Highway Renewable Energy:
Photovoltaic Noise Barriers

Photo source: TNC Consulting

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4. POTENTIAL PVNB PROJECTS IN THE UNITED STATES

This section draws upon information gathered from interviews and correspondence with transportation professionals in the United States. The project team identified experts through existing professional networks.

4.1 Highway Noise Governance

The Federal-Aid Highway Act of 1970 includes mandates for FHWA to develop standards for the consideration of the effects of highway noise from projects. FHWA implemented those standards through noise regulations, which are codified in 23 Code of Federal Regulations (CFR) 772, describe procedures for abating highway traffic and construction noise on projects where a State Department of Transportation (SDOT) receives Federal funding. SDOTs must use FHWA's Traffic Noise Model (TNM) in their traffic noise prediction analysis for all projects subject to 23 CFR 772.[26] The FHWA TNM is a state-of-the-art, three-dimensional model that calculates traffic noise levels and noise level reductions based on user input of roadways, barriers, terrain features such as hills, valleys, woods, and lakes; structures, and traffic data. Otherwise, SDOTs have flexibility in determining the feasibility and reasonableness of noise abatement on roadways to balance the benefits of abatement measures with the social, economic, and environmental costs as described in FHWA approved policies.

The regulations define three types of highway noise projects:

- Type I projects involve the construction of new highways or improvements to existing highways. They typically involve the construction of noise barriers as part of projects that significantly change the horizontal or vertical alignment of an existing highway, increase the number of through traffic lanes of an existing highway, or relocate interchange ramps.

- Type II projects, also called retrofit projects for noise abatement, are standalone Federal or Federal-aid highway projects that involve construction of noise barriers on existing highways. Type II projects are voluntary noise abatement projects and constructed as state funding allows. They account for approximately 14 percent all noise barriers constructed in the United States.[27]

- Type III projects are Federal or Federal-aid highway projects that do not meet the classifications of Type I or Type II projects. Type III means the proposed activity does not require a noise analysis.

[26] Per 23 CFR 772.7(a), the regulation applies to all Federal or Federal-aid Highway Projects authorized under title 23 U.S.C. and therefore any highway project or multimodal project that:
(1) Requires FHWA approval regardless of funding sources or (2) Is funded with Federal-aid highway funds.

[27] See www.fhwa.dot.gov/environment/noise/noise_barriers/inventory/ for more information on noise barriers constructed in the U.S. as of December 31, 2013.

In each case, states must consider noise abatement measures where noise impacts are determined to occur as per FHWA's Noise Abatement Criteria, which are absolute noise levels for varying land uses (See Table 1 at 23 CFR Part 772). The noise regulations do not expressly prohibit the deployment of PVNBs, either as part of the retrofitting of existing noise barriers with PV modules or through the integration of PV modules with new barriers. While the regulation does not allow funding from third parties to make a barrier feasible or reasonable, the regulation does allow contributions from third parties for appurtenances, such as PVNBs.

4.2 Massachusetts DOT's Lexington Solar Retrofit Pilot Program

Since 2015, the Massachusetts Department of Transportation (MassDOT) has installed 5.5 MW of ground-mount[28] PV panels within its highway ROW as part of its "Solar PV Energy Program."[29] MassDOT has a goal of achieving 6 MW of aggregated capacity from ground-mount solar across the state. However, with limited space remaining for new ground-mount arrays on MassDOT properties, the agency has been interested in exploring other opportunities for accommodating renewable energy technologies, including noise barriers.

In 2015, a company approached MassDOT to discuss the concept of PVNBs. After two years of coordination and conceptual design work, MassDOT is now working to pilot a PVNB project along Interstate 95 in Lexington, MA (Figure 13). The project will be a retrofit of an existing noise barrier and will be financed through a public-private partnership. MassDOT plans to use the results of the pilot, including information about noise impacts, maintenance, cost, and community perception, to determine whether to make the pilot location permanent and whether to expand PVNB use elsewhere in the State.

MassDOT considered 25 potential sites for the PVNB pilot, ultimately selecting the Lexington site due to its orientation to the sun, the length of the noise barrier, topography and offset from the road, vegetation in the area, and access to a grid interconnection point. The noise barrier, which is on the north side of the highway, is 3,000 feet (~915 m) long, 20 (~6 m) feet tall, and is constructed of reinforced concrete. A critical aspect of the pilot program is to monitor noise levels to understand whether, if at all, the PVNB affects the noise levels that abutters perceive or that occur on the other side of the highway. The racks of solar panels will be installed on the highway side of the barrier, while the side of the barrier facing abutters would not change significantly.

[28] Ground-mount arrays are affixed to support structures that penetrate the ground.
[29] For more information on MassDOT's Solar PV Energy Program, see: www.massdot.state.ma.us/planning/Main/SustainableTransportation/RenewableEnergy.aspx

Figure 13. Visualization of proposed configuration of solar panel retrofit on existing noise barrier in Massachusetts. *Source: Massachusetts DOT*

The exact size of the PV module system has not yet been determined, but MassDOT anticipates that if the full length of the noise barrier is used, approximately 825,000 kWh will be generated annually. This would be the equivalent of supplying 120 homes per year with electricity. The project will add a small transformer within the ROW in order to connect to the electricity grid.

MassDOT would not incur any capital costs. Instead, MassDOT plans to release a request for proposals (RFP) for the project, and the selected developer will be responsible for the financing, installation, and maintenance of the solar panels, as well as any necessary upgrades to a nearby electricity substation. Although MassDOT is still working out the details of the partnership in the RFP, it is likely that the project would benefit MassDOT by allowing the agency to purchase the electricity at a guaranteed, long-term rate. The developer would likely receive credits under the Massachusetts solar renewable energy credit program or the new Solar Massachusetts Renewable Target (SMART) Program, a renewable energy tariff program.[30] The developer would also likely receive a Federal Solar Investment Tax Credit, which is currently a 30 percent tax credit claimed against the tax liability of residential, commercial, and utility investors in solar energy property.[31]

MassDOT solicited input on the project from abutters and other Lexington residents through letters to those living near the project site, a public meeting, and meetings with other stakeholders, such as Sustainable Lexington, a local advocacy group. Stakeholders raised several concerns before and during the public meeting, including potential changes to noise levels on both sides of the highway and noise impacts of the transformer and other equipment. MassDOT plans to address these

[30] For more information on the SMART program, see www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/rps-aps/development-of-the-next-solar-incentive.html.
[31] For more information on the Federal Solar Investment Tax Credit, see www.seia.org/policy/finance-tax/solar-investment-tax-credit.

concerns by conducting a final noise analysis prior to the solar panel installation; if the analysis finds that negative noise effects are created, the project will not move forward. At the conclusion of the public meeting, MassDOT held a referendum for abutters to vote on the pilot project (abutters not at the meeting were also able to request a ballot). In accordance with noise barrier standards,[32] a two thirds majority in support of the project was needed for it to move forward. Eleven votes were cast, all of which were in support of the pilot project.

The RFP will likely be issued summer 2017, and the pilot is expected to last two years from the date the solar panels are operational. MassDOT is developing evaluation criteria for the pilot project that it will use to evaluate whether to keep the site in operation after the two-year demonstration period, as well as whether to expand PVNBs to other locations in the State. The evaluation criteria have not yet been finalized, but will likely include changes to the noise abatement characteristics of the noise barrier, required maintenance of the solar panels, impacts to the longevity of the noise barrier, total costs, and community feedback. If the pilot project is successful, MassDOT may consider options for retrofitting other noise barriers with PV modules, as well as piloting the PV integrated concept when a new noise barrier(s) is constructed.

4.3 The Ray: A Potential Testing Ground for Prototype Solar Noise Barriers

In 2014, the Georgia legislature named an 18-mile stretch of Interstate 85 (I-85) in west Georgia in honor of the late Ray C. Anderson, a leader in industrial sustainability. To align with its goals of enhancing the environmental stewardship and sustainability, the Ray C. Anderson Foundation (Foundation) labeled the I-85 section "The Ray" to be a living laboratory for emerging innovations related to sustainable transportation. The Foundation set a goal for The Ray to become a "net zero" highway that eliminates all deaths, waste, and carbon emissions. It has partnered with the Georgia DOT (GDOT) and other stakeholders to test innovations along and at a visitor center on the highway segment. Innovations demonstrated to date include solar-powered vehicle charging stations, a roll-over tire check safety station, bioswales to clean water runoff, a pollinator garden, and a novel solar-pavement technology.

Moving forward, The Ray may be a testing ground for a prototype PNVB. The Foundation is currently working with a consultant on a feasibility study that evaluates different types of PVNB technology, including noise barriers with mounted panels, thin film solar cells, concentrating PVs along the periphery of noise barriers, and a noise barrier that itself is a wall of solar cells. The Foundation plans to choose a technology that could be deployed in a PVNB demonstration project on The Ray based on the feasibility study's results.

A site has not yet been identified, but the Foundation is working with partners, including (GDOT) to explore opportunities. One option being considered is the construction of a new noise barrier at a location between The Ray and an adjacent high school. If a PVNB were constructed at the site, the team envisions the electricity being used nearby, for example to power lights at the school or one of

[32] For more information, see the MassDOT Type I and Type II noise barrier guidebook at www.massdot.state.ma.us/Portals/8/docs/environmental/noisebarrier2012/NoiseProgramGuidebook_121412.pdf

its ball-field scoreboards. The team has pointed out, however, that first and foremost a PVNB demonstration along The Ray would need to be a noise barrier project. A wall would not be the optimal setting or configuration for a solar array. The Foundation plans to continue working with public and private stakeholders to assess noise abatement needs along The Ray and potentially find a suitable site and situation for the PVNB pilot.

5. CONCLUSIONS

In 1999, researchers quantified the technical potential of existing and planned highway noise barriers in Europe to produce renewable energy.[33] Data suggested peak capacity along roadways in 6 countries to be 580 MWp (~ 200 Wp per linear meter) and that a total of nearly 500 Gigawatt hours per year (GWh/yr) of renewable energy was possible. Extrapolating from these figures and FHWA's noise barrier inventory, the technical potential[34] for generating capacity along highway noise barriers in the U.S. is estimated to be on the order of at least 500 MWp and the renewable energy possibly delivered to be likely at least 400 GWh/yr. The latter is roughly equivalent to the annual electricity use of 37,000 homes (see Appendix C for calculations).

These are likely conservative approximations given that they only account for existing noise barriers constructed before December 31, 2013, and they only account for noise barriers made of select materials: berm only, concrete, concrete precast, concrete block, concrete cast-in-place, and combination berm/concrete. Over 45 percent (1,200 miles or 1,900 km) of noise barriers in the U.S. are made of other materials. This should not suggest, however, that noise barriers that are not berm or concrete cannot integrate PV modules. Additionally, the efficiencies of solar panel technologies have improved over time. State-specific estimates may vary considerably due to factors such as latitude and solar irradiance, noise barrier orientation and PV placement, and topography.

In general, large surface areas are necessary to generate electricity from PV modules.[35] Noise barriers offer surface area additional to land and rooftops to accommodate PVs and can provide better land utilization ratios for energy production than conventional solar PV farms.[36] Nevertheless, although PVNBs provide for the multiple use of road space, deciding whether to implement a PVNB in a highway setting is not based simply on renewable energy potential or performance. Rather, State DOTs will likely need to employ a holistic planning approach that balances broad view concepts, such as land use and sustainability goals, with site-specific details, such as safety, maintenance needs, and noise mitigation. While other sites, such as rooftops, may be more efficient than noise barriers from an energy generation perspective, transportation agencies should consider assessing their noise barriers for PV opportunities in conjunction with their other properties given the numerous potential benefits of PVNBs.

5.1 Lessons Learned Summary

The case studies of existing PVNBs in Europe and planned PVNBs in the United States provide several insights for transportation agencies interested in implementing PVNBs. The following table summarizes key lessons learned.

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[33] Goetzberger *et al.* (1999).

[34] "Technical potential" in this case assumes that all existing noise barriers made of the materials in the bulleted list will be upgraded with PV.

[35] The National Renewable Energy Laboratory has estimated approximately 181 m^2 of land area is required for PV per person to meet U.S. energy demands. http://dx.doi.org/10.1016/j.enpol.2008.05.035.

[36] Wadhawan and Pearce (2017).

PVNB technology	PV modules have been both deployed as retrofits to existing noise barriers and integrated into new noise barriers. Bifacial solar cells, which allow light to enter and be absorbed on both sides, are being used in Europe. These panels provide an advantage in that they can be used in any orientation. Other potential PVNB technologies include thin film solar cells, concentrating PV cells along the periphery of noise barriers, and luminescent solar concentrators.
Financial feasibility	The financial feasibility of PVNBs is highly dependent on the price of the PV panels, the price of electricity, and government incentives for renewable energy (such as net metering, feed-in tariffs, or tax credits) – all of which vary depending on the location and policy context. In the United States, organizations that implement PVNBs may be able to take advantage of statewide renewable energy credit programs, which are used to track progress towards meeting renewable portfolio standards, or net metering policies, which allow solar panel owners to sell excess energy back to the grid.[37] At the Federal level, the Solar Investment Tax Credit (ITC) provides a 30 percent tax credit claimed against the tax liability of residential, commercial, and utility investors in solar energy property (note that public entities such as State DOTs cannot directly take advantage of the ITC, since they have no tax liability). Many PVNB projects have been structured as public private partnerships where a developer takes on the construction and maintenance of the PVNB. This arrangement allows States to install solar panels with no upfront costs, allows the developer to take advantage of incentives that the State DOT may not be able to access, and provides the State with a long-term source of electricity, often at a fixed, guaranteed price.
Noise characteristics	Typically, the noise abatement characteristics of noise barriers have not significantly changed after being retrofit with PV modules, and new PVNBs can be designed to adhere to all relevant noise requirements. Since, PVNBs are primarily noise barriers with the added functionality of generating electricity it is important to measure noise levels before and after the installation of the PV to ensure that desired and required noise attenuation is achieved.
Safety	There is little to no evidence to date that PVNBs significantly affect driver safety. Driver distraction and glare can be minimized by locating the PV modules high on noise barriers and/or set back from the roadway, and by ensuring that the panels are at proper angles to minimize glare. PVNBs with a vertical design, such as the Australian PVNB, have not been shown to create glare. Additionally, solar panels are designed to absorb rather than reflect light. PVNBs are not expected to cause crashes if located behind a guard rail(s) or beyond the clear zone.
Maintenance	Several international examples have shown that existing PVNB technologies have minimal maintenance needs. In Germany, the PV panels are not typically cleaned, because the cost of doing so would outweigh any potential efficiency gains. In Australia, the vertical orientation of the PVNB minimizes accumulated dirt on the panels.

[37] For information about state solar incentives, see the Database of State Incentives for Renewables & Efficiency at www.dsireusa.org/