RESEARCH ARTICLE OPEN ACCESS

WALK TO POWER: A Sustainable Energy Solution

Bindhu G V*, Chaithanya M C*, Manushree R*, Monisha T*, Dr.Drakshayini M N**

*(Electronics And Communication Engineering Department, T John Institute of Technology) Email: bindubinduvenki@gmail.com, mcchaithu20@gmail.com, manushreemanu7107@gmail.com, moniishaaa123@gmail.com

**(Head of Department and Associate Professor, Electronics and Communication Engineering Department, T John Institute of Technology)

Email: tjitecehod@tjohngroup.com

--************************--

Abstract:

Recently, the planet has had to deal with significant energy troubles, primarily due to the soaring global energy demand, thus the environment has become the prime topic of the market. The present methodological research aims to produce power from Piezo-conductive human steps as the prime energy source. The mentioned piezoelectric property in some materials is that they produce an electric voltage when they are subjected to mechanical stress, like when someone steps on them. The arrangement of the piezoelectric sensors will be in clusters, and there will be a microcontroller to oversee and control their operations for the purpose of monitoring and regulating. The energy produced will be stored in a lead-acid rechargeable battery, after which it will be provided as either DC or AC through an inverter. The envisioned system will have a monitor that will display the voltage, current, and energy stored in real-time. The testing outputs indicate that converting human footfalls into electrical energy can be done very efficiently, and thus, the electricity can be used on walkways or other areas where people walk a lot. In such a case, the smart rising feet technology could be utilized in places like busy urban transport hubs, educational campuses, and other smart environments that prioritize energy saving. Besides, this approach will reduce our reliance on conventional grid-based power supplies in the future as a result, we will also be in line with the current environmental sustainability initiatives.

Keywords **—Piezoelectric , sustainability, Piezo-conductive, renewable energy, energy harvesting**

--************************--

I. INTRODUCTION

An enormous demand for energy is continuously increasing all over the world because of various reasons such as worldwide population growth, technology expansion, increased movement, and development of urban infrastructure. Conventional power systems that use fossil fuels, although the most common, are causing a lot of pollution and damage to nature through their emissions of greenhouse gases. The reduction of the fossil fuel dependency and the rise of reliance on renewable and sustainable energy sources together with the latter being the most environmentally friendly sources have thus become a global priority and at the same time a necessity. In addition, the energy gap in developing countries and their crowded places further confirms that the use of alternative energy sources that are decentralized and less polluting is necessary—the need for cleaner energy generation methods. Among all renewable sources of energy, the kinetic human activity is still the most underutilized source despite its ubiquitous presence in indoor locations like airports, shopping malls, railway stations, schools, stadiums, and walkways. Powering this huge mechanical movement to generate electrical energy will be at the core of the smart and sustainable infrastructure. Piezoelectric energy harvesting is the approach based on the discovery of the phenomenon by Jacques and Pierre Curie in 1880; it opens the way for converting mechanical stress into electrical energy by means of piezoelectric materials. These materials, when put underneath the walking areas, will be subjected to pressure from the feet and thus will generate electrical output. This generation will be so small that it could only be used for low-power applications and real-time use. The idea of "Walk to Power" is a clear indication of this movement - everyday foot traffic now transformed into substantial energy production.

II. PROBLEM STATEMENT

The energy industry is currently going through a challenging period that is both highly innovative and challenging.

1. Energy Crisis: Many countries are experiencing severe disruptions in their energy supply, and reliance on non-renewable resources is not sufficient to significantly improve domestic conditions.
2. Environmental Impact: Conventional methods of producing electricity, such as standby generators, are a major source of noise and air pollution, which deteriorates the ecosystem.
3. Economic Burden: As fossil fuel prices rise, consumers are feeling the pinch more, which has a negative impact on the infrastructure's overall development..

III. LITERATURE REVIEW

3.1 Prototypes of Piezoelectric Floor Tiles

According to Selim, Yehia, and Saleeb (2024), an experimental floor tile system based on piezoelectricity was developed for the purpose of low-power energy applications. The authors carried out research under the title of "Energy Harvesting Floor Tile Using Piezoceramic Patches" and proved that it is possible to convert the footsteps of the people walking on the floors into measurable electrical power through the use of piezoelectric ceramic patches buried underneath the flooring. The prototype contained rectification and storage circuitry for stabilizing the output produced. The outcome indicated that these kinds of setups can be used for IoT devices that require power and also can be extended to smart infrastructure applications.

3.2 Footstep-Based Piezoelectric sensor implementation

In the paper "Piezoelectric Sensors Pressed by Human Footsteps for Practical Energy Capture", Selim (2024) also opened up a new field of research on the practical deployment of piezoelectric systems. Various tile configurations were set up to test the behavior of the output with different human weights and pressure patterns. A microcontroller-based measurement system was used to monitor the system, allowing for the real-time capture of voltage and step data. The results indicated that piezoelectric sensors are indeed capable of transforming pedestrian activity into electrical energy that can be used and thus can be part of the public flooring system.

3.3 Triboelectric Flooring for Human-Motion Energy Conversion

The idea of a new solid-state energy harvesting flooring based on the triboelectric effect has been presented by Kuntharin and colleagues (2023). The research paper "Smart Triboelectric Floor Based on Calcium-Silicate Carbon Composite" has shown how the walking on floors made of a combination of different materials and layers can produce electric energy by means of charge transfer phenomena. Even though the technology is not absolutely piezoelectric, it still falls under the category of human-motion-powered energy harvesting and gives valuable insights for the incorporation of hybrid smart floor systems in the context of urban smart city planning.

3.4 Hybrid Piezoelectric–Triboelectric Energy Harvesting for Smart Infrastructure

Theoretical physicist Hussain et al. (2025) came up with an idea of a dual-energy harvesting model that combines the characteristics of piezoelectric and triboelectric nanogenerators. The authors explained their theory in the paper "Piezoelectric-Triboelectric Hybrid Nanogenerator for Enhanced Biomechanical Harvesting," where it was demonstrated that the application of both effects together results in a very significant increase in the output efficiency as compared to the case when either one of the effects is used by itself. The study draws attention to the idea of hybrid flooring as a solution that can not only energize the distributed smart infrastructure of a city which comprises sensors, signage, and low-power communication devices but can also help such cities be more eco-friendly.

IV. OBJECTIVES

The main goals of this research are

1. System Development - To design and build a complete piezoelectric step power generation system, which will convert the mechanical energy produced by human movements into electrical energy, with high efficiency.
2. Performance Optimization - To adjust the configuration of the system in a way that maximum power generation is attained while cost and continuity aspects are also taken into consideration.
3. Energy Storage Integration - To utilize efficient energy storage methods that can not only capture but also store the produced electrical energy for using it in practical applications.
4. Real-time Monitoring - To create a monitoring system that will deliver immediate feedback regarding the electrical parameters and overall performance of the system.
5. Practical Implementation - To showcase the system's capability for commercial applications in diverse environments and scenarios.
6. Sustainability Assessment - To compare the environmental and economic advantages of the proposed system with those of conventional energy sources.

V. PROPOSED METHODOLOGY

5.1 System Architecture

The "Walk to Power" system is built on a structured design for energy collection, storage, and utilization. The architecture of the system is comprised of different hardware and control units that are interlinked and that participate together in the process of converting the mechanical energy from footsteps into electrical energy which is usable.

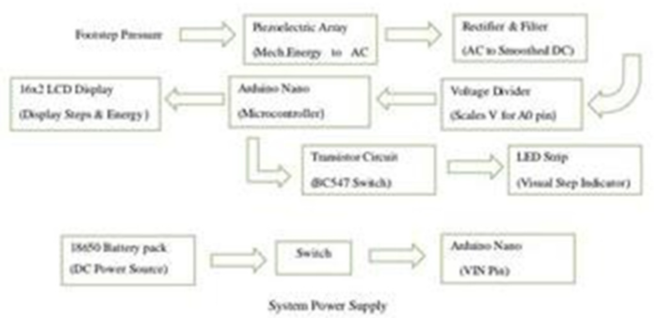

Figure 5.1. Block diagram of the Walk-to-Power sustainable energy system.

5.2 Energy Conversion Process

The electricity harvesting and changing process go as follows:

1. Mechanical Input: Footsteps give mechanical pressure to the piezoelectric tiles that are beneath the surface.
2. Piezoelectric Conversion: The piezoelectric material through the direct piezoelectric effect generates an electrical voltage by transforming mechanical strain.
3. Signal Conditioning: The alternating current (AC) voltage produced is changed into direct current (DC) by the circuits of rectification and voltage regulation.
4. Energy Storage: The regulated DC power is stashed away in a battery or supercapacitor, which is rechargeable, depending on the need.

5. Power Distribution: The energy that is stored can be used to power the load or can be transferred to secondary devices when needed.

5.3 Control System

An Arduino Uno-based microcontroller is the control unit that takes care of:

- the efficiency of energy harvesting
- battery charging
- load management
- LCD monitoring
- safety functions

5.4 System Integration

The whole system combines both hardware and embedded software to make a flow, automated and sustainable energy harvesting system that can be used in the real world. Examples of such applications are smart walkways, public areas, and IoT-based infrastructure.

VI. CIRCUIT DESIGN

6.1 Circuit Architecture

The electrical architecture is composed of four principal functional subsystems:

(A) energy harvesting part,
(B) power conditioning and storage,
(C) measurement & control, and
(D) user interface and load output.

The final schematic in Figure 7.1 is meant to illustrate these four blocks along with the interconnections explained later.

A. *Energy harvesting front-end (piezo array)*

• The mechanical-to-electrical conversion involves the use of several piezoelectric discs or tiles which are connected in a series-parallel topology to give a practical combination of voltage and current. For instance, 4 strings of 5 discs in series and then paralleled — this increases the current and keeps the voltages within the limits of the components. • An AC pulse is produced by each piezo element (from tens of millivolts to several volts depending on the element and force). The piezo leads are connected to a common input node through short, shielded wiring.

B. *Power conditioning & Storage*

• Bridge rectifier: A full bridge (for instance, four × 1N4007 or Schottky diodes for less drop) transforms the piezo electrical pulses into d.c pulsating. Low-vfSchottky diodes (say, SR560) or a synchronous rectifier circuit can be used for high efficiency.

• Surge clamp & filtering: High-frequency spikes are reduced by an RC snubber and a small series resistor (10–100 Ω). A TVS diode (for example, the SMBJ series) shields lower power electronics from damage due to overvoltages that occur during transients.

• Smoothing capacitor: A large electrolytic or polymer capacitor (for instance, 1000 µF /16 V) cleans up the rectified waveform to get a stable DC converter input voltage.

• Energy buffer (supercapacitor): A supercapacitor (recommended 1 F @ 5.5 V or higher) gives fast charge/discharge, low-impedance buffering to catch short, high-power pulses from footsteps.

• Power management / converter: A DC-DC module (adjustable boost/buck, for example, the MT3608 boost or an efficient buck/boost module) controls the buffered voltage to stable rails: +5 V for Arduino and peripherals and battery charge voltage for a storage battery. If charging a Li-ion battery, use a dedicated charge controller (for example, TP4056) or an appropriate lead-acid charger circuit for lead-acid batteries.

• Blocking & isolation diodes: Schottky diodes block the reverse current from battery to harvester and separate multiple energy storage elements.

C. *Measurement & control (Arduino Uno)*

• Voltage sensing: By using a voltage divider made up of a 100 kΩ resistor (R1) and a 47 kΩ resistor (R2), the DC rail is reduced to the level of the Arduino ADC. A 10 kΩ resistor and a 100 nF capacitor should be connected or added at the ADC pin for anti-aliasing and input protection.

• Step detection: The piezo pulse (which has gone through the rectifier and a small RC peak detector) can be either sent through a comparator (like LM393) or taken directly by the ADC. A hardware comparator guarantees solid thresholding and produces interrupts for the Arduino.

• Control logic: The Arduino implements the charge control strategy, steps counting, instantaneous power and energy accumulation calculation, and switching devices (e.g., MOSFET gate) control signal issuing to connect/disconnect load.

D. *User interface & loads*

• I2C LCDs (3 × 16 × 2): Using an I ² C multiplexer (TCA9548A) or addressable I ² C backpacks permits three individual displays on the same bus. If the backpack allows address selection, you can also use different addresses. SDA → A4, SCL → A5 on Arduino Uno.

• Loads: Low-power loads such as LED arrays, sensor nodes, and signage are supplied with power from the regulated 5 V rail or through a dedicated inverter if AC output is required. • Microcontroller: Arduino Uno (ATmega328P)

• I2C multiplexer: TCA9548A (for three identical LCD addresses) or MCP23017-based backpack modules

• Protection: TVS diode, 1 A fuse, transient resistor.

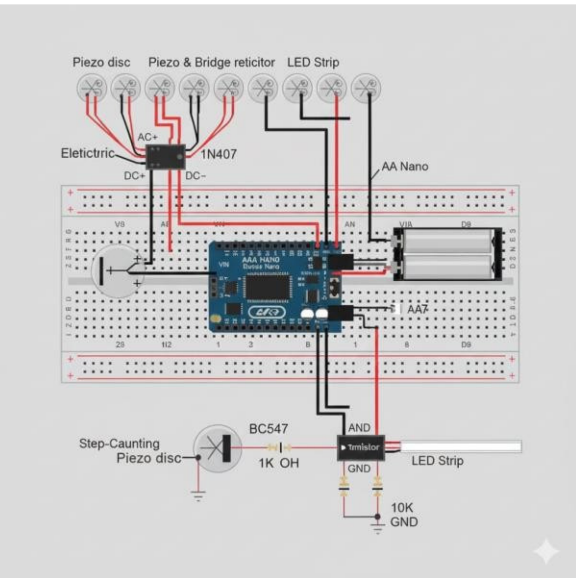

Figure 6.1 Circuit Architecture

6.2 Circuit Operation

Below is a stepwise operational description with practical signal conditioning and control details. Each numbered step corresponds to the signal path shown in the schematic.

1. *Mechanical excitation and AC generation (piezo stage)*

A footstep compresses a piezo tile; the element generates a transient AC voltage pulse. Typical open-circuit peaks vary widely (0.5 V–20 V) depending on the element and applied force. The pulse duration is short (tens to hundreds of milliseconds).

2. *Rectification and peak capture*

The piezo outputs from all tiles are combined via the series–parallel network and fed to the full-bridge rectifier. The rectifier converts the AC pulses into unipolar pulses. Using Schottky devices reduces the forward voltage loss and improves capture efficiency for low-voltage pulses.

3. *Pulse smoothing and buffering*

Pulsating DC is first filtered by a small series resistor and the smoothing capacitor (Cfilter, e.g., 1000 μF) to produce a quasi-DC rail. Because a single step may not fully charge the capacitor to the converter input threshold, a supercapacitor provides a larger energy sink so accumulated pulses quickly raise the available energy level.

4. *Voltage regulation & power conversion*

The buffered DC feeds the DC-DC converter (boost or buck/boost) which produces a stable 5 V rail for control electronics and small loads. The converter should be enabled only when the buffer voltage exceeds a set threshold to avoid brownouts.

Use a voltage supervisor or Arduino-managed MOSFET to connect the converter only when sufficient energy is available (threshold hysteresis avoids oscillation). Example thresholds: enable at 6.0 V, disable at 4.5 V.

5. *Battery charging and storage management*

Excess energy goes to the long-term storage element, which can be a lead-acid battery or a Li-ion battery, through a charge controller. If using a lead-acid battery, you can use either a simple multi-stage charger or a CC/CV circuit suitable for that battery chemistry. A blocking diode should be added to prevent current from flowing back from the battery to the harvester at night. - In a mixed storage system, the super capacitor charges first in a very quick process. After that, a small amount of current goes to the battery based on its constant demand.

6. *Sensing, step detection, and control (Arduino)*
Methods for step detection:

Comparator interrupt: A rectified but unfiltered piezo pulse is sent to a comparator with an adjustable threshold (for example, 0.5-1.0 V). An interrupt from the comparator increases the step count and records the time of events.

ADC sampling: ADC sampling occurs at specific intervals (for example, 500-1000 Hz) to capture the pulse signal. Software peak detection with hysteresis will help reduce false triggers.

The Arduino measures the DC rail voltage using a voltage divider and ADC, calculates the instantaneous power using $P=V\times I$ (if current is measured), or estimates the energy contributed per step by calculating the charge added to the storage buffer. The Arduino also updates the displays and logs cumulative energy.

7. *User interface and load control*

The Arduino sends voltage readings, step counts, and accumulated energy to three separate 16×2 I²C LCDs (using a TCA9548A multiplexer or separate addresses).Once the stored energy exceeds a user-defined threshold, the Arduino activates the loads (using a MOSFET or a relay). For AC loads, an inverter only turns on if the battery SOC and buffer voltage are within safe limits.

VII. Experimental Results

7.1 Performance Evaluation

The experimental evaluation of the" Walk to Power" system demonstrates its effectiveness in converting mechanical energy from steps into usable electrical power.

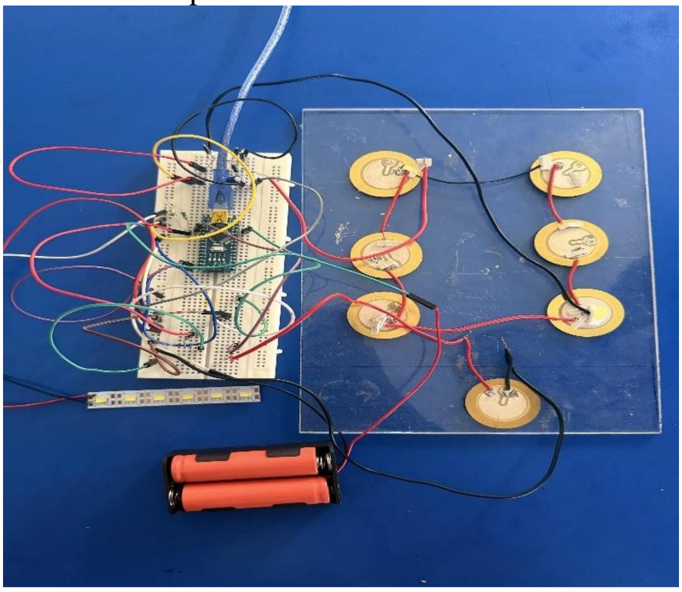

Figure 7.1 Representation of experimental affair

7.2 Key Performance Metrics

Power Generation
-Average power per step 0.5- 2.0 watts
- Peak voltage generation 3- 12 volts
- Energy conversion effectiveness 15- 25
System Response
- Response time< 100 milliseconds
- Recovery time< 500 milliseconds
-functional continuance> 100,000 cycles
Energy Storage
- Battery charging effectiveness> 85
- storehouse capacity 12V, 7Ah lead- acid battery
- Discharge effectiveness> 90

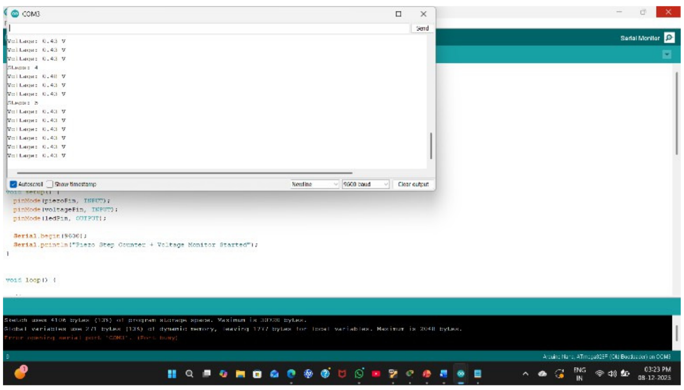

Figure 7.2 Output display on serial monitor

7.3 Environmental Testing

The system was tested under colorful environmental conditions

- Temperature range-10 °C to 50 °C
- moisture range 20 to 90 RH
- cargo variations 50 kg to 150 kg per step

7.4 Performance Analysis

The experimental results demonstrate that the system successfully converts mechanical energy from mortal steps into electrical energy. The power affair varies with the applied force, walking speed, and frequency of steps. The system shows harmonious performance across different stoner weights and walking patterns.

VIII. FUTURE ENHANCEMENTS

8.1 Material Improvements

- Development of more efficient piezoelectric materials
- Integration of advanced composite materials
- Exploration of bio-compatible energy harvesting materials

8.2 System Optimization

- Implementation of maximum power point tracking (MPPT)
- Advanced energy storage solutions
- Wireless power transmission capabilities

8.3 IoT Integration

- Internet of Things connectivity for remote monitoring
- Cloud-based data analytics
- Predictive maintenance systems

8.4 Scalability Enhancements

- Large-scale deployment strategies
- Grid integration capabilities
- Standardization of installation procedures

CONCLUSION

The "Walk to Power: A Sustainable Energy Solution" research presents an innovative approach to renewable energy generation through piezoelectric footstep power harvesting. This technology shows how mechanical energy from everyday human activities can be converted into usable electrical power. It offers a practical way to meet increasing energy demands while supporting environmental sustainability. The experimental results confirm the system's effectiveness, demonstrating consistent power generation from pedestrian movement, efficient energy storage, and real-time monitoring capabilities. The system’s modular design and scalable structure make it suitable for various uses, ranging from small-scale projects to large urban infrastructure developments.

The environmental benefits of this technology are significant. It provides a clean, renewable energy source that produces no emissions and operates silently. The economic benefits, including low operating costs and long-term energy savings, make it an appealing alternative to traditional power sources. Additionally, involving communities in sustainable energy generation fosters environmental awareness and participation in green technology initiatives. The wide range of potential applications includes transportation hubs, commercial spaces, smart cities, and educational institutions. This variety showcases the versatility and potential impact of the technology. As urban populations grow and energy demands rise, footstep power generation offers a decentralized, sustainable solution that can complement current energy infrastructure.

Although challenges like initial setup costs and improving material efficiency remain, advancements in piezoelectric materials and energy storage technologies are enhancing the feasibility and effectiveness of this approach. Integrating IoT capabilities and smart grid technologies further supports large-scale deployment and optimization. This research adds to the growing knowledge in renewable energy harvesting and lays the groundwork for future developments in sustainable urban energy solutions.

The "Walk to Power" system represents a meaningful step toward creating smarter, more sustainable cities where human activity contributes to the energy ecosystem, reduces carbon footprints, and fosters a more environmentally responsible future. The project's success shows that innovative engineering can effectively tackle environmental challenges while delivering practical benefits to society. As we move toward a more sustainable future, technologies like footstep power generation will increasingly play vital roles in building resilient, eco-friendly energy systems that harness human activity for everyone's benefit.

REFERENCES

[1] Boby, K., Paul, A. K., Anumol, C. V., & Nimisha, K. K. (2014). Footstep power generation using piezoelectric transducer. *International Journal of Engineering and Innovative Technology*, 3(10), 264-267.

[2] Raja, R. R., & Mathew, S. (2014). Power generation from staircase (steps). *International Journal of Innovative Research in Science, Engineering and Technology*, 3(1), 9091-9097.

[3] Prabaharan, R., Jayramaprakash, A., & Vijay Anand. (2013). Power harvesting by using human foot step. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(7), 3001-3009.

[4] Vino, A. P. J. A. (2011). Power generation using footstep. *International Journal of Engineering Trends and Technology*, 1(2), 25-27.

[5] Taliyan, S. S., Biswas, B. B., Patil, R. K., & Srivastava, G. P. (2010). Electricity from footsteps. *Reactor Control Division, Electronics & Instrumentation Group*, 21, 1-4.

[6] K. Selim, H. M. Yehia, and D. A. Saleeb, "Energy harvesting floor tile using piezoelectric patches for low-power applications," Journal of Vibration Engineering & Technologies, vol. 12, no. 7, 2024.

[7] K. K. Selim, "Piezoelectric sensors pressed by human footsteps for practical energy capture," Energies, vol. 17, 2024, Article 2297.

[8] K. Mou, et al., "Using piezoelectric technology to harvest energy from pavement mechanical loads: A review," [Journal Name], 2025.

[9] M. Asadi, et al., "Footstep-powered floor tile: Design and evaluation of an energy-harvesting tile (frequency up-conversion technique)," [Journal Name], 2023.

[10] L. Olatomiwa, et al., "Piezoelectric floor mat systems for sustainable energy harvesting," Saudi Journal of Engineering & Technology, 2025.

[11] K. K. S. Owindi and N. A. Hemali, "Piezoelectric energy harvesting from human energy waste: A review of materials, performance, and environmental potential," Journal of Environmental Professionals Sri Lanka, 2025.

[12] K. A. Chandra, S. Narayan, K. A. Mamun, A. A. Chand, D. Prasad, and M. R. Ahmed, "A review of footstep energy harvesting systems," IEEE Access, 2025.

[13] "Smart footstep energy harvesting system with real-time monitoring," Journal of Footstep-Sensor Networks, 2024.

[14] R. Nandhagopal, J. K. Kumar, B. S. J. Rahman, and S. M. Kannan, "Advanced footstep-based power generation system using piezoelectric sensors and IoT," International Journal of Scientific Research in Science and Technology (IJSRST), Jan.–Feb. 2025.

[15] "Harvesting footstep energy: Piezoelectric sensor — A practical implementation and analysis," International Journal of Creative Research Thoughts (IJCRT), Oct. 2024.

[16] "Energy harvesting using piezoelectric floor tiles," International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), 2024.

[17] "Floor tile energy harvester: Design, analysis and practical considerations," Asian Engineering Journal (AEJ), 2025.

[18] G. Wang, G. Hu, and J. Liang, "Low-cost and compact piezoelectric energy harvesting floor tile for battery-free wireless smart pavement," [Conference/Journal Name], 2025.

[19] "Piezoelectric energy harvesting from footsteps," IRE Journals, 2025.

