Assess the Technical Applicability of Piezoelectric Floor Tile Energy Harvesting as a Renewable Energy Source for Public Buildings in Sri Lanka

J. A. D. V. S. W. Jayasundara[1*], W. N. Kawmudi[1], U. M. Samararathne[1] and I. U. Atthanayake[2]

[1]Department of Quantity Surveying, Faculty of Built Environment and Spatial Sciences (FBESS),General Sir John Kotelawala Defence University, Sri Lanka
[2]Department of Mechanical Engineering, Faculty of Engineering (FOE), Open University Sri Lanka
[*]38-bqs-0015@kdu.ac.lk

Abstract - With rising energy demands and diminishing fossil fuel resources, there is an urgent need for sustainable and alternative energy solutions, especially in developing countries like Sri Lanka. High-traffic public buildings present an untapped opportunity to harness human kinetic energy through piezoelectric floor tiles, offering a supplementary renewable energy source. Piezoelectric energy harvesting systems convert mechanical pressure into electrical energy, and when integrated into pedestrian zones of public spaces, they can contribute to localized energy needs. However, challenges such as low energy conversion efficiency, system durability, maintenance concerns, and limited public awareness hinder their widespread adoption. Addressing these concerns, this research evaluates the technological feasibility of implementing piezoelectric floor tiles in Sri Lanka public buildings, using the Colombo Fort Railway station as a case study. Employing a mixed-method approach, including energy output estimations, performance simulations, and stakeholder surveys. The study assessed the potential of piezoelectric flooring to contribute to the daily energy demands of low-power appliances in high-traffic public spaces. The analysis estimates that approximately 83Wh/day could be generated from 200,000 pedestrian footsteps, which is sufficient to power low-consumption devices such as LED, CCTV cameras or smart panels. Comparative analysis reveals piezoelectric floor tiles' unique advantage for indoor applications, maintaining consistent output regardless of sunlight conditions. Environmental assessments demonstrate significant reductions in indirect carbon emissions compared to conventional power generation methods. When combined with other renewable energy sources like solar power, this technology shows great potential as an additional solution, even though it is insufficient as a stand-alone energy source. The stakeholder analysis also revealed a gap in awareness, emphasizing the importance of education and engagement initiatives to support future adoption. As a conclusion, the study highlights the technical viability of piezoelectric floor tiles as a supplementary renewable source for Sri Lankan public infrastructure and recommends pilot projects and further research and development to test feasibility and performance. The finding contributes to the foundational knowledge and policymaking efforts required to support innovative energy solutions like piezoelectric energy harvesting in the Sri Lanka context.

Keywords: Piezoelectric floor tile, Energy harvesting, Sustainable energy, Technological feasibility, Sri Lanka

1 Introduction

The growing global demand for renewable energy is driven by limited fossil fuel reserves and the urgent need to reduce environmental impacts. According to the International Energy Agency (IEA), global power consumption is expected to increase by nearly 80% between 2012 and 2040, emphasizing the necessity for a clean energy revolution to improve energy security, sustain economic growth, and mitigate climate change (Hybrid & Graphics, 2023). In Sri Lanka, over 50% of electricity generation relies on fossil fuel imports, imposing a significant economic burden due to limited indigenous resources (Development Bank, 2017). Consequently, Sri Lanka must prioritize renewable energy development to meet rising demand and reduce dependence on imports.

Piezoelectric energy harvesting, which converts mechanical pressure from human movement into electrical energy, presents a promising yet underutilized renewable source, especially in public spaces where foot traffic is high (Solban & Moussa, 2019). Research indicates that piezoelectric floors could power electrical devices like lighting and display systems in public infrastructure, with potential applications extending to indoor environments (Elhalwagy et al., 2017); (Yingyong et al., 2021). Despite its potential, this technology remains largely unexplored within Sri Lanka's public building sector.

This study assesses the technological feasibility and technical performance of integrating piezoelectric energy harvesting floors in Sri Lankan public buildings, comparing them with traditional renewable sources like solar energy. The research highlights the, potential and resilience that piezoelectric systems could offer, promoting sustainable energy solutions aligned with global goals such as the United Nations' "Affordable and Clean Energy" initiative (United Nations Development Programme, 2023).

2 Literature review

Energy harvesting converts wasted ambient energy like vibrations, heat, and human movement into usable electricity (Du et al., 2023); (Song et al., 2020). Mechanical energy is ideal due to its availability and density. Piezoelectric harvesting offers high efficiency, durability, and simplicity, making it practical for real-world use (Ahmed et al., 2020); (Rashmi et al., 2023); (Song et al., 2017).

The process of piezoelectric energy harvesting typically encompasses three main phases of energy transformation, as illustrated in the Fig. 1. energy flow diagram. These stages represent the fundamental steps through which mechanical energy is captured and converted into usable electrical power using piezoelectric materials and devices.

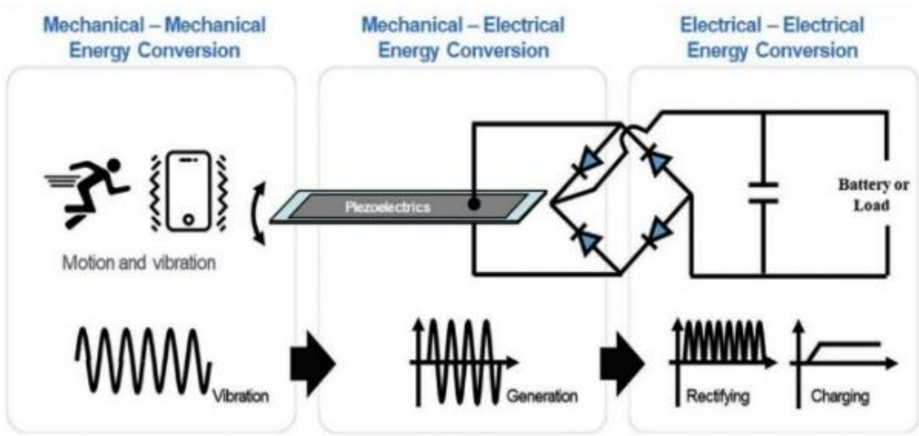

Fig. 1. Energy Conversion and Flow Diagram of Piezoelectric Energy Harvesting
Source: (Song et al., 2020)

Several global case studies highlight the practical applicability and efficiency of piezoelectric tiles in generating clean energy from foot traffic while reducing dependency on non-renewable energy sources. At Macquarie University, tiles installed in only 3.1% of the library floor space generated up to 9.9 MWh/year, showcasing their potential in high-traffic zones despite high costs (Li & Strezov, 2014). KLIA explored adoption factors using the TEMIF model (Chew et al., 2017), while installations in Portugal, Japan, and the Netherlands demonstrated energy savings up to 65% in bridges and clubs (Solban & Moussa, 2019) in Kuwait, 209.9 kWh/week was generated on sports tracks (Khalil, 2020).

Egypt's Rod El-Farag Metro station achieved 99.9% savings, with Wayenergy tiles generating 4560 kWh/day (Moussa et al., 2022). These examples support the study's objectives: evaluating piezoelectric tiles' potential to produce renewable energy and assessing their effectiveness as an alternative to traditional energy methods in high-footfall urban interiors. There are several varieties of piezoelectric tiles, as illustrated in Table 1.

Table 1. Piezoelectric Floor Manufacturers

	Company	**Average generating Power**
1	Pavegen	5W continuous power for footstep
2	Wayenergy	10W per step
3	Energy floors	35W/315W

Source: (Elhalwagy et al., 2017a); (Sharma et al., 2022)

This summarizes piezoelectric tile types based on their technical features and summarizes data from worldwide firms' product specifications for piezoelectric tiles. Also, shows the characteristics of different types of piezoelectric tiles, including size, energy output. (Solban & Moussa, 2019).

Public buildings in Sri Lanka serve as key spaces for public engagement, cultural expression, and social cohesion, blending colonial and modern architectural styles with climate-responsive features like high ceilings and verandas. Despite traditional materials, modernization has led to increased use of mechanical systems such as air conditioning (Gang et al., 2015). Efficient energy management remains a challenge, with studies highlighting the need for balance between environmental, social, and economic factors (Ozgun, 2020). Adaptive reuse of historic buildings offers sustainable solutions by reducing energy consumption, emphasizing user engagement amid global energy concerns (Ariyarathna et al., 2023); (Fouda et al., 2021).

Sri Lanka's public buildings face increasing energy demand due to modernization yet lack context-specific research. A comprehensive strategy addressing social, economic, and environmental factors is essential. Global studies (Alahakoon et al., 2022); (Catrini et al., 2020); (Pavlović et al., 2021) highlight the need to explore innovative renewable energy solutions locally.

3 Methodology

This study presents a mixed-methods approach to assess technical feasibility of piezoelectric energy harvesting in Sri Lankan public buildings. It involves analyzing energy needs, foot traffic data, product specifications, and stakeholder input through qualitative and quantitative methods. Using purposive sampling, the study adopts a pragmatic philosophy, combining technical and social analyzes for feasibility assessment.

Population and sample assessed piezoelectric energy harvesting in Sri Lankan public buildings including schools, universities, libraries, transport hubs, and museums – a representative sample of industry professionals, suppliers, and stakeholders from Sri Lanka and abroad will be surveyed. Respondents will be randomly selected from the industry.

a. Data Collection Methods

Evaluate the feasibility and effectiveness of piezoelectric energy harvesting in Sri Lankan public buildings, the study utilized two main data collection methods to gather comprehensive and reliable information. These methods ensured both practical field insights and theoretical background data for analysis.

In this study, a structured questionnaire was distributed to academic and industry professionals in Sri Lanka’s building services sector to assess the technological feasibility of piezoelectric energy harvesting [Refer annexure A]. It was designed for clarity and accessibility, incorporating input from both groups to accommodate varying levels of prior knowledge. 50 questionnaires were distributed via Google Forms and in person, targeting 30% industry experts and 20% academic professionals. As above-mentioned this survey aimed to assess the technological feasibility, compared to solar energy, and implementation potential of piezoelectric floor tiles in Sri Lanka. It included open- and close-ended questions across two sections: respondent background and topic-specific insights, tailored to academic and industry groups.

Semi-structured interviews were conducted with renewable energy experts using purposive sampling, both in person and online. Open-ended questions covered two sections, similar to the questionnaire. Interviews with piezoelectric tile suppliers focused on the legal, and social feasibility of implementing such systems in Sri Lanka. Sessions were recorded for accuracy and reference.

Document review of existing academic literature, technical reports, case studies, and government policies related to renewable energy technologies, including piezoelectric floors and solar. Furthermore, include technical data on energy output, efficiency, and cost from existing piezoelectric projects and compare it with other renewable technologies (ex: solar).

There is a need to select the most suitable public building to validate this research subject and findings. Transportational hubs were the best option to validate this research according to higher foot traffic volume. Within the proportional number of buildings from each group, using purposive sampling evaluated the applicability of this piezoelectric energy harvesting technology.

Colombo Fort Railway Station, established in 1908, is the central transit hub in Sri Lanka's capital, featuring 10 platforms, waiting areas, utility rooms, and accessible facilities (Colombo Fort Railway Station, 2024). As a key public space, it functions beyond transportation serving as a commercial and social hub with diverse patterns, including daily commuters during peak hours and leisure travellers on weekends. Serving nearly 200,000 passengers daily, the station reflects high public usage (Colombo Fort Railway Station, 2024). Factors such as city population, tourism, economic activity, and transport accessibility influence its foot traffic. This high traffic volume poses challenges in management but also presents strong potential for sustainable innovations like piezoelectric energy harvesting through floor tiles (Gang et al., 2015).

b. Data Analysis Methods

Content analysis was used to examine qualitative data from interviews and questionnaires, supporting the study's goal of exploring piezoelectric energy implementation in Sri Lanka, while also contributing to assessing its technological feasibility. Some analysis was based on assumptions due to limited practical evaluation during data collection. Technological possibility, was conducted using Sri Lankan government frameworks and a case study at Colombo Fort Station to assess implementation feasibility. Below energy calculation establish a framework to estimate piezoelectric energy generation in Sri Lankan public buildings using foot traffic data, energy per step, and system efficiency.

-Footsteps = Number of average pedestrian steps per day
-Energy per steps = Average joules harvested per step (J)
-Efficiency = System efficiency
-1Wh = 3600J

$$\boxed{\text{Daily energy (Wh)} = (\text{Footsteps x Energy per step x Efficiency}) / 3600} \quad (1)$$

Source: Rumman & Elnaklah, (2024); Selim et al., (2024) Equation 1, assumes a linear foot traffic-energy harvesting relationship, which is that the energy generation increases proportionally with the number of footsteps (Elhalwagy et al., 2017b). And the average steps in Colombo fort railway station was obtained by primary and secondary resources in accordance with the studied time period. For the average energy generated per step has obtained from research studies & real-time suppliers' interviews (Azmi & Adnan, (2024); Pavegen, (2025)). Efficiency is included to account for electrical losses in rectification, storing and transferring (Yue & Du, 2024).

This simulation results were compared against available real-world implementations, such as the piezoelectric pilot project at Japan-Tokyo station. Which reported average outputs 10-15Wh/day per m^2 under heavy foot traffic [(C et al., 2017; S et al., 2024; Thanach-Issarasak et al., 2021). However, the model outputs for this case study project fall within a similar scope order of magnitude, thereby providing this extracted equation for this study validation.

4 Data Analysis

a. Analysis Of Technological Feasibility by Validation Using Public Buildings in Sri Lanka

A simulated example was created based on important criteria, including densely populated, high-traffic regions (the Colombo Railway Station in particular) and other carefully chosen public areas, in order to verify the technological viability of this study.

The following assumptions were made:

- Average energy output per Footstep: 2 – 5 joules (Selim et al., 2024)
  Assumed minimum footsteps are equal to passenger count.
- Energy tile efficiency: 50% (Selim et al., 2024)
  Assumed 50% energy loss to storage and conversion procedures.
  According to actual parameters and above assumptions,

The estimated daily energy output is:

[Please note that 3J/step at 50% efficiency chosen as conservative midpoint to avoid over-estimation in the feasibility analysis]

Daily energy output = 200,000 x 3 J x 0.5/3600
= 300,000 J (or 83.33 Wh)

- Daily footsteps: 200,000 (Colombo Fort Railway Station, 2024)

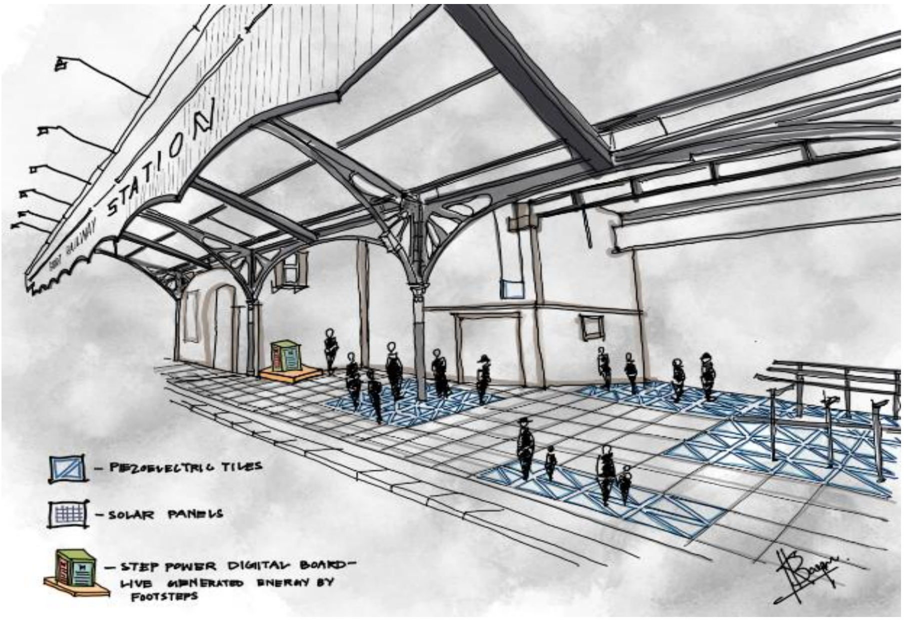

Fig. 2. Proposed Piezoelectric Flooring for Fort-Railway station
Source: Assumptions and interviewee data

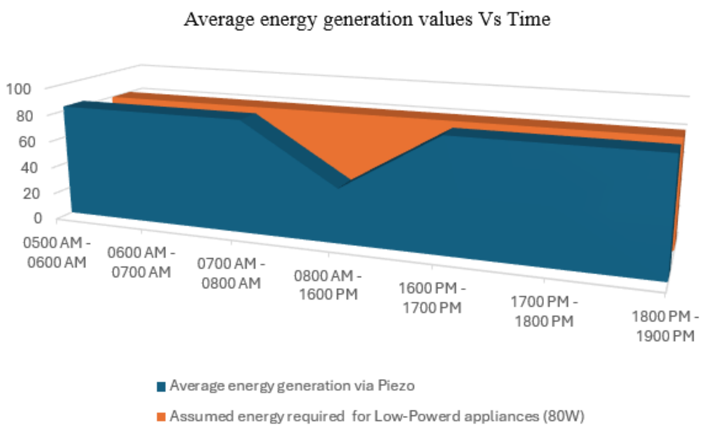

Fig. 3.

Technically, by evaluating the above simple analysis and graph detail, energy generation fluctuates across the day, with peaks corresponding to morning and evening rush hours (05:00am-08:00am and 16:00pm-19:00pm). This trend aligns with Colombo Fort commuter inflows, indicating that piezo harvesting may provide a predictable daily energy curve useful for low-power appliances load planning. So, using this technology some amount of energy can be harvested to cover up targeted energy demand. Following table will provide a summary for projected energy yields against some potential devices that can compatible.

Table 2. Projected energy yields & device compatibility

Device	**Typical Power Rating**	**Operating hours Supported (Per day) with 83.33Wh**
Ceiling Fan (60W)	60 W	~1.4 hours
LED Tube Light (15W)	15 W	~5.5 hours
CCTV Camera (10W)	10 W	~8.3 hours
Mobile Charging (5W)	5 W	~16.6 hours

b. Comparison with Solar Energy

Energy generation from a solar PV panel under Colombo's average solar irradiance of ~5.0kWh/m^2/day(SLSEA, 2022). Assuming a commercial panel efficiency of 18%, and this would yield ~900Wh/day per m^2, which is an order of magnitude higher than piezoelectric tiles. Nevertheless, unlike solar panels, piezo systems can independently work on any weather conditions and directly from foot traffic.

The above bar chart shows that general comparison between both systems, main concern of this chart is to demonstrate the applicability of this piezoelectric floor tile against solar systems. While solar panels currently offer higher efficiency due to more advanced technology, piezoelectric systems have a lower environmental impact, suggesting future potential as technology improves, according to expert opinions. Interviewees noted major practical challenges for the technological feasibility of piezoelectric tiles:

- Lack of skilled engineers
- Limited material availability
- Low energy conversion efficiency

Maintenance issues due to unawareness; are the main challenges when implementing this technology into Sri Lanka

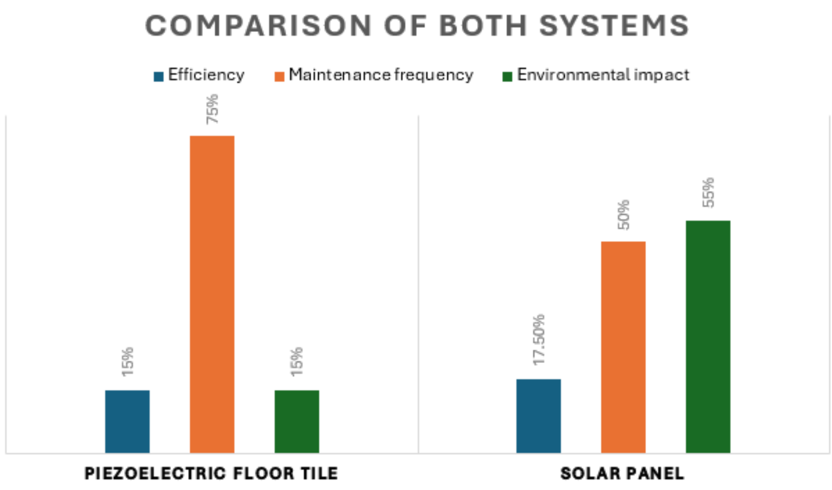

Fig. 4. General comparison between Solar and Piezo
Source: Ambrożkiewicz et al., (2023); Antwi et al., (2024); Verma et al., (2022); Zhang et al., (2024)

As previously mentioned, piezoelectric tiles have several long-term benefits as well. Environmental Benefits (Reduction of using fossil fuels) (Mohammed et al., 2024), Energy independence (Innovative energy contribution for country demands) (Uvaraj Mane et al., 2024), Public awareness (Innovative energy awareness) (Padmanegara Putra et al., 2024).

Piezoelectric tiles can power low-energy appliances but face durability and efficiency challenges in tropical climates; hybrid integration with solar panels is recommended for better energy reliability.

c. Technological Feasibility Analysis Based on Interview and Questionnaire Findings

Awareness and Understanding

About more than 50% of academics and industry professionals are already familiar with the concept, showing moderate readiness. However other remaining parties still remain unfamiliar, indicating that for public-scale deployment such as Fort station, awareness campaigns and pilot demonstrations would be essential to build this stakeholder trust.

Challenges Identified

Higher initial cost woold be the most significant matter for these kinds of projects. Most of professionals have suggested to have this as research & development project or PPP funding. Lack of expertise, 65% of respondents have less expertise on this technology, therefore training programs, campaigns or some introduction courses would be more effective on this. Maintain difficulties also raised challenge throughout the interviews, so the suggested way is to have more durability testing and integrated ways to implement with this technology.

Applicability by Building Type

Public buildings like railway stations allocated as moderated benefited as per the respondent responses, while commercial spaces may show faster returns, fort station’s symbolic visibility and very high pedestrian density make it strong candidate for piloting as well.

Academic Options

Researchers noted that data and prior studies are limited also making large -scale adoption challenging as well. Fortunately, they emphasized research contributions, new material development and academia-industry collaborations as crucial benefits.

Feasibility Outlook for Fort Station

As per most respondents’ technological feasibility is positive, given the heavy consistent foot flow as mentioned and evaluated earlier in the study. Challenges like upfront cost, durability and skilled expertise remain but these may mitigate by implementing this technology as integrated model with solar. Ultimately implementing this project at heavy crowded area like fort station will serve as demonstration project, also it will cover the awareness gap and attract new stakeholders or investors for government support.

5 Conclusions

This study explored the technical applicability of piezoelectric energy harvesting in Sri Lankan public buildings, addressing technology, and social acceptance facts. Furthermore, this analysis indicates that a energy harvesting piezoelectric tile could generate approximately 83.33Wh/day in accordance to assumed foot print in Colombo fort railway station at assumed parameters. While modest compared to solar, this generated output significantly enough for low-power consumption applainces such as LED, CCTV cameras or smart panel boards. Though the lack of suitable engineering, long-term benefits such as reduced fossil fuel use and lower environmental impact are promising [(Pasindu et al., 2017); Farnoosh, 2002)]. These findings are aligning with Sri Lankan national renewable energy vision, which target as 70% renewable energy sourced by 2030 and also net-zero pathway by 2050 as well (SLSEA, 2022). Integration with solar power is recommended for efficiency. Key barriers include harvesting engineering method, limited expertise, and maintenance challenges (Chew et al., 2017), but these can be overcome through strategic implementation and stakeholder engagement, making the technology viable for Sri Lanka.

6 Recommendations

To support piezoelectric energy adoption, pilot or R & D projects should test real-world feasibility. Hybrid systems combining piezo tiles with solar are recommended for better energy efficiency. Government incentives, like tax exemptions (Pasindu et al., 2017), can reduce initial costs and encourage stakeholder adoption. Awareness campaign and academic-industry collaborations are vital to build knowledge and promote implementation through universities and training programs (Farnoosh, 2002)

7 Research Limitations and Future Research Directions

This study focused solely on technological aspects in according to Sri Lankan context. The time frame of the investigation was confined to the recent years coinciding with the onset of the digital collapse in Sri Lanka. The recommendations that put forth in this study purely based on insights and expertise provided by industry or academic professionals within the industry.

This study establishes the adoption of piezoelectric energy technology in Sri Lanka; it is essential to explore the most suitable implementation methods and study its long-term impact on local energy demand and weather conditions. Further research is needed to identify the most efficient energy harvesting techniques, and establishing local production is a crucial direction to improve accessibility and reduce costs.

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