Towards elimination of energy poverty in Cairo by using piezoelectric tiles

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Abstract :This study investigates methods to eradicate energy poverty in Cairo by utilizing piezoelectric tiles. Energy poverty is a widespread problem in developing countries like Egypt, where many citizens cannot afford or access reliable electricity. Conventional electricity generation methods are inadequate for meeting the escalating energy needs of cities such as Cairo. Piezoelectric tiles offer a novel and promising solution to this issue. The research primarily focuses on assessing the feasibility of implementing these tiles in specific areas of Cairo, such as densely populated streets and public spaces, to alleviate energy poverty. The study concludes that piezoelectric tiles can potentially eliminate energy poverty and promote sustainable development in Cairo. The previous statements were achieved through a combination of methods, including a literature review of related research and an analysis of piezoelectric tile implementation case studies to determine their electricity-saving potential. The anticipated outcome is that these tiles will generate sufficient electricity for daily use.
Keywords: piezoelectric tiles ; footstep energy ; Energy poverty ; generating electricity

1 Introduction

Energy poverty, a significant issue in developing nations' urban areas like Cairo, Egypt, is defined by inadequate and costly energy access. [4] This situation negatively impacts citizens' daily lives, the environment, and economic growth. Conventional energy sources are expensive, scarce, and cause pollution, necessitating sustainable and alternative energy solutions. [1] Piezoelectric tiles, a novel technology, harness pressure from foot traffic and vehicles to generate electricity. [6] These tiles convert kinetic energy into electrical energy, making them suitable for urban settings like walkways and roads. They are durable, affordable, and can produce substantial electricity over time. By implementing piezoelectric tiles, cities like Cairo can obtain a reliable and sustainable energy source, alleviate energy poverty, boost environmental sustainability, and foster economic development. [2]

Methodology :
To gain a deeper understanding of eliminating energy poverty in Cairo by using piezoelectric tiles this study will employ a qualitative research methodology. Data will be collected through a systematic review of academic articles published in the past ten years. And quantitative research method for the applied study for counting number of people at the British university through observation.

Research Aim and objectives.
The study intends to propose piezoelectric tiles to decrease energy usage in Cairo and mitigate issues caused by power outages. It will:

- Analyze the uses and constraints of piezoelectric tiles in generating energy.
- Assess the possibility of incorporating these tiles into buildings for energy extraction and resource management efficiency.
- Investigate the potential advantages of implementing piezoelectric tiles in public spaces.

2 literature

2.1 Energy poverty in Cairo:

On July 2, 2023, at dawn, Cairo, Egypt, faced a massive power outage impacting millions of inhabitants [4] The fact lasted around eight hours, leading to disturbances in the city's transportation systems, hospitals, and businesses. According to authorities, the cause was a technical issue at one of the city's primary power plants [4]. Although backup generators were activated in specific areas, they were inadequate to meet the high electricity demand during the summer period. Egypt's electricity sector has grappled with aging infrastructure, insufficient investment, and high electricity subsidies [14]. The fact has resulted in recurring power cuts and load shedding, causing inconvenience and economic losses to the citizens and businesses[1]. In response to the 2023 outage, the government declared plans to modernize the country's electricity infrastructure and diversify its energy sources, as seen in Table 1 including investing in renewable energy [4] However, executing these plans might take time, and until significant enhancements are made, residents of Cairo may still face the risk of power outages. [4]

Table 1 timetable for electricity outage[10] developed by author.

Region (electricity outage from 9pm to 10 pm)	Street
Nasr city	sixth region Eighth region Abbas elakkad street
New cairo (el rehab city)	Second region
Ain shams	El akkad street

2.2 The reason for electricity poverty in Cairo:

The ongoing conflicts worldwide have a complex, indirect connection to energy accessibility in Cairo, Egypt. Although there is no direct cause-and-effect relationship, various factors contribute to this indirect relationship. [2] Wars often disrupt global energy markets, mainly involving significant oil-producing or exporting nations. Production disruptions can manifest in various ways, such as reduced oil production when oil-producing countries are entangled in conflicts, leading to factors like infrastructure damage, labor shortages, and political instability[1]. This decrease in supply can increase global oil prices [1]

Additionally, wars may lead to trade restrictions and sanctions, which can impede the flow of energy resources across borders. [1] These restrictions can intensify energy shortages and price hikes[1] Like many cities globally, Cairo heavily depends on imported oil to meet its energy needs. Consequently, disruptions in global energy markets due to wars can significantly impact Cairo's energy accessibility, resulting in higher energy costs and energy shortages [16]

2.2.1 The reason for electricity outage in Cairo in July 2023

Load shedding, or daily power outages, has become common in Egypt for several reasons. Firstly, insufficient fuel supply to production stations is a significant issue, as the quantities of diesel and gas fluctuate, exacerbating the problem. [1] Secondly, high temperatures and increased air conditioner usage have led to higher daily consumption, as seen in Figure 2. Although temperatures have dropped recently, consumption remains high. [12] Thirdly, some houses occupied by refugees have increased consumption. Lastly, electricity theft has become a significant problem, with over 6% of total capacity stolen monthly. [14].

Fixed electricity prices, which have not changed, also contribute to the issue. That makes electricity consumption cheaper than other services, putting a strain on the state budget. [2] The gap between production and sale prices of electricity is another challenge. Egypt has tried to import diesel fuel to solve the problem, but high prices have forced them to stop. Due to these factors, power outages in major cities like Cairo and Alexandria have lasted over 8 hours a day. [14]

To improve the situation, Egypt plans to export electricity from renewable energy sources to countries like Jordan, Sudan, and Libya in exchange for US dollars. The country aims to become a regional energy center and has received offers from European countries to export surplus electricity production. Egypt currently produces 58,000 megawatts of electricity daily, with a consumption of 33,000 megawatts. They are working on electrical connection projects with neighboring countries like Greece, Saudi Arabia, and Italy to export electricity and boost their economy. [14]

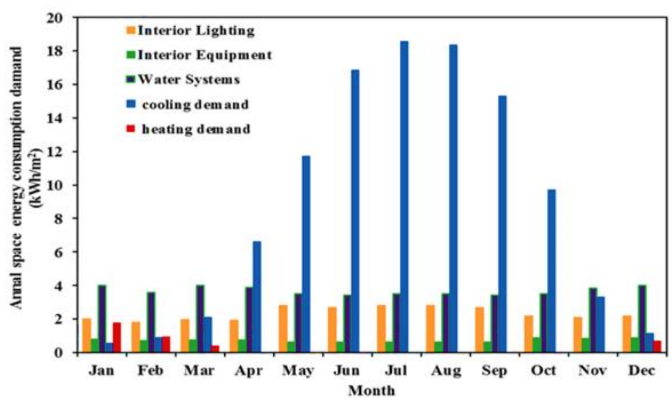

Figure 1 base case monthly space energy consumption (kWh/m2 per month) *[12]*

2.3 Conclusion

Although wars do not directly affect energy accessibility in Cairo, an indirect correlation is noticeable. Wars may disturb worldwide energy markets, causing increased energy prices and possible shortages. Alongside these disruptions, other elements like economic and political instability can further reduce energy availability for households and companies in Cairo.

2.4 population in Cairo:

As Egypt's capital, Cairo is a significant urban hub in Africa and the Middle East. With an estimated population of around 21 million in 2021, it is the largest city in Africa and the Arab world as per United Nations data. Over the last century, the city's population has experienced a substantial increase, with a yearly growth rate of 2.4% between 1960 and 2020 **[13]** The high population density in Cairo is attributed to both natural population growth and migration from rural areas. In 2019, the crude birth rate in Cairo was 18.3 births per 1,000 population, while the crude death rate was

4.6 deaths per 1,000 population, as **[11]**. The total fertility rate in the city is comparatively high at 3.3 children born per woman. **[13]**

Table 2: Cairo population 2023 *[11]*

City name	population
Cairo	22,183,000
Alexandria	5,588,00
Bur said	778,00
As-suways	673,000
Al-Mansoura	585,000
Tanta	523,000
Aswan	365,000

2.5 Exploiting population in Cairo to generate electricity.

Transforming Cairo's abundant waste energy, due to its high population, into usable power via energy-harvesting tiles offers prospects for eco-friendly advancement. These tiles may lessen the city's dependence on conventional energy sources and enhance air quality, yet obstacles remain. Before widespread usage, concerns about cost, longevity, upkeep, and appearance must be resolved through additional study. It will help these tiles become a practical replacement for traditional energy sources in Cairo's densely inhabited zones.

2.6 Piezoelectric tiles and its types.

Piezoelectric flooring is a technology that generates electricity and small amounts of energy when pressure is applied to its tiles. [3] When these tiles are subjected to pressure, they produce an electrical charge. Researchers have indicated that these tiles can be utilized in diverse settings, including busy places such as train stations, airports, shopping malls, and residential buildings, where they can generate energy from foot traffic and other sources. [17] [8] Piezoelectric tiles, like Waynergy Floor, Sustainable enegy floor, and Pavegen tiles, are innovative flooring solutions that generate electricity from footsteps. [9] These tiles, made of materials such as piezoelectric tiles ceramic, produce an electric charge under mechanical pressure. The collected charge powers nearby devices or feeds into the grid. Waynergy Floor generates up to 10 watts per square meter, while SEF can produce 25 watts. Pavegen tiles are for outdoor use and collect foot traffic data. Piezoelectricity is also used in other applications, such as generating sound or vibration in small electronic devices. This technology offers sustainable energy generation and additional benefits like data collection and improved accessibility for people with disabilities. [17] [8]

Table 3: types of piezoelectric tiles*[17]* developed by author.

Feature/ type	Waynergy floor	Sustainable energy floor	pavegen	Sound power	Piezo tiles ceramic	Parquet PVDF layers	Drum harvester piezo buzzer	Drum harvester piezoelectric ceramics
efficiency	25%	20%	20-30	10	35-50	15-20	5	10-5
durability	High	Moderate	High	Moderate	High	High	Moderate	Moderate
Cost	Moderate	Moderate	High	low	low	low	low	Moderate
Scalability & integration	high	high	high	moderate	high	high	high	moderate
Environmental impact	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low	Moderate
Design	Limited variety	Limited variety	Limited variety	Limited variety	Limited variety	High customized	Limited variety	Limited variety
maintenance	Easy	Easy	moderate	Easy	Easy	Easy	Easy	Easy
Application	Floor walkways, industrial machinery	Floor walkways	Floor walkways , transportation	Public spaces, concerts	Floor walkways, industrial machinery	Floor walkways, industrial machinery	Wearable electronics, sensors	Energy harvesting from vibrations
Life sppan	20	15	20	20	20	20	20	20
Size	40x40cm	50x50 cm	edge	50x50cm	Small size	layers	vary	75x75cm
Energy generated	10W per step	Up to 30W	5W per step	0.2W per step	8.4MW	2.1MW per puls with loads of about 70kg	Around 2.463 mW	Up to 25KW per year

2.7 *Mechanism of piezoelectric tiles :*

Piezoelectric tiles convert mechanical stress into electrical energy through a series of steps. First, mechanical stress is applied due to external forces like foot traffic or vibrations. This stress causes deformation in the tiles, inducing mechanical stress within the piezoelectric material [6] Next, the material responds by distorting its crystalline structure, which separates positive and negative charges, creating an electric potential [5] The accumulated charges on the electrodes lead to an electric potential difference, generating an electric field. Finally, when an external circuit is connected, the charges flow as an electric current, which can be utilized to power devices or stored in batteries or capacitors [7]

2.8 *Case studies :*

In Japan, the power-producing floor of these tiles is at Tokyo station's Yaesu North Exit ticket entryways. The generated power was used to cover some of the electrical output for station facilities like automated ticket gates and electroluminescence screens. [17] The first trial occurred from October 16, 2006, to December 18, 2006, followed by a second trial on January 19, 2008. The second trial used 90 square centimeter tiles and covered a 25m2 area. The generated power was estimated at more than 1.0 watt-seconds per person, providing daily 500kW of electricity, enough to light a 100W bulb for 80 minutes. [17] The annual cost of illuminating the bridge was over $1,445,072 while installing the tiles was $27,090. The experiment showed potential for energy savings in three decades. [17]

Table 4 :comparative analysis between two case studies (developed by author).

	Case study 1	Case study 2
Picture		
Location	Rotterdam	Tokyo
Type of project	Night club	Metro station
Cost	115,124$	27.090 $
Area	38 m2	25 m2
Energy saved	30%	Energy to power facilities of metro station
Tile size	75x75x20	90cm2x2.5cm
Type	Sound power tile	SEF
No of people / day	1400	400,000

3 *Applied studies.*

The British University in Egypt (BUE) is a case study for implementing piezoelectric tiles at Gate 2 stairs . Universities experience high foot traffic, making them ideal candidates for this energy-harvesting technology. Gate 2 stairs, a high-volume access point, would likely generate the most power due to concentrated pedestrian movement. Analyzing data from piezoelectric tiles at Gate 2 would provide valuable insights into real-world energy production and cost-effectiveness in an educational setting. The success of this pilot program could then be a blueprint for wider implementation across the university and potentially inspire other institutions to adopt sustainable energy solutions. Observational map is done to observe people count at the university's gate 2

Figure 2 (gate 2) six stairs.

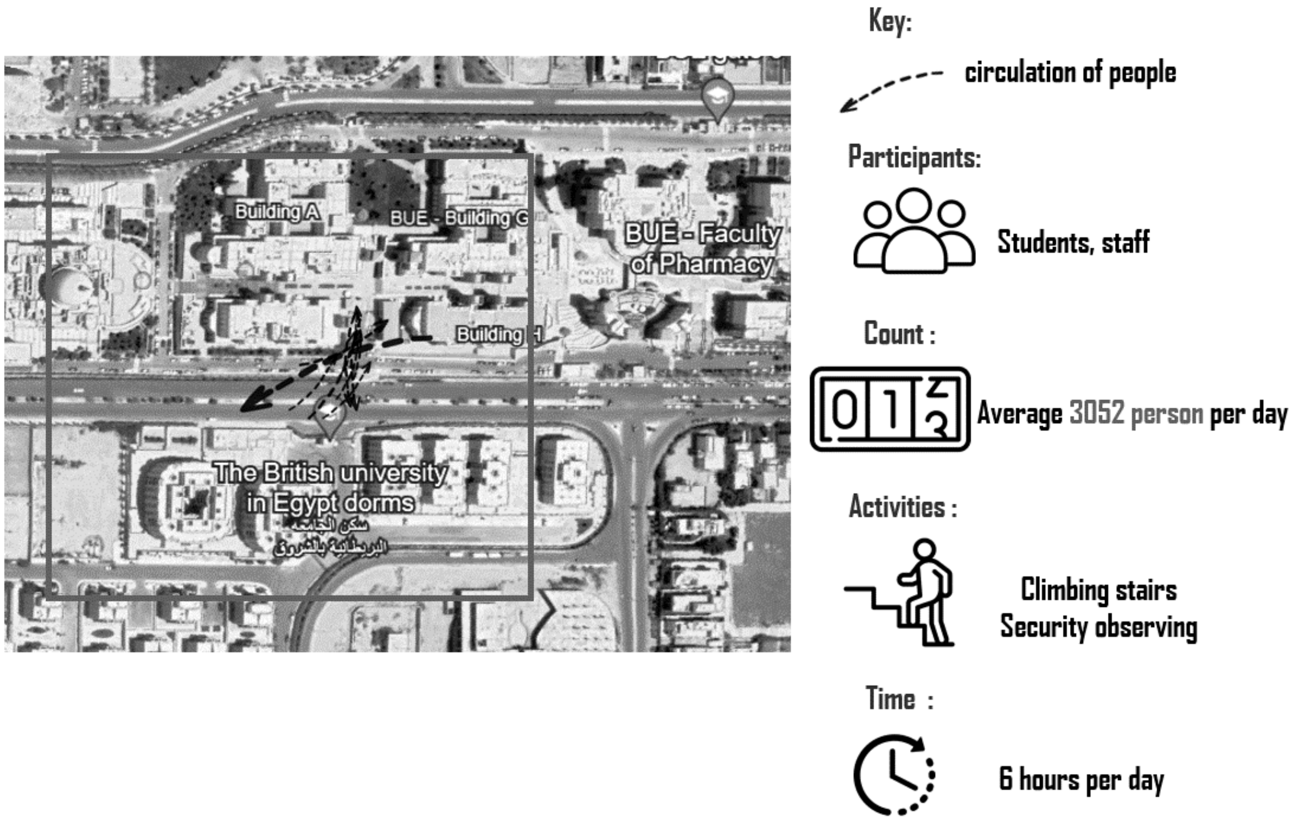

Figure 3 observational map (developed by author)

There are 3052 person per day using the six stairs at gate 2 , by assuming implementation six piezoelectric tiles (waynergy) that generate 10 W per step as shown in (Table 3) to calculate generated electricity number of steps (which is 3052 x 6) multiply 10 W (the generated electricity per tile) multiply number of tiles (which is six tiles) The calculation is : (3052 x6) x 10 x 6= 1,098,720W or 1,098.72 KW per day

Table 5 generated electricity (by author)

Time	Generated electricity (KW)
Per day	1,098.72
Per month	21,974.4
Per 7 months (academic year)	153,820.8
After 20 years	3,076,416

4 Conclusion and recommendations:

Piezoelectric tiles will help increase electricity production by exploiting the Cairo population and help eliminate energy poverty in Egypt. This table shows how the piezoelectric tile is a sustainable innovation help eliminating energy poverty in Cairo (table 5).

Table 6: how piezoelectric tiles affect energy poverty by author.

Factor	Energy Poverty in Cairo	Implementing Piezoelectric Tiles
Access to electricity	Lack of access to electricity limits the use of appliances and devices that run on electricity, affecting daily life and economic activities.	Piezoelectric tiles can generate electricity from everyday activities, providing a source of power in areas without electricity access.
Environmental impact	Traditional energy sources contribute to air pollution and greenhouse gas emissions.	Piezoelectric tiles are a clean and renewable energy source, reducing the environmental impact of energy consumption.
Sustainability	Reliance on traditional energy sources is not sustainable in the long term.	Piezoelectric tiles offer a sustainable energy solution, reducing dependence on finite fossil fuels.
Economic development	Energy poverty hinders economic development by limiting access to electricity, which is essential for businesses and industries.	Piezoelectric tiles can promote economic development by providing a reliable and affordable energy source for businesses and communities.
Public health	Energy poverty can lead to health problems, such as respiratory infections and exposure to hazardous cooking methods.	Piezoelectric tiles can improve public health by providing access to clean energy and reducing reliance on harmful cooking practices.

It is recommended to increase electricity production by implementing piezoelectric tiles in the most crowded places in Cairo, such as metro stations and public places such as malls and airports.

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