The Exploratory Advanced Research Program Fact Sheet

Harnessing Pavement Power

Developing Renewable Energy Technology in the Public Right-of-Way

Exploratory Advanced Research . . . Next Generation Transportation Solutions

The United States has over 4-million mi (6-million km) of roadways.[1] The renewable energy potential on this size of land is enormous and could significantly contribute to the electricity demands of the United States. Developing piezoelectric technology to harness this unused power is the goal of "New Technologies for Development of Renewable Energy in the Public Right-of-Way," a Federal Highway Administration (FHWA) Exploratory Advanced Research (EAR) Program study awarded to the Virginia Tech Transportation Institute (VTTI).

Renewable Energy in the Right-of-Way

The transportation sector consumes about one third of the national energy production, and is responsible for more than one third of the pollution.[2] Although recent development of fossil fuel resources in the United States show promise for the short term in meeting excess demand, in the long run fossil energy prices are expected to rise. The innovation potential in harnessing renewable resources now will make it likely to be competitive in the future.

There are many renewable energy technologies to explore, including solar, wind, and geothermal, but piezoelectric energy harvesting has two unique advantages of particular relevance to pavement applications in the public-right-of-way. First, the technology can harvest the excess energy lost in pavement deformation and vibrations caused by the more than 250 million registered vehicles in the United States.[3] Second, piezoelectric materials may also serve as part of a smart-sensing network capable of indicating the overall integrity of the pavement structure while satisfying functional requirements.

A New Pavement Concept

This research represents an important step for a U.S.-based full-scale evaluation of piezoelectric generators in roadway pavements. If successful this technique will provide a method to recapture energy lost to pavement deformation from traffic loading that would otherwise be lost and convert it to electricity for transportation infrastructure needs, such as lighting or distributed sensing for improved operations or health monitoring. It introduces the concept of an entirely new method of smart pavement, capable of self-powering, that can be installed in existing pavements or new roadways with negligent changes to roadway surface profile. The system must be highly resistant to damage from vehicles and adverse weather while also being low in installation and maintenance costs.

Harvesting Energy

When a vehicle is driven on a road, part of its driving energy is turned into mechanical energy in the form of deformation and vibration. The energy is ultimately lost as heat but part of this excess mechanical energy may be harnessed and converted into usable energy. This project examines a kinetic-to-electric conversion (KEEC) system that could be used to harvest this mechanical energy as vehicles pass over. The piezoelectric technology implemented by the KEEC system exploits the electric charge that accumulates in certain solid materials when a force or stress is applied. The aim is to use this technology to capture excess kinetic energy from within pavements up to 1.5 in (3.8 cm) below the surface.

The System

The KEEC system consists of multiple generators, each constructed of thin piezoelectric ceramic and polymer layers. Researchers plan to develop the KEEC system and initially evaluate it in two full-scale instrumented pavement sections. Laboratory experiments and field testing will be conducted to develop the piezoelectric generator and produce a KEEC system that is durable and optimized for energy output. The system will be evaluated under controlled and real traffic conditions in preparation for broader implementation. If successful, the system will ultimately be used to generate and supply

[1] *2010 Status of the Nation's Highways, Bridges, and Transit: Conditions and Performance*, Federal Transit Administration, Washington, DC, 2010 (http://www.fhwa.dot.gov/policy/2010cpr/pdfs/cp2010.pdf).
[2] *Monthly Energy Review*, U.S. Energy Information Administration, Washington, D.C., May 2013 (http://www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf).
[3] *2013 Pocket Guide to Transportation,* Research and Innovative Technology Administration Bureau of Transportation Statistics, Washington, DC, 2013 (http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/pocket_guide_2013_1.pdf).

U.S. Department of Transportation
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electricity for various transportation operational demands.

A comprehensive report will be produced as part of this project, describing how the piezoelectric generator and KEEC system are manufactured, installed, operated, and maintained, as well as the background information on the theories used in developing the technology.

Renewable Energy Challenges

A limiting issue with most renewable energy sources is their dependence on unpredictable resources such as wind and solar. In other cases, such as tidal or geothermal, the resource may be too far from the demand for practical use. The KEEC technology differs because it has an ensured energy input derived from the flow of traffic. The KEEC does require some pavement deformation to operate and is more suited for flexible pavement applications, which limits the amount of locations for implementation. The presence of a reliable traffic pattern is also a factor that may limit the application to areas such as deceleration zones where traffic is expected to have excess energy loss regardless of the presence of the KEEC generators.

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The kinetic-to-electric conversion system undergoing laboratory testing.

Image other side: Field testing the piezoelectric generator.

Credit: © Virginia Tech Transportation Institute

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System Impact

It is not expected that the KEEC system will replace major power sources such as coal, natural gas, or nuclear; however, widespread use of the technology could measurably offset utility charges associated with roadway operational demands, such as lighting and signals. It may also serve as an energy source for distributed infrastructure health monitoring systems involving networked sensors and wireless communication of data. The current sensor designs provide 0.03 kWh (0.108 MJ) of power per month. It would therefore require 15,840 generators per mi (1.6 km) to generate enough power for 36 typical homes, requiring installation in 75 mi (120 km) of pavement. At this early stage it is expected that advances in materials and manufacturing processes will yield significantly better results in the future at reduced cost. "This project is well aligned with EAR Program goals to identify technologies, materials, and approaches that can change the role of public right-of-way in a more productive manner toward energy production and storage," said Eric Weaver at FHWA. "This innovative technology may lead to a significant reduction in highway agency operating costs and reduce the overall environmental impact of roadways," he added.

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on long-term, high-risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives.

To learn more about the EAR Program, visit the Exploratory Advanced Research Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events. For additional information, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@dot.gov), or Terry Halkyard at FHWA, 202-493-3467 (email: terry.halkyard@dot.gov).

Learn More

For more information on this EAR Program project, contact Eric Weaver, FHWA Office of Infrastructure Research and Development, at 202–493–3153 (email: eric.weaver@dot.gov).