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www.jasdg.com
Volume 1 Issue 3 Pages 2151-2162

FEASIBILITY AND EFFICIENCY ANALYSIS OF FOOTSTEP ENERGY HARVESTING TILES IN UNIVERSITY HALLWAYS

Engr. Jed G. Concepcion, MBA, MIT
City of Malabon University
Malabon City, Metro Manila, Philippines
Email: jed.concepcion@cityofmalabonuniversity.edu.ph

Jay G. Concepcion
Far Eastern University - Roosevelt
Marikina City, Metro Manila, Philippines
Email: concepcion.jhay@gmail.com

Corresponding Author

Jay G. Concepcion
Far Eastern University - Roosevelt
Marikina City, Metro Manila, Philippines
Email: concepcion.jhay@gmail.com

Abstract

As universities pursue smart, sustainable infrastructure, the ambient kinetic energy of high-traffic hallways offers a way to reduce reliance on the conventional power grid. Empirical data on the conversion efficiency, storage behavior, and financial viability of footstep harvesters under real pedestrian traffic remain scarce. This study evaluates the technical feasibility, energy conversion efficiency, and economic viability of a piezoelectric footstep energy-harvesting tile deployed in a high-density university hallway. We fabricated a prototype tile incorporating a 4 × 4 array of PZT-5H (lead zirconate titanate) transducers, bridge rectifiers, a buck-boost converter, and a supercapacitor bank, and flush-mounted it in an engineering-building hallway for a 5-day observation period. We combined controlled tests (pedestrian masses of 50 to 95 kg; cadences of 1.0 to 2.5 Hz) and uncontrolled logging of natural traffic with a cost-benefit analysis. An average footfall under a mean impact force of 650 N produced a peak output voltage of 14.2 V and an instantaneous power of 28.4 mW. Peak voltage increased linearly with pedestrian mass (9.8 to 20.8 V for 50 to 95 kg), and higher cadence raised the energy accumulation rate by 38%. At the optimum load of 10 kΩ, the maximum conversion efficiency was 11.4%. At a daily footfall density of 12,000 steps, the tile yielded 11.4 Wh (0.95 mWh per step), sufficient to continuously power low-power hallway auxiliary sensors and LED emergency indicators. A 10-tile installation (US$850) had an estimated payback period of 4.2 years. The findings support the technical and economic feasibility of scaling kinetic harvesting tiles across university corridors, with a projected return on investment (ROI) within 4.2 years of continuous operation. Multi-site, longer-duration validation is needed to confirm durability and generalizability.

Keywords: *piezoelectric energy harvesting; footstep tile; PZT; supercapacitor; smart campus; energy conversion efficiency; return on investment*

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Volume 1 Issue 3 Pages 2151-2162

INTRODUCTION

Modern university campuses operate large-scale facilities that draw electrical power continuously for baseline illumination, environmental monitoring, and security networks. Against a backdrop of rising energy costs and global commitments to reduce carbon footprints (Alshuwaikhat & Abubakar, 2008), integrating renewable micro-energy harvesters into existing infrastructure offers a practical supplement to centralized grids (Elhalwagy et al., 2017; Li & Strezov, 2014). High-foot-traffic zones, such as main corridors, stairwells, and building lobbies, are especially promising because they contain mechanical kinetic energy that currently goes uncaptured (Moussa et al., 2022; Shenck & Paradiso, 2001; Starner, 1996).

Footstep energy harvesting rests on mechanical-to-electrical energy conversion (Anton & Sodano, 2007; Safaei et al., 2019). Piezoelectric transducers generate an electric charge when subjected to mechanical stress, which makes them well suited to embedding in floor tiles owing to their compact profile and solid-state reliability (Kim et al., 2011; Sodano et al., 2004). Despite this promise, limited empirical data on power conversion efficiency (η), energy storage stability, and long-term financial viability under real-world human traffic still hinder practical adoption (Sharma et al., 2022).

This study addresses that gap by investigating the real-world performance of a piezoelectric footstep energy harvester installed in a university hallway. Its specific objectives are to:

1. Quantify the voltage, current, and total power output generated across varying footfall frequencies and pedestrian weights.

2. Evaluate the power conversion efficiency (η) and energy storage performance in a supercapacitor bank.

3. Conduct a financial feasibility and Return on Investment (ROI) analysis for campus-wide deployment.

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METHODS

Prototype Design and Hardware Architecture

The energy-harvesting tile was constructed with a dual-plate housing (300 mm × 300 mm × 45 mm) and a high-density acrylic top plate supported by industrial-grade springs that ensure mechanical return after depression. Earlier footstep tile designs have also used spring-based mechanisms to protect the piezoelectric elements from direct loading (Hwang et al., 2015). Inside the enclosure, a 4 × 4 array of PZT-5H piezoelectric ceramic discs (35 mm diameter; Song et al., 2014) was wired in a series-parallel configuration to balance voltage accumulation and current throughput (Du et al., 2017). Table 1 summarizes the prototype specifications, and Figure 1 shows the component architecture.

Table 1. Specifications of the prototype footstep energy harvesting tile and test instrumentation.

Component	Specification
Housing	Dual-plate enclosure, 300 mm × 300 mm × 45 mm; high-density acrylic top plate
Mechanical return	Industrial-grade springs
Transducers	4 × 4 array of PZT-5H ceramic discs (35 mm diameter), series-parallel wiring
Rectification	One full-wave Schottky bridge rectifier per element (16 in total)
Power management	High-efficiency DC-DC buck-boost converter, regulated at 5 V output
Energy storage	Supercapacitor bank, 5.5 V, 1.0 F
Vertical tile displacement (d)	5 mm
Bill of materials	US$85.00 per prototype tile
Instrumentation	Tektronix TBS1052B oscilloscope; Arduino-based telemetry unit; overhead optical beam counter

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Figure 1: Hardware Architecture and Component Diagram of PZT Footstep Energy Harvesting Tile

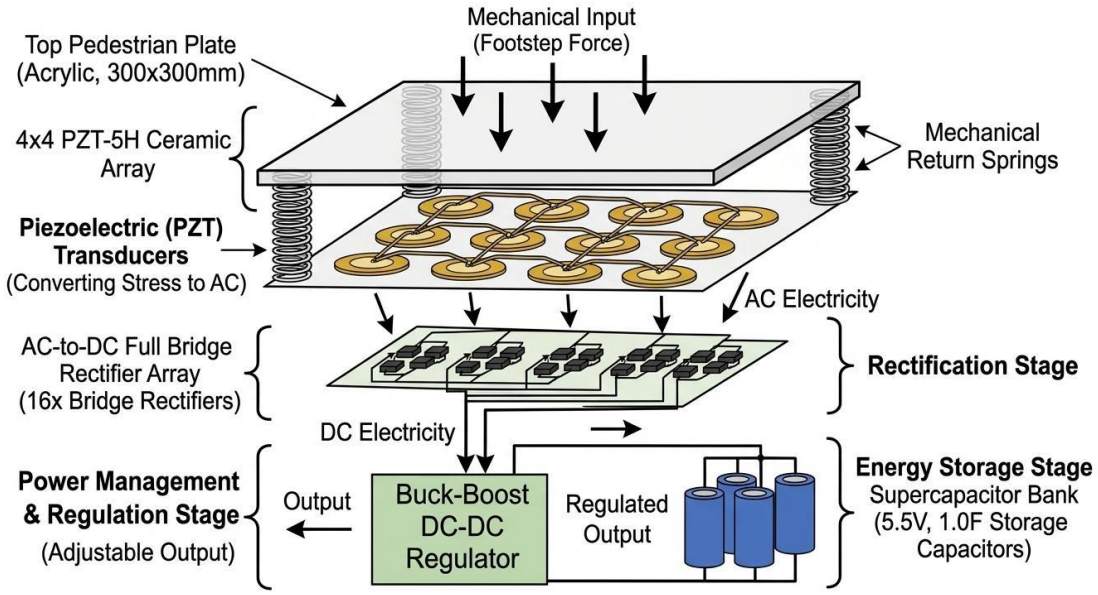


Figure 1. Hardware architecture and component diagram of the PZT footstep energy harvesting tile, showing the top pedestrian plate, mechanical return springs, 4 × 4 PZT-5H ceramic array, rectification stage (16 bridge rectifiers), buck-boost DC-DC regulation stage, and supercapacitor bank (5.5 V, 1.0 F).

Each piezoelectric element was connected to a full-wave Schottky bridge rectifier to convert the generated alternating current (AC) pulses to direct current (DC) (Cascetta et al., 2018). The rectified output was fed into a high-efficiency DC-DC buck-boost converter regulated at a 5 V output (Ottman et al., 2002), which supplied a 5.5 V, 1.0 F supercapacitor bank (Guan & Liao, 2007; Guan & Liao, 2008).

Experimental Setup and Field Deployment

The prototype tile was flush-mounted in the central hallway of the University Engineering Building and observed over a 5-day period (8:00 AM to 5:00 PM). An overhead optical beam counter logged pedestrian traffic to provide the footfall count (N). Data collection was divided into two phases:

- **Controlled weight testing:** participants categorized by mass (50 kg, 65 kg, 80 kg, and 95 kg) stepped on the tile at controlled cadences from 1.0 Hz to 2.5 Hz.
- **Uncontrolled field testing:** natural traffic was logged during class transition intervals (peak traffic of 1,800 to 2,400 steps/hour).

Instrumentation and Data Acquisition

Voltage and current waveforms across fixed resistive loads (100 Ω to 100 kΩ) were recorded using a digital storage oscilloscope (Tektronix TBS1052B) and logged via an Arduino-based telemetry unit.

Power, Energy, and Efficiency Calculations

The instantaneous power delivered to a resistive load (P) was calculated from Ohm's law as:

$$P = V_{peak}^2 / R_L \quad (1)$$

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where V_{peak} is the peak voltage across the optimal load resistance R_L (Cascetta et al., 2018; Ottman et al., 2002). The peak power values reported for the controlled tests (Section 3.1) correspond to the product of the measured peak voltage and peak current. Total energy harvested (E) per footfall was determined by integrating instantaneous power over the duration (t) of mechanical impact:

$$E = \int P(t)\, dt \text{ (integrated from } t = 0 \text{ to } T) \quad (2)$$

Mechanical work input (W_{in}) was defined as:

$$W_{in} = F \cdot d \quad (3)$$

where F is the impact force in newtons and $d = 5$ mm is the vertical tile displacement. Power conversion efficiency (η) was then computed as the ratio of the electrical energy stored (E_{out}) to the mechanical work input:

$$\eta = (E_{out} / W_{in}) \times 100\% \quad (4)$$

Financial Feasibility Analysis

The financial analysis was based on the total bill of materials (BOM) of the single-tile prototype and an assumed 10-tile corridor installation. Projected savings combined direct grid substitution with reduced maintenance overhead for localized battery-powered hallway sensors. The simple payback period was defined as the initial capital expenditure divided by annual net savings and compared against the expected 10-year lifespan of PZT ceramics.

Data Analysis

The relationship between pedestrian mass and peak voltage was examined by ordinary least-squares linear regression on the four mass categories in Table 2. The effect of cadence was expressed as the percentage change in energy accumulation rate between 1.0 Hz and 2.5 Hz.

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RESULTS

Impact Mass and Footfall Frequency Response

Under the mean impact force of 650 N, an average footfall generated a peak output voltage of 14.2 V and an instantaneous power of 28.4 mW. Controlled testing demonstrated a strong linear correlation between pedestrian mass and generated peak voltage (Table 2). Across the 50 kg to 95 kg range, peak voltage rose from 9.8 V to 20.8 V (a 2.1-fold increase) and power output from 11.76 mW to 64.48 mW (a 5.5-fold increase). A linear fit of peak voltage against mass gave a slope of approximately 0.245 V/kg with $R^2 > 0.999$ (n = 4 mass categories).

Table 2. Electrical output of the prototype tile by pedestrian mass. Power output corresponds to the product of peak voltage and peak current.

Pedestrian Mass (kg)	Average Force (N)	Peak Voltage (Vpeak)	Peak Current (mA)	Power Output (mW)
50	490.5	9.8 V	1.2 mA	11.76 mW
65	637.65	13.5 V	1.9 mA	25.65 mW
80	784.8	17.2 V	2.6 mA	44.72 mW
95	931.95	20.8 V	3.1 mA	64.48 mW

Varying the footfall cadence from 1.0 Hz to 2.5 Hz increased energy accumulation rates by 38%, owing to reduced charge dissipation periods across the internal capacitance of the piezoelectric transducers.

Electrical Storage and System Efficiency

The optimum matching load resistance for the PZT array was determined to be 10 kΩ. At this load, the system achieved a maximum mechanical-to-electrical conversion efficiency (η) of 11.4%.

Field Energy Yield and Sensor Operation

During uncontrolled field testing, the average energy harvested per step across a diverse population was 0.95 mWh per footfall. Over an 8-hour operational window recording 12,000 steps, the tile generated a net total energy of:

$$E_{\text{total}} = 12{,}000 \text{ steps} \times 0.95 \text{ mWh/step} = 11.4 \text{ Wh } (41.04 \text{ kJ}) \quad (5)$$

This daily yield successfully maintained a 5 V micro-sensor node (drawing 15 mA continuously) for more than 14 hours without drawing power from the main building supply.

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Financial Feasibility and ROI

The total BOM of the single-tile prototype amounted to US$85.00. For a 10-tile corridor installation (US$850.00 initial capital expenditure) yielding 114 Wh/day, direct grid substitution savings combined with reduced maintenance overhead for localized battery-powered hallway sensors resulted in an estimated payback period of 4.2 years, well within the 10-year expected lifespan of PZT ceramics.

Summary of Key Findings

Table 3 consolidates the principal performance and financial metrics of the prototype.

Table 3. Summary of key performance and financial metrics.

Metric	Value	Conditions
Peak output voltage	14.2 V	Mean impact force of 650 N
Instantaneous power	28.4 mW	Mean impact force of 650 N
Optimum load resistance	10 kΩ	PZT array
Maximum conversion efficiency (η)	11.4%	At the optimum load
Cadence effect	+38% energy accumulation rate	1.0 Hz to 2.5 Hz
Energy per footfall	0.95 mWh	Uncontrolled field testing
Daily energy yield	11.4 Wh (41.04 kJ)	12,000 steps; 8-hour window
Sensor operation	More than 14 h	5 V, 15 mA micro-sensor node
Capital expenditure	US$850.00	10-tile corridor; 114 Wh/day
Payback period	4.2 years	Expected PZT lifespan: 10 years

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DISCUSSION

Interpretation of Principal Findings

The tile's electrical output scales predictably with the applied mechanical load. The strong linear relationship between pedestrian mass, impact force, and peak voltage (Table 2) is consistent with the expected piezoelectric response, in which greater applied stress produces greater charge generation (Anton & Sodano, 2007; Kim et al., 2011). The 38% increase in energy accumulation rate at higher cadences indicates that footfall frequency, in addition to pedestrian mass, is a meaningful determinant of harvest rate, an effect attributed to shorter charge dissipation periods across the internal capacitance of the transducers. This agrees with reports that step frequency influences floor-harvester output (He et al., 2019) and that vertical ground reaction force varies with walking speed (Keller et al., 1996). Together, these findings imply that corridors with dense, fast-moving traffic, such as those observed during class transition intervals, are the most productive deployment locations.

The 10 kΩ optimum load and the 11.4% maximum conversion efficiency establish a quantitative baseline for the series-parallel 4 × 4 PZT-5H configuration. Reported per-step outputs for floor tiles vary widely by transducer type, tile size, and loading mechanism (Asadi et al., 2023; Panthongsy et al., 2018; Sharma et al., 2022; Wang et al., 2021), so comparisons across studies require like-for-like test conditions. The harvested energy of 0.95 mWh per footfall and the 11.4 Wh daily yield at 12,000 steps were sufficient to sustain a 5 V, 15 mA micro-sensor node for more than 14 hours without drawing on the main building supply, supporting the practicality of the system as a decentralized power source for emergency pathway LEDs and IoT environmental sensors.

Economic Implications

At a prototype BOM of US$85.00 per tile, a 10-tile corridor installation requires US$850.00 in capital expenditure and produces an estimated 114 Wh/day. The projected payback period of 4.2 years, which combines direct grid substitution savings with reduced maintenance overhead for battery-powered hallway sensors, falls well within the 10-year expected lifespan of PZT ceramics. This supports the economic viability of scaling kinetic harvesting tiles across high-traffic university corridors. Building-level modeling indicates that piezoelectric flooring can supply only a small fraction of a building’s total energy demand (Li & Strezov, 2014), which supports positioning the tiles as a supplement to the grid and as a power source for low-power loads; case studies of public buildings likewise compare tile costs, lifespans, and savings on a site-specific basis (Elhalwagy et al., 2017; Moussa et al., 2022). The estimate is sensitive to footfall density and local electricity costs, and should be recalculated for each prospective installation site.

Limitations

Several limitations should be considered when interpreting these findings. First, the results derive from a single prototype tile at one location (the central hallway of the University Engineering Building) over a 5-day observation window (8:00 AM to 5:00 PM), which limits generalizability across seasons, building types, and traffic patterns. Second, controlled testing covered four pedestrian mass categories and a cadence range of 1.0 Hz to 2.5 Hz, so behavior outside these ranges was not characterized, and the linear fit in Section 3.1 rests on only four data points. Third, the 10-year lifespan and the 4.2-year payback period are projections; long-term durability under repeated mechanical loading was not tested in this study. Fatigue studies of PZT-5H transducers report appreciable output degradation after millions of loading cycles (Wang et al., 2021), and at 12,000 steps per day a tile would experience roughly 44 million loading cycles over ten years. Fourth, the financial analysis rests on an assumed 10-tile installation and on estimated grid substitution and maintenance savings.

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Future Work

Future work should focus on optimizing hybrid energy management circuits and investigating recycled composite materials for the tile housing to further reduce initial manufacturing costs. Candidate approaches include nonlinear interface circuits such as synchronized switch harvesting on inductor (SSHI) and synchronous electric charge extraction (SECE) (Guyomar et al., 2005; Lefeuvre et al., 2005; Shu et al., 2007), as well as hybrid piezoelectric–electromagnetic–triboelectric harvesters (Tang et al., 2022). Multi-site, longer-duration deployments with larger tile arrays, together with accelerated fatigue testing, would strengthen the evidence base for campus-wide adoption.

CONCLUSION

This study quantified the electrical output, conversion efficiency, and financial feasibility of a piezoelectric footstep energy-harvesting tile in a high-traffic university hallway. Output increased linearly with pedestrian mass and rose further with footfall cadence; at the optimum 10 kΩ load, the system reached a maximum conversion efficiency of 11.4%, and the tile generated an average of 0.95 mWh per step. This yield was sufficient to run emergency pathway LEDs and IoT environmental sensors as a decentralized power source, and a 10-tile installation was projected to pay back its US$850 capital cost in 4.2 years. These results indicate that piezoelectric footstep energy harvesting tiles are technically efficient and economically viable for high-traffic university corridors, subject to validation across additional sites and over longer operating periods.

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REFERENCES

Alshuwaikhat, H. M., & Abubakar, I. (2008). An integrated approach to achieving campus sustainability: Assessment of the current campus environmental management practices. *Journal of Cleaner Production*, *16*(16), 1777–1785. https://doi.org/10.1016/j.jclepro.2007.12.002

Anton, S. R., & Sodano, H. A. (2007). A review of power harvesting using piezoelectric materials (2003–2006). *Smart Materials and Structures*, *16*(3), R1–R21. https://doi.org/10.1088/0964-1726/16/3/R01

Asadi, M., Ahmadi, R., & Abazari, A. M. (2023). Footstep-powered floor tile: Design and evaluation of an electromagnetic frequency up-converted energy harvesting system enhanced by a cylindrical Halbach array. *Sustainable Energy Technologies and Assessments*, *60*, Article 103571. https://doi.org/10.1016/j.seta.2023.103571

Cascetta, F., Lo Schiavo, A., Minardo, A., Musto, M., Rotondo, G., & Calcagni, A. (2018). Analysis of the energy extracted by a harvester based on a piezoelectric tile. *Current Applied Physics*, *18*(8), 905–911. https://doi.org/10.1016/j.cap.2018.04.015

Du, S., Jia, Y., & Seshia, A. A. (2017). Piezoelectric vibration energy harvesting: A connection configuration scheme to increase operational range and output power. *Journal of Intelligent Material Systems and Structures*. https://doi.org/10.1177/1045389X16682846

Elhalwagy, A. M., Ghoneem, M. Y. M., & Elhadidi, M. (2017). Feasibility study for using piezoelectric energy harvesting floor in buildings' interior spaces. *Energy Procedia*, *115*, 114–126. https://doi.org/10.1016/j.egypro.2017.05.012

Guan, M. J., & Liao, W. H. (2007). On the efficiencies of piezoelectric energy harvesting circuits towards storage device voltages. *Smart Materials and Structures*, *16*(2), 498–505. https://doi.org/10.1088/0964-1726/16/2/031

Guan, M. J., & Liao, W. H. (2008). Characteristics of energy storage devices in piezoelectric energy harvesting systems. *Journal of Intelligent Material Systems and Structures*, *19*(6), 671–680. https://doi.org/10.1177/1045389X07078969

Guyomar, D., Badel, A., Lefeuvre, E., & Richard, C. (2005). Toward energy harvesting using active materials and conversion improvement by nonlinear processing. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, *52*(4), 584–595. https://doi.org/10.1109/TUFFC.2005.1428041

He, M., Wang, S., Zhong, X., & Guan, M. (2019). Study of a piezoelectric energy harvesting floor structure with force amplification mechanism. *Energies*, *12*(18), Article 3516. https://doi.org/10.3390/en12183516

Hwang, S. J., Jung, H. J., Kim, J. H., Ahn, J. H., Song, D., Song, Y., Lee, H. L., Moon, S. P., Park, H., & Sung, T. H. (2015). Designing and manufacturing a piezoelectric tile for harvesting energy from footsteps. *Current Applied Physics*, *15*(6), 669–674. https://doi.org/10.1016/j.cap.2015.02.009

Keller, T. S., Weisberger, A. M., Ray, J. L., Hasan, S. S., Shiavi, R. G., & Spengler, D. M. (1996). Relationship between vertical ground reaction force and speed during walking, slow jogging, and running. *Clinical Biomechanics*, *11*(5), 253–259. https://doi.org/10.1016/0268-0033(95)00068-2

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Kim, H. S., Kim, J.-H., & Kim, J. (2011). A review of piezoelectric energy harvesting based on vibration. *International Journal of Precision Engineering and Manufacturing*, *12*(6), 1129–1141. https://doi.org/10.1007/s12541-011-0151-3

Lefeuvre, E., Badel, A., Richard, C., & Guyomar, D. (2005). Piezoelectric energy harvesting device optimization by synchronous electric charge extraction. *Journal of Intelligent Material Systems and Structures*, *16*(10), 865–876. https://doi.org/10.1177/1045389X05056859

Li, X., & Strezov, V. (2014). Modelling piezoelectric energy harvesting potential in an educational building. *Energy Conversion and Management*, *85*, 435–442. https://doi.org/10.1016/j.enconman.2014.05.096

Moussa, R. R., Ismaeel, W. S. E., & Solban, M. M. (2022). Energy generation in public buildings using piezoelectric flooring tiles: A case study of a metro station. *Sustainable Cities and Society*, *77*, Article 103555. https://doi.org/10.1016/j.scs.2021.103555

Ottman, G. K., Hofmann, H. F., Bhatt, A. C., & Lesieutre, G. A. (2002). Adaptive piezoelectric energy harvesting circuit for wireless remote power supply. *IEEE Transactions on Power Electronics*, *17*(5), 669–676. https://doi.org/10.1109/TPEL.2002.802194

Panthongsy, P., Isarakorn, D., Janphuang, P., & Hamamoto, K. (2018). Fabrication and evaluation of energy harvesting floor using piezoelectric frequency up-converting mechanism. *Sensors and Actuators A: Physical*, *279*, 321–330. https://doi.org/10.1016/j.sna.2018.06.035

Safaei, M., Sodano, H. A., & Anton, S. R. (2019). A review of energy harvesting using piezoelectric materials: State-of-the-art a decade later (2008–2018). *Smart Materials and Structures*, *28*(11), Article 113001. https://doi.org/10.1088/1361-665X/ab36e4

Sharma, S., Kiran, R., Azad, P., & Vaish, R. (2022). A review of piezoelectric energy harvesting tiles: Available designs and future perspective. *Energy Conversion and Management*, *254*, Article 115272. https://doi.org/10.1016/j.enconman.2022.115272

Shenck, N. S., & Paradiso, J. A. (2001). Energy scavenging with shoe-mounted piezoelectrics. *IEEE Micro*, *21*(3), 30–42. https://doi.org/10.1109/40.928763

Shu, Y. C., Lien, I. C., & Wu, W. J. (2007). An improved analysis of the SSHI interface in piezoelectric energy harvesting. *Smart Materials and Structures*, *16*(6), 2253–2264. https://doi.org/10.1088/0964-1726/16/6/028

Sodano, H. A., Inman, D. J., & Park, G. (2004). A review of power harvesting from vibration using piezoelectric materials. *The Shock and Vibration Digest*, *36*(3), 197–205. https://doi.org/10.1177/0583102404043275

Song, H. J., Choi, Y.-T., Wereley, N. M., & Purekar, A. (2014). Comparison of monolithic and composite piezoelectric material–based energy harvesting devices. *Journal of Intelligent Material Systems and Structures*. https://doi.org/10.1177/1045389X14530592

Starner, T. (1996). Human-powered wearable computing. *IBM Systems Journal*, *35*(3–4), 618–629. https://doi.org/10.1147/sj.353.0618

Tang, G., Wang, Z., Hu, X., Wu, S., Xu, B., Li, Z., Yan, X., Xu, F., Yuan, D., Li, P., Shi, Q., & Lee, C. (2022). A non-resonant piezoelectric–electromagnetic–triboelectric hybrid energy harvester for low-frequency human motions. *Nanomaterials*, *12*(7), Article 1168. https://doi.org/10.3390/nano12071168

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Volume 1 Issue 3 Pages 2151-2162

Wang, J., Qin, X., Liu, Z., Ding, G., & Cai, G. (2021). Experimental study on fatigue degradation of piezoelectric energy harvesters under equivalent traffic load conditions. *International Journal of Fatigue*, *150*, Article 106320. https://doi.org/10.1016/j.ijfatigue.2021.106320

Wang, S.-H., Tsai, M.-C., & Wu, T.-H. (2021). The analysis and design of a high efficiency piezoelectric harvesting floor with impacting force mechanism. *Crystals*, *11*(4), Article 380. https://doi.org/10.3390/cryst11040380

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