

## PENERAPAN *PIEZOELECTRIC ENERGY HARVESTING* DI BANDAR UDARA: SUMBER ENERGI, MATERIAL DAN DESAIN

### APPLICATION OF PIEZOELECTRIC ENERGY HARVESTING AT AIRPORTS: ENERGY SOURCES, MATERIALS AND DESIGN

### Direstu Amalia<sup>1</sup>, Viktor Suryan<sup>2</sup>, M. Indra Martadinata<sup>3</sup>, Yeti Komalasari<sup>4</sup>, Almuzani<sup>5</sup>, M. Alamsyah<sup>6</sup>, Nabila Hasna Arinda<sup>7</sup>, Made Putra Darsana<sup>8</sup> <sup>1,2,3,4,5,6,7</sup>Politeknik Penerbangan Palembang

direstu@poltekbangplg.ac.id

### ABSTRACT

Airports have many areas with intensive activities that can be potential sources for Piezoelectric Energy Harvesting because airports are places that produce much mechanical energy that has not been realized. This mechanical energy comes from various sources, such as passenger and visitor traffic, vehicle movement, elevator and conveyor use, and aircraft activity on runways and taxiways. The research methodology used is a Literature Review. This article reviews the factors that affect PEH, namely energy sources, materials, and design, and it is a literature study article related to smart airport technology. This article aims to establish hypotheses of influence between variables as a reference for further research. This literature review article will produce: 1) Energy source affects Piezoelectric Energy Harvesting; 2) Materials affect Piezoelectric Energy Harvesting; and 3) Design affects Piezoelectric Energy Harvesting. This research will produce a deeper understanding of the potential mechanical energy sources. Hopefully, this article will provide an overview of designing Piezoelectric Energy Harvesting suitable for airports.

Keywords: Piezoelectric, Energy Harvesting, Energy Sources, Materials and Design.

#### ABSTRAK

Bandar udara memiliki banyak area dengan aktivitas intensif yang dapat menjadi sumber potensial untuk Piezoelectric Energy Harvesting karena bandar udara adalah tempat yang menghasilkan banyak energi mekanis yang selama ini belum disadari kebermanfaatannya. Energi mekanis ini berasal dari berbagai sumber, seperti lalu lalang penumpang dan pengunjung, pergerakan kendaraan, penggunaan elevator dan conveyor, serta aktivitas pesawat di runway dan taxiway. Metodologi penelitian yang digunakan adalah literature review sehingga artikel ini melakukan review terhadap faktor-faktor yang mempengaruhi Piezoelectric Energy Harvesting, yaitu Sumber Energi, Material dan Desain, sebuah artikel studi literatur terkait smart airport technology. Tujuan penulisan artikel ini untuk menegakkan hipotesis pengaruh antar variabel sebagai acuan bagi riset lanjutan. Artikel literature review ini akan menghasilkan: 1) Sumber Energi berpengaruh terhadap Piezoelectric Energy Harvesting ; 2) Material berpengaruh terhadap Piezoelectric Energy Harvesting ; dan 3) Desain berpengaruh terhadap Piezoelectric Energy Harvesting ; dan 3) Desain berpengaruh terhadap Piezoelectric Energy Harvesting . Penelitian ini diharapkan menghasilkan pemahaman yang lebih mendalam tentang potensi energi mekanis yang dapat dimanfaatkan di bandara dan bagaimana teknologi energy harvesting dapat diterapkan untuk mengoptimalkan sumber energi mekanis tersebut. Harapannya, artikel ini memberi gambaran dalam melakukan perancangan Piezoelectric Energy Harvesting yang sesuai dengan bandar udara.

Kata Kunci: Piezoelectric, Energy Harvesting, Energy Source, Material, Design.

### PENDAHULUAN

Airports require large amounts of energy for various purposes, such as lighting, cooling, operation of security systems, navigation equipment, and others. With the increasing number of passengers and flight frequency, this energy demand also continues to increase. It encourages airport managers to find solutions to increase energy supply efficiently and sustainably. Using conventional energy sources, such as fossil fuels, creates negative environmental impacts, including greenhouse gas emissions and air pollution, and global pressure to reduce carbon footprints and adopt cleaner energy sources. On the other side, we can find several energy sources that we can harvest from the ambient. Piezoelectric Energy Harvesting can be part of the solution, as it utilizes mechanical energy converted into without electrical energy harmful (Sezer & Koc. emissions 2021). Piezoelectric Energy Harvesting is a mechanical energy harvesting system from the most ubiquitous derived environmental energy that can be captured and converted into useful electrical power. Piezoelectric transduction is a prominent mechanical energy harvesting mechanism. Several studies mentioned potential energy Piezoelectric sources for Energy Harvesting such as wind, vibration from buildings, friction from equipment, friction from skin or and pressure from footsteps (Abadi et al., 2018; Bairagi et al., 2023; Orrego et al., 2017; Sharma et al., 2022; Tianchen et al., 2014; N. Wu et al., 2021; Y. Wu et al., 2021), and categorized the types of piezoelectrics used according to the energy source.

Piezoelectric types are generally divided into three classes: ceramic. polymer, and composite (Kováciková et al., 2023; Zhao & Wang, 2020). The ceramic type is the strongest in piezoelectric properties but is stiff and compared brittle polymer to and composite, so this type is most widely applied (Habib et al., 2022; Sapkal et al., 2022). However, when implemented in medical equipment and textiles, the polymer type is more suitable, while composite materials are more suitable for tactile sensors and gait energy harvesting. Energy harvesting at the airport has been done by modifying the runway pavement structure, utilizing the energy source in the form of vibrations from aircraft taking off on the airside (Kováciková et al., 2023; Zhao & Wang, 2020). The indicators of Piezoelectric Energy Harvesting are its high electromechanical coupling factor and piezoelectric coefficient compared to electrostatic, electromagnetic, and triboelectric transduction.

Piezoelectric Energy Harvesting is also described as an energy harvesting technique based on the properties of piezo materials in generating electric fields when mechanical force is applied. *Piezoelectricity* is a phenomenon that shows the ability of a material or several materials to produce electric voltage when given input in the form of pressure or voltage. This phenomenon is known as the direct piezoelectric effect (Covaci & 2020). The Gontean. dimensions or indicators of applying Piezoelectric Energy Harvesting are the energy source, energy harvesting mechanism, and place where PEH is implemented.

Piezoelectric Energy Harvesting is a new energy solution and piezoelectric mechanism. new idea regarding a piezoelectric energy harvesting from environmental vibrations and natural explains which resources that the dimensions or indicators of Piezoelectric Energy Harvesting are the mechanism and flexibility piezoelectric of energy generation materials. Factors that also affect Piezoelectric Energy Harvesting are the type of material and installation technique (Pradeesh et al., 2022). The application of Piezoelectric Energy Harvesting has been widely studied by previous researchers, including (Abadi et al., 2018; Febrawi & Wonoyudo, 2013; Lee & Youn, 2011; Sharma et al., 2022; Yang et al., 2018).

Based on the movement data 2023 at Sultan Mahmud Badaruddin II Airport average 305.783 Palembang, an of passengers arrived and departed. The average take-off aircraft amounted to 2,137 aircraft per month, and the total baggage recorded by passengers passed on the conveyor amounted to 2,319,826 By installing piezoelectric baggage. materials in strategic areas, energy from the pressure generated by passenger footsteps or vehicle wheel movements can be converted into electrical energy. This energy can then be used for various purposes at the airport, such as lighting, charging electronic devices, and monitoring systems. Considering the

increasing energy demand, the pressure to use green energy, the vast potential of airport locations, strategic and the economic and operational advantages, Piezoelectric Energy Harvesting emerges as a relevant and promising solution. The design of this technology at airports can be a step forward in the effort to achieve sustainability greater and energy efficiency. It is expected to help save energy and reduce operational costs in the long run. The initial investment in this technology can be offset by reducing conventional energy costs and contributing to the company's sustainability goals. In addition, an additional sustainable energy source can improve the reliability of the energy supply at the airport.

Based on the background, problems can be formulated and discussed to build hypotheses for further research: 1) Does energy source affect piezoelectric energy harvesting? 2) Does Material Affect Piezoelectric Energy Harvesting? 3) Does Piezoelectric design affect Energy Harvesting? This article discusses the influence of Energy Sources, Materials, and Design on Piezoelectric Energy Harvesting, a literature review study in harvesting technology. energy This expected to provide research is an overview of what factors need to be considered when implementing Piezoelectric Energy Harvesting at the airport in terms of energy sources, types of and designs following the materials. characteristics of airport activities.

# METHOD

This research is a literature review that studies the theory and the relationship between variables: energy source, material, and design. The literature review is a method that can be employed to carry out research endeavors. The literature review is considered the most authoritative form of evidence. Literature reviews are a systematic process employed to collect information or strategies for addressing specific issues. They entail a systematic procedure that generates reports to conduct research or concentrate on a specific topic. Nevertheless, the evidence suggests that conducting a literature review might be difficult because researchers must thoroughly understand how to investigate a specific issue to compile a review. According Zed's research to (Kartiningrum, 2015), the literature review is needed as preliminary research to understand emerging societal issues better. Using this research, the researchers hope to gain a deeper insight into the potential application of piezoelectric nanogenerators at airports. In his 2018 research, Cronin states that to create a comprehensive literature review effectively, a writer must meticulously adhere to five distinct steps preparation and during the writing (Cahyono et al., 2019).



This research collects scientific articles from trusted publisher journals with indexes. The library studies are structured and grouped to approach methodological assumptions. The library study is presented inductively and exploratory to provide a clear overview of current literary references to the theme of piezoelectric energy harvesting.

# **RESULT AND DISCUSSION**

# Piezoelectric Energy Sources in Airports

Energy sources for piezoelectric energy are ambient energy sources, usually solar, heat, and vibrational energy. Among these energy sources, vibrational energy is continuously present in nature and manmade structures (Safaei et al., 2019). Mechanical energy generated by the pressure of people or objects has also been shown to be a source of PEH (Abadi et al., 2018; Sharma et al., 2022; Yulia et al., 2016). The Energy Source indicator for ambient energy is a stable source and transduction mechanism that can convert vibrational energy into useful electrical energy.

Energy sources are produced by flexible piezoelectric devices that harvest wind energy (Orrego et al., 2017). Energy source indicators include wind stability Piezoelectric Energy Harvesting and design. Energy Source for piezoelectric energy harvesting uses direct energy conversion from vibration and mechanical deformation into electrical energy. Piezoelectric Energy Harvesting is a promising technique for supplying power sources in standalone electronic devices, wireless sensor nodes, micro-electronic devices, etc (Kang et al., 2016). Energy Source indicators are simple structural designs and materials influencing higher energy conversion efficiency. Energy Sources obtained from noise and vibration include noise from aircraft near airports, vibrations from jet and supersonic aircraft, aircraft engine tests, aircraft runway noise, and supersonic booms (Kováciková et al., 2023). Indicators of energy sources are the intense vibrations that are produced.

The energy source is obtained from the flexible airfield pavement structure, the pressure generated by aircraft activity on the aircraft runway (Zhao & Wang, 2020). The indicators of the Energy Source are the strength of the pressure generated and the stackable design of the piezoelectric system embedded in the flexible pavement. Energy sources have been extensively studied by previous researchers, including (Altabey & Kouritem, 2023; Bairagi et al., 2023; & Wonoyudo, 2013: Febrawi Mohammadpourfazeli al.. 2023: et Nechibvute et al., 2012; Sarker et al., 2022).

Airport characteristics can be a potential Piezoelectric Energy Harvesting source as places with intensive activities generate much wasted mechanical energy.

This energy comes from various sources, such as passenger and visitor traffic, vehicle movement, elevator and conveyor use, and aircraft activity on runways and taxiways (Lee & Youn, 2011; Safaei et al., 2019; Sekhar et al., 2023). In addition, airside wind speeds and vibrations generated by building structures also offer an additional energy source. Converting mechanical energy into alternative electrical energy through piezoelectric technology can improve airport operations' and energy efficiency sustainability. **Piezoelectric Materials in Airports** 

The materials used in energy harvesting activities are divided based on type of effect used. the namelv piezoelectric (PENG), triboelectric (TENG), and pyroelectric (PyENG), which was first developed by Wang in 2006 (Indira et al., 2019). The indicators are the energy source, material characteristics, and implementation based on the type of effect selected. Materials that utilize the piezoelectric effect are divided into three types: polymers, ceramics, and composites (Sekhar et al., 2023). These material indicators are energy sources, properties, and characteristics appropriate to the application's location.

Polymer-type materials are usually selected with a focus on the flexibility and malleability of inorganic, polymeric, and bio-piezoelectric materials, explaining properties monitoring their for physiological signals, motion detection, and force sensing (Mohammadpourfazeli et al., 2023), where (Y. Wu et al., 2021) Therefore. PLLA/PDMS. electro-spun PVDF, and ZnO/PVDF have a higher elastic modulus and are more suitable for wearable devices. The dimensions or indicators of the material are the types of polymers and composites that match human skin as the modulus of elasticity. The lead zirconate titanate or PZT ceramic type material is most widely used because of its durability (Kang et al., 2016) because it is considered to have the highest piezoelectric effect even though the

characteristics of PZT are classified as stiff and brittle (Habib et al., 2022). The power generated from this type of Piezoelectric Energy Harvesting is capable of biasing several electronic devices at once (Ambrosio et al., 2011). PZT material dimensions or indicators are material characteristics capable of providing optimal performance, as evidenced by the resulting power output.

Composite materials have advantages compared to ceramic and polymer materials because the nature of the material is easy to modify, both in structure and composition (Fabiani et al., 2019; Habib et al., 2022. For example, piezoelectric polymer nanofibers were successfully embedded in composite laminates for self-sensing applications, as mentioned in the research (Selleri et al., 2022). Material indicators are the flexibility of structure and composition. Many studies related to materials have been conducted by previous researchers, including (Habib et al., 2022; Liu et al., 2018; Safaei et al., 2019; Sekhar et al., 2023).

The type of materials has to match the airport's energy source. The airport's energy source character can be found based on the activities that generate much wasted mechanical energy. Ceramic materials have strong piezoelectric properties but are stiff and brittle. Where PZT has the highest piezoelectricity compared to others. In addition, the modified BaTiO3 and KNN also have suitable piezoelectric constants. However, AlN and LiNbO3 are better choices at high temperatures. Therefore, all ceramic piezoelectric materials in this study have high Young's modulus values, making them unlikely to be employed in applications requiring large deflection, except microfabricated PZT. Although polymer materials are lighter and more flexible than ceramic materials, they do exhibit excellent piezoelectric not performance. Cellular PP, likewise categorized as a ferroelectric, is the

exception. It has been determined that composite materials combine the best qualities of ceramic and polymer materials with the flexibility to change their composition and structure to achieve the desired results.



# Figure 1. PZT material and design for footstep (source: owner documentation)

In addition, each material's advantages vary depending on the application. Composite materials are better suited for tactile sensors and energy harvesting from gait, polymer materials for electronic textiles and biomedical devices, and ceramic materials for underwater sonar and MEM resonators.

# Piezoelectric Design in Airports

The design by (Diniardi et al., 2017) combines a piezoelectric membrane and solar cells as a medium for producing electrical energy from the influence of compressive or impact forces originating from raindrops and sunlight-based regions in Indonesia. The design dimensions or indicators are designed accurately, which includes accuracy in calculating forces, distance between piezos, and the stress obtained. The design by (Sivasubramanian et al., 2021) combines photovoltaic hybrid cells and nanogenerators as a medium for producing electrical energy. The design indicators are the design structure and the resulting energy output. Piezoelectric sourced from energy designs from footsteps were reviewed by (Sharma et al., 2022). Several Piezoelectric Energy Harvesting designs are embedded in and building floors state that the dimensions or design indicators lie in the installation mechanism and electronic circuit design specified.

The piezoelectric design (Nuh & Hendrowati, 2017) took the form of a Piezoelectric Energy Harvesting prototype, which was tested in the laboratory using a case study on ocean waves. These design dimensions or indicators are related to the energy harvesting mechanism and the amount of input generated from sea waves. has been The design extensively previous researched by researchers, including (Ambrosio et al., 2011; Bairagi et al., 2023; Diniardi et al., 2017; Febrawi & Wonoyudo, 2013; Nechibvute et al., 2012; Orrego et al., 2017; Selleri et al., 2022). Based on the result above, we can describe the three relations of piezoelectric energy harvesting with an energy source, material, and design, as stated below.

## Influence of Energy Source on Piezoelectric Energy Harvesting in Airport

Sources influence Energy Piezoelectric Energy Harvesting where the indicators of energy sources in airports include stable sources and transduction mechanisms that can convert vibrational energy into valuable electrical energy, influencing indicators of Piezoelectric Energy Harvesting in research (Bairagi et al., 2023; Febrawi & Wonoyudo, 2013; Mohammadpourfazeli et al.. 2023: Nechibvute et al., 2012) which is determined by the size and stability of the energy source obtained (Safaei et al., 2019).

Another source of Piezoelectric Energy Harvesting comes from sea tides (Nuh & Hendrowati, 2017), requiring stability of the energy source and several stages of testing to obtain design accuracy. We can find a water flow in the airport in the water treatment system. It is necessary to identify a harvest location for energy sources that is stable, large enough, and equipped with the necessary design and testing stages in order to maximize the potential for adopting piezoelectric energy harvesting by paying attention to energy sources (Orrego et al., 2017).

Piezoelectric Energy Harvesting in Airports may influenced by the type of energy sources used. Employing the appropriate technology to collect energy sources will generate a Piezoelectric Energy Harvesting effect. It may be inferred that mechanical energy sources notably influence its performance. The findings indicated that vibration was piezoelectric energy harvesting's most efficient energy source, surpassing other mechanical energy sources. The results of this study have consequences for the development and improvement of systems, particularly in applications that necessitate energy utilization. This aligns with the research (Covaci & Gontean, 2020; Liu et al., 2018; Pradeesh et al., 2022; Sapkal et al., 2022).

# Influence of Material on Piezoelectric Energy Harvesting in Airports

Materials influence Piezoelectric Energy Harvesting in airports, where indicators of mechanical energy sources originating from vibration. pressure. friction, wind, and waves influence indicators of the amount of electrical energy output produced. To improve Piezoelectric Energy Harvesting by paying attention to energy sources, the correct selection of materials must be made, which influences higher energy conversion efficiency (Kang et al., 2016).

Materials influence Piezoelectric Energy Harvesting. Suppose the material has appropriate energy harvesting characteristics. In that case, this will improve quality and provide optimal performance, as evidenced by the power output produced by Piezoelectric Energy Harvesting (Ambrosio et al., 2011; Habib et al., 2022).

Materials influence Piezoelectric Energy Harvesting conclusions obtained from previous research results show the significant impact of piezoelectric materials on Piezoelectric Energy Harvesting performance in airports. The results show that PZT is the most effective material for Piezoelectric Energy Harvesting in airports, followed by lead zirconate and barium titanate. The findings of this research have implications for the design and optimization of Piezoelectric Energy Harvesting systems, especially in applications that require mechanical energy. The results of this research align with research conducted by (Habib et al., 2022; Safaei et al., 2019; Sekhar et al., 2023).

## Influence of Design on Piezoelectric Energy Harvesting

Design influences Piezoelectric Energy Harvesting where the indicators of Energy Sources in airports resulting from vibration, pressure, friction, wind, and waves influence the indicators of Piezoelectric Energy Harvesting, design accuracy, which includes accuracy in material selection, calculation of force, between piezo. and distance stress obtained (Diniardi et al., 2017). In order to enhance Piezoelectric Energy Harvesting in airports, it is crucial to focus on the design, installation mechanism, and design of the specific electronic circuit that fits the situation of the airport. These factors have a direct impact on the energy output that is obtained (Sivasubramanian et al., 2021).

Design influences implementation in airports; if a stable energy source is supported by a transduction mechanism that can convert vibration energy into electrical energy, this will improve the quality of Piezoelectric Energy Harvesting (Kang et al., 2016). Design is proven to affect Piezoelectric Energy Harvesting in conclusions from previous airports; research results show that energy harvester design significantly affects its performance. The size. the material properties, and the distance between the piezo, the transducer, and the rectifier for maximizing the voltage obtained should be appropriately calculated to make the best performance of the energy harvesting system in airports.

The design of piezoelectric energy harvesting systems at airports must consider several critical (Sivasubramanian et al., 2021) factors. These include placing piezoelectric sensors in areas with the highest vibration frequencies, integrating with airport electrical systems, and ensuring long-term maintenance and durability. The design must also ensure that the sensor installation does not interfere with normal airport activities and adheres to strict safety standards. An efficient energy management system is also needed to store and distribute the energy produced. This significantly influences the accuracy of Piezoelectric Energy Harvesting and plays an essential role in determining its performance. This conclusion is in line with research conducted by (Ambrosio et al., 2011; Bairagi et al., 2023; Diniardi et al., 2017; Febrawi & Wonoyudo, 2013; Nechibvute et al., 2012; Orrego et al., 2017; Selleri et al., 2022; Sharma et al., 2022).

The conceptual framework is structured based on problem formulation, theoretical study, relevant research, and discussion related to the influence between variables x1, x2, and x3, thus obtaining the framework of thinking below.





Based on the conceptual framework above, Energy Sources, Materials, and Design influence Piezoelectric Energy Harvesting in airports. In addition to the three exogenous variables that affect Piezoelectric Energy harvesting, many other variables influence it, including a) x4: System testing steps by (Arimurti et

## al., 2020), b) x5: Location to implement by (Zhao & Wang, 2020), c) x6: Hybrid System by (Diniardi et al., 2017; Sivasubramanian et al., 2021)

**Table 1. Relevant Study** 

(year)         this article         this article           1.         Sekhar et al. (2023)         Review ing Energy sources (x1). Materials Sc2), and interature related to (x2) and Phezoelectric Energy Marenals, Canad Applications (x3).         Reary sources (x1). Materials (x2), and interature related to (x2) and Phezoelectric Energy Sources (x1). Materials (x2), and and design inpact Phezoelectric Energy influence on positive and significant and design inpact Phezoelectric Energy Harvesting (PEH).         Design, focusing on the airport.           2.         Shaukat et al. (2023)         Energy Sources (x1). Materials and design inpact of sin source and show the development of PEH applications is energy use for sources. (x4). Harvesting (PEH).         Design, focusad applications is energy use for an airport article focuses on the arenery use for an airport article focuses on the avainus fields, such and applications.           3.         Arimurti et al. (2020)         Energy Sources (x1). Materials and besign in anterials (x2), and test materials (x2), and test material (x3), and test materials (x3), and test materials (x3), and test material (x3) functions.         Energy Sources (x1) and Energy Sources for mergy for sources or for the super vehicle traffic on the only discussed the material (x3) transducer vehicle traffic on the only discussed the material (x3) transducer.           4.         Yulia et al. (2016)         Energy sources (x1) and Energy sources for the system.         The adsign of the system.           5.         Zhao & Wang (2020)         Energy sources (x1) and Energy sources of the only discussed the vehicle traffic and prezoelectric Energy police received input from more vehicle.	(year)         Interval           har et al. (2023)         Reviewing Energy Sources (x1), Materials Applications (x3).         Energy Materials (x2), and Piezoe Harve           ukat et al. (2023)         Energy sources (x1).         Energy Sources (x1).         Energy Piezoe Harve           ukat et al. (2023)         Energy sources (x1).         Energy Piezoe Harvesting (PEH).         This applic article focuses on the variou development of PEH as ene technology in general.           mutri et al. (2020)         Energy Sources (x1).         Energy materials (x2), and test material (x2), and test stages (x4) have a influence on material (x2), and test stages (x4) have a influence on material (polyvinylidene fluoride).         Materi stages (x4) have a influence on material (polyvinylidene fluoride).           ia et al. (2020)         Energy Harvesting. This study discussed the material type polycrystalline ceramic and the piezo vibration sensor of PVDF material (polyvinylidene fluoride).         Harvesting Piezoelectric Energy Piezoelectric Energy Piezoelectric Energy Piezoelectric Step police received input from motor vehicle pressure with a cantiliver system for the system.           o & Wang (2020)         Energy Sources (x1) and Energy Harvesting. This research suggests that designs can affect power output and the borizontal location or energy harvesters.           o & Wang (2020)         Energy Harvesting. This research suggests that designs can affect power output and the borizontal location or piezoelectric Energy Harvesting. This research suggests that designs can affect power output and the borizontal supersonic aircraft, nicraft engine tests, airplane runway n	ılt Similar	rities with	Differences with	1
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3. Arimurti et al. (2020)/Energy sources (x).       Energy Sources (x).       The research deals only with one source stages (x4) have a lnfluencing of energy: forotsteps impact on Pizoelectric Harvesting.       The research deals only with one source stages (x4) have a lignificant Pizoelectric Energy and the type of energy: forotsteps on polycrystalline ceramic material (all the pizzo vibration materials, and energy sources (x1) and Energy sources (x1) and Energy sources from (Yulia et al., 2016)         4. Yulia et al. (2010)       Energy Sources (x1) and Energy sources from (Yulia et al., 2016) design (x3) transducer systems positively and slepping police and energy sources of significantly influence design influence the vehicle traffic and Piezoelectric Energy Plarvesting.         9. Zhao & Wang (2020)/Energy sources (x1) and Energy sources of montor vehicle montor vehicle montor vehicle montor vehicle traffic and Piezoelectric Energy police received input from motor vehicle motor vehicle traffic and Piezoelectric Energy police received input from motor vehicle motor vehicle traffic and Piezoelectric Energy police received input from motor vehicle m	and the mutri et al. (2020)Energy sources (x1). Energy materials (x2), and test Mater stages (x4) have a linflue positive and significant Piezoe impact on Piezoelectric Harve Energy Harvesting. This study discussed the material type polycrystalline ceramic and the piezo vibration sensor of PVDF material (polyviny)Idene fluoride). Energy sources (x1) and Energy else yources (x1) and Energy Piezoelectric Energy Piezoelectric Energy Piezoelectric Energy Piezoelectric Energy Harvesting. This research suggests that designs can fifted provention build (x5), testing techniques in plut and the piezoelectric Energy Harvesting. This research suggests that designs can affect power output and the horizontal location of energy harvesters. The size of the energy Harvesting. The size of the energy Harvesting and for the size of the sources (x1) and Energy harvesters. The size of the energy Harvesting. The research suggests that designs can affect power output and the horizontal location of energy harvesters. The size of the energy Harvesting. The research uses sources at the airport that include aircraft noise near airports, vibrations from jet and supersonic aircraft, aircraft engine tests, airplane runway noise, and supersonic noise. Taubramaniant et Material (x1). Design Mater 3(x2), hybrid influe (x2), hybrid influe runway noise, and supersonic entergy Harvesting. The research uses ources at the airport that include aircraft noise near airports, vibrations from jet and supersonic noise. Taubramaniant (x1), Design Mater 3(x1), Design Mater 3(x1), Design Mater 3(x2), hybrid influe find affect and supersonic aircraft noise near airports, vibrations from jet and supersonic noise. Taubramaniant (x1), Design Mater 3(x1), Design Mater	wearable	electronics,		
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### CONCLUSION

By considering the theory, relevant publications, and debates, it is feasible to develop hypotheses for future research. One such hypothesis is that energy sources impact Piezoelectric Energy Harvesting in airports. 2) At airports, Materials impact

the process of converting mechanical energy into electrical energy, known as piezoelectric energy harvesting. 3) Designs impact the Piezoelectric Energy Harvesting system airports. at Implementing piezoelectric energy harvesting technology at airports has the potential to be an innovative solution that promotes sustainability and enhances energy efficiency. Piezoelectric materials can convert mechanical energy into electrical energy by harnessing vibrations and pressure generated by activities at the airport, such as passenger movement, airplane operations, and car traffic. Using piezoelectric energy harvesting technology, airports can decrease reliance on traditional energy sources and minimize carbon emissions. This represents a significant advancement in incorporating environmentally friendly technologies into contemporary infrastructure, enhancing airports' sustainability and efficiency

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