the Transportation Research Board, No. 2191, Energy and Global Climate Change 2010.
This report contains 22 papers that explore the effect of wide-based single tires on truck fuel efficiency; miles per gallon illusions and corporate average fuel economy distortions; freight transport, energy use, and emissions trends in Spain; diesel truck activity and fuel economy based on electronic control module data; cost of hydrogen fuel cell vehicles; electric vehicle charging impact on electricity costs; and an economic assessment of electric-drive vehicle operation.
Keywords: renewable energy, climate change, transportation

West-wide Energy Corridor Programmatic EIS Information Center. http://corridoreis.anl.gov/
The Energy Policy Act of 2005 directed the Department of Agriculture, Commerce, Defense, Energy and the Interior to designate energy corridors on federal land in 11 western states. The Agencies conducted a detailed environmental analysis at the programmatic level. The programmatic environmental impact statement analyzed

two alternatives: a no action alternative and a proposed action, which involves designating 6,112 miles of energy corridors on federal lands in the 11 contiguous western states. Designated corridors would be the preferred locations on federally managed lands for future energy transport projects. The Bureau of Land Management and the Forest Service each issued a record of decision amending land use plans in support of the designation of the energy transport corridors outlined in the PEIS.
Keyword: energy corridor

SOLAR ENERGY

Billitzer, Barbara. May/June 2010. Making It Happen: An unconventional thinker brings the nation's first solar highway to Oregon. Right of Way Magazine.
www.oregon.gov/ODOT/HWY/OIPP/docs/Solar_ROWstory.pdf
This article describes Oregon DOT's experience in establishing the nation's first "solar highway." According to the author, the system, which is located in the interchange of Interstate 205 and Interstate 5, is producing 30 percent of the energy needed to light the interchange at night.
Keywords: solar energy; solar highway; transportation; Oregon DOT; right of way

Carder, D.R., L. Hawker and A.R. Parry. March 2007. Motorway Noise Barriers as Solar Power Generators. Proceedings of the Institution of Civil Engineers.
During 2001 the United Kingdom's Highways Agency commissioned a study to assess the feasibility of generating renewable energy on motorways and trunk roads. The researchers recommended that the Highways Agency undertake a full-scale trial of noise barriers incorporating solar panels. In 2004, two rows of solar barriers were installed in a cutting to the east of junction 9 of the M27. The trial was carefully monitored and showed that south-facing land alongside highways can successfully be used for solar barriers. In terms of maintenance, rainfall was effective in washing the panels; however, vegetation needs to be cut back at least annually unless the barrier is installed in a paved area. There was no evidence that drivers were distracted by the presence of the barriers or that noise reflected from the barriers would create any significant disturbance opposite the site. Although solar barriers are a feasible means of generating renewable energy on the highway estate, a whole-life cost analysis showed that the electricity generated over 30 years would not pay for the cost of installing the barriers unless the price of electricity was many times its current value.
Keywords: renewable energy; solar energy; noise barriers; research and development; roads and highways

Center for Resource Solutions. October 2010. Best Practices in Public Claims for Solar Photovoltaic Systems.
The document presents a series of question and answers regarding PV and the issues specific to selling and claiming RECs for such systems.
Keywords: PV, solar, renewable energy credit

Covert, Adrian. August 27, 2009. Solar Panels Built Into Roads Could Be the Future of Energy. Popular Science.
www.popsci.com/scitech/article/2009-08/solar-panels-built-roads-could-be-future-energy
The Idaho-based company "Solar Roadways" was awarded a Small Business Innovation Research grant to develop 12-by-12-foot solar panels that could be embedded into roads, pumping power into the electric grid. It is estimated that each solar road panel, which would cost approximately $7,000 each, could generate roughly 7.6 kwh of power per day. The panels may also feature LED road warnings and built-in heating elements that could prevent roads from freezing. Additional web links: www.solarroadways.com/main.html; http://solarroadways.com/people.shtml.
Keywords: solar energy; solar road; pavement technology

Dorsey, Michael. August 11, 2008. Alternative Energy Hits the Road: Research at WPI Explores Turning Highways and Parking Lots into Solar Collectors. www.wpi.edu/news/20089/asphaltnews.html
The Worcester Polytechnic Institute has evaluated how well asphalt can collect solar energy, as well as the best ways to construct roads and parking lots to maximize their heat-absorbing qualities. The research team studied the energy-generating potential of asphalt using computer models and by conducting small- and large-scale tests. The tests were conducted on slabs of asphalt in which were imbedded thermocouples, to measure heat penetration, and copper pipes, to gauge how well that heat could be transferred to flowing water. Hot water

flowing from an asphalt energy system could be used "as is" for heating buildings or in industrial processes, or could be passed through a thermoelectric generator to produce electricity. According to the project team, "roads and lots are typically resurfaced every 10 to 12 years and the retrofit could be built into that cycle. Extracting heat from asphalt could cool it, reducing the urban 'heat island' effect. Finally, unlike roof-top solar arrays, which some find unattractive, the solar collectors in roads and parking lots would be invisible."
Keywords: solar energy; asphalt; pavement technology

Ellard, William. December 29, 2008. A New Place for Solar Energy: Highway Right of Way. CleanTechnica.com.
http://cleantechnica.com/2008/12/29/a-new-place-for-solar-energy-highway-right-of-way/
The author asserts that right of way highway solar could be a solution to the nation's energy needs and could also reduce costs to manage highway right of ways. Another potential benefit would be to help wildlife managers create wildlife corridors for both human and wildlife safety. According to the author, a conservative estimate for US highway solar would be 20 million megawatts of total capacity.
Keywords: solar energy; solar highway; right of way

Good Company. 2010. Life-Cycle Greenhouse Gas Analysis for the Proposed West Linn Solar Highway Project.
A life-cycle GHG analysis was conducted on behalf of the Oregon DOT to quantify net GHG emissions over the life cycle of the proposed West Linn solar power facility. The analysis includes the following emissions sources and reductions: Life-cycle Stage 1 – Before (Planning and Construction); Life-cycle Stage 2 – During (Operation - Electricity Generation and Maintenance); and Life-cycle Stage 3 – After (Transport and Disposal of Facility Building Materials).
Keywords: greenhouse gas, life-cycle analysis, solar highway

Good Company. 2011. Solar Highway Program: From Concept to Reality.
www.oregon.gov/ODOT/HWY/OIPP/docs/SolarManual.pdf
This guidebook is intended to provide an overview for state DOTs of the process for developing solar PV projects in the highway ROW. The goal is help others navigate the process toward a successful solar PV installation by providing step-by-step information, case studies, and additional resources.
Keywords: highway, solar power

Kalki Energy. March 13, 2009. Technology Competitive Intelligence Report: Solar Energy and Power Generation.
A competitive intelligence landscape analysis was conducted to identify key owners behind issued patents and published patent applications in the field of solar energy; specifically pertaining to power generation by harnessing solar energy. According to the report, the last five years have witnessed a growth in developing, improving, and utilizing power derived from renewable energy sources. At a time when the world economy is going through a significant change, more and more organizations are looking forward to and are likely to invest in the 'energy for the future.' Therefore, it is likely that the a few prominent solar energy companies may play a pivotal role in changing market conditions and the competitive landscape in the world's most inhabited areas.
Keywords: solar energy; annual trends

Kilbert, C. *et al.* January 7, 2010. Research Services for Solar Power at Turkey Lake Service Plaza. University of Florida.
A University of Florida research team collaborated with the Florida Turnpike Authority and Florida Department of Transportation staff to examine contemporary solar technologies, particularly solar PV systems, for their potential to meet the energy needs of the Turkey Lake Service Plaza. The scope of the research included: (1) Evaluation of Solar Electric (PV), Solar Thermal (hot water), and Solar Lighting systems; (2) Assessment of the renewable energy generation potential of the Service Plaza; (3) Designing and planning of photovoltaic systems to determine the energy output; (4) Identification of innovative financing options; (5) Development of a marketing and education concept for the project. The research team concluded that by implementing the Net Zero Energy scenario, the annual electrical energy needs of all the facilities at the Turkey Lake Service Plaza could be met.

West, Larry. Sunny Side of the Street: Can Roads Be Used to Generate Solar Power? About.com.
http://environment.about.com/od/renewableenergy/a/solar_roads.htm

The British firm Astucia has developed a road stud that contains small solar panels and emits LED light to illuminate dark roadways. On the 120 UK roads where the new studs have been installed, nighttime accidents are down some 70 percent. The Dutch firm Ooms Avenhorn Holding BV has developed a way to siphon solar heat from asphalt road surfaces and use it to de-ice roads and to help power nearby buildings. Additional web links: www.astucia.co.uk/case-studies

Keywords: solar energy; solar highway; right of way; waste heat recovery

WIND ENERGY

Cavanaugh, Rebecca. January 10, 2007. The *New* Jersey Barrier. Metropolismag.com.
www.metropolismag.com/story/20070110/the-new-i-jersey-barrier

Mark Oberholzer, runner-up in the 2006 Metropolis Next Generation Design Competition, proposed integrating turbines into the barriers between highway lanes that would harness the wind passing cars generate.

Keywords: wind energy; micro-wind turbine; highway; right of way; jersey barrier

Committee on Environmental Impacts of Wind Energy Projects, National Research Council. 2007. Environmental Impacts of Wind-Energy Projects.

As wind energy development continues to expand, federal, state and local agencies should adopt a consistent approach to evaluating the planning, regulation, and location of wind-energy projects. This report proposes a framework that can help in evaluating tradeoffs between the benefits of new wind-energy projects and risks of adverse environmental impacts before projects begin. It emphasizes the need to create opportunities for public input by incorporating participation by those whose well-being may be affected by siting decisions so these impacts can be minimized or avoided.

Illinois Center for Transportation. February 2009. Wind-Powered Electrical Systems – Highway Rest Areas, Weigh Stations, and Team Section Buildings.
http://ict.illinois.edu/Publications/report%20files/FHWA-ICT-09-034.pdf

This project considered the use of wind for providing electrical power at Illinois Department of Transportation (IDOT) highway rest areas, weigh stations, and team section buildings. The goal of the project was to determine the extent to which wind power could offset electricity costs, provide a reasonable return on investment, offset energy use, and provide educational opportunities. The analysis show that there are some combinations of location and wind turbines that may produce electricity at a competitive rate. One of the most important factors in this analysis is the cost of wind turbines, which is generally unknown (but can be approximated) and depends on many factors.

Keywords: wind energy

Kwartin, R. et al. December 2008. An Analysis of the Technical and Economic Potential for Mid-Scale Distributed Wind. National Renewable Energy Laboratory. www.nrel.gov/wind/pdfs/midscale_analysis.pdf

This report examines the status, restrainers, drivers, and estimated development potential of mid-scale (10 kW to 5,000 kW) distributed wind projects. This segment of the wind market has not enjoyed the same growth that central-station wind has experienced. The purpose of this report is to analyze why and to assess the market potential for this technology under current market and policy conditions. According to the researchers, one of the most significant barriers to the development of distributed wind is a general scarcity of turbine choices and turbine inventory available for purchase. Other barriers, such as siting issues, burdensome interconnection rules, aesthetic concerns, and fragmented state rules regarding net metering, are discussed. Additionally, most of the economic potential for distributed wind in the contiguous United States occurs in New York, Massachusetts, and Vermont.

Keywords: wind energy; distributed energy

McDonald, Colin. February 7, 2010. Wind-generated electricity will require wide swaths of land. Mysanantonio.com.

This article describes some of the concerns regarding land requirements of wind energy projects that property owners in Texas have expressed. According to the article, the Sierra Club supports wind power and

transmission line expansion if their routes follow existing utility lines and highways even if that option is more expensive.

Prok, Josh. Spring 2008. Interstate Wind: Using New Technology to Enhance Transportation Fuel Investments. Transportation Law Journal.
http://law.du.edu/pdfdocuments/v35/PROK_Note.pdf
This paper addresses the possibilities of harnessing the wind created by vehicles on interstate highways to generate electricity through recent technological advances. The researchers noted that the wind industry has been slow to view "wind" as anything more than a natural phenomenon (and thus ignores, for example, wind turbulence created on or in ground transportation corridors). Additional findings suggest that Congress failed to consider the benefits of capturing vehicle wind byproducts and, thus, should redouble its efforts to help American industries bring technologies, such as micro-wind technologies, into the domestic and international markets.
Keywords: wind energy; transportation

Renewable Energy Research Laboratory. Wind Data Report Blandford Rest Area: December 2008 to February 2009. University of Massachusetts.
www.umass.edu/windenergy/downloads/pdfs/Blan2_2009_QuarterlyReport_Winter.pdf
Wind monitoring equipment was installed at the Blandford Rest Area in January 2008. This report summarizes the wind data collected during the Winter of 2008-2009, between December 2008 and February 2009. The mean recorded wind speed was 5.99 m/s (13.4 mph*) at 50 m and the prevailing wind direction was from the west-northwest. The average wind shear exponent between the two measured heights was 0.286. The average turbulence intensity at 50m for wind speeds between 10 m/s and 11 m/s was 0.2.

University of Hong Kong. March 15, 2007. HKU and Motorwave Limited Jointly Developed Micro-Wind Turbine Technology for Crowded Cities. Press Release. www.hku.hk/press/news_detail_5535.html
The Department of Mechanical Engineering of The University of Hong Kong and Motorwave Limited have jointly developed and launched a new development in micro-wind turbine technology that enables wind turbines to start generating electricity at wind speeds as low as 2 meters per second and to be installed on balconies at home or rooftops of buildings. By using specially designed plastic gearwheels, as small as 26 cm in diameter, with a small generator, a micro-wind turbine can be arranged in an array of shapes and sizes, up to thousands of square meters. They can be located where conventional small wind turbines would not be allowed. Additional web link: www.motorwavegroup.com/
Keywords: wind energy; micro-wind

U.S. Department of Energy, Energy Efficiency and Renewable Energy. July 2008. 20% Wind Energy by 2030.
www.20percentwind.org/20percent_wind_energy_report_revOct08.pdf
The report considers some associated challenges, estimates the impacts, and discusses specific needs and outcomes in the areas of technology, manufacturing and employment, transmission and grid integration, markets, siting strategies, and potential environmental effects associated with a 20 percent wind scenario.

U.S. Government Accountability Office. September 2005. Wind Power: Impacts on Wildlife and Government Responsibilities for Regulating Development and Protecting Wildlife.
www.gao.gov/new.items/d05906.pdf
The GAO report assessed (1) what available studies and experts have reported about the impacts of wind power facilities on wildlife in the United States and what can be done to mitigate or prevent such impacts, (2) the roles and responsibilities of government agencies in regulating wind power facilities, and (3) the roles and responsibilities of government agencies in protecting wildlife. GAO reviewed a sample of six states with wind power development for this report. GAO recommends that FWS provide state and local regulatory agencies with information on the potential wildlife impacts from wind power and the resources available to help make decisions about where wind power development should be approved.

SOLAR AND WIND ENERGY

American Wind Energy Association and Solar Energy Industries Association (February 2009). Building a Path to America's Clean Energy Future.

The United States lacks a modern interstate transmission grid to deliver carbon-free electricity to customers in highly populated areas of the country. Green power superhighways, an interstate transmission system to deliver remote renewable electricity resources to population centers, would address many of the transmission challenges facing our country. This paper outlines recommended steps policymakers can take to make green power superhighways a reality.
Keywords: clean energy; transmission grid, carbon-free electricity

Louis Berger Group, Inc. March 2011. Feasibility Study of Using Solar or Wind Power for Transportation Infrastructure. NCHRP 25-25/64. http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP25-25(64)_FinalHandbook.pdf

The purpose of this research is to provide DOTs with technical and case study data on the use of solar or wind power as an alternative power source for across a wide variety of transportation infrastructure settings. The research considers existing technologies and those soon to become commercially viable that have not been applied to transportation settings but with some thought/creativity could have a transportation application.
Keywords: solar energy; wind energy; transportation; infrastructure

Permitting Solar and Wind Projects on Federal Lands: Webinar. July 29, 2010.

The panel discussed the current siting and permitting processes on Federal lands, and explored how the allocation of land and some of the new permitting mechanisms might affect current applicants and future developments. Presentations given included:

Bell, Andrew. The Law Office of Andrew C. Bell. "California's Desert Renewable Energy Conservation Plan" presentation.

Brady, Ray. Bureau of Land Management. "New Energy for America" presentation.

Daue, Alex. The Wilderness Society. "Renewable Energy and Wildlands Conservation" presentation.

Lazerwitz, David. Farella Braun + Martel LLP. "Permitting Solar and Wind Projects on the Federal Public Lands" presentation.

Pogacnik, Tom. California State Office of the Bureau of Land Management. "Managing Major Right-of-Way Permits: Notes from the Field" presentation.

Watson, Rebecca. Welborn Sullivan Meck and Tooley, P.C. "Permitting Solar/Wind Projects" presentation.

Keywords: solar energy; wind energy; Federal lands; permitting

Tres Amigas LLC. November 5, 2009. The Tres Amigas Superstation Project: Discussion Materials. www.tresamigasllc.com/docs/epri-discussion.pdf

Tres Amigas, LLC has plans to unite the nation's electric grid. Utilizing the latest advances in power grid technology, Tres Amigas is focused on providing the first common interconnection of America's three power grids to help the country achieve renewable energy goals and facilitate the smooth, reliable and efficient transfer of green power from region to region. The Discussion Materials presentation discusses why a superstation project is necessary and how it is planned to operate.
Keywords: renewable energy; smart grid; transmission

Venner, Marie and Antonio Santalucia. June 2010. Environmental Corridor Management: NCHRP 25-25/63. http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP25-25%2863%29_FR.pdf

Many state DOTs are exploring the use of the right of way for energy and GHG reduction opportunities. Small renewable energy installations are now a widely promoted technological option for use in both remote locations and for use as part of broader energy supply configurations at DOTs, transportation authorities and other public sector entities. This research describes several examples from Europe and Australia where transportation agencies have installed REIs along highway right of ways. The authors also discuss details from Oregon DOT's experience with its Solar Highway Initiative. According to the study, the project will avoid roughly 43.5 metric tons of carbon dioxide equivalent each year that it operates. The estimated carbon payback period is less than five years. ODOT estimates that arrays on 120 miles of their 16,000 lane-miles of right-of-way could supply all

of the electricity that the agency uses annually. In terms of wind energy, the researchers note that emerging policy and technological developments will only increase the practicality and feasibility for DOTs.
Keywords: solar energy; solar arrays, wind energy; highway; right of way

GEOTHERMAL ENERGY

Brown, Brian. October 1995. Klamath Falls Downtown Redevelopment Geothermal Sidewalk Snowmelt. GHC Bulletin.

The Klamath Falls area has had a long history of geothermal heat utilization. One notable example is the heating of the Esplanade Street ramp and bridge in 1948, which is still operating successfully. As of 1995, it was generating 58 Btu/hr/ft^2.
Keywords: geothermal energy; roadway heating

Lund, John W. 2000. Pavement Snow Melting. Geo-Heat Center, Oregon Institute of Technology.
http://geoheat.oit.edu/pdf/tp108.pdf

This report provides an overview of the current state of the practice of using geothermal resources to heat pavement snow melting systems. Examples of systems in New Jersey, Wyoming, Virginia, Oregon, Japan, Switzerland, and Argentina are presented. Related Article: Boyd, Tonya L. 2003. New Snow Melt Projects – Klamath Falls, Oregon. Geo-Heat Center Quarterly Bulletin, Vol. 24, No. 3, Geo-Heat Center, Oregon institute of Technology.
Keywords: geothermal energy; roadway heating

Lienau, Paul, Gene Culver, and John Lund. 1989. Klamath Falls Geothermal Field, Oregon: Case History of Assessment, Development and Utilization. Geothermal Resources Council 1989 Annual Meeting.

The urban portion of U.S. 97 on Esplanade Street, a major truck route with a steep grade, was reconstructed in 1948, in order to widen the bridge across the U.S. Bureau of Reclamation's "A" canal. Since the approach and stop at an intersection caused difficulty with traffic stopped on the eight percent adverse grade, geothermal de-icing was incorporated in the design as an experiment. It was estimated that the pavement would be sufficiently clear of snow and ice to provide free travel at a temperature of -100F (-230C), and under conditions of a 3 inch (75 mm) per hour snow fall. Based on calculations in the report, the heat flow can melt up to 1/2 inch (12 mm) per hour snowfall, with heavier snow falls taking four to six hours to melt entirely. According to the authors, this has been substantiated by observations.
Related Article: Rea, Sharon. March 17, 2009. Geothermal Energy Resource Area – Klamath Falls. Associatedcontent.com.
www.associatedcontent.com/article/1572745/geothermal_energy_resource_area_klamath.html?cat=16
Keywords: geothermal energy; roadway heating

Nydahl, John, et al. 1982. Geothermal Heating of Highway Structures. Transportation Research Record 860: Snow Control, Traffic Effects on New Concrete, and Corrosion

This report focuses on a Colorado Department of Highways' feasibility study to incorporate geothermal heating systems at critical locations in a proposed interstate in Glenwood Canyon. Results indicated that snow-cover duration on the roadways above the installed heat pipes was reduced by 96 percent or more than the unheated control areas. According to the authors, in cases requiring minimal snow-melting capability or involving preferential icing problems, the water temperature could possibly be as low as 10^{0}C (50^{0}F), which means that well water or municipal water supplies would be feasible water sources.
Keywords: geothermal energy; snow control

Strawn, Jon A. and Ivar A. Engen. February 1982. Geothermal Applications for Highway Rest Areas. EG&G Idaho, Inc. for USDOE.

This report describes a feasibility study, made for the South Dakota DOT, regarding geothermal applications for highway rest areas. Preliminary findings, which included estimates of capital, operation, and maintenance costs for the system, suggested that the retrofit of the heating systems in rest area structures at the test site was feasible.
Keywords: geothermal energy; rest areas; heating systems

WAVE AND TIDAL ENERGY

NREL (W. Musial). August 2008. Status of Wave and Tidal Power Technologies for the United States. www.nrel.gov/wind/pdfs/43240.pdf

This paper presents the status of marine applications for renewable energy as of 2008 from a U.S. perspective. The technologies examined include wave, tidal, and ocean current energy extraction devices that are currently being demonstrated in at least one ocean project. The paper also examines the resources for each of these technologies, the limitations to the current assessments, and the research and development needs of the marine renewable energy industry based on the author's experience and opinions.
Keywords: Wave energy; tidal energy

ALTERNATIVE FUELS

EIA. April 2010. Alternatives to Traditional Transportation Fuels 2008. www.eia.gov/cneaf/alternate/page/atftables/afv-atf2008.pdf

These data include figures on the number of alternative fuel vehicles supplied, in use, and the amount of alternative fuels they consumed during 2008.
Keywords: alternative fuels; alternative fuel vehicles

Energy Information Administration. April 2010. Historical Data: Alternative Transportation Fuels and Alternative Fueled Vehicles www.eia.doe.gov/cneaf/alternate/page/atftables/afv_hist_data.html

These archived data include figures on the number of alternative fuel vehicles supplied, in use, and the amount of alternative fuels they consumed. Data are available for 1994 through 2008.
Keywords: alternative fuels; alternative fuel vehicles; historical data

Kaiser, Jerry and Steve Bruckerhoff. January 2009. Switchgrass for Biomass Production by Variety Selection and Establishment Methods for Missouri, Illinois, and Iowa. Missouri National Resources Conservation Service, Agronomy Technical Note MO-37. www.mo.nrcs.usda.gov/technical/agronomy/out/Agron%20Tech%20Note%2037.pdf

Keywords: biomass, Missouri, Illinois, Iowa, switchgrass

Newman, Yoanna, Curtis Rainbolt, Mary J. Williams and Joao Vendramini. January 2008. Production of Biofuel Crops in Florida: Switchgrass. Agronomy Department, University of Florida, Institute of Food and Agricultural Sciences, Florida Cooperative Extension Service. http://edis.ifas.ufl.edu/ag296

Keywords: biofuels, switchgrass, Florida

O'Connor, Cindy. September 14, 2010. Classifying Biofuel Subsidies: Farm Bill and WTO Considerations. Advanced Biofuels USA. http://advancedbiofuelsusa.info/classifying-biofuel-subsidies-farm-bill-and-wto-considerations

Nationwide, switchgrass is recommended for biofuel production because of its wide range of adaptation and high potential dry matter yield with relatively low fertility input. It can be used for both lignocellulosic ethanol production and in electricity generation, complementing coal as a co-firing agent supplement. This research investigates potential switchgrass biomass yields in Florida.
Keywords: biofuels, Farm Bill

Rinehart, Lee. 2006. Switchgrass as a Bioenergy Crop. National Sustainable Agriculture Information Service. http://attra.ncat.org/attra-pub/switchgrass.html

This publication details the production of switchgrass for use as a cellulose-to-ethanol and direct-combustion feedstock, and focuses on the agronomic and ecologic considerations of switchgrass production.
Keywords: bioenergy, biofuels, switchgrass

Sullivan, Colin. March 10, 2009. California Planning for Alternative Fuel Highway. Scientific American. www.scientificamerican.com/article.cfm?id=alternative-energy-fuel-highway

California Governor Arnold Schwarzenegger's Vision 2010 plan sought to build, by 2010, a hydrogen highway

composed of 150 to 200 fueling stations spaced every 20 miles along California's major highways. By 2009, only 24 hydrogen fueling stations had been built, most of them near Los Angeles. The lack of stations was due, in part, to a lack of commercially available hydrogen-fueled vehicles. Instead of the highway concept, the new goal is to develop "clusters" – a network of stations in a specific region to fuel the cars where they reside. The market for hydrogen-fueled vehicles is expected to increase as a result of the state's zero-emissions vehicles rule, which requires automakers to make 7,500 pure zero emission vehicles in 2012-2014, and 25,000 in 2015-2017.
Keywords: hydrogen, alternative fuels

USDA. October 2010. Effects of Increased Biofuels on the U.S. Economy in 2022.
www.ers.usda.gov/Publications/ERR102/ERR102.pdf
This report examines how meeting the RFS-2 would affect various key components of the U.S. economy.
Keywords: Bioenergy, ethanol, petroleum, RFS-2

USDOE Biofuels Program. www1.eere.energy.gov/biomass/

Yacobucci, Brent. January 7, 2005. Alternative Transportation Fuels and Vehicles : Energy, Environment, and Development Issues. CRS Report for Congress. http://ncseonline.org/nle/crsreports/05Jan/RL30758.pdf
One of the strategies for reducing the dependence on petroleum imports is to produce vehicles that run on alternatives to gasoline and diesel fuel. This report examines consumption rates, costs, infrastructure requirements, performance, and safety considerations for each alternative fuel. According to the report, "any policy to support alternative fuel vehicles must address performance and cost concerns, as well as the issue of fueling infrastructure. Within this context, a 'chicken and egg' dilemma stands out: The vehicles will not become popular without the fueling infrastructure, and the fueling infrastructure will not expand if there are no customers to serve."
Keywords: alternative fuels; propane; natural gas; biodiesel; ethanol; methanol; electricity; hydrogen; coal-derived liquid fuels

Yacobucci, Brent and Tom Capehart. March 31, 2008. [Updated] Report for Congress: Selected Issues Related to an Expansion of the Renewable Fuel Standard. Congressional Research Service, RL34265.
www.nationalaglawcenter.org/assets/crs/RL34265.pdf
This report outlines some of the supply issues facing biofuels industries, including implications for agricultural feedstocks, infrastructure concerns, energy supply for biofuel production, and fuel price uncertainties.
Keywords: biofuels, feedstocks, Renewable Fuel Standard

NEWS, OPINION, AND COMMENTARY

Abuelsamid, Sam. May 1, 2007. Highway wind turbines to capture energy from passing vehicles. Green.autoblog.com.
http://green.autoblog.com/2007/05/01/highway-wind-turbines-to-capture-energy-from-passing-vehicles/
Joe De La Ree, an Arizona State University student, proposed a way of re-capturing some of the energy expended by vehicles moving at high speeds on highways. The proposal involved mounting horizontal wind turbines above the roadway that would be driven by the moving air generated by the passing traffic. Original blog entry: www.archinect.com/schoolblog/entry.php?id=55756_0_39_0_C374
Keywords: wind energy; wind turbines; highway

Ellard, William. December 13, 2008. A New Use for Solar Energy: Highway Right of Way. Seekingalpha.com.
http://seekingalpha.com/article/110509-a-new-use-for-solar-energy-highway-right-of-way
The author suggests that highways provide good locations for solar power systems. He argues that land managers could also funnel wildlife away from dangerous highway crossings and into safe wildlife corridors with the proper alignment of such systems.
Keywords: solar energy; highway; right of way

Hirsh, Art. July 20, 2010. Right of Way and Alternative Energy. TerraLogic Blog.
www.terralogicss.com/_blog/Sustainable_Transportation/post/Right_of_Way_and_Alternative_Energy/

TerraLogic has teamed with David Evans and Associates and Colorado State University-Pueblo to identify innovative energy generation capabilities within CDOT ROW to power rest areas, maintenance facilities and intersection lighting and signaling. The goals and objective of the ongoing CDOT Alternative Energy Project are: (1) identifying energy resources within CDOT ROW that are high in quantity and quality and will result in reduced operation costs, (2) conceptualize and identify potential energy cost saving measures using alternative energy generation that will reduce CDOT energy costs, (3) evaluate the physical and operational potential of using CDOT ROW areas to generate and sell energy to electric utility companies throughout Colorado, and (4) implement cost effective alternative energy sources into CDOT operations state-wide thus saving financial resources and reducing indirect greenhouse gas emissions. The final report is expected to be delivered to CDOT in January 2011.
Keywords: alternative energy, right of way

Isaac, Matt. July 23, 2010. The Interstate Wind Dilemma. Brighthub.com.
www.brighthub.com/environment/renewable-energy/articles/49606.aspx
This opinion article asserts that vertical-axis wind turbines should line the nation's interstate highway system.
Keywords: wind energy; wind turbines; highway

Jacobs, Karrie. November 11, 2009. Revolutionary Road. Op-Ed Contributor. New York Times.
www.nytimes.com/2009/11/11/opinion/11jacobs.html
The opinion article recommends a number of new uses for the 47,000-mile long Interstate highway system. The author asserts that highway corridors are well-suited for the transportation of energy. Power generated from rural wind farms and solar panels can be transmitted along the right-of-way, and plug-in hybrids can recharge from this grid.
Keywords: renewable energy; alternative energy; solar energy; highway

Levinson, Yoni. June 23, 2009. The Green Roadway – A Good Idea, But Not New. Ecogeek.org.
http://ecogeek.org/human-powered/2870-the-green-roadway-good-idea-but-not-new
The article argues that installing solar panels and wind turbines along the road may achieve additional and previously unconsidered goals than simply generating clean electricity. Instead, according to the author, "by bringing the instruments of clean, renewable energy into the public eye (on the road as opposed to being hidden at a coal plant, for example), projects such as The Green Roadway could help establish these technologies in the public consciousness.
Keywords: clean energy; highway; wind; solar

Moskowitz, Ira. May 27, 2010. Israel's Innowattech to Provide Renewable Energy for Highway Signs in Italy. Green Prophet. www.greenprophet.com/2010/05/israel%E2%80%99s-innowattech-to-provide-renewable-energy-for-highway-signs-in-italy/
Israel-based Innowattech, which develops technology to convert mechanical energy from vehicular or rail traffic into electricity, is working with Italian infrastructure and civil engineering contractor Impregilo SpA to light road signs on the Venice-Trieste highway in Italy. The generators developed at Innowattech will be placed beneath the highway's upper asphalt layer. The electrical charge generated by the technology is created during the movement of vehicles on the road. The electrical charge is stored via dedicated electrical systems and will supply electrical energy for lighting Variable Message System signs. Drivers will read traffic reports on electronic signs, which will be powered by electricity from the drivers' own vehicles.
Keywords: vehicular energy, highway

Moskowitz, Ira. April 27, 2010. Israel Plans Wind-Powered Lighting for Coastal Highway. Green Prophet.
www.greenprophet.com/2010/04/israel-plans-wind-powered-lighting-for-coastal-highway-takes-initial-step-to-buttress-shoreline-cliffs/
The Israel National Roads Company is initiating steps to install small turbines on lighting poles on the coastal highway running along Israel's Mediterranean coastline to take advantage of the sea winds. It is also looking into using the thousands of acres of available land at interchanges to place photovoltaic solar arrays.

New York Times. July 23, 2009. Harvesting Clean Energy Along the Road.
http://green.blogs.nytimes.com/2010/01/19/solar-power-advocates-hopeful-for-2010/
The article highlights potential strategies to develop clean energy along roadways, including the Green

Roadway project. The project founders hold multiple patents for wind, solar, and geothermal technologies. The technologies can be used to create utility-scale systems that can plug into the existing grid infrastructure. The article suggests that each 10-mile stretch of the Green Roadway system could generate enough energy to power up to 2,000 homes. According to the author, the installed cost would be about $2.6 million and $4.2 million for the solar and wind components, respectively.
Keywords: clean energy; highway; wind; solar; geothermal

Scott, Paul. September 26, 2011. A Ready Path for Green Powerlines. Engineering News-Record.
http://enr.construction.com/opinions/viewpoint/2011/0926-allowutilitiestoplacelinesalongfreeways.asp
This opinion article describes how, in the author's view, the use of existing freeway ROW offers an attractive option for transmitting renewable energy, as well as serving as a suitable location for the installation of renewable generating facilities on structures, roadside slopes, along fence lines and within the pavement itself.
Keywords: renewable energy; highway; freeway; utility

Valen, Don. June 22, 2009. Pipelines can now share Texas highway right of way. Fort Worth Business Press.
www.texasrightofway.com/articles/fw_business_press_06-22-09.pdf
In 2009, the Texas state legislature passed a bill enabling the Texas State Highway system to allow subsurface access to a controlled access highway ROW.
Keywords: right of way; Texas State Highway; pipelines

Walzer, Robert. January 19, 2010. Solar Power Advocates Hopeful for 2010. New York Times.
http://green.blogs.nytimes.com/2010/01/19/solar-power-advocates-hopeful-for-2010/
According to this article, 500 to 600 megawatts of solar power will be built during 2010 across the United States, approximately double the figure from 2009. States expected to produce the most solar energy are California and New Jersey.
Keyword: solar energy

Woody, Todd. August 10, 2010. Recycling Land for Green Energy Ideas. New York Times.
www.nytimes.com/2010/08/11/business/energy-environment/11solar.html?_r=2&pagewanted=1&hpw
The article describes examples from across the country of a "new approach" to locating renewable energy projects: putting them on polluted or previously used land.
Keywords: renewable energy