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The circular circulation of energy: A solution to energy dilemma

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Abstract. This paper presents novel solution for turning noise pollution into an energy source. To support this stance, theoretical calculations along with schematic diagrams on circuit boards and details regarding assembly plans of prototypes used during experimentation phases are also presented. The installation of the proposed device along airport runway lights has an initial cost of $102,150. As per specifications laid out in the article, this unit will have a capacity to generate 1.44MkWh energy for everyday use as compared with 0.074 Mk/h from airport runway lighting and aircraft generating around 0.072 MwH each day respectively. Additionally, Cost-Benefit Analysis demonstrates that this project offers positive benefits (Net Present Value & Benefit-Cost Ratio). This proposal would involve a one-year project with an expected recovery period of one quarter. Adopting this plan may bring various benefits, such as reduced carbon emissions and less cost.
Keywords: Circular circulation; Combination of energy law and thermodynamics; Runway's lights; Monte Carlo Simulation; Renewable resources; Noise pollution
JEL: Q29; C63; O13.

1. Introduction

We stand at the end of fossil fuel use (Ansari, 2017). All power needs are met through non-renewable fuels (Garg et al. 2015). Energy is the backbone of an economy and becoming the most affected issue of every country. Energy inputs are essential for economic growth. Energy inputs are subject to constraints on energy security, availability, and affordability. Sustainable development requires the proper utilization of domestic energy resources for power generation. The absence of substantial investments in the power sector and long-term political instability both at the provincial and national levels, are to blame for such a situation. Due to this, large hydro and coal projects could not be deployed, resulting in an increasing reliance on fossil fuel imports. Corruption in the power sector is further exacerbated by the low recovery of electric bills. Closing the supply-demand gap is imperative, especially for a developing country, which has historically experienced severe power crises, requiring proper long-term energy planning (Raza, et al., 2022).

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As a result of the technological boom, a shortage of electricity has been avoided by applying eco-friendly sources in appropriate conditions. Apart from nuclear, other renewable energy resources are also insufficient for our demands. Besides this, these sources require a lot of money and space to install (Ansari, 2017). However, these resources harnessing acoustic energy from wind, solar, and biomass are not efficient. In the case of solar energy, the efficiency of solar cells under normal conditions is twenty percent (Gupta et al., 2014). In addition to this, the availability of these resources is also associated with certain preconditions like weather. If the wind blows slowly and solar panels are not operating at night, renewable energy cannot be produced from renewable resources (Hossain et al. 2021).

The interconnection between energy law and thermodynamics has created another source of energy in this technological era. At this point, the results of human action might potentially be used as inputs for more human activity. The Law of Energy states that energy cannot be created and destroyed, and it is transformed from one form to another form (Gupta et al., 2014). The law of thermodynamics converts mechanical energy into electrical energy (Abate et al. 2016). The issue of energy scarcity has a remedy now that sound can be used to create power. The energy situation has also been made worse by the growth of several economic sectors. In addition, noise is regarded as a major pollutant (Ge, 2017). The solution to lessen pollution effects is recycling, as there is no other feasible way to clean our surroundings of noise (Baldovino, 2018). In 2021, the demand for energy has climbed by 6% as economies recover from catastrophic weather and pandemics (International Atomic Energy Agency, 2022). Another shock, in the form of the Russian-Ukraine war, would also lead to a rise in energy and oil prices. The prospect of raising energy prices by more than fifty percent is appalling for developing countries. (World Bank, 2021, cited in Ministry of Finance, 2022). Technological advancements and inventions have led to an enormous increase in energy consumption in the last decade. Consequently, energy is at the heart of all human activities. Countries, especially developing ones, need affordable and reliable energy. Because they are experiencing expansion in economic sectors including agriculture, trade, and transport. A developing country must import energy due to deficient investments in its indigenous resources (such as hydroelectricity, lignite, and natural gas). Environmental concerns impose restrictions on coal-fired power plants. Oil and gas firms are also scheduled to be privatized. Independent Power Producers (IPPs) and state-owned companies generate electricity at their full potential. This power deficiency can be traced back to two decades ago when fuel mix transformation occurred and relied more on imported furnace oil than hydropower. As the problem evolves over the years, chronic power supply deficits eventually became chronic cash flow problems. We have overburdened the system. Consumers, distribution companies, and government disturb cash flow. Circular debt growth was 1.6 percent of GDP in 2008 and reached 5.2 percent of GDP in 2020 in Pakistan (Ministry of Finance, 2021).

Using renewable and abundant resources, this research paper modifies nave dynamic microphones to produce green, cheap, and clean electricity. This article outlines the design process, including the cost, from a schematic diagram to a prototype model.

2. Literature review

Various techniques based on several principles have been applied to the concept of conversion of sound energy to electric energy etc. Electromagnetic induction, piezoelectric materials, triboelectric, and electrostatics (Shao et al., 2020). A company specializing in aircraft design, manufacture, and distribution has developed a system to harness acoustic energy from aircraft's sound and filed a patent (MachineDesign, 2015). Another method of converting is through thermal energy, but it is not efficient (Tomar et al., 2016). Vinu et, al. (2016) prove that with the help of PZT transducers, sound energy can be converted to electric energy. Another method is proposed by Abate et al. (2016) that is based on electromagnetic induction by Faraday's law. This drawback is cured by using another PZT material like artificial Lithium Niobate Crystal (Ge, 2017). Ansari (2017) confirms the applicability of the transition from sound energy to electric energy by applying both a microphone and piezoelectric (PZT). His circuit charges mobile phones. In Yuan et al. (2017) developed a tunable Helmholtz resonator that generates 3.49 microwatts in the presence of 100 dB. The output, however, is much lower than the projected project outlined in this article. While a cantilever beam based on Euler-Bernoulli's theory is designed to absorb energy from passing cars' sound (Instructables, 2017). While experiments show that aluminum oscillators are better than nylon oscillators, voltages are lower. As a result, Noh in (2018) chooses a high-speed train with 100 dB noise using a Helmholtz resonator that generates 0.7V, sufficient for powering hard system devices. Deshpande, Sajjan, & Pujar (2019) convert sound to electricity. But PZT material is suitable under certain conditions. Lead zirconate ceramics do not work at high frequencies and temperatures. Vanier (2020) proposes another harvester unit. It consists of three parts with PZT material. The first part is an enhancer that transforms long wavelengths into short wavelengths. The second part is a confined part that confines sound waves, and the third part is based on converting it into an electromechanical signal. The literature mentions harvesting electricity using sound differences. But piezoelectric articles have one downside: PZT material is expensive, and the span is short. By using nanotechnology that can vibrate for a long time with a wide range of sensitivity from -30dB to +300db than other transducers,

A more enhanced circuit using PZT material is built by Vanier (2021) that lights a 9W LED lamp. Electricity can also be generated by using speakers as transducers (Hossain et al. 2021). With the help of a 3D printer Patel, Flanagan, Nielsen, Prescott, & Tamer in (2021) present a successful prototype electromagnetic induction model. Another low-cost 3D-designed acoustic triboelectric nanogenerator (A-TENG) is developed by Yuan et al. (2021) that can produce 4.33-microwatt power when 100 decibels are present.

2. Methodology

This article presents a proposal to implement the concept of conversion of sound waves into electricity through a Printed Circuit Board Assembly (PCBA). Simulator software is used to carry out the conversion of mechanical energy. Dynamic microphones can be used as transducers. When sound passes through the diaphragm, the attached coil starts to move. This creates a magnetic field that produces current as per Faraday’s Law. To gain maximum voltage it passes through a set-up transformer. The DC has now been converted into AC with the help of a diode. The resulting voltage is stored in a battery. See the schematic view along with the Printed Circuit Board Assembly in Figure 1.

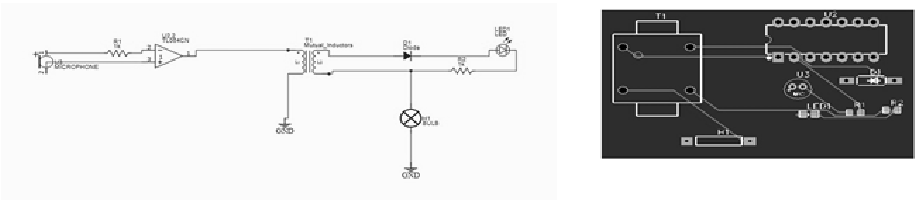

Figure 1. *Schematic View and Printed Circuit Board Assembly (PCBA)*

2.1. Device Design

Based on the structure of the human auditory system, a sound energy harvester is developed (see Figure 2). An outer section of the harness device is designed to resemble the shape of the external ear to increase the decibel level by approximately ten to fifteen decibels. Approximately 55 degrees is the angle of the oval tympanic membrane (SalfordAcoustic, 2019; University of Nebraska Medical Center, 2023).

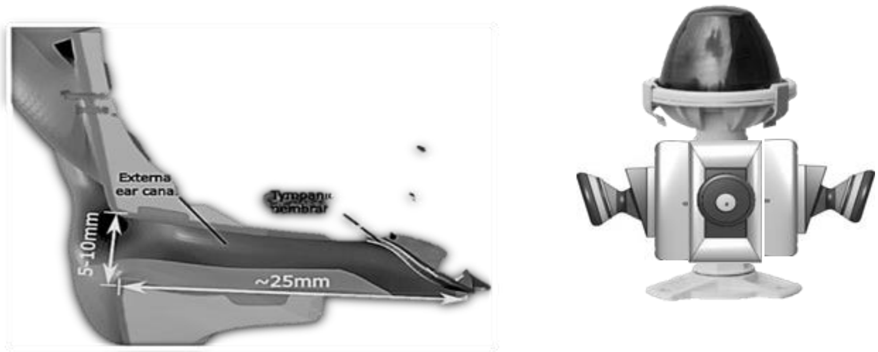

Figure 2. *Device Design*

2.2. Cost-Benefit Analysis

This paper evaluates the consumption and production associated costs of this proposed proposal. Greenhouse gas emissions are primarily attributed to the aviation industry. In this regard, airports, and the aviation industry, in general, are taking steps toward reducing their carbon footprints (Sukumaran & Sudhakar, 2017). It has been reported by Schluneger (2023) that the average airport uses 180MkWh per year out of which fifteen percent is devoted on lighting. According to OUC (2020) there are fifteen hundred lights on both sides of a runway including an Approach Lighting System with Sequenced Flashing Lights (ALSF), edge, touchdown zone, and centerline.

The total amount of energy emitted by the source is estimated through sound power level (SPL) (Purwanto, et al., 2020). The average noise level prescribed by International Civil Aviation and AWNOT-062-AWRG equals 97.1dB . For the given scenario, an aircraft radiates 0.00513 watts per unit of time. Runway occupancy requires fifty seconds. It indicates that during this time, the aircraft emits 0.2565 watts. Statistics show there are more than a thousand and fifteen hundred lights installed on runways today (Aerosavvy, 2016). If it is assumed that there are 62.58 flights per day at XYZ Airport, 72.2329 kWh/day XYZ airport can produce. The need for energy of an airport's runway lighting is 0.074MkWh/day while aircraft can generate 0.072MkWh/day. As specified in the designed device's specifications, it can produce 1.44MkWh per day. PCBA costs $22.70 (constant 2015) which includes 4 wire kelvin tests, set up fee, stencil, and confirm parts placement. Besides this, the cost of hardware (device structure, cable, etc.) is also included. Then the cost of a PCBA of fifteen hundred lights is $34,050. If it is installed in 3 dimensions, then the cost will be $102,150. This cost is entirely the cost of purchasing and installing the system. Once the device is installed there is no fuel cost associated with its operation and instead to repair the PCBA it is better to install the new one as the repair cost is high.

CBA is employed, which is considered a classical, and irreplaceable, method for assessing the reciprocity of any activity that involves cash flows inflows, and outflows. As a result of the use of specialized techniques, such as the Contingent Valuation Method (CVM), the monetary value attributed to the affected quantities can either represent commercial values or result from personal preferences combined with commercial values. Furthermore, it involves a comparison of expected financial benefits across different investment scenarios. Investments are assessed based on all cost and benefit parameters in a CBA. Analysis can evaluate the monetary impact of an investment. CBA requires that all cost and benefit parameters be expressed in monetary terms, considering their escalation over time. One problem arises because many of the quantities entering the analysis are characterized by significant uncertainties, particularly those about economic matters. In the case of renewable energy sources, uncertainties are either associated with purely monetary factors (e.g., purchasing costs, interest charges, maintenance charges, future energy costs, etc.), or they are related to technical parameters that indirectly affect monetary quantities (for example, useful life cycles, failure frequencies, and expected conventional energy savings).

Sensitivity analysis is a specialized approach to uncertainty treatment. This analysis consists of varying the range of every uncertain parameter. It tries to trace the source of uncertainty. The application of a CBA based on a Monte-Carlo simulation is compatible with current perceptions of information treatment under uncertainty. In this approach, an appropriate probability distribution is constructed with the available knowledge of cost and benefit parameters (Mathioulakis, et al., 2013).

This paper follows a Monte Carlo simulation procedure. Identifying risk factors along with their distribution is the first step in the process. Monte Carlo with 10,000 trials estimates the output parameter distribution. Three indices, Net Present Value (NPV), Benefit-Cost Ratio (BCR), and payback period are used in the present scenario. Uniform distribution is selected for the cost (replacement) and benefit (avoided fuel cost) (see Figure 3).

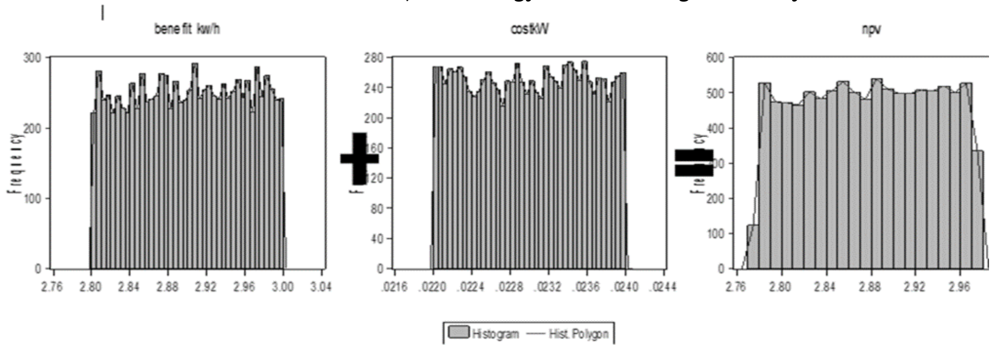

Figure 3. *Input and Output Parameters Distribution*

It is recommended to use triangular distribution (uniform distribution) when the number of information is limited (Dubel & Jastrzebski, 2018; Wolfram MathWorld, 2023).

Table 1. *Estimated NPV, BCR, and Payback Period of Proposed Project*

Parameter		Minimum Value/unit	Maximum Value/unit
Cost	Replacement cost	$0.022	$0.024
Benefit	Avoided fuel cost	$2.8	$3
Initial Investment		$102150	
NPV		$18557.37101/unit	
BCR		$126.069/unit	
Payback period		One quarter	

Note: Authors own calculations

It is found that the NPV of the project is positive 28663.11305/unit over a year timespan by using the discount rate zero. It means that this project will pay back a higher return rate than the minimum return rate. In contrast, the BCR indicates that for every $1 of project costs, $126.06 in expected benefits will be generated. It is estimated that the initial investment is recovered within a quarter according to PP. This shows the risk associated with the project is an abbreviated time.

Table 2 presents the cost of generating electricity per unit from diverse sources. Noise and nuclear are more cost-effective sources of electricity production in terms of per unit production. And unlike coal, oil, and gas less carbon emissions are generated through nuclear fission (International Atomic Energy Agency, 2022).

Table 2. *Cost of Generations Electricity from Different Sources*

Source	Operating cost /kWh	Capital Cost /KW
Oil	---	$1000
Hydropower	Less than 0.01	$2680
Geothermal	0.01-0.03	$2800
Coal	$1.46-$2.56	$3500-3800
Nuclear	$0.02-0.05	$6000
Noise	$0.022	$102.15

Wind Turbine(includes offshore wind)	Less than 0.01	$1200-5000
Photovoltaic	Less than 0.01	$4500 and up
Natural Gas	$0.04-0.10	$600
Biogas	$5.11-21.17	3000-6500
Biomass	$1.83-8.03	2500-4500

Source: (Farnoosh, 2022; PennState, 2023)

It can be seen clearly in Table. 2 that the setup cost of electricity being created through noise is among cheapest options. With-respect to operating cost oil, coal, gas and nuclear are the cheapest sources respectively (Scholarly Community Encyclopedia, 2023). While the other, such as nuclear and hydropower, has other issues that includes of plant security, input material etc. the device can generate electricity through aircraft noise 1.44MkWh/day while the need of runway lighting is 0.074MkW/day. It means 1.366MkWh/day additional energy can become the part of national grid or fulfil other airport needs.

3. Conclusion

In this technological era, electricity generation from clean and cheap sources is the need of the time. This paper attempts to provide solution to cope with energy crises. In comparison to other renewable and non-renewable sources, this is the cheapest source. The growing need for electricity may be met by a large-scale deployment of this small-scale circuit. The situation of energy crisis could be lessened with the help of the investment of $102150. The ideal place to implement this project is Airport runway where the dB is around 97.1. There is a need for 0.074MkWh of energy to light runways at airports, while aircraft can generate 0.072MkWh of energy. As specified in the designed device's specifications, it can produce 1.44MkWh per day. This project's positive NPV and BCR values aid in the repayment of the investment within a quarter.

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Methodology	X	X		
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Investigation	X	X		
Resources	X	X		
Data curation	X	X		
Writing –original draft	X	X		
Writing –review & editing	X	X		
Visualization	X	X		
Supervision	X	X		
Project administration	X	X		
Funding acquisition	X	X		

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