Alternative Uses of Highway Rights-of-Way

Accommodating Renewable Energy Technologies

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In recent years, the capacity, generation, and consumption of energy derived from renewable sources have grown significantly on a global level. To increase renewable energy production in the near term, state and local transportation agencies have recently expressed more interest in installing decentralized renewable energy technologies on spaces not traditionally considered for energy generation. Many transportation agencies have demonstrated the viability of utilizing the highway right-of-way (ROW) for decentralized renewable energy production. Following these leads, several U.S. state departments of transportation are exploring similar prospects, given that the ample lands that they manage are in proximity to power loads and, in some cases, have already been disturbed or are no longer held for their environmental attributes. From a highway ROW perspective, however, considerable economic, ecological, legal, and political uncertainties are related to whether accommodating renewable energy technologies can be a practical highway land management practice. This study provides transportation agencies with information that will enable them to consider better the implications and evaluate the feasibility of implementing renewable energy and fuel options in the ROW. The lessons that early adopters have learned should inform others.

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 (kW-h) of electricity, or 10% of the nation's total electricity consumed. This amount represents an approximately 8% increase from what was generated in 2008 and a roughly 14% 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. Although there is debate, some view a prompt transition from fossil fuels to renewable sources as a critical component in a stable climate and sustainable society (*2*). 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, policy initiatives to increase renewable energy production are emerging.

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Transportation Research Record: Journal of the Transportation Research Board, No. 2270, Transportation Research Board of the National Academies, Washington, D.C., 2012, pp. 23–30.
DOI: 10.3141/2270-04

Traditionally, efforts to increase renewable energy production have focused on developing large, 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, public agencies have expressed a growing interest in installing decentralized renewable energy technologies on spaces not traditionally considered as sites for electricity generation. Decentralized production, also called distributed generation, refers to electricity produced on site or close to the load center and interconnected with 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 (*3*). 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 right-of-way (ROW) for decentralized renewable energy production. Following these leads, several U.S. state departments of transportation (DOTs) 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. With more than 8 million lane miles of public roadways under state DOT supervision, the properties that DOTs manage are presumably locations with the potential to generate significant amounts of renewable energy.

METHODOLOGY

This study is based on telephone discussions with stakeholders representing highway ROW renewable energy projects that are in varying stages of completion and that utilize or are pursuing a range of technologies (Table 1). A peer exchange convened in March 2011 among the interviewees and additional stakeholders enhanced the information collected during the telephone 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 telephone discussion and peer exchange notes to identify the recommendations presented here.

RENEWABLE ENERGY TECHNOLOGIES IN ROW

Overview of Renewable Energy Activities

Renewable energy has been used in roadway applications for at least 60 years. In 1948, transportation engineers in Oregon incorporated a geothermal deicing mechanism into a bridge redesign project, an

TABLE 1 Case Study Initiatives Included in This Research

Initiative	Case Study
Renewable energy in ROW feasibility research	Colorado DOT Ohio DOT Texas DOT Massachusetts DOT
Solar energy projects	Oregon DOT Solar Highway Projects California Proposed Highway 50 Solar Energy Projects Carver, Massachusetts, Proposed Route 44 Solar Energy Project Ohio DOT Veterans' Glass City Skyway Bridge Solar Array Project
Wind energy projects	Massachusetts DOT Proposed Wind Energy Project along the Massachusetts Turnpike Ohio DOT Wind Turbine Project
Bioenergy projects	Utah DOT and Utah State University Freeways to Fuel Pilot Project North Carolina DOT Bioenergy Pilot Project

NOTE: Contact information for each case study is available from the authors.

application that several other transportation agencies have adapted since (*3*). By comparison, generating renewable energy within a 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 (*4*). Only recently has the focus turned to localized, small-scale applications, which can be sited near end users. Currently, solar, wind, and biomass growth and 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. For example, the Idaho-based company Solar Roadways has been awarded Small Business Innovation Research grants to develop 12-by-12-ft solar panels that could be embedded in roads to provide power to the electrical grid.

Several state DOTs, including those of Colorado, Massachusetts, Ohio, and Texas are conducting comprehensive statewide renewable energy feasibility studies to identify promising renewable energy technologies and locations to implement them. In 2010 the Colorado DOT evaluated the potential for alternative energy sources, including wind, solar, biomass, geothermal, and hydropower, of its ROW and other built features (*5*). A previous study conducted by the Colorado Governor's Task Force on Renewable Energy Generation identified areas of the state with strong renewable resource potential. Geographic information system (GIS) data for each alternative energy type were superimposed on Colorado DOT ROW maps to calculate the total energy potential within usable ROWs. The Colorado DOT classified usable ROW on the basis of resource-specific criteria, including slope, ROW width and accessibility, proximity to existing electrical transmission, and potential for use by the Colorado DOT.

The Massachusetts DOT is currently conducting a similar assessment of its Highway Division's real estate holdings, including buildings, structures, and ROWs, to identify potential sites suitable for large- and small-scale wind and solar installations. To identify potential sites, GIS data on Massachusetts DOT land holdings and facilities will be overlaid on solar and wind resource data for the state. Massachusetts DOT 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 electrical transmission, and feasible construction access.

The Oregon DOT has also conducted a statewide GIS analysis of its operating and nonoperating ROWs for potential additional solar highway project sites. The Oregon DOT has identified over 600 additional sites and is in the process of applying additional criteria to narrow down the list to an inventory of truly feasible sites. The Oregon DOT may further utilize these data and perform additional analysis in a future phase to search for sites for other types of renewable energy projects such as wind, biomass, or public electric vehicle–charging infrastructure.

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 W of power, can be connected to form modules that in turn form solar arrays. There are 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.

The implementation of solar cell applications alongside travel lanes (versus in the road itself) has been most fully realized in Europe and recently in Canada, Austria, France, Germany, the Netherlands, Switzerland, and the United Kingdom, for example, have been installing PV noise barriers along highways and railways (*6, 7*) since the 1980s. More recently, in 2009 the German Unity Motorway Planning and Construction Company began installing a 2.8-MW solar system on the roof of a tunnel on the A3 highway near Aschaffenburg, Germany.

Encouraged by international activities, several state DOTs throughout the United States are beginning to pursue similar projects as well as directives to find ways to reduce statewide GHG emissions. The first U.S. solar highway project was developed in 2008 in Oregon. Partnering with Portland General Electric (PGE), the Oregon DOT developed the project, now commonly known as Oregon's Solar Highway Demonstration Project, at the interchange of Interstate 5 and Interstate 205 in Tualatin, Oregon. The project consists of a 594-panel, 104-kW ground-mounted solar array system and has produced approximately 130,000 kW-h 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. The Oregon DOT purchases the electricity that the solar array produces from SunWay 1 at the same rate it pays for conventional power from the grid. The Oregon DOT 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 proposes to install a 1.75-MW direct current solar array, which includes approximately 6,994 panels of 250-W. Construction of the Baldock project began in August 2011.

In the eastern United States, the 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-ft LED-lighted structure on the Veterans' Glass City Skyway Bridge near Toledo, Ohio (Figure 1). The test array, which consists of both rigid and flexible solar panels made in Ohio, will be used to help the 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.

Several other states have solar energy projects under way. The California Department of Transportation (Caltrans) is partnering with the Sacramento Municipal Utility District (SMUD) to develop solar energy projects at two potential sites along Highway 50 in Sacramento County. The projects have a planned capacity of 1.4 MW and will utilize both traditional PV and CPV technologies. The environmental review for the project was completed in July 2011. SMUD is currently in the process of identifying a partner to design, construct, and operate the solar system. SMUD will purchase the renewable electricity that the solar facility produces from the developer for resale to its utility customers through its Solar Shares program.

The Massachusetts DOT 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 the 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-kW PV system to support the water system's energy needs. In November 2010, the town selected a preferred vendor, which will install, own, and operate the solar panels. The town, which will purchase the renewable electricity from the vendor, anticipates that construction of the solar array will be completed in February 2012.

Wind Energy and Highway ROW

Wind can be used to generate electricity through the use of wind turbines. Wind turbines generate electricity through the following simplified process: 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, midsized, and utility-scale systems. Wind turbines can operate with naturally occurring wind, a resource consistently available in many parts of the United States, or from less location-dependent manufactured wind resources, such as the air flow produced by traveling vehicles. Past research has focused generally on improving the technology of midsized and utility-scale wind systems that capitalize on naturally occurring wind resources.

The relative size of highway ROWs would likely make the accommodation of current midsized 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 along 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 microwind turbine technology. The Department of Mechanical Engineering of the University of Hong Kong and MotorWave Limited have jointly developed and launched a new microwind turbine technology that enables wind turbines to start generating electricity at wind speeds as low as 2 m/s. The microwind 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 (*8*). As an example, researchers are studying the practicality of using a modified version of the Jersey barrier, a concrete median, to harness wind produced by passing vehicles. The concept involves double-stacked Darrieus, or vertical-axis, wind turbines within the structure that would capture the wind that vehicles produce while passing the median in either direction (*9, 10*). Some critics debate that such turbines could only be placed on high-volume roads and that such turbines could reduce vehicle efficiency by imposing increased drag.

(a) **(b)**

FIGURE 1 Test solar array along I-280 in Toledo, Ohio: (*a*) rigid First Solar panels and (*b*) flexible Xunlight Corporation solar panels. (Source: Ohio DOT.)

To date, only a few state DOTs have examined the feasibility of installing wind turbines in highway ROWs with most potential applications being at highway rest areas or on facilities. The former Massachusetts Turnpike Authority, now part of the Massachusetts DOT, analyzed potential wind turbine sites along the Massachusetts Turnpike, a 138-mi highway extending across the state from east to west, in support of the state's Leading by Example Program that established GHG emission 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. Over 13 months, the Turnpike Authority conducted a feasibility study, by collecting wind speed and other site condition information (*11*). 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 proposals 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-ft 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.

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 (*12*). 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 agents to rigorously compare the prices and returns for given locations and turbine manufacturers.

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. However, corn- and other feed-based ethanol have come under scrutiny with regard 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 change 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 Congressional action committing the nation to goals that increase the amount of biofuels produced and used domestically in the transportation sector over the next 10 years (*13*). Increased biofuel use in the nation's vehicle fleet is a primary strategy of the Energy Independence and 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 the risk of long-term industry investment and create a long-lasting market demand for ethanol and biodiesel.

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 nontraditional agronomic lands such as roadside ROW, military bases, and airports for the growth of biofuel feedstock crops across the country. F2F seeks to increase the production of biofuel without affecting food, fiber, feed, or flower production by targeting lands that are not currently in production. F2F began in 2006 as a cooperative program between the Utah DOT and Utah State University. The Utah DOT 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 plots 20 ft by 8 ft in four locations along the I-15 corridor. Ultimately, arid conditions and heavily compacted soil led the team to conclude that growing biomass in Utah faces significant challenges that might not be manifested in other states. To address this issue, Utah State University developed an aerator tool that could be attached to state DOT planting equipment. On the basis of lessons learned from the Utah pilot project, Utah State University developed a set of criteria by which the feasibility of a potential biomass in the ROW 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.

Since that time, the alliance has grown to include other state DOTs and land grant universities. The North Carolina F2F project started in 2009 and is now largely regarded as one of the most promising programs in the Alliance. The state's moist climate, fertile soils, and support from the state legislature have made North Carolina DOT's biomass-growing efforts a national model (Figure 2). The first North Carolina project began with four 1-acre plots of canola or sunflower crops. The North Carolina DOT, in coordination with North Carolina State University, selected crops that were believed to provide the greatest yield in the ROW. By working with seasonally rotated crops on the same plot, the North Carolina DOT has been able to meet or exceed national standards for crop production. In 2010, the North Carolina DOT extracted 3,000 lb of canola seed, which produced 100 gal of virgin oil. This production in turn created 150 gal of B100, which was cut with conventional diesel to produce approximately 600 gal of B20, a blend of 20% biodiesel and 80% diesel, a product that the North Carolina DOT used to power its dump trucks, tractors, and other equipment. Media coverage and public feedback for the effort have been overwhelmingly positive. The North Carolina DOT now has its fourth crop planted, the Tennessee DOT is monitoring sites it has planted, the Michigan DOT has planted its first roadside plots, and five other states may have plots in 2012 pending funding decisions.

FIGURE 2 North Carolina DOT crews planting canola along I-40 in Raleigh. (Source: North Carolina DOT's photostream, www.flickr.com/photos/ncdot.)

GOVERNANCE OF UTILITIES IN HIGHWAY ROW

Federal Regulations

Before 1988, FHWA prohibited the installation of utilities within Interstate ROW, and many states adopted the same policy for state highways. In 1988, that FHWA policy changed to allow each state to decide whether to permit utilities within Interstate ROW and to specify the conditions for approval. The 1988 FHWA policy also stated that public utilities that were "in the public interest" could be allowed in Interstate ROW under the state DOT's approved utility accommodation policy (UAP) manual or plan as long as the utilities were accommodated in ways that were safe for the traveling public. The emergence of opportunities for locating renewable energy technologies within highway ROW has caused FHWA and the states to reexamine the existing definition for "utility."

Currently, 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 in the ROW are

- Title 49: Transportation, Part 18.31(b), Code of Federal Regulations (CFR), Section 18.31(b) (real property);
- U.S. Code, Title 23: Highways, Section 111 (use and access to ROW, Interstate System);
- Title 23: Highways, CFR 645, Subpart B (accommodation of utilities); and
- Title 23: Highways, CFR 710 (ROW and real estate).

Some current federal restrictions on highway real property use and commercialization may limit abilities of state DOTs to construct renewable energy technologies along the highway ROW. The use of highway real property is limited by 49 CFR 18.31(b) except in circumstances in which other federal statutes allow for the originally authorized purposes as long as the property is needed for those purposes. 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, 3 years later, this provision was repealed. This repeal left the ability to approve any noncommercial uses of the rest areas at the discretion of the FHWA Administrator. The Administrator now determines whether noncommercial uses 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 by whether the utility meets the federal definition. As defined in federal regulations, 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). Since FHWA has determined that the use of highway ROWs to accommodate public utility facilities is in the public interest, when such utilities serve the public interest (as opposed to a private or proprietary interest), DOTs can accommodate them under an approved 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. The AASHTO *Policy on the Accommodation of Utilities within Freeway Right-of-Way* (*14*) establishes guidelines for states' UAPs, which FHWA ultimately reviews and approves.

The use of highway ROW to accommodate facilities that will serve private or proprietary interests may also be accommodated; however, it is necessary for those accommodations to be approved under the airspace leasing requirements of 23 CFR 710 Subpart D. The right to use the ROW for interim nonhighway 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 nonhighway users (*15*). The DOT should charge current fair market value or rent for the use of the land; the income received from airspace leases should be used for transportation purposes. Federal regulations do provide an exception to charging fair market rent if the DOT shows, and 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. 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 Interstate system ROW (*16*). The guidance provides an expanded discussion on how 23 CFR Part 645 and 23 CFR Part 710 are applicable 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. In addition, the agreement should include provisions governing lease revocation, removal of improvements, adequate liability insurance to hold the DOT and the FHWA harmless, and access by the transportation agency for inspection, maintenance, and reconstruction of the facility.

Finally, all actions in the highway ROW that are classified as a 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. 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.

State Regulations

In 2005 AASHTO first 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 technologies relating to renewable energy in the ROW. State DOTs may need to reexamine their respective policies on the definition of utilities when the accommodation of renewable energy technologies is considered.

The project team distributed a questionnaire to the 52 FHWA division offices in order to identify any state-specific policies or regulations governing the accommodation of renewable energy facilities in highway ROW that may exist. Forty-two responses representing 39 division offices (including the District of Columbia and Puerto Rico) were received.

According to the responses, 29 states allow for the use of highway ROW to accommodate public utility facilities per FHWA's guidance on utilization of highway ROW (*16*). 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 on the Interstate (Nebraska), or the longitudinal placement of high-voltage transmission lines—potentially for compensation—when there is no other practical alternative (Florida).

However, 29 states also indicated that their UAPs do not characterize renewable energy facilities as utilities. 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 nonrenewable energy facilities. Some states noted that although renewable energy facilities are not specifically distinguished as utilities in their UAPs, the permissibility of those facilities would likely be open to legal interpretation.

Nevertheless, 36 states have no laws or other requirements allowing or prohibiting 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, and the third has an encroachment policy that may discourage the ROW accommodation of some renewable energy technologies.

CONCLUSIONS AND RECOMMENDATIONS

State DOTs are increasingly recognizing the threats posed by climate change effects to 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 unused ROW land presents to develop sustainable energy sources. Doing so not only reduces reliance on fossil fuels but also can promote energy security and conservation, and foster the creation of a local green job market while reducing highway maintenance and operational costs (e.g., in instances when a partner agency assumes maintenance responsibility). Renewable energy opportunities in highway ROW might also generate additional revenue for transportation agencies. The lessons that early adopters have learned and the best practice recommendations presented in the following paragraphs should inform others seeking to generate renewable energy within the highway ROW:

1. Consider revising 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 that they are consistent with current needs and that the UAP definition of a utility includes or allows for renewable energy technologies.

2. Identify statutory or regulatory constraints that preclude resource development and devise resolutions that would instead foster such development. Accommodating renewable energy technologies in the ROW will likely expose legal constraints that limit opportunities for renewable resource development. A state's utility rules for net metering and 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), a higher cost per kilowatt installed, decisions to pursue renewable energy credit–based projects instead of those that would be net-metered, or all four consequences.

The development of an administrative net-metering 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. Although a state DOT might not necessarily take the lead on this action, its involvement and partnership with other agencies will likely be important.

3. 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. In addition, transportation agencies should collaborate with utility companies and public utility boards to share data and maps on subsurface utility facilities for any new renewable energy installations. This teamwork would mitigate issues when new transportation projects come along and would help outline potential future utility conflicts.

4. Review long-range transportation plans to identify potential siting conflicts or to develop guidelines for how renewable energy projects might be included in statewide transportation planning. A transportation improvement program is a multiyear capital improvement program of transportation projects. Each metropolitan planning area develops a transportation improvement program, which is then incorporated into the statewide transportation improvement program. Transportation agencies also develop long-range transportation plans that outline the vision for the region's or state's transportation system and services. In metropolitan areas, the long-range transportation plan indicates all of the transportation improvements scheduled for funding over the next 20 years.

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

State DOTs are also encouraged to consider how renewable energy accommodation can be better integrated into their transportation planning processes at the state, regional, and corridor levels. This integration would enable states to accommodate renewable energy projects in the ROW in a systematic process rather than on a case-by-case basis.

5. Develop an internal interdisciplinary team to address the unique issues presented by renewable energy projects in the ROW. 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 state DOT, including real estate services, maintenance, operations, safety, environment, planning, and legal services. 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. It was noted by one state DOT 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 discussions to help minimize the potential for delays.

6. Create partnerships with external stakeholders. It can be beneficial for state DOTs to build partnerships with external stakeholders, such as utilities, public utility boards, banks, private energy developers, and alternative energy vendors. Building such relationships can be a valuable asset in educating the DOT and in facilitating issues that may arise later in project development and design. For example, the 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. In addition, it is important to coordinate with the utility company early in the development of renewable energy projects when the local utility is not an active partner. This coordination is particularly important if a proposed project does not have an identified customer for the electricity that will be produced.

Specifically regarding wind energy project development, wind project proponents should first consult with the FAA, the Joint Program Office, and any local Department of Defense installations about the siting of their project in order to avoid delays and unnecessary investigation expense. This consultation should be a preliminary step in the development process. Early consultation with the FAA and the Joint Program Office 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.

7. Be flexible and creative in contemplating and implementing renewable energy projects. Renewable energy and alternative fuel projects in the ROW raise issues with which the parties involved may have had little or no experience. Flexibility and creativity on the part of the state DOT and its partners are necessary to devise solutions that meet the needs of all those involved. State 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's ability to implement a successful project, regardless of the success measure or measures chosen.

The approach to develop renewable energy projects in the ROW is largely dependent on 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, or attaining a certain level of public acceptance, among others. Even within a state, the approach followed may differ from project to project. A prototype model may emerge as the DOTs develop more experience in implementing renewable energy projects in the ROW. Until then, however, state DOTs and their partners will need to be flexible and creative when they contemplate, implement, and evaluate renewable energy and alternative fuel projects.

8. Develop comprehensive value-based selection criteria for renewable energy projects in the highway ROW. Renewable energy projects in the ROW can help agencies achieve their environmental and sustainability goals. When cost is the primary selection criterion 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 the PV modules were procured for its solar demonstration project, the Oregon DOT evaluated proposals by using a set of value-based selection criteria that it developed. In addition to corporate qualifications, technical characteristics of the proposed PV modules, and price, the selection criteria 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.

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The Waste Management and Resource Efficiency in Transportation Committee peer-reviewed this paper.