



Roads That Power Themselves A Look at Piezoelectric Energy Harvesting

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COSMOS
July 31, 2026



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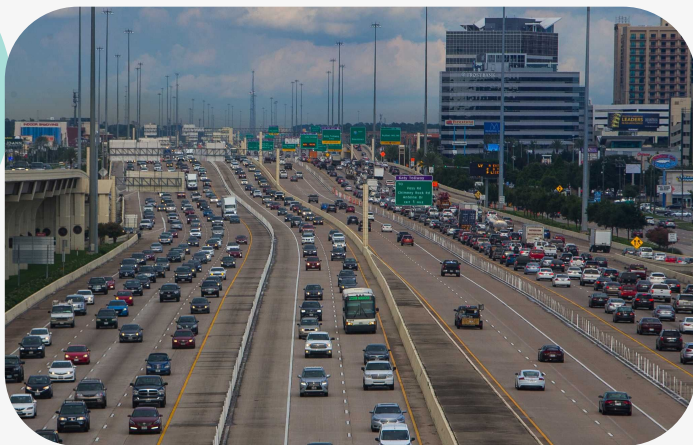
- Introduction to piezoelectric roads
- Research question
- Methodology
- Results
- Conclusion & possibilities



Japan's footsteps

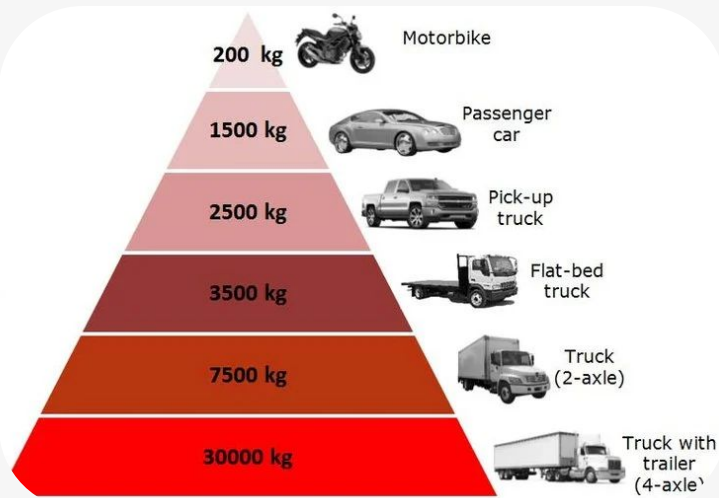
- “Japan turned footsteps into electricity” — Tokyo Station, 2008
- ~25 m² of piezoelectric tiles
- One footstep $\approx$ 0.1 watts of power
- Viral as a “smart futuristic city” idea





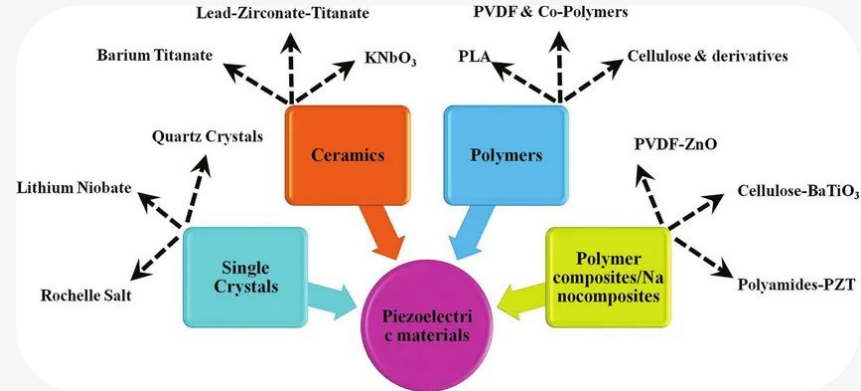
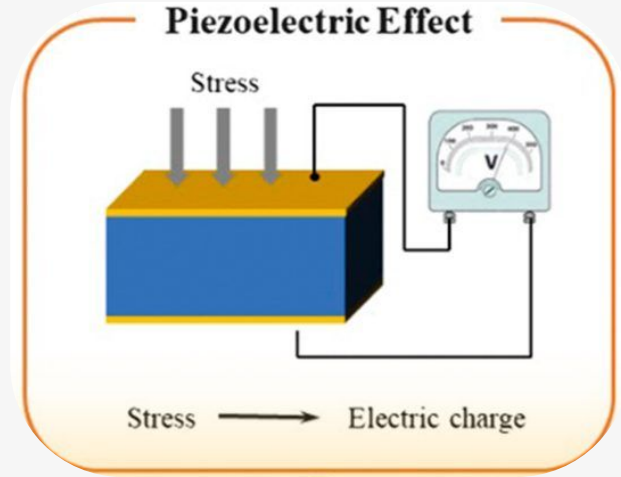
The opportunity

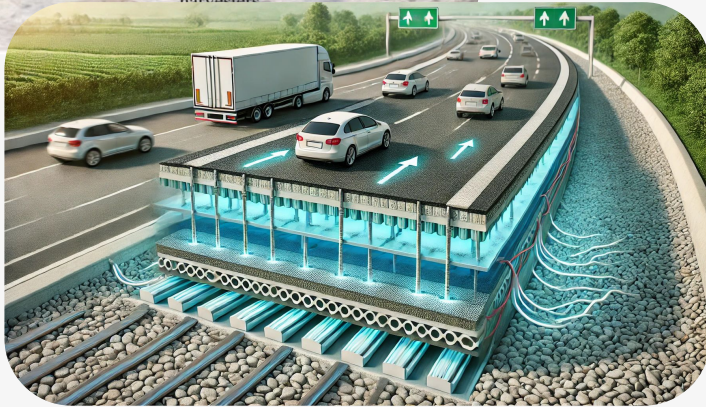
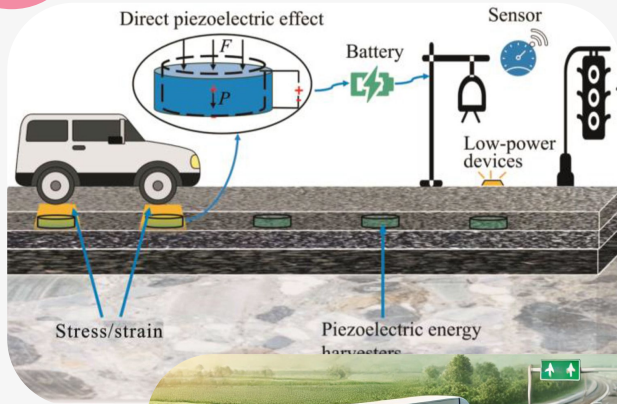
- Roads carry huge mechanical energy wasted as heat
- Cars weigh ~3,300 lbs, semi-truck ~45,000 lbs
- Heavy traffic in major roadways
- New type of clean energy



The Piezoelectric Effect

- Materials generate electric charge when mechanically stressed
- When electric field is applied, these materials deform
- Unaffected by weather
- Powers sensors, igniters, ultrasonic devices, etc.





The current state

- 2 decades of research + pilot tests
+ fundings in the U.S. & globally
- Possible future prospect of energy
- No real-use of piezoelectric
highways exist anywhere



Research Question

Why hasn't piezoelectric road energy harvesting been widely implemented despite decades of research, and what technological and economic advances would make it viable in the future?



Why now?

Rise of EVs

- New power demands
- Lack of charging infrastructure
- More mechanical load

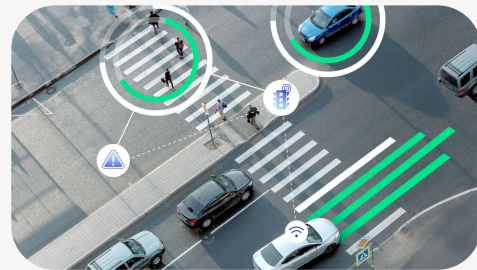
“Smart Roads”

- Sensors
- Require constant power
- Reduce labor costs



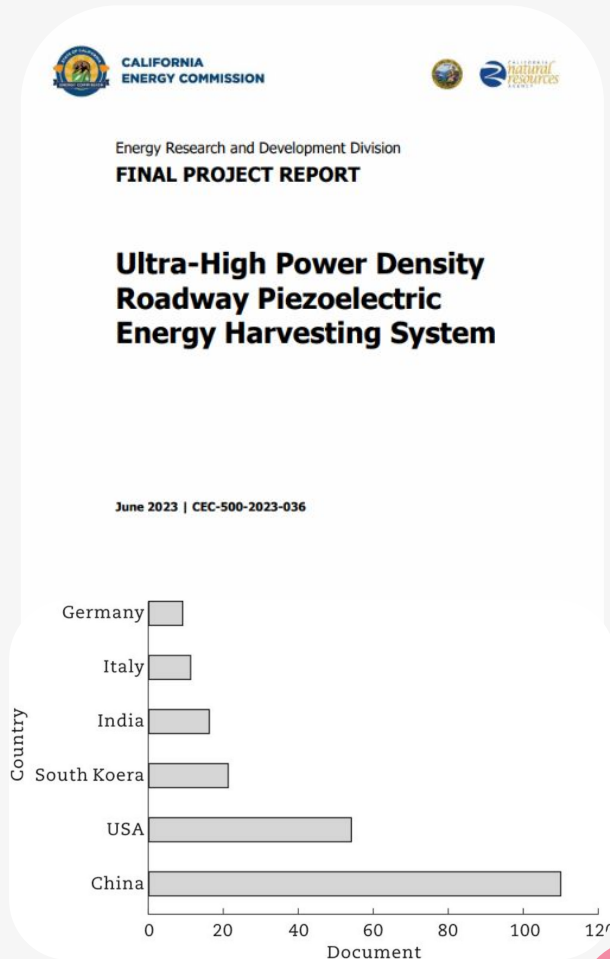
Clean/Renewable Energy

- Harvest wasted mechanical energy
 - Clean-energy targets
- Compete w/ current energy sources



Our approach

- Lit review & meta-analysis
- Recent U.S. & international sources + peer-reviews
 - Domestic sources: 2023 CA Energy Commission reports (UC Merced pilot program) & other U.S. universities
 - International sources: Israel, China, U.K., etc.
- Evaluation criteria: power output, efficiency, cost, durability, etc.



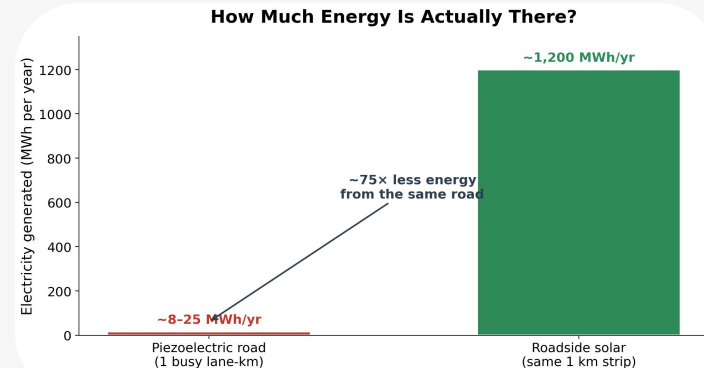
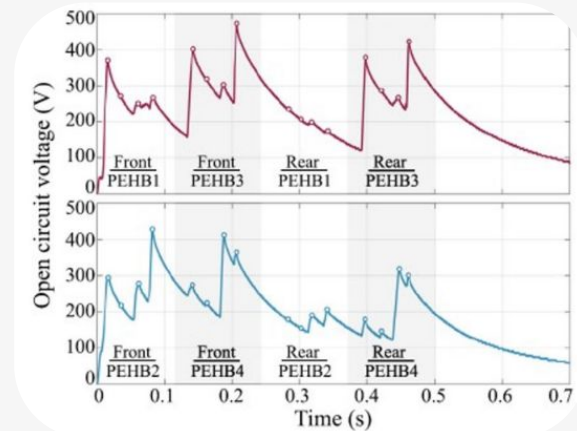


Results



It does not generate enough power

- Road carries **very little** recoverable energy
- **Conversion is inefficient:** 30% engine efficiency x 10% piezoelectric conversion = **3% energy recovered**
- Output: ~1–3 kW average per busy lane-km $\approx$ **8–25 MWh/year**, average U.S. household uses 10.8 MWh/year
- Orders of magnitudes below roadside solar



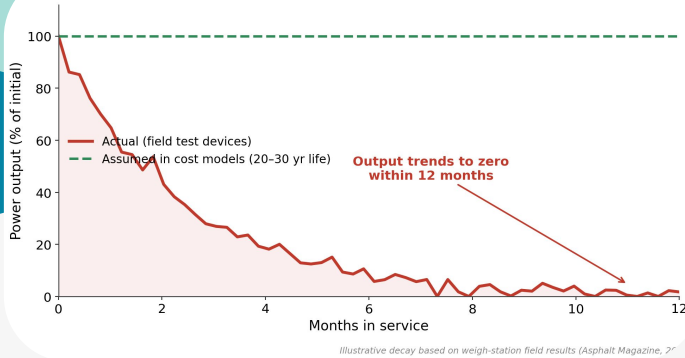
Estimates: Energy Solutions (2026); CEC (2023). Solar assumes ~15-20% capacity factor.



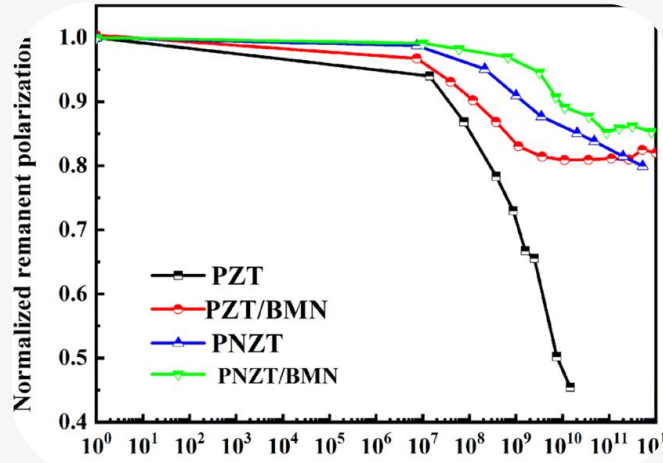
Is the energy truly free?

- **First Law of Thermodynamics**
 - Generating electricity requires **physical deformation**, meaning the road must yield beneath the tires
 - Vehicle forced to **drive “uphill” constantly**
 - Increased **rolling resistance** requires extra energy
 - **Net energy loss** compared to traditional power generation
- 

The Durability Problem



Power output over time for a device



Lifecycle of PZT with stress applied

It is not durable

- Piezo ceramics (PZT) are rigid and brittle
- Field tests: output near zero within a year
- Electronics in asphalt breaks during road maintenance
- Possible durable material (flexible PVDF) produces far less power

It costs too much to build

- Innowattech, 2009: ~\$2,000–4,000

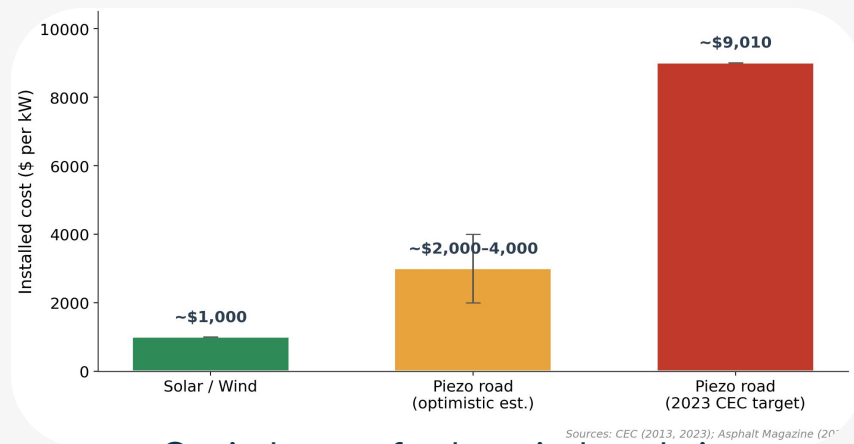
per kW

- CA R&D target (Merced, 2023):

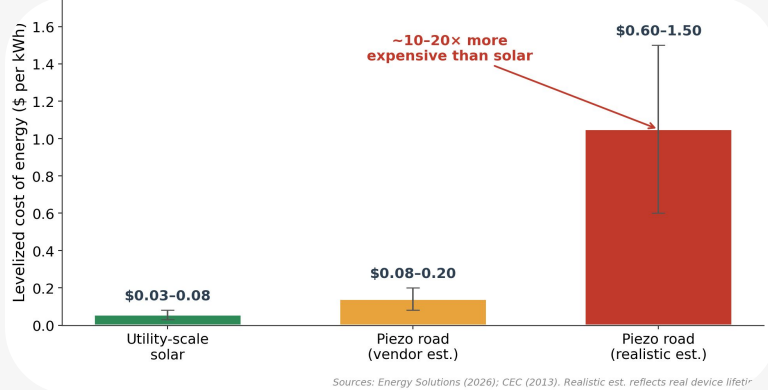
~\$9,010 per kW

- Solar or wind: ~\$1,000 per kW

- 2–9× more expensive to build



Capital cost of solar, wind, and piezo



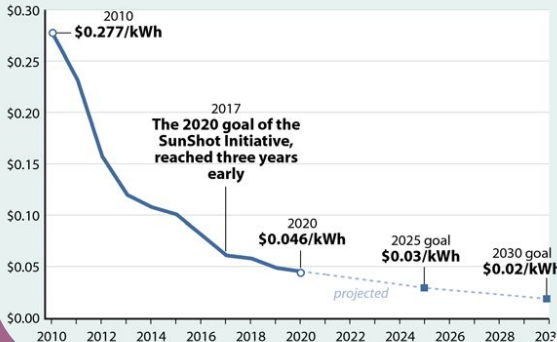
Operating costs of solar wind and piezo

The Falling Costs of Solar

The Department of Energy has set a new goal of reducing the cost of utility-scale solar power to 2 cents per kilowatt-hour by 2030. This follows the 2011 SunShot Initiative, which set a goal for 2020 and reached it three years early. Figures show the levelized cost of energy, which takes into account costs of construction and operation.

U.S. UTILITY-SCALE SOLAR POWER COST

Per kilowatt-hour, 2010 projected to 2030



It costs too much to run

- Lab data: \$0.08 – 0.20 per kWh (20 years lifetime)
- Long-term pilots: \$0.60 – 1.50 per kWh (12 months lifetime)
- Utility solar: \$0.03 – 0.08 per kWh (25 – 40 years lifetime)
- 10–20x more expensive



Our answer

Piezoelectric road energy harvesting hasn't been implemented because of **technological and economical challenges**, and **no current or foreseeable advances in the near future will make it viable** for grid-wide energy production.



Possible improvements... and their ceiling

- **Materials:** rigid PZT vs. flexible PVDF, need material with both characteristics
- **Design:** resurfacing shouldn't destroy the system
- **Pavement:** lower bending stiffness & smaller damping coefficient
- **Cost & efficiency:** manufacturing scale, better electronics, and efficient storage



Ideal deployment locations

- **Heaviest loads + repetitive traffic + local use**
- Port & freight yards: loaded trucks, on-site power needs, owner maintain
- Slow & heavy traffic zones
 - Truck weigh stations: heavy vehicles, mandatory slow, short segments, powers local sensors
 - Toll approach & queue lanes: constant traffic, powers lighting & toll infrastructure
 - Airport drop off zones: constant & heavy traffic, shuttle buses
- Freight corridors, heavy truck routes, & freeway truck lanes



“Be practical as well as generous in your ideals. Keep your eyes on the stars, but remember to keep your feet on the ground.”

- Theodore Roosevelt



Thanks for listening!

Main Sources:

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