FHWA-NJ2023-001
January 2023

New Jersey Department of Transportation Bureau of Research

Research at a Glance

Technical Brief

Principal Investigator

Dr. Hao Wang

Associate Professor

Dept. of Civil and Envi. Eng.

School of Engineering

Rutgers University

848-445-2874

hwang.cee@rutgers.edu

Energy Harvesting On New Jersey Roadways

This project presents new developments and recommendations to apply energy harvesting technologies on roadway and bridge assets.

Research Problem Statement

The discovery of green energy resources that are renewable is one of the critical challenges facing the world for sustainable development. Energy harvesting is a promising technique that can produce renewable and clean energy and improve sustainability of infrastructure. In recent years, researchers have begun to harvest electrical energy from the ambient environment using different techniques, such as piezoelectric, thermoelectric, electromagnetic, and photovoltaic energy harvesting.

Transportation agencies can benefit from renewable energy by utilizing various solar power technologies in roadway infrastructure, such as solar farms at right-of-way (ROW). However, it is desired to avoid creating a large land footprint by implementing solar integrated infrastructure on roofs, canopies, noise barriers, street lights, and traffic signs. On the other hand, energy harvesting could provide continuous power support for in-situ monitoring sensors placed on roadways and bridge decks. To ensure the continuity of data collection from sensors without interruption, one feasible solution is to develop micro energy harvesters to supply in-situ power for sensors.

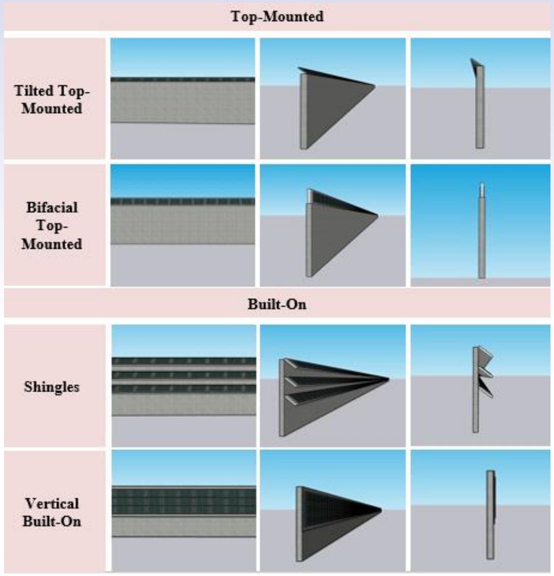
Research Objectives

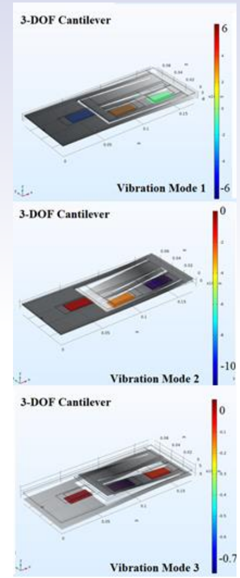
The objective of this research is to identify potential energy harvesting technology for applications on roadways and bridges and conduct feasibility analysis and performance evaluation of selected technologies for large-scale and micro-scale energy generation. The research outcome provides recommendations for future implementation of energy harvesting in the roadway and bridge network of New Jersey for development of sustainable and smart transportation infrastructure.

Methodology

Comprehensive literature review on energy harvesting techniques and application is performed. The solar energy outputs of ROW and noise barriers in NJ are analyzed at project and state levels, respectively. Three retrofitting designs of PVNB are compared and evaluated in details. On the other hand, new designs of piezoelectric cantilevers are developed for providing wide-band of resonant frequency to better match vibration modes. An optimization approach is proposed for piezoelectric energy harvester to maximize power outputs from bridge vibrations.

FHWA-NJ2023-001
JANUARY 2023





Research Project Manager

Giri Venkiteela, PhD

Research Scientist

NJDOT Bureau of Research

609-963-2239

Giri.Venkiteela@dot.nj.gov

Results

The preferred energy harvesting technology for roadway and bridge applications may vary depending on the working principle and application purpose.

Solar energy harvesting on roadways can be achieved on ROW, rest area, noise barrier, street light, and etc. The solar energy potential at ROW of NJ roadway is estimated to be 4,271GWh per year. For PVNB, the design configuration with the shingles built-on has the highest energy output. The state-level energy output estimation for all existing noise barriers in NJ is 56,164MWh per year with shingles built-on configuration. A decision-making framework is further proposed for site selection of PVNB considering different factors to increase economic return, reduce environmental impacts, and improve public welfare.

Piezoelectric energy harvesting can be r stress-based or vibration-based. The new multi-DOF cantilever designs are proposed for producing more energy under different vibration modes with an optimization approach. The power output improvement achieved by the proposed approach was demonstrated on a full-scale bridge testing facility. The multiple-DOF cantilever designs can generate considerable energy outputs after proper geometric design optimizations to match resonant frequencies with vibrational frequencies of host structure. Under one loading pass, the optimized 2-DOF and 3-DOF cantilevers was capable of generating 30.5 μJ and 23.4 μJ electrical energy, respectively.

Future implementation of PVNB should consider the quantified economic, environmental benefits for site selection and configuration design in the project planning phase. Future study of vibration-based piezoelectric energy harvesting should be conducted to further optimize the design based on real bridge structures and integrate with sensor applications.

U.S. Department of Transportation
Federal Highway Administration

This brief summarizes FHWA-NJ-2023-01, Energy Harvesting from Roadways and Bridges, produced through the New Jersey Department of Transportation Bureau of Research, 1035 Parkway Avenue, P.O. Box 600, Ewing, NJ 08625 in cooperation with the U.S. Department of Transportation Federal Highway Administration.