Global Science Publishing

ISRM

Intelligent Systems & Robotic Mechanics
https://ojs.sgsci.org/journals/isrm

Article

Sound-Driven Lighting: An Innovative Approach to Energy Generation through Sound-to-Electricity Conversion

Yashmit Malik [1], Nayana Sohalkar [1], Latesh Malik [2,*], Shreya Malik [3] and Gagan Malik[4]

[1] *Bhavan's B. P. Vidya Mandir, Trimurti Nagar, Nagpur, Maharashtra 440022, India*
[2] *Government College of Engineering Nagpur, Nagpur, Maharashtra 441108, India*
[3] *Indian Institute of Information Technology, Bongora, Gauhati 781015, India*
[4] *Varun Beverages, Aurangabad, Maharashtra 431107, India*

Abstract: The increasing reliance on non-renewable energy sources for lighting has led to significant environmental challenges, necessitating the exploration of sustainable alternatives. This paper presents a novel approach to energy generation by converting sound energy into electricity, specifically for lighting applications. By leveraging the principles of electromagnetic induction, this study demonstrates the potential of using sound waves to generate electrical power through a system that captures sound using woofers, converts it into mechanical vibrations, and subsequently transforms it into usable electricity. The proposed system stores the generated electricity in batteries, offering a sustainable alternative to traditional lighting solutions in various settings, such as bus stops, hotels, theaters, honk areas, and markets. The paper reviews the theoretical underpinnings of sound energy conversion, analyzes the system's efficiency, and explores its practical applications. The findings suggest that sound-driven lighting could serve as an eco-friendly and cost-effective solution, contributing to the broader goal of sustainable energy development. Future research directions are proposed to optimize conversion efficiency and expand the range of applications for this innovative technology.

Keywords: Sound energy conversion; renewable energy; electromagnetic induction; LED lighting; sustainable energy solutions

1. Introduction

The global energy landscape is currently dominated by non-renewable sources such as coal, oil, and natural gas. These energy sources are not only finite but also contribute significantly to environmental degradation, including air pollution, greenhouse gas emissions, and climate change. As the world grapples with the urgent need to reduce its carbon footprint and transition to cleaner energy, the exploration of renewable and sustainable energy alternatives has gained momentum. However, many of the existing renewable energy solutions, such as solar and wind power, face challenges related to high initial costs, variability in energy production, and infrastructure requirements.

Renewable energy technologies such as solar, wind, and hydropower have emerged as promising

Received: 10 September 2024; Accepted: 26 September 2024.

* Corresponding: Latesh Malik (shreya120malik@gmail.com)

alternatives to fossil fuels. These sources harness natural processes that are continually replenished, offering a more sustainable path forward. However, the deployment of these technologies often faces challenges. The installation and maintenance of renewable energy systems can be expensive, particularly in regions lacking the necessary infrastructure. Solar and wind energy are dependent on weather conditions, leading to intermittent energy supply, which can limit their reliability. The effectiveness of renewable energy technologies can be constrained by geographical factors, such as the availability of sunlight or wind, making them less viable in certain regions.

These limitations have spurred the exploration of novel energy generation methods that could complement existing renewable technologies and provide more versatile solutions. Traditional energy sources for lighting are often non-renewable and environmentally damaging; the renewable sources turn out to be expensive. This project addresses the problem of finding a viable method to convert sound energy into electrical energy, specifically for lighting LEDs, as a solution to sustainable energy.

2. Literature Review

The concept of converting sound energy into electricity is a relatively new and underexplored area in renewable energy research. While the principles of energy transformation and electromagnetic induction have been well-established for over a century, their application in sound energy conversion for practical uses like lighting remains nascent. This literature review examines the existing research on sound energy conversion, the technologies involved, and the potential applications, highlighting gaps in the literature that this paper aims to address.

Sound energy, as a form of mechanical energy, arises from the vibration of particles in a medium, such as air, water, or solids. This energy is typically dissipated as heat, but it can also be harnessed and converted into electrical energy. The concept of sound energy conversion relies on capturing acoustic waves and transforming them into electrical signals through various mechanisms, such as electromagnetic induction and piezoelectric effects.

The most referenced method for converting sound into electricity is electromagnetic induction, a phenomenon first described by Michael Faraday in 1831. According to Faraday's Law, a changing magnetic field induces an electromotive force (EMF) in a conductor [1, 2]. This principle is the foundation for many energy conversion devices, such as generators and transformers. However, its application in capturing low-frequency sound waves for practical energy generation is still being explored.

Another approach involves the piezoelectric effect, where certain materials generate an electric charge in response to mechanical stress. Piezoelectric materials, such as quartz and certain ceramics, can convert the mechanical vibrations caused by sound waves directly into electrical energy [3, 4]. Research in this area has focused on developing materials and devices that maximize energy output from ambient sound sources**.**

The conversion of mechanical energy into electrical energy has been widely studied in the context of various renewable energy technologies**:**

Wind turbines convert kinetic energy from wind into electrical energy using electromagnetic induction [5,6]. This technology is mature and widely deployed, but it requires specific environmental conditions, such as consistent wind speeds, which are not always available. Vibration energy harvesting devices capture mechanical vibrations and convert them into electrical energy, often using piezoelectric materials [7, 8]. These devices are used in applications ranging from powering small sensors to charging mobile devices. Research has shown that piezoelectric materials can generate electricity from ambient vibrations, including those caused by sound, but the energy output is typically low and requires optimization.

Acoustic energy harvesting is an emerging field that focuses specifically on converting sound waves into usable electrical energy [9,10]. Studies have explored the use of microphones, speakers, and other transducers to capture sound waves and convert them into electrical signals. The efficiency of these devices varies significantly based on the frequency and intensity of the sound, as well as the materials and design of the transducer.

Sound energy conversion has potential applications in various fields, although its practical deployment is still limited: Research has demonstrated that sound energy can be used to power small electronic devices, such as sensors and microcontrollers [11, 12]. These applications are particularly useful in environments where traditional power sources are not readily available. Sound-driven sensors can be deployed in noisy environments to monitor environmental conditions, leveraging the ambient sound to power the devices [13,14]. This approach is being explored for applications in smart cities and industrial settings. While the idea of using sound energy to power lighting systems is innovative, there has been little practical research in this area. The concept of sound-driven lighting, particularly using LEDs, offers a novel approach to sustainable lighting in environments with abundant noise, such as urban areas, transportation hubs, and commercial spaces [15,16].

Despite the theoretical foundations and preliminary research, there are significant gaps in the literature regarding the practical application of sound energy conversion, particularly for lighting: Most existing studies focus on the basic principles of sound energy conversion but do not address the efficiency of these systems in real-world applications. The conversion efficiency from sound energy to electrical energy remains a major challenge, with many devices producing only small amounts of power. There is limited research on scaling up sound energy conversion systems for larger applications, such as powering lighting in public spaces. Most studies focus on small-scale devices, and there is a need for research into how these systems can be scaled and integrated into existing infrastructure. The economic viability of sound energy conversion systems has not been thoroughly examined. Research is needed to compare the cost-effectiveness of sound-driven systems with other renewable energy technologies, particularly in terms of installation, maintenance, and energy output.

3. Theoretical Background

One emerging area of interest is the conversion of sound energy into electrical energy. Sound, a form of mechanical energy, is ubiquitous in our environment, generated by various sources such as human activities, industrial processes, and natural phenomena. Unlike solar or wind energy, sound is not limited by time of day or weather conditions, making it a potentially reliable and constant energy source.

Sound energy is defined as the energy produced when an object vibrates, creating pressure waves that travel through a medium such as air, water, or solids. The human ear can detect sound within a frequency range of 20 Hz to 20 kHz, but sound waves extend beyond this audible range, encompassing both infrasound (below 20 Hz) and ultrasound (above 20 kHz). The concept of harnessing this mechanical energy and converting it into electricity is rooted in the principle of energy transformation, where energy changes from one form to another without being created or destroyed.

The idea of converting mechanical energy into electrical energy is not new and is fundamentally based on the principle of electromagnetic induction, discovered by Michael Faraday in 1831. Faraday's Law states that a changing magnetic field within a coil of wire induces an electromotive force (EMF), which can be harnessed to generate electric current. This principle is the foundation of many modern electrical generators and motors.

Applying this principle to sound energy involves capturing sound waves and converting them into mechanical vibrations. These vibrations can then induce an electrical current when they interact with a magnetic field. While the conversion of sound energy to electricity has been theoretically established, its practical application, particularly for low-power uses such as lighting, remains largely unexplored.

4. Proposed System

While the concept of sound-driven lighting is promising, there is a lack of case studies or real-world implementations to demonstrate its feasibility. Research should focus on designing, testing, and deploying sound energy conversion systems in practical settings.

The project develops a system that converts sound energy into electrical power. By utilizing woofers to capture sound waves, this approach aims to demonstrate an innovative method of energy generation. By storing electricity in batteries for later use, this project offers a sustainable alternative to traditional lighting for different purposes like bus stops, Hotels, Theatre, Honk area and vegetable grocers. This solution offers a novel approach to eco-friendly lighting, Display boards and energy generation.

Given the challenges associated with existing renewable energy sources and the theoretical potential of sound energy conversion, there is a growing need to investigate this novel approach. Sound-driven lighting offers an innovative solution to the problem of sustainable energy generation, particularly in environments where sound is abundant and continuous, such as urban areas with high levels of ambient noise.

The development of a system that efficiently converts sound energy into electrical power for lighting could provide a cost-effective and eco-friendly alternative to traditional lighting methods. Such a system would be particularly valuable in settings where access to conventional energy sources is limited or where there is a high demand for sustainable energy solutions, such as in public transportation hubs, commercial spaces, and areas with significant noise pollution.

The concept of sound-driven lighting involves capturing sound waves, typically through a device such as a woofer, which then converts these waves into mechanical vibrations. These vibrations move within a magnetic field, inducing an electrical current that can be stored in batteries for later use. This approach is particularly innovative as it leverages a previously underutilized form of energy ambient sound—and converts it into a valuable resource for lighting and potentially other low-power applications. Importance of Project Study to highlight the significance of this research in contributing to eco-friendly and sustainable energy solutions.

Faraday's Law and its application in converting sound energy into electrical energy. Electromagnetic induction is the principle used to convert sound energy into electricity. This phenomenon, as described by Faraday's Law, states that a changing magnetic field induces an electromotive force (EMF) in a conductor. A microphone, typically equipped with a coil or diaphragm, is used to capture the sound waves produced by sound energy The sound waves cause the coil or diaphragm to vibrate mechanically. The vibrating coil or diaphragm moves within a magnetic field. The movement of the coil or diaphragm changes the magnetic flux passing through it. Hence Induced EMF, According to Faraday's Law.

Figures 1 – 3 Describe the components used in the project, including woofers/microphones, Condenser, Diodes, LED and batteries. Woofers capture sound waves. Conversion of sound waves to mechanical vibrations, and then to electrical signals through electromagnetic induction. The electrical signals generated by the woofer are in alternating current (AC) form. These signals need to be converted to direct current (DC) to be suitable for storage and use in lighting. The DC power generated is stored in a battery. This stored energy can then be used to power bulbs or other electrical devices for lighting LEDs.

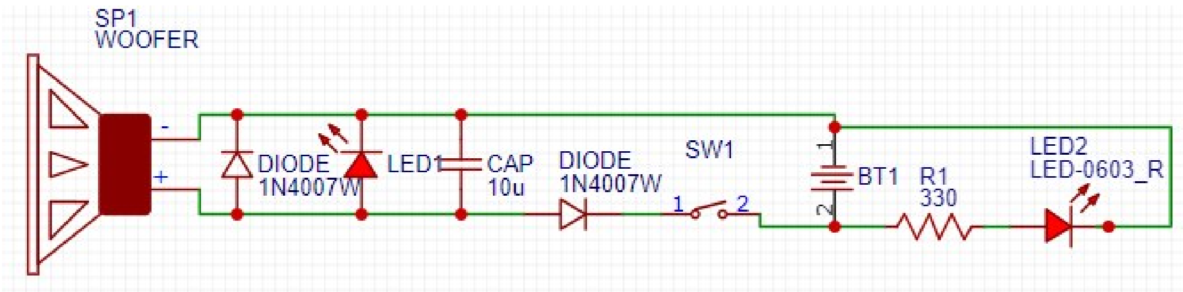

Figure 1. Circuit layout of Sound Energy to Light.

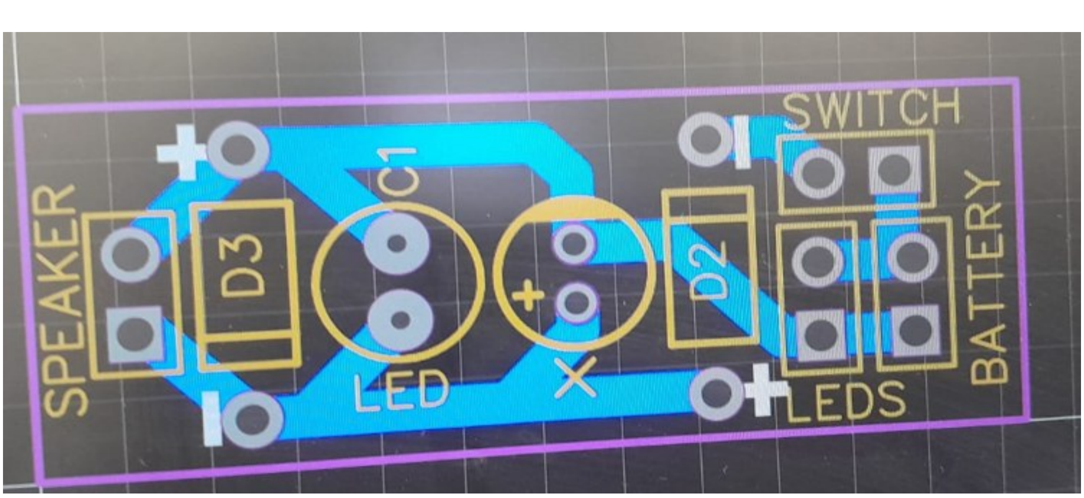

Figure 2. Circuit Diagram.

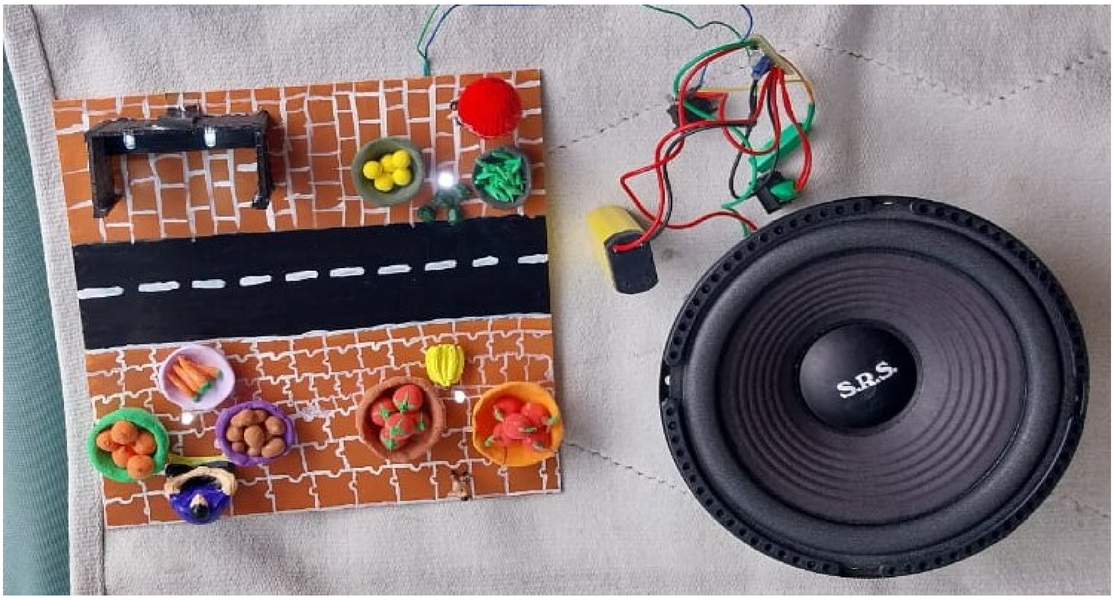

Figure 3. Depicted Scenario and Implemented Prototype Model. Distance from speaker (r): 1 m. Speaker diameter: 8 inches = 0.2032 m. Sound Pressure Level (SPL): 110–120 dB, Average 115 dB at 1 m from the horn. Reference Sound Pressure (p_0): 20×10^{-6} Pa. Density of Air (ρ): 1.21 kg/m^3. Speed of Sound in Air (v): 343 m/s.

Step 1: Convert Sound Pressure Level to Sound Pressure p

$p = p_0 \times 10^{SPL/20}$

$p = 20 \times 10^{-6} \times 10^{(115/20)} = 20 \times 10^{-6} \times 10^{5.75} = 11.24$ Pa

Step 2: Calculate the Area of the Speaker (A)

Area of the circular diaphragm of the speaker:

$A = \pi \times R^2$

$A = 3.14 \times (0.2032/2)^2 = 0.0324\ m^2$

Step 3: Calculate the Acoustic Power P

$P = p^2 \times A/(\rho \times v) = (11.24)^2 \times 0.0324/(1.21 \times 343) = 0.00986$ W

Step 4: Converting Acoustic Power to Electrical Power

The electrical power output from converting sound to electricity depends on the efficiency of the transducer.

Measured Electrical Power is 0.591 milli W

Efficiency, η = Electrical Power/Acoustic Power = 0.000591 W/0.00986 W=0.06 6% efficiency for the sound-to-electrical conversion

5. Results and Discussion

We analyzed the energy output based on different sound intensities and frequencies. At a distance of 1m from a speaker with an SPL of 115 dB and an 8-inch diameter, the estimated acoustic power is approximately 9.86 milliwatts, the electrical power output would be approximately 0.59 milliwatts. With a 6% efficiency in converting sound energy to electrical energy and this conversion efficiency very less as compare it with other renewable energy sources.

6. Conclusion

This paper sets the stage for exploring the potential of sound-driven lighting as a sustainable energy solution. By addressing the limitations of current renewable energy technologies and leveraging the principles of sound energy conversion, this research aims to contribute to the development of innovative methods for generating electricity. This novel approach has the potential to complement existing energy systems, offering a versatile and environmentally friendly solution to the global energy challenge. The above work has potential applications of sound-driven lighting in various settings like bus stops, hotels, theaters, honk areas, and vegetable markets. This model generated electrical energy can be used for lighting of LEDs in bus stops, vegetable and fruit sellers, Hotels with Music, Theatre, Honk area as well as shops like grocery and stationary. It is also ideal in areas with a high rate of irregular vibrations–noise.

Funding

Not applicable.

Author Contributions

Conceptualization, data collection, analysis, L.M.; Writing—original draft preparation and writing—review and editing, Y. M., N. S., L. M. S. M. and G. M. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement Statement

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

References

1 Faraday MV. Experimental Researches in Electricity. *Philosophical transactions of the Royal Society of London* 1832; **31**(**122**): 125–162.
2 Pippard AB, Pippard AB. *Electromagnetic Induction*. Forces and Particles: An Outline of the Principles of Classical Physics 1972; 242–271.
3 Cady WG. *Piezoelectricity: AnIntroductionto the Theory and Applications of Electromechanical Phenomenain Crystals*; McGraw-Hill: New York, NY, USA, 1946.
4 Uchino K. *Piezoelectric Actuators and Ultrasonic Motors*; Springer Science & Business Media: Berlin, Germany, 1996.
5 Burton T, Jenkins N, Sharpe D, Bossanyi E. *Wind Energy Handbook*; John Wiley & Sons: Hoboken, NJ, USA, 2011.
6 Manwell JF, McGowan JG, Rogers AL. *Wind Energy Explained: Theory, Design and Application*; John Wiley & Sons: Hoboken, NJ, USA, 2010.
7 Priya S, Inman DJ. *Energy Harvesting Technologies*; Springer: New York, NU, USA, 2009.
8 Beeby SP, Tudor MJ, White NM. Energy Harvesting Vibration Sources for Microsystems Applications. *Measurement Science and Technology* 2006; **17**(**12**): R175.
9 Pillai MA, Deenadayalan E. A Review of Acoustic Energy Harvesting. *International Journal of Precision Engineering and Manufacturing* 2014; **15**: 949–965.
10 Avent AW, Bowen CR. Principles of Thermoacoustic Energy Harvesting. *The European Physical Journal Special Topics* 2015; **224**(**14**): 2967–2992.
11 Rabaey JM, Ammer MJ, Da Silva JL, Patel D, Roundy S. PicoRadio Supports Ad Hoc Ultra-Low Power Wireless Networking. *Computer* 2000; **33**(**7**): 42–48.
12 Roundy S, Wright PK, Rabaey J. A Study of Low Level Vibrations as a Power Source for Wireless Sensor Nodes. *Computer Communications* 2003; **26**(**11**): 1131–1144.

13 Pottie GJ, Kaiser WJ. Wireless Integrated Network Sensors. *Communications of the ACM* 2000; **43**(**5**): 51–58.

14 Stojanovic M, Preisig J. Underwater Acoustic Communication Channels: Propagation Models and Statistical Characterization. *IEEE Communications Magazine* 2009; **47**(**1**): 84–89.

15 Tsao JY, Saunders HD, Creighton JR, Coltrin ME, Simmons JA. Solid-State Lighting: An Energy-Economics Perspective. *Journal of Physics D: Applied Physics* 2010; **43**(**35**): 354001.

16 Narendran N, Deng L, Pysar RM, Gu Y, Yu H. Performance Characteristics of High-Power Light-Emitting Diodes. In Proceedings of the Third International Conference on Solid State Lighting, San Diego, CA, USA, 26 January 2004; Volume 5187, pp. 267–275.