Renewable Energy Potential from Energy Floors

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Introduction

Kinetic floors are tiles that generate electricity via the pressure people produce from walking, dancing, or jumping on them. These tiles utilize piezoelectricity to generate power at smaller, local scales in high traffic areas. Energy floors are relatively new, having been developed in the early 2000s and only seeing commercial applications in the past decade. The goal of this technology is not only to harvest available energy from common practices as human beings, but also to increase public awareness on energy consumption and renewable practices due to the prevalence of these devices in high-traffic public areas.

Background Information

A premier company in the field of kinetic floors is Energy Floors. Energy Floors is a Dutch company that was founded in 2008 by Michel Smit and Jan-Peter Doomernik. The company gained early attention for its Sustainable Dance Floor, which was set up in several nightclubs and events across Europe from 2008 to 2009. The Sustainable Dance Floor used embedded LEDs to show the energy generated by dancers on the floor, and provided enough power to operate the lights and DJ booth of the nightclubs it was installed in. Over the years, Energy Floors has taken their dance floor concept and made it into a rentable event/party attraction, selling their dance tiles to festival organizers, conventions, and permanent installations at institutions worldwide (Skhijah, 2021).

Another notable force in the industry is Laurence Campbell-Cook and the company Pavegen. Beginning in 2009 as a prototype, Cook developed his own design of kinetic flooring tiles and founded the company Pavegen after gaining enough startup funding and interest. With a strong social media marketing strategy and high-profile public interest, Pavegen installed kinetic floors in notable locations such as the Heathrow airport for the 2012 London Olympic games, and the turf of the Rio di Janeiro soccer stadium in Brazil (Eagleman, 2015). Pavegen is currently a leader in kinetic floors and operates some of the most effective power generating tiles on the market, as will be discussed further in later sections.

Theory and Analysis

How it Works

Energy floors utilize piezoelectricity to generate power. The piezoelectric effect is a phenomenon in which certain materials generate an electrical charge when subjected to mechanical stress or pressure. This effect is caused by the structure of the materials, usually crystals, which have a unique arrangement of atoms that allows them to produce an electric charge in response to external forces. Under no load, these materials are electrically neutral, with individual atom's dipole moments cancelling each other out. When a piezoelectric material is subjected to stress, the crystal structure of the material deforms slightly, causing a separation of electrical charges within the material. This creates a potential difference between the opposite faces of the material, which can be measured as an electrical voltage. Conversely, if an electrical voltage is applied to the material, it will cause the crystal structure to deform, generating a mechanical force. This is the principle many quartz watches use to keep time; a voltage is sent through the crystal which causes it to vibrate at a consistent rate and keep time for the watch.

According to a 2022 research article published in the journal *Energies*, energy floors typically consist of several layers of materials, first with a top layer of high-strength and durable materials such as concrete or rubber, a middle layer of piezoelectric materials, and a bottom layer of insulation and support materials. When a person steps on the top layer of the energy floor, the piezoelectric materials in the middle layer are compressed, which generates an electric charge. This electric charge is then collected by electrodes and sent to an energy storage system or directly to a power grid. Voltage output from these systems is often very low and must be converted to higher voltages in order to be useful over greater distances. Due to this, energy floors are used mainly for low voltage, local operations, such as nearby lighting and speaker systems. Additionally, constant compression of the floor tiles is needed to maintain a consistent power flow, making energy floors practical only in high traffic areas (Visconti et. al, 2022).

Results and Discussion

Cost and Output

Piezoelectricity is the fundamental idea behind energy floor production, yet it is rarely seen in energy conservation applications. Types of energy floors using piezoelectricity are divided into 3 categories based on high, medium, and low power output (Figure 1). The cost of each tile has been considered among other factors such as the necessary power for the surrounding area, installation and maintenance costs, the power output per step and the number of steps that would hit a tile when analyzing the amount of electricity generated for each floor type.

To predict the amount of electricity that could be generated in a certain area, case studies were performed in a Cairo metro station. In contrast, another study was held in a large company office building. With each tile dimensioned to approximately 50 by 50 cm (Figure 1), Pavegen laid 16 tiles, costing 560,000 EGP (~$20,000) and lost 7,471,800 EGP (~$241,807) (Elhalwagy, Adnan Mohamed, et al, 2017).

No.	Company - Technology	Product dimension	Generated energy	Price/ Egyptian pounds	Estimated lifespan by years	Ref.
1	Waynergy Floor	40 x 40 cm tile	10 W per step	4000	20	[2]
2	Sustainable Energy Floor (SEF)	75 x 75 cm tile 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 nominal output per module (average 7W)	15000	15	[3]
3	pavegen tiles	V3 Tile 50 cm each edge	5 Watts continuous power from footsteps	35000	20	[4]
4	(EAPs) Electro-Active Polymers	Sheets	1w	unknown	20	[5] [6]
5	Sound Power	50 x 50 cm tile	0.1 watt per 2 steps	unknown	20	[7][8] [9]
6	PZT ceramic (Lead zirconate titanate)	Manufacturing in a small size	8.4mW	unknown	20	[10][11] [12]
7	Parquet PVDF layers	layers	2.1mWs per pulse with loads of about 70 kg	unknown	20	[13]
8	Drum Harvesters - Piezo buzzer Piezoelectric Ceramics	vary	Around 2.463 mW	Estimated 500 /tile	20	[14]
9	POWER leap PZT	Tile 24" x 24"	0.5mW per step	The project has stopped	20	[15][16]
10	hybrid energy floor - combines human power with solar energy	75 x 75 cm tile 1 x 2 meter tile	up to 60kWh per year, per tile up to 250 kWh per year, per tile	Estimated 15000	20	[17]
11	PZT Nanofibre - nanogenerator &PZT textile nanogenerator	Sheets The volume of the material used is 0.2cm3	6mW/cm3 0.03 µW power density up to 2.4 $\mu W/cm^3$ [20]	available commercially at low cost and in a variety of designs	20	[18][19]
12	Pvdf nanofibre		4 $\mu W/cm^3$ 7.2 pW	unknown	20	
13	ZnO nanowire VINGs		5 pW 11 mW/cm^2 2.7 mW/cm^3	very economically	20	
14	BaTiO3		~7 mW/cm^3	available commercially at low cost and in a variety of designs		

Figure 1: Piezoelectric technology types of main technical specifications (Elhalwagy, Adnan Mohamed, et al., 2017)

This feasibility study illustrated that in predictably low activity areas companies would lose about 1500% of their money spent on installation as well as keeping the building efficiently powered. The study identified the hot spots footfall areas in the station where the experiment could be applied efficiently, and it was found that the 16 metro ticket gates (turnstiles) had the peak number of pedestrians. Using the data collected, it was found that the Pavegen solution, which requires 14 tiles, was the most suitable to cover the needs of the station (Elhalwagy, Adnan Mohamed, et al, 2017). Other solutions were found to be less efficient based on the high pedestrian distribution areas of this space that did not match with other solutions' tiles number.

The cost feasibility of the solution was achieved, and since the needs of power were covered with a small area of tiles compared with the high pedestrian area of this space, the extra number of tiles is feasible also, but it is more than needed power. The study found that it is possible to exploit this area as a "crowd farm," and the extra power generated can be exported to any power supplier as an investment to keep the feasibility of cost. The study concluded the investment in energy harvesting floor tiles must be after achieving power and cost feasibility, depending on the space data like high pedestrian's area distribution and steps numbers.

In the case study of low pedestrian private spaces, a private residential apartment with five users was chosen for analysis. The study found that Waynergy tiles were by far the most feasible (Elhalwagy, Adnan Mohamed, et al, 2017), yet they still had an incredibly low saving percentage, scraping by to cover initial setup costs. The restriction of this case study was the low pedestrian numbers. The study recommended using harvesting floor tiles in a separate way to generate and save energy in low pedestrian spaces like apartments. Using high generated power tiles can be used as a power source for LED lighting systems, and other types of harvesting exceptionally low power can be used as a trigger for self-powered sensors that track the users and control all equipment depending on their movement. Overall, energy floor tiles are not useful in saving money and power when placed in low traffic spaces, wasting more money and power for the environment.

In terms of this case study's cost and output, the investment in energy harvesting floor tiles must be carefully evaluated for power and cost feasibility. The cost of installing the tiles needs to be balanced against the potential energy savings generated from the tiles. The output of the energy generated depends on the number of tiles installed, the type of tile used, and the number of pedestrians passing through each space. The case study showed that high pedestrian public spaces have the potential for greater energy output, while low pedestrian private spaces may have limited energy output potential.

Ethics

In modern conversations about energy, most of the talk relates to the climate crisis, how it correlates to the energy crisis, moving away from fossil fuels, and how to move toward solutions. The solutions typically consist of unconventional approaches of capturing energy renewably. Energy floors are an instance of this unconventional approach: capturing energy through the natural movements of everyday individuals. The technology that upholds energy floors is objectively impressive, but the underlying idea is nothing more than commodifying a natural part of our lives.

Modern solutions to the energy crisis do not consider decreasing energy consumption and production. Global energy consumption in 2021 totaled to over 176,000 terawatt-hours, a 44% increase since 2000, and that number continues to grow at exponential rates (Ritchie, Hannah, et al., 2022). Despite the grandiose amount of energy already produced on today's Earth, many people still do not have access to it. In 2020, 733 million people went without electricity access, amounting to about 9% of the population. To decrease this number, the United Nations' Sustainable Development Goals looks to increase energy efficiency annually by 3.2% until 2030. The constant need for more drives the process of finding solutions. Thus, the desire for constant growth often understates the ethics of new energy systems.

People having access to electricity and other energy forms necessary for survival in the modern world may not benefit from an increase in energy production in the world but may benefit more by distributing the energy that we already produce in an equitable manner. There is plenty of energy for everybody, but entities at the top tend to take the lion's share of it. For example, in 2018, the US Department of Defense consumed almost 200 terawatt-hours of energy (Crawford, 2019). This extreme amount of energy could have been used to provide electricity to almost 2 million households for a year. Is the proper solution to generate more energy, or distribute the energy production properly? Further, are energy floors and other modern, atypical methods of capturing renewable energy through the commodification of people's natural movements necessary and ethical? When diving into new energy systems, these questions must be asked.

Conclusion and Recommendations

Advantages

Energy floors come with many advantages. First, simplicity: a commonly used technology, piezoelectricity does not take too much to implement. Much research has gone into piezoelectricity in the past, so putting it into practice is nothing new. Second, people do not need to go out of their way to use the floors, it occurs naturally. After creating the floors, their requires almost no manual labor to keep them producing. Natural tendencies do the work. Lastly, the floors last a long time. Floors must be usable for many years; thus, they do not need to be replaced often. One study tested one million fatigue cycles on energy harvesting tile and no changed in output occurred during the entire process (Puscasu, Onoriu, et al., 2018). As seen in figure 1, most models have an expected lifespan of 20 years (Abdalla, Ahmed, et al., 2018). This takes away the need for constant replacement and upkeep, saving time, complexity, and money.

Disadvantages

The main disadvantage of energy floors is the low energy production. For the floors focused on walking, the energy produced by the heel strike of a person's walk is 1-5 joules or 2 – 20 watts per step (Jintanawan, Thitima, et al., 2020). Most researchers do not see energy floors powering building systems like primary lights, heating, air conditioning cost-effectively. Rather, energy floors have potential in low power applications, like low-level lighting, environmental sensors, or other monitoring devices (Puscasu, Onoriu, et al., 2018). These low power applications do not have to be connected to the main grid, so if the main electric grid malfunctions, these backups will continue to run, and they will run autonomously.

Another disadvantage, to be useful, energy floors must only be utilized in high trafficked areas. This includes shopping centers, offices, airports, train stations, fitness centers, parking garages, etc., but family homes or personal spaces do not have enough foot traffic to have sufficient energy production. This limits the potential applications of the technology. Moreover, the energy produced may be inconsistent depending on the setting. The foot traffic in certain places varies by time or season. For example, the traffic in a university corridor shows inconsistencies because of limitations on the weekends and during university holidays (figure 2). Lack of consistency limits the usefulness of energy floors in the long term.

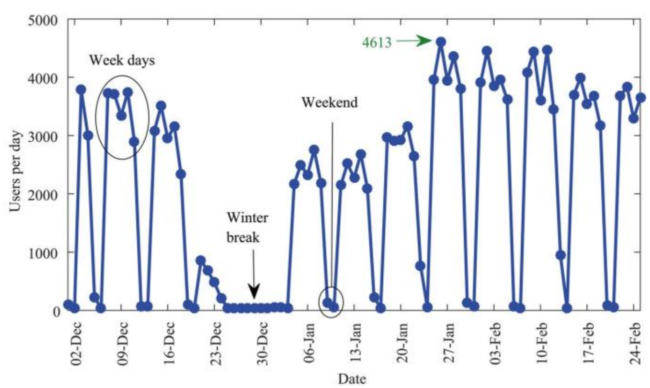

Figure 2: Traffic in a busy university corridor, as recorded using an optical counting system (Puscasu, Onoriu, et al., 2018).

Energy floors have obvious disadvantages, but they still represent a unique idea of creating energy simply, thus proving to have potential. Their innovative process in utilizing natural tendencies may have invasive roots but could prove successful because of the long-term durability and ease in implementation. However, as a tool for raising public awareness of renewable energy and the energy crisis, energy floors are particularly useful, as they find themselves prominent in high-traffic, high profile areas during people's normal activity. In finding solutions to the energy crisis and moving away from fossil fuels or other energy resources that devastate the planet, creativity is essential. Scientists, researchers, and inventors must be creative when developing renewable energy ideas, and the creators of energy floor did just that.

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