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## **Piezoelectric Tiles Is a Sustainable Approach for Designing Interior Spaces and Creating Self- Sustain Projects.**

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# Piezoelectric Tiles Is a Sustainable Approach for Designing Interior Spaces and Creating Self-Sustain Projects.

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**Abstract.** These days, the third worlds countries such as Egypt are facing a hug challenge toward energy production. Energy crisis is the most critical issue facing these developing countries. In the recent couple of years Egypt has experienced a serious shortage in the power supply which affect negatively the industry sector as well as the residential sector due to the shortage of natural gas production and fossil fuel which prevented the government from providing the basic needs of Energy to the community. Moreover, it affects negatively the developing of this country and building a new mega projects. Renewable energy sources can be an extraordinary method to tackle the energy issue in Egypt, the increasing of energy costs and decreasing of fissile fuel production helps in decreasing the gap between the cost of generating Energy from renewables and fissile fuel. It is important to set up public Egyptian facilities based on renewable energy as metro stations instead of relying upon fossil fuel as a main source of power. Generating electricity from piezoelectric cells to power metro station is a sustainable solution for the environment, economy, and social needs. Using piezoelectric cells in high density projects helps in creating energy self-sustain projects, people will start to produce energy from walking throughout the facility. The aim of this research is to highlight the importance of replacing ceramic and granite tiles with sustainable piezoelectric tiles, which will create a self-sustain project by redesign an interior space of public facilities. Designing the flooring tiles that integrate piezoelectric cells produce a useful amount of energy for electrifying public facilities using the visitor's high population density. The research started to analyses projects that replaced regular tiles with piezoelectric tiles to understand the objectives and constrains of using this sustainable building material in Egyptian public facilities.

**Keywords:** Sustainability; Interior spaces; Piezoelectric Tiles; Energy Harvesting.

## 1. Introduction

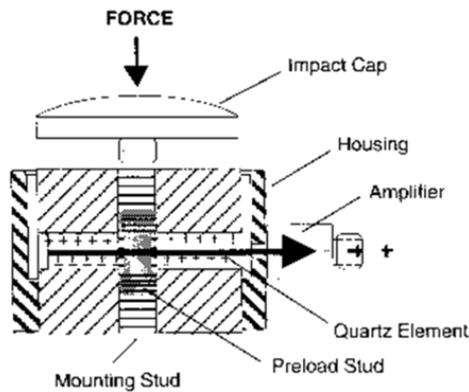
Interior Design is a multi-faceted career in which innovative and specialized solutions are connected inside a structure to accomplish a built good environment. These solutions are practical, upgrade the personal satisfaction and culture of the inhabitants, and are stylishly appealing [1]. This research intend to study the efficiency of using piezoelectric tiles instead of ceramic or granite tiles in interior spaces.

Piezoelectric materials are crystals that produce power when compressed or vibrated as shown in figures (1 & 2). They fall inside a class of various solid state materials that can create power with the use of some boost, for example, heat, stress, or light [2 & 3]. Piezoelectric gadgets inserted in roadways may recover energy as vibration and pressure under the vehicle tires [3].



Utilizing piezoelectric to reap vibration energy from people strolling, apparatus vibrating, or vehicles moving on a roadway is intriguing, as it is a clean and not expensive energy [3]. Piezoelectric materials creating a voltage about  $2 \times 10^9$  V, but the material is not accessible yet [4].

Piezoelectric energy transformation creates moderately higher voltage and power contrasted with the electromagnetic framework [4].



**Figure 1.** Illustrates the cross-section of piezoelectric cells.



**Figure 2.** Piezoelectric cells.

## 2. Types and Properties of Piezoelectric Tiles

Many previous research classified piezoelectric technology differently. In table (1), the research will classify the main types of piezoelectric according to its technical specifications. Table (1), presents the properties or technical specifications of each type of piezoelectric tiles includes size of each tile, energy produced from one tiles, the initial cost of the tile and average lifespan.

**Table 1.** Piezoelectric technology types main technical specifications, price and lifespan.

Company	Tiles Size	Energy Produced	Price in US \$	Life span by years
<b>Waynergy Floor</b>	40 x 40 cm	10 W per step	451.5	20
<b>Sustainable Energy floor (SEF)</b>	75 x 75cm OR 50 x 50 cm tile	Up to 30 watt of continuous output. Typical power output for continuous stepping by a person lies between 1 and 10W (average 7W)	1,693	20
<b>Pavegen tiles</b>	50 x 50 cm	5 W continuous power from footsteps	395	20
<b>(EAPs) Electro-Active Polymers</b>	Sheets	1W	-----	20
<b>Sound Power</b>	50 x 50 cm	0.1W per 2 steps	270.9	20
<b>PZT ceramic (Lead Zirconate Titanate)</b>	Manufacturing in a small size	0.0084 W	36.1	20
<b>Parquet PVDF layers</b>	Layers	0.0021 W per pulse with loads of about 70 kg	-----	20
<b>Drum Harvesters - Piezo buzzer Piezoelectric Ceramics</b>	Vary	Around 0.002463 W	56.4	20

<b>POWER leap PZT hybrid energy floor - combines human power with solar energy</b>	60 x 60 cm	0.5mW per step	-----	20
	75 x 75 cm tile	up to 250 kWh per year, per tile	1,693	20
	<u>OR</u> 100 x 200 cm			

As it shown in table (1), “PZT ceramic” is the cheaper tile which produces an average of 8.4mW per tile. On the other hand, Sound Power produce only 0.1W per 2 steps and its initial cost is almost 5 times more than “PZT Ceramic”.

Each type of piezoelectric tiles has a specific feature and form, some of them has already been used in existing interior projects while others are still under experimental process. Table (2) summarize the uses and features, form and implemented projects of each type of piezoelectric tiles.

**Table 2.** Piezoelectric technology types according to uses and features

Company	Uses and features	Form	Implemented project
<b>Waynergy Floor</b>	<ul style="list-style-type: none"> <li>The output power consumed or stored.</li> <li>Can be used for indoor or outdoor uses.</li> <li>Using in lighting, traffic control gadgets supply.</li> <li>High pedestrian areas, Security systems supply, Crosswalks, walkways, and Public transport stations.</li> </ul>		Ponte 25 De Abril 
<b>Sustainable Energy floor (SEF)</b>	<ul style="list-style-type: none"> <li>Use to power road lights and signage.</li> <li>The tiles can be fully customized.</li> <li>Many projects used it.</li> <li>Used in pavements and high pedestrian regions as airplane terminals, sport fields, shopping centres, railroad stations and Office and condo squares.</li> </ul>		Dance Floor, “Club Watt” 
<b>Pavegen tiles</b>	<ul style="list-style-type: none"> <li>Used in various sectors including train stations, shopping centres airports and public spaces.</li> <li>Can improve data-driven smart cities.</li> <li>Each tile is equipped with a wireless API that transmits real-time movement data analytics whilst directly producing power when and where it is needed.</li> <li>Can power interactive messages, billboards and signage.</li> <li>Able to connect to a range of mobile devices and building management systems.</li> <li>Footfall tracking &amp; Identifying Footfall hotspots.</li> </ul>		Mercury mall, London 
<b>(EAPs) Electro-Active Polymers Sound Power</b>	<ul style="list-style-type: none"> <li>Generally generated high voltages</li> <li>Sensor Network Technology, sensor matrix.</li> <li>Pressure mapping in order to trigger a Control, warning or alarm signal.</li> <li>Power Sources for many applications.</li> <li>Utilized in the emergency stairs</li> <li>0.1 watt of electricity when a person steps on them is enough to illuminate 50 to 100 “Christmas-tree” LED lights wired to the</li> </ul>		



### Hybrid energy floor (HEF)

- DC power.
- Combines human power with solar energy.
- Converts solar power and kinetic energy from human movement to electrical energy.
- Designed for installation on commercial streets, public squares, parks and pavements.
- It uses photovoltaic panels with CIS (Copper Indium Selenide) solar technology. Main benefits of CIS solar technology are its excellent performance in shady areas and its maximum energy production with minimum power use.



From analysing the different types of piezoelectric tiles in table (2 and 3), architects and interior designers can use table (2 and 3) as a guidelines for using piezoelectric tiles in interior spaces. Table (2) helps to select the type of piezoelectric tiles according to the budget, energy production, cost and size. While, table (3) presents the best function for using the tiles, shapes, materials and configuration of each type.

### 3. Case Studies.

This section will present three case studies implemented piezoelectric tiles in local project and benefit from the non-stop energy produced but also some of them were not very efficient.

The case studies will present the benefits and problems occur from using piezoelectric tiles.

#### 3.1. Case Study 1: Club Watt, World's First Sustainable Dance Club.



**Figure 3.** Dance floor.

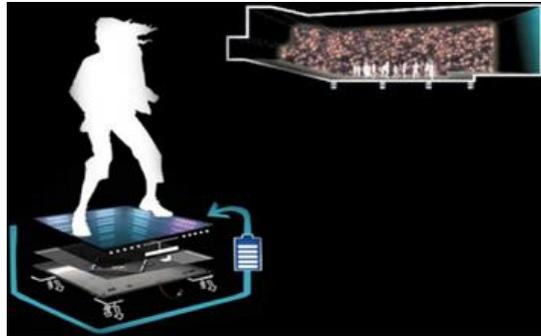
Source: [5].

The Club Watt, World's opening Date as in 12, September 2008 it is located in Rotterdam. The club consists of four areas; a lobby with capacity of 1,500, basement for 300, two rooftops with relax space for smoking, and the Lulu Café with 20 covers at road level.

The club used piezoelectric tiles “Sustainable Energy Floor (SEF) tiles” to generate clean and efficient energy. It was noticed that the piezoelectric tiles made significant savings on Energy consumption within average 30%. This sustainable project used also sustainable techniques to save water with average 50%, CO<sub>2</sub> reduction with 50% and Waste saving with 50%.

The Sustainable Dance Floor modules flex a little when moved on. Inside each tile is an electromechanical framework, which changes the little vertical motion created by moving individuals into a rotating motion that drives a generator. Every module size is 75x75x20 cm can create up to 35

watts. Round to 5-20 Watt for every individual. The dance floor comprises of tiles divided to two sections: energy collecting and lighting as shown in figures (3 & 4) [5].



**Figure 4.** Dance floor.

Source: [5]

The sustainable system was based on, each Watt produced from the dancing floor includes an assortment of sustainable procedures that incorporate the utilization of LED lighting rather than power hungry spotlights, a water catchment framework that provisions water for its toilets, and waterless urinals which will spare a normal 1000 cubic meters of water every year. The club's LED dance floor transforms every person's kinetic energy into 20W, enabling it to power itself. These highlights put the club well on its approach to achieving the half reduction in CO<sub>2</sub> discharges commanded by the Rotterdam Climate Initiative [5].

With the recent innovation, one individual can produce 5-20 Watts, contingent upon their weight and movement level (the harder they move the greater power they will make). That implies one individual could electrify a couple LED lights and two individuals could electrify a CFL light [5].

The energy cost for Illumination the bridge is almost year \$ 274,834.56 per year. While, Investing in installing piezoelectric tiles (Sustainable Energy Floor (SEF)) will cost \$ 115,124. The saving per year will be about \$ 82,450.37 and that will Payback with less than 4 years. The percentage of energy saving is almost 30%. The average savings in 10 years is almost \$ 824,503.68.

### 3.2. Case Study 2: Tokyo Station's Yaesu North Exit.



**Figure 5.** Tokyo Station

Source: [6]

This case study was an experiment made by JR East Company to measure the efficiency of using piezoelectric tiles in public facilities. The company installed the piezoelectric tiles "Power-producing floor" at Tokyo station's Yaesu North Exit ticket entryways (Japan) ticket doors as shown in figure (5), where there is high movement, utilizing the power created to cover a segment of the electrical yield for

such station offices as automatic ticket gates and electroluminescence screens. The experiment starts installing the tiles in 19, January 2008 to start operation in March, 2008 [6].

### 3.2.1. The first Experiment.

The Between 16, October 2006 and 18, December 2006 the first experiment took place by installing 6m<sup>2</sup> of piezoelectric tiles in the ticket gates. The experiment results, generation of power achieved was about 10,000 watt-seconds out of every day (equal to the power expected to light a 100W light for 100 seconds). From the third week of the trial period generation of power diminished because of the degradation of durability [6].

### 3.2.2. The Second Experiment.

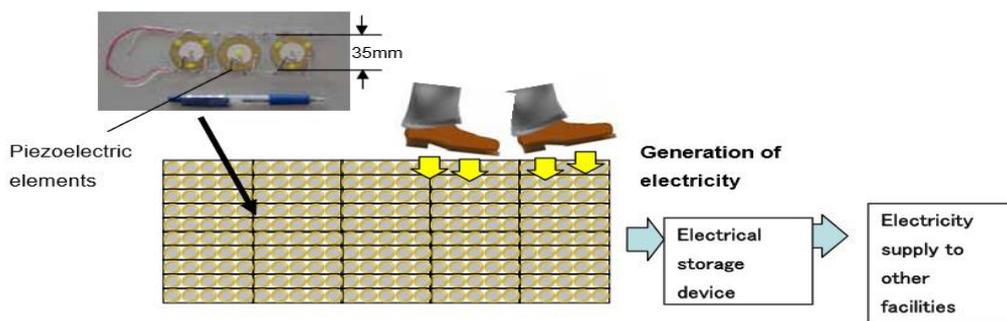
The second experiment Installed tiles with size 90-square-centimeter, 2.5-centimeter-thick in an area of 25 m<sup>2</sup> of piezoelectric tiles at ticket gates, the concourse, and stairs. Number of passenger's passing through the station is around 400,000 each day. The Power Generated in this experiment was estimated by more than 1.0 watt-second when a man goes through the ticket gate, to deliver day by day power of 500Kw-Seconds, equal to the power expected to light a 100W light for 80 minutes [6]. The energy cost for Illumination the bridge is almost \$ 1,445,072 per year. While, investing in installing piezoelectric tiles (Sound Power Tile) will cost \$ 27,090. That will save Payback within 3 years. The experiment used piezoelectric tiles type "Sound Power Tile" as shown in figure (6 & 7).



**Figure 6.** LED board.

Source: [6].

It creates power each time an individual move on it, illuminating a Holiday light screen on one of the wall of the station. It additionally electrifying a LED board that refreshes, continuously, the total sum of power generates. It is evaluated that 2.4 million individuals go through the gigantic Shibuya Station each day as shown in figure (7).



**Figure 7.** Mechanism of the floor.  
Source: [6].

3.3. Case Study 3: Ponte 25 De Abril.



**Figure 8.** Ponte 25 De Abril.  
Source: [7].

The presented case study installed piezoelectric tiles in bridge Located in Lisboa, Portugal. The type of piezoelectric tiles used was “Waynergy Tiles” with size 0.25 x 3 m. the traffic density on the bridge is around 155.000 vehicles/day.

The energy cost for Illumination the bridge is almost 10.000 €/year. While, Investing in installing piezoelectric tiles (Waynergy) will cost 30.000 €. The installed power is 6 kW which will Payback with less than 5 years. The percentage of energy saving is almost 65%. The average savings in 10 years is almost 35.000 €.

**4. Case Studies Analysis.**

According to the pervious case studies, the research will summarize the case studies in this section to analysis the efficiency of using piezoelectric tiles in interior spaces as shown in table (3).

**Table 3.** Analysing the case studies.

Case Study	Ponte 25 De Abril	Tokyo Station	Club Watt
<b>Picture</b>			
<b>Project Type</b>	Bridge	Metro Station	Dance Club
<b>Location</b>	Lisboa, Portugal	Tokyo, Japan	Rotterdam
<b>Cost</b>	\$ 67,200	\$ 27,090	\$ 115,124
<b>Area</b>	–	25 m <sup>2</sup>	38 m <sup>2</sup>
<b>Amount of</b>	240 W / Vehicle	Day by day power of 500 kW-seconds	25 watts per module

<b>energy</b>			
<b>Energy saved</b>	65% of the bridge power	Enough to power station facilities as automatic gates and electroluminescence display	Reduces the club consumption by 30%
<b>Tile Shape</b>	Rectangle	Square	Square
<b>Tile Size</b>	0.25 x 3 m	90 square centimeter, 2.5 centimeter thick	75 x 75 x 20 cm
<b>Configuration</b>	Replacing tiles	Over tiles	Replacing tiles
<b>Colour</b>	Black	Black	Transparent with LED multicolor lights
<b>Number of users per day</b>	155.000 vehicle	400,000	1400
<b>Type of Piezoelectric tiles</b>	Waynergy	Sound Power Tile	Sustainable Energy Floor (SEF)

## 5. Advantages and disadvantages of using piezoelectric tiles.

**Table 4.** Advantaged and disadvantages of piezoelectric tiles

Advantages	Disadvantages
Smooth and will not disturb people. Do not produce sound. Will produce low electric bills.	Durability Costly It has high temperature sensitivity.
Unaffected by external electromagnetic fields.	High impedance: The piezoelectric crystals have high impedance so they have to be connected to the amplifier and the auxiliary circuit, which have the potential to cause errors in measurement. To reduce these errors amplifiers high input impedance and long cables should be used.
Low Maintenance. Easy replacement of equipment. Can come at any shape needed. Clean source of energy. Do not produce harmful emissions for people. Will Reduce the CO <sub>2</sub> emissions. Pollution Free. High output Voltage. Need no batteries. High sensitivity. High output: They offer high output that be measured in the electronic circuit. High Mechanical stiffness unidirectional sensitivity Can withstand a large amount of strain Rugged construction and small size High output with negligible phase shift.	Can pick up stray voltage in connecting wires

## 6. Conclusion.

Egypt is seeking for new developments and investments, but there are some challenges facing it. One of these challenges is the energy crisis as, in the last years, rising energy needs and falling gas and oil yield have switched Egypt from exporter to importer of both, a move that represents a considerable danger to its economy. Therefore, if there's ability to increase the self-sustain projects, that would decrease the energy consumption and will help to direct this surplus into the new developments and investments that the country is seeking for.

Other Egypt's population growth rate is in continuous increasing and piezoelectric tiles are depending on people footprints, so that will help for generating more clean energy and reducing the carbon gas emissions as in 2007 a 168.7 M tonnes of carbon outflows were evaluated in Egypt from energy, so by decreasing this rate with 5490 pounds per KWh that will lead to a better environment and will improve human well-being.

All the developing countries should start to use this technology to start to depend on its own clean energy without harming the environment and to seek to be developed.

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