

Piezoelectric Energy Harvesting System Market – Global Industry Size, Share, Trends, Opportunity, and Forecast Segmented by Technology (Light Energy, Vibration Energy, Thermal Energy, Others), By Component (Transducer, Power Management Integrated Circuit, Storage Systems), By Region, By Competition 2018-2028.

<https://marketpublishers.com/r/P89E8A132E19EN.html>

Date: November 2023

Pages: 178

Price: US\$ 4,500.00 (Single User License)

ID: P89E8A132E19EN

Abstracts

Global Piezoelectric Energy Harvesting System Market was valued at USD 597.93 Million in 2022 and is anticipated to project robust growth in the forecast period with a CAGR of 4.75% through 2028. Piezoelectric energy harvesting is the process that converts mechanical energy to electrical energy, depending upon the amount of stress applied in deforming or compressing the material, the type and amount of deformation of the crystal of the material, and the frequency or speed of vibration or compression to the material. Its effect is a reversible process in which material exhibiting direct piezoelectric effect i.e. charge separation due to stress also exhibits the converse piezoelectric effect i.e. the occurrence of stress and strain when the electric field is applied.

Key Market Drivers

Growing Demand for Sustainable Energy

The global demand for sustainable energy sources has become a driving force behind the growth of the Piezoelectric Energy Harvesting System Market. As the world grapples with environmental concerns and the need to reduce its carbon footprint, piezoelectric energy harvesting systems have emerged as a compelling solution,

offering a clean, renewable, and eco-friendly source of power. One of the primary drivers for the adoption of piezoelectric energy harvesting systems is the increasing awareness of climate change and the urgent need to transition away from fossil fuels. As nations and industries strive to meet ambitious sustainability goals and reduce greenhouse gas emissions, the focus has shifted to renewable energy technologies that can help mitigate the environmental impact of energy generation. Piezoelectric energy harvesting aligns perfectly with this agenda, as it generates electricity from mechanical vibrations and movements without producing harmful emissions.

Additionally, the need for sustainable energy sources extends beyond just addressing climate change. It also encompasses a desire for energy security and resilience. Piezoelectric energy harvesting systems can provide localized power generation in various applications, reducing dependence on centralized energy grids and enhancing energy resilience, particularly in remote or off-grid locations. In parallel, there is a growing recognition of the economic benefits of sustainable energy. Piezoelectric energy harvesting can lead to cost savings by reducing the reliance on traditional energy sources and batteries. These systems can be particularly advantageous in applications where battery replacement and maintenance costs are high, such as in remote monitoring devices or infrastructure sensors.

Moreover, the global commitment to sustainable practices has led to regulatory incentives and subsidies to promote the adoption of renewable energy technologies, including piezoelectric energy harvesting. Governments and organizations around the world are offering financial incentives and support to encourage the integration of these systems into various applications. As the demand for sustainable energy solutions continues to surge, the global piezoelectric energy harvesting system market is poised for substantial growth. These systems not only offer an environmentally friendly alternative but also contribute to energy security, economic savings, and energy resilience. In a world increasingly focused on sustainability, piezoelectric energy harvesting systems are well-positioned to play a pivotal role in shaping the future of clean and efficient energy generation.

Miniaturization and IoT Devices

Miniaturization and the burgeoning Internet of Things (IoT) landscape are poised to be potent drivers propelling the Global Piezoelectric Energy Harvesting System Market to new heights. The convergence of these two trends has sparked a surge in demand for compact, efficient, and sustainable power sources, and piezoelectric energy harvesting

systems have emerged as a perfect fit. The rapid proliferation of IoT devices is reshaping the way we interact with our environment and gather data. These devices, ranging from smart thermostats to wearable fitness trackers and industrial sensors, are becoming an integral part of our daily lives and industries. However, the Achilles' heel of many IoT devices is their dependence on traditional batteries, which can be cumbersome, finite, and environmentally unfriendly. This is where piezoelectric energy harvesting steps in as a game-changer.

Piezoelectric energy harvesting systems harness mechanical vibrations and movements, converting them into electrical energy. In the context of miniaturized IoT devices, this means that everyday actions, such as walking or even the subtle vibrations of machinery, can be tapped into as a power source. This not only extends the operational lifespan of IoT devices but also reduces the need for frequent battery replacements, lowering maintenance costs and minimizing environmental impact. Furthermore, miniaturization is not just about making devices smaller; it's also about making them more efficient and self-sustaining. Piezoelectric materials can be integrated into the very structure of IoT devices or incorporated into their components, making them more power-efficient and environmentally friendly. This integration can lead to energy-autonomous devices that can operate indefinitely in the right conditions.

As IoT continues to permeate various industries, including healthcare, manufacturing, agriculture, and smart cities, the demand for piezoelectric energy harvesting systems will rise exponentially. These systems align with the core principles of IoT—connectivity, sustainability, and efficiency—making them indispensable for the IoT revolution. With advancements in materials and technology, the future of miniaturized IoT devices powered by piezoelectric energy harvesting systems looks exceptionally promising, driving growth in the global market and contributing to a more sustainable and interconnected world.

Key Market Challenges

Limited Energy Output

The limited energy output of piezoelectric energy harvesting systems stands out as a significant hurdle in the path of the Global Piezoelectric Energy Harvesting System Market. While these systems offer a promising source of renewable energy, their relatively low energy production capacity poses challenges and limitations that can hinder their widespread adoption. One of the foremost issues is the insufficient energy output for certain applications. Piezoelectric energy harvesting systems primarily rely on

mechanical vibrations and movements to generate electricity. These vibrations are often subtle and may not provide enough energy to power devices or systems with higher energy demands. As a result, piezoelectric energy harvesting is more suitable for low-power and intermittent applications, such as sensors, wireless devices, and certain IoT applications.

This limitation becomes particularly evident when compared to other renewable energy sources like solar or wind, which can generate significantly more power. Solar panels, for instance, can produce a consistent supply of electricity under the right conditions, making them more practical for larger-scale or continuous power needs. In addition to the limited energy output, the variability of vibration sources poses another challenge. The efficiency of piezoelectric energy harvesting is highly dependent on the frequency and amplitude of the vibrations. In real-world scenarios, these factors can fluctuate, affecting the consistency and reliability of power generation. For instance, in urban environments, vibrations from foot traffic or vehicles may not always align with the energy needs of the devices. Moreover, the cost-effectiveness of piezoelectric energy harvesting systems can be questioned when considering the energy output. In some cases, the cost of implementing and maintaining these systems may outweigh the benefits, especially when compared to more established and efficient energy sources.

Efforts to overcome these challenges include research into advanced materials and engineering techniques to improve energy conversion efficiency, as well as the development of energy storage solutions to store harvested energy for use during periods of low vibration. However, addressing the limited energy output remains an ongoing challenge in expanding the applicability of piezoelectric energy harvesting to a broader range of energy-intensive applications. In summary, while piezoelectric energy harvesting systems offer undeniable advantages in terms of sustainability and eco-friendliness, their limited energy output remains a significant challenge. Overcoming this limitation is crucial to unlock the full potential of piezoelectric energy harvesting and expand its market reach beyond low-power, intermittent applications.

Vibration Source Variability

The variability of vibration sources presents a notable obstacle to the growth of the Global Piezoelectric Energy Harvesting System Market. Piezoelectric energy harvesting systems, which rely on converting mechanical vibrations and movements into electrical energy, are highly dependent on the characteristics of these vibrations. The inconsistency and unpredictability of vibration sources can significantly hamper the reliability and efficiency of these systems. One of the fundamental challenges is the

irregular nature of vibrations in real-world environments. These vibrations can vary in frequency, amplitude, and direction, making it challenging to design piezoelectric energy harvesting systems that consistently capture and convert this energy into electricity. For instance, in an urban setting, foot traffic, vehicular movement, and other sources of vibrations may occur at irregular intervals and intensities, making it difficult to predict when and how much energy can be harvested.

Variability in vibration sources is exacerbated by the fact that different applications and industries may have unique vibration profiles. For example, the vibrations experienced in industrial machinery differ from those encountered in transportation systems or consumer electronics. This diversity of sources necessitates customized solutions and engineering, increasing the complexity and cost of piezoelectric energy harvesting system implementations. Moreover, the efficiency of piezoelectric energy conversion is highly dependent on resonance frequencies. If the vibrations do not align with the resonance frequency of the piezoelectric materials used, the energy conversion efficiency can be suboptimal, resulting in energy losses. Achieving resonance with varying and unpredictable vibration sources can be a challenging task.

Reliability is another critical concern. In applications where consistent and dependable power is required, such as in remote monitoring devices or certain IoT applications, the variability of vibration sources can lead to power interruptions or insufficient energy generation. This unreliability can undermine the trust in piezoelectric energy harvesting systems for critical applications.

Addressing the challenge of vibration source variability requires innovative engineering solutions, adaptive algorithms, and the development of materials and designs that can work efficiently across a range of vibration conditions. Moreover, predictive modeling and data analytics can play a role in better understanding and harnessing varying vibration sources. In conclusion, the inconsistency and unpredictability of vibration sources pose a substantial challenge to the broader adoption of piezoelectric energy harvesting systems. Developing versatile and adaptable solutions that can cope with these variations is essential to enhance the reliability and effectiveness of these systems across a wide range of applications and industries.

Material Properties

Material properties stand out as a significant challenge in the context of the Global Piezoelectric Energy Harvesting System Market. Piezoelectric energy harvesting systems rely on specialized materials that can convert mechanical vibrations into

electrical energy. While these materials have unique properties that make them suitable for this purpose, several challenges related to material properties need to be addressed to promote the widespread adoption of these systems. One of the primary challenges is finding materials that strike the right balance between efficiency, durability, and cost-effectiveness. Piezoelectric materials must exhibit a high piezoelectric coefficient, which determines their ability to efficiently convert mechanical energy into electrical energy. Achieving high efficiency is crucial to maximize the energy harvested from vibrations. However, materials with superior piezoelectric properties can be expensive and challenging to manufacture in large quantities.

Durability is another crucial factor. Piezoelectric energy harvesting systems are often used in applications where they are exposed to environmental factors, including temperature variations, humidity, and mechanical stress. The materials used must withstand these conditions without significant degradation over time. Developing materials that are both highly piezoelectric and durable remains a challenge, particularly for long-term applications in harsh environments. Another aspect of material properties is the selection of appropriate materials for specific applications. Different materials may be better suited to certain vibration frequencies or amplitudes. The challenge lies in matching the material properties with the characteristics of the vibration source to ensure optimal energy conversion efficiency. This requires a deep understanding of the piezoelectric material landscape and the ability to tailor materials to specific application requirements. Additionally, the availability and sourcing of these materials can be a challenge. The market demand for high-quality piezoelectric materials is increasing with the growth of energy harvesting applications, which can lead to supply chain constraints and price fluctuations. Furthermore, while research continues to advance piezoelectric materials, finding sustainable and environmentally friendly materials is becoming increasingly important, given the overarching goal of reducing the environmental impact of energy generation.

Efforts to address these challenges involve ongoing research into new piezoelectric materials, manufacturing techniques, and material combinations. Researchers are working to enhance the performance, durability, and cost-effectiveness of piezoelectric materials to make them more attractive for a wider range of applications. In conclusion, material properties represent a crucial challenge in the Global Piezoelectric Energy Harvesting System Market. The development of materials that excel in terms of efficiency, durability, and cost-effectiveness is essential to unlock the full potential of piezoelectric energy harvesting and promote its adoption in diverse industries and applications.

Key Market Trends

Rise in IoT and Wireless Sensor Networks

The rise in IoT (Internet of Things) and wireless sensor networks is a compelling driving force propelling the Global Piezoelectric Energy Harvesting System Market to new heights. This trend is transforming the landscape of connected devices and sensors across various industries, and piezoelectric energy harvesting systems are playing a pivotal role in meeting the power needs of these devices. Here's how the proliferation of IoT and wireless sensor networks is driving the market, Low-Power Device Proliferation: IoT devices and wireless sensors are typically designed to be low-power and energy-efficient to extend their operational lifespan. Piezoelectric energy harvesting systems perfectly complement this requirement by providing a sustainable and reliable source of energy for these devices.

Battery Replacement and Maintenance Reduction: In many IoT and sensor applications, frequent battery replacements can be logistically challenging and costly, especially for remote or inaccessible devices. Piezoelectric energy harvesting reduces or eliminates the need for battery replacements, reducing operational costs and maintenance efforts. **Extended Device Lifespan:** IoT devices and sensors powered by piezoelectric energy harvesting systems can operate for extended periods without interruption. This longevity is particularly valuable in applications where consistent data collection and communication are critical.

Environmental Sensing: IoT and wireless sensor networks are heavily involved in environmental monitoring, such as air quality measurement, weather stations, and pollution control. Piezoelectric energy harvesting enables these devices to operate autonomously in remote or environmentally sensitive areas, improving the quality and accuracy of data collection. **Smart Building and Infrastructure:** In smart building applications, piezoelectric energy harvesting can be integrated into structures to power IoT sensors for occupancy detection, temperature monitoring, and energy management. Similarly, in infrastructure applications, piezoelectric materials can capture energy from structural vibrations in bridges and roads, enhancing the efficiency of smart city initiatives. **Wearable Devices:** The wearable technology market is booming, and many wearable devices incorporate IoT capabilities. Piezoelectric energy harvesting can be used to power these wearables by harnessing energy from the wearer's movements, reducing the need for frequent charging.

Industrial IoT (IIoT): In industrial settings, wireless sensor networks are used for

condition monitoring, predictive maintenance, and process optimization. Piezoelectric energy harvesting can provide a self-sustaining power source for these sensors, ensuring continuous data collection without downtime. Environmental Sustainability: IoT devices powered by piezoelectric energy harvesting contribute to environmental sustainability by reducing the reliance on disposable batteries and minimizing electronic waste. Research and Development: The research and development efforts in piezoelectric energy harvesting technology are driven by the growing demand from the IoT and sensor network sectors. This results in innovations in materials and system design that further enhance energy harvesting efficiency. In summary, the rise in IoT and wireless sensor networks is revolutionizing various industries, and piezoelectric energy harvesting systems are at the forefront of this transformation. These systems offer a reliable and sustainable solution to power the vast network of low-power devices, making them more efficient, cost-effective, and environmentally friendly. As IoT continues to expand, the Global Piezoelectric Energy Harvesting System Market is poised for substantial growth.

Advancements in Piezoelectric Materials

Advancements in piezoelectric materials are poised to be a major driving force behind the growth of the Global Piezoelectric Energy Harvesting System Market. These materials are at the heart of piezoelectric energy harvesting, and ongoing research and development efforts are continuously improving their efficiency, durability, and versatility. Here's how advancements in piezoelectric materials are shaping the market, Enhanced Efficiency: One of the primary benefits of advanced piezoelectric materials is their improved energy conversion efficiency. Researchers are developing materials with higher piezoelectric coefficients, which means they can efficiently convert mechanical vibrations and movements into electrical energy. This higher efficiency allows piezoelectric energy harvesting systems to generate more power from the same input, making them more practical and cost-effective.

Expanded Frequency Range: Advanced piezoelectric materials can operate over a broader range of frequencies, enabling them to capture energy from a wider spectrum of vibration sources. This adaptability is essential for various applications, from low-frequency vibrations in industrial machinery to high-frequency vibrations in consumer electronics. Durability and Reliability: Durability is a critical factor, especially in applications where piezoelectric energy harvesting systems are exposed to harsh environments. Advancements in materials have led to more robust and durable options that can withstand temperature variations, humidity, and mechanical stress without significant degradation. This enhances the reliability and longevity of these systems.

Miniaturization: As the trend toward smaller and more compact devices continues, piezoelectric materials are also evolving to meet these demands. Advanced materials can be tailored for miniaturized applications, allowing for the integration of energy harvesting capabilities into smaller and more efficient devices, such as wearables and IoT sensors. **Customization and Tailoring:** Researchers are developing piezoelectric materials that can be customized and tailored to specific applications. This flexibility allows for the optimization of materials to match the vibration characteristics and requirements of different industries and use cases.

Sustainability: Advancements in materials are also focusing on sustainability. Eco-friendly and lead-free piezoelectric materials are being developed to align with environmental regulations and sustainability goals. **Cost-Effective Solutions:** While high-performance materials are essential, researchers are also exploring cost-effective solutions to make piezoelectric energy harvesting systems more accessible. This involves finding the right balance between performance and affordability. **Integration:** Advanced piezoelectric materials can be integrated more seamlessly into various structures and devices, enhancing their practicality and versatility. This integration capability opens up new opportunities for energy harvesting in infrastructure, buildings, and even clothing.

In conclusion, advancements in piezoelectric materials are at the forefront of innovation in the Global Piezoelectric Energy Harvesting System Market. These materials hold the key to improving the efficiency, reliability, and sustainability of energy harvesting systems, expanding their applicability across diverse industries and driving the market's growth. As research in this field continues, we can expect even more exciting developments and applications in the future.

Segmental Insights

Technology Insights

Light Energy Harvesting will dominate the market, the piezoelectric energy harvesting system market is segregated into light energy harvesting and electromagnetic energy harvesting. In 2019, light energy harvesting technology held the largest share of the energy harvesting system market. The growth of light energy harvesting is also attributed to the increasing number of companies involved in the production of solar products for building automation, consumer electronics, and security applications. While electromagnetic harvesting is which converts flow energy into electrical energy by fluid

flow and electromagnetic induction. A finite element model for estimation of the generated voltage of the energy harvester is developed.

Regional Insights

North America is expected to dominate the market during the forecast period. Due to the region's ongoing and rapid technical advancements, North America has emerged as the most critical market for investments in building and home automation, which employ renewable energy and propel the demand for energy harvesting systems.

The majority of the region's revenue came from the United States. Due to the administration's intention to make the nation an energy-independent state and the thriving industrial and transportation sectors, the industry is anticipated to experience significant expansion.

Comparatively to other markets, the North American market is seeing a high level of industrial IoT adoption, boosting the need for energy harvesting systems.

Government programs to reduce energy emissions from outdated and public buildings have also contributed to this growth. For instance, 50 of the federal government's most energy-intensive buildings will have installed sophisticated and smart building technology due to a deal the U.S. General Services Administration signed with IBM.

Additionally, the smart cities project launch has altered the local market environment. In addition to holding events to promote collaboration and knowledge sharing amongst cities, businesses, and colleges involved in creating smart cities around the nation, this effort also includes various grants and funding packages.

Key Market Players

Powercast Corporation

Texas Instruments Incorporated

Fujitsu Limited

ABB Ltd.

Honeywell International Inc.

STMicroelectronics N.V.

EnOcean GmbH

Voltree Power Inc.

Bionic Power Inc.

Energy Partners.

Report Scope:

In this report, the Global Piezoelectric Energy Harvesting System Market has been segmented into the following categories, in addition to the industry trends which have also been detailed below:

Global Piezoelectric Energy Harvesting System Market, By Technology:

Light Energy

Vibration Energy

Thermal Energy

Others

Global Piezoelectric Energy Harvesting System Market, By Component:

Transducer

Power Management Integrated Circuit

Storage Systems

Global Piezoelectric Energy Harvesting System Market, By Region:

North America

United States

Canada

Mexico

Asia-Pacific

China

India

Japan

South Korea

Indonesia

Europe

Germany

United Kingdom

France

Russia

Spain

South America

Brazil

Argentina

Middle East & Africa

Saudi Arabia

South Africa

Egypt

UAE

Israel

Competitive Landscape

Company Profiles: Detailed analysis of the major companies presents in the Global Piezoelectric Energy Harvesting System Market.

Available Customizations:

Global Piezoelectric Energy Harvesting System Market report with the given market data, Tech Sci Research offers customizations according to a company's specific needs. The following customization options are available for the report:

Company Information

Detailed analysis and profiling of additional market players (up to five).

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