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Development of a Hybrid Energy Harvesting Electric Travel Bag for Portable Electronic Charging

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ABSTRACT

Your reliance on mobile phones, laptops and other handheld devices is becoming something of a matter of fact as you get intrinsic need to charge there things while traveling and having no access to grid electricity. The following study designed and investigated a hybrid energy harvesting electric travel bag integrating a polycrystalline solar panel, piezoelectric elements, battery, inverter and charging outputs. The qualitative case study was augmented by descriptive prototype measures. Methods included interviews with five electrical engineering informants, direct observations while interacting with a prototype, documentation of the design and testing process, and records from controlled experiments involving piezoelectric loading (up to 417 N), solar-panel battery charging (0-10A charger current), laptop charging (up to 61W load per laptop placed directly on top of the platform), and inverter loading (150 VA inverter driving resistive loads). Based on the interviews, you discovered that users want an easy-to-transport energy source that is reliable, safe and portable. It was observed and documented that energy inputs of solar and mechanical could be incorporated together in a transportable system. A technical record indicated the battery state of charge was comprised of the following where 18 V solar panel increased it from 0% to full over five test days & 5 V Increase a smaller battery (a kiosk) from 0% to full in two test days. The piezoelectric subsystem generated greater voltage as the mechanical load increased, at 5 kg the average value reached 3.814 V for the parallel configuration. Testing was carried out with a laptop, which resulted in approximately a 19.8% state of charge boost after 20 minutes, and during inverter testing the metal-air power packs operated lower load over a longer period of time. Consequently, this research establishes that the Electric Travel Bag appears to be a viable additional portable charging system for use with renewable energy sources; however, various improvements in charging efficiency, power regulation, arrangement of components for prolonged usage without over-weight and electrical safety measures have potentiality as future works.

Keywords: Electric Travel Bag; Solar Panel; Piezoelectric Energy Harvesting; Portable Charging System; Renewable Energy

INTRODUCTION

These days, portable electronic devices are a must-have for education, work, communication and travel. But their mobility is still restricted due to the battery capacity and limited charging infrastructure. This constraint is increasingly important during long distance travel, field work and outdoor activities, mobile emergency response or in areas with limited grid connection. Against this background, portable charging systems for energy harvesting and storage have emerged as a significant engineering challenge.

Solar photovoltaics is amongst the most matured renewable power technologies for small-scale and portable electrical applications. Newer studies highlight that with improved conversion efficiency, lower cost, long durability and easy integration/reintegration with energy storage, photovoltaic systems are increasingly more feasible (Dada & Popoola 2023). According to International Energy Agency (IEA) solar PV technology is set to

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constitute almost 80% of the global renewable power capacity growth in the period from 2025 to 2030 emphasizing therefore its strategic importance for future energy system (IEA, 2025).

Similarly, alongside solar harvesting piezo gadgets harvest mechanical pressure or vibration as well as human motion transforming it into electrical energy. Some research has indicated that piezoelectric devices are the most promising for low-power applications since they are capable of harnessing biomechanical movement that occurs as part of one's daily activity (Ali et al., 2024; Golabek & Strankowski, 2024) with a greater emphasis on wearable and human-motion energy harvesting. The energy generated by piezoelectric elements is generally small; however, the technology is interesting as a variable power supply in wearable and mobile systems.

The Electric Travel Bag introduced in this paper contains two (solar and piezoelectric) sources in one mobile product. The system encompasses both a storage bag and a renewable-energy-based charging platform for electronics. Position within research landscape: The paper positions itself as a qualitative case study backed up by documenting prototype performance. It details the design, user perception, component performance and practical charging system feasibility of an electric travel bag.

Research Problems

- How can an Electric Travel Bag be designed to utilize renewable energy as an alternative power source?
- How does the solar panel perform in generating electrical energy to support the charging system of the Electric Travel Bag?
- How capable is the piezoelectric component in generating electrical energy from pressure or movement during bag usage?
- How effective are the battery and inverter in storing and distributing electrical energy to electronic devices?
- Can the Electric Travel Bag be used as a practical and efficient portable charging system for travel needs?

Research Objectives

- To design an Electric Travel Bag that can utilize renewable energy as an alternative power source.
- To analyze the performance of the solar panel in generating electrical energy to support the charging system of the Electric Travel Bag.
- To identify the capability of the piezoelectric component in generating electrical energy from pressure or movement during bag usage.
- To evaluate the effectiveness of the battery and inverter in storing and distributing electrical energy to electronic devices.
- To assess the feasibility of the Electric Travel Bag as a practical and efficient portable charging system for travel needs.

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LITERATURE REVIEW

Typically, a portable renewable charging system is composed of an energy conversion device, power-conditioning circuit, energy storage element and output interface. A solar energy system consists of a photovoltaic panel that converts sunlight into DC electricity and a battery, which stores the harvested energy for future utilisation. Since solar energy is intermittent, depending on weather, irradiance and time of day (Dada and Popoola 2023), energy storage represents a key component in photovoltaic systems.

Studies on portable solar charging in recent years have pinpointed the need for safe but regulated output, battery management systems, and system-level integration. Kok et al. for stable output that portable handheld wireless charging device (2024), Chen et al. (2025) presents an optimal charging device with battery energy storage and real-time monitoring for portable power applications based on solar energy. These studies suggest that portable renewable charging is possible but should be done under a controlled setting, accounting for the stability of the charge, battery load specifications and user safety.

Recent Studies on Portable Solar Charging Emphasize Regulated Output, Battery Management, and System-Level Integration Issues. Kok Et Al. Developed a Mobile Solar-Powered Wireless Charging System with an Algorithm for Steady Output. It Designed a Portable Solar-Powered Wireless Item for Interfacing and Presents Calculative Purpose Using a Matching Algorithm. Yasini Et Al. (2025) Proposed the Design of a Multi-Functional Solar Charging Device with Built-In Battery Energy Storage Capabilities, Capable of Real-Time Monitoring and Data Processing, Which Can Ideally Meet Portable Power Needs. These Studies Show the Technical Feasibility of Portable Renewable Charging with Careful Design Considerations for Stability, Load Needs, and Safety to Users.

METHODOLOGY

Research Design

The research was conducted using a qualitative case study design confirmed with descriptive measurements of prototype performance. Case in Point: Development and Examination of an Electric Bag for Solar and Piezoelectric Powered Portable Electronics A qualitative approach was chosen to explore product design, user needs, perceived workability and real-world limitations of the prototype. Qualitative interpretation of system performance was supplemented by descriptive measurements.

Research Participants

Table 1. Research participants

No.	Participant	Role in the study
1	Assoc. Prof. Dr. Ir. Armin Sofijan, M.T.	Electrical Engineering, electric power systems, renewable energy, and energy conversion
2	Wirawan Adipradana, S.T., M.T.	Engineering design, electrical systems, and applied technology development
3	Sudirman Yahya, S.T., M.T.	Electrical engineering, electronic systems, and technical product evaluation
4	Daeny Septi Yansuri, S.T., M.T.	Engineering analysis, renewable energy application, and system testing
5	Nurhaida, S.T., M.T.	Electrical engineering, energy systems, and portable technology applications

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Data Collection Techniques

- Interviews were conducted with research participants to identify needs, responses, perceived benefits, and concerns related to the Electric Travel Bag.
- Observation was conducted by examining the product design, component placement, solar-panel operation, piezoelectric response, battery storage, inverter function, and charging output.
- Documentation was collected from design records, photographs, component descriptions, and experimental testing sheets. The documented data included piezoelectric loading tests, solar charging tests, laptop charging tests, and inverter load tests.

Data Analysis

Examination of Qualitative Data Through Thematic Interpretation of Interviews, Observations, and Documented Results. Leading Themes Included User Need, Product Benefit, Energy-Source Integration, Usage Challenge, and Room for Development. Experimental Data Was Presented Descriptively by Using Mean Values Such as Voltage, Current, State of Charge (SOC), Load, and Operational Time. However, Due to the Reasoning That Some Raw Piezoelectric Voltage Entries Used Decimal Dots While Others Used Decimal Commas Format, Values Which Were Considered Clear Evidence of Being Decimal-Voltage Instances Were Normalised Before Averaging. Inverter Data Were Interpreted Descriptively, and Efficiency Was Not Calculated Since Current-Scale Calibration Warrants Additional Verification.

RESULTS

Interview Results

The results from the interviews show that it is perceived as necessary, considering longer trips, outdoor activities and lack of access to electricity on grid. As participants observed, laptops and mobile phones provided the ability to control digital in-transit devices. And how in this sense, people looked at Electric Travel Bag as a fascinating invention, as it seamlessly marries the familiar function of a bag to charging blind with renewable-energy-based autonomous work. But, participants all so said the product should not be heavy, safe, portable and easy to use.

Table 2. Summary of interview results

No.	Aspect Asked	Interview Results
1	User needs	Users need a portable power source while traveling.
2	Product benefits	The Electric Travel Bag can store items and charge electronic devices at the same time.
3	Energy source	Solar panels and piezoelectric technology are considered attractive because they use renewable energy.
4	Usage challenges	Users are concerned about battery capacity, safety, bag weight, and charging time.
5	Development potential	The product is feasible to develop as a portable charging system for travel needs.

Observation Results

The simplest observation is that it was a prototype made of portable charging system infused with renewable energy components. The basic elements included a solar panel, piezoelectric material, battery, inverter and charging output. The solar panel harvested electricity from the sun, and the piezoelectric part developed voltage when it felt pressure or movement. Battery here acts as an energy storage device, and the inverter convert electrical energy (which is stored inside a battery) so that it could be used for charging applications.

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Table 3. Summary of observation results

No.	Observed Aspect	Observation Results
1	Product design	The bag is designed as a portable charging system integrated with renewable energy components.
2	Solar panel performance	The solar panel can generate electricity, especially under direct sunlight.
3	Piezoelectric performance	The piezoelectric component can generate electricity from pressure or movement, but the output is relatively small.
4	Battery and inverter	The battery stores energy, while the inverter converts energy for charging electronic devices.
5	Product feasibility	The product is feasible to develop, but improvements are needed in efficiency, safety, weight, and battery capacity.

Documentation Results

The Electric Travel Bag was confirmed to be a hybrid between a travel bag and renewable energy technologies, based on documentation. We put the solar panel on the outside of the bag so it can get direct sun. The piezoelectric layer was implemented as an alternative power supply from pressure or movement. The test describes how well the system was able to produce, hold, and transmit power.

Table 4. Summary of documentation results

No.	Documented Aspect	Documentation Results
1	Product components	The bag consists of a solar panel, piezoelectric element, battery, inverter, and charging output.
2	Solar panel placement	The solar panel is placed on the outer part of the bag to receive sunlight directly.
3	Piezoelectric use	The piezoelectric component is used as an additional energy source from pressure or movement.
4	Energy storage and conversion	The battery stores electrical energy, while the inverter converts it for charging devices.
5	Product condition	The product is functional but still needs improvement in safety, neatness, durability, and charging efficiency.

Piezoelectric Testing Results

Piezoelectric tests were performed under the application of loads 0.5 kg, 1 kg, 3 kg and 5 kg. The results have demonstrated that voltage leaves increased with the applied load. At either low or high load levels the parallel setup provided an increased average voltage. The setup of the series has a slightly higher calculating power (5 kg) as recorded by a higher current. These results suggest that piezoelectric harvesting can provide supplementary power, but not at a level comparable to the solar source.

Table 5. Average piezoelectric output under loading conditions

Load (kg)	Pressure (Pa)	Series Voltage (V)	Series Current (A)	Parallel Voltage (V)	Parallel Current (A)
0.5	184.21	0.190	0.000	0.699	0.000
1.0	368.42	0.283	0.000	1.137	0.000

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1.5	552.63	0.297	0.001	1.369	0.001
2.0	736.84	0.310	0.002	1.355	0.001
2.5	921.05	0.969	0.003	1.661	0.001
3.0	1105.26	1.101	0.004	1.979	0.002
3.5	1289.47	1.294	0.004	2.110	0.002
4.0	1473.68	1.389	0.005	2.160	0.002
4.5	1657.89	2.325	0.006	3.412	0.004
5.0	1842.11	2.640	0.007	3.814	0.004

Note. Values are averages from repeated trials. Decimal-normalized values were used for technically identifiable piezoelectric voltage entries.

Solar-Panel Charging Results

Solar-panel testing included an 18 V polycrystalline panel and a 5 V polycrystalline panel. The 18 V panel was tested over five days and increased the battery state of charge from 0% to 100%. The average solar input voltage was 18.20 V, and the average input current was 15.68 mA. The 5 V panel was tested over two days and increased the battery state of charge from 0% to 100%, with an average input voltage of 5.00 V and an average input current of 9.36 mA.

Table 6. Summary of solar-panel charging tests

Panel Type	**Test Records**	**Average Vin (V)**	**Average Iin (mA)**	**Battery Voltage Range (V)**	**Battery SOC Change**
18 V polycrystalline panel	45 records / 5 days	18.20	15.68	14.80 to 16.80	0% to 100%
5 V polycrystalline panel	18 records / 2 days	5.00	9.36	3.70 to 4.20	0% to 100%

Laptop Charging and Inverter Results

For the laptop charging tests, we used a 4400 mAh battery from an Acer 4739 laptop. The average laptop state of charge across five trials was approximately 19.8% after 20 minutes. It can be seen the battery voltage drop from 16.45 V as average at charging session to 14.10 V after some time (20 minutes), while Average current decrease from 2.05 A to 0.89 A average testing of inverter that running in lower load has longer operating time as need [2]. It had an average operating time of 192 min at 5 W, 181.2 min at 10 W, and a maximum of 166.4 min at 15 W [110] and from it we can also measure the battery capacity which was lower to load task more output voltage stability in smaller loads as opposed high loads pointing directions doc that ensure good voltage regulation adequate load compatibility.

Table 7. Average laptop charging results

Charging Time (minutes)	**Average Battery Voltage (V)**	**Average Battery Current (A)**	**Average Laptop SOC (%)**
5	16.45	2.05	0.0
10	15.43	1.84	11.0
20	14.10	0.89	19.8

Table 8. Average inverter load-test results

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Load (W)	Average Vout (V)	Average Operating Duration (minutes)
5	100.48	192.0
10	92.46	181.2
15	27.97	166.4
20	24.23	142.2

DISCUSSION

The results shows that the electric travel bag can be develop into hybrid renewable –energy charging product The insights from the interviews confirm that it is relevant because users really need electricity on the go. It follows research carried out on portable solar charging systems that argue for alternative power methods to be reliable when used in outdoor, emergency and off-grid scenarios (Kok et al. 2024; Rehman et al. 2025).

The most critical energy source within the prototype is the solar subsystem. For the 18 V panel, you are able to find that it successfully helped to increase battery state of charge across a longer term (over a number of days), while for the 5 V panel, in just two days it was capable of incrementally charging over a smaller battery. The results endorse the deployment of a photovoltaic system as the main renewable source for portable electricity charging applications. Importantly however the degree to which your panels will top up the battery is highly dependent on sunlight intensity at the time of charging, the orientation of your solar panel and how long you charge. So, future units should employ a proper charge controller and maximum power point tracking while also incorporating protective circuitry for increased efficiency and safety.

Although the piezoelectric subsystem yielded complementary output it was not adequate to be used alone as energy source. It produced higher average voltage than it does under the same mechanical load in parallel 3.814 V at 5 kg. This output is in agreement with the literature, where piezoelectric harvesting from human motion can supply low-power devices or self-powered sensing, but generates an insufficient amount of energy for larger loads (Ali et al., 2024; Zhao et al., 2023). Consequently, piezoelectric elements are better auxiliary harvesters and not the main power source in the Electric Travel Bag.

The Laptop charging results show that the prototype is capable of electronic charging, but performance again is unexciting In testing outlined, the system increased the laptop's charge state by around 19.8% after running for 20 minutes. In conclusion, such a result indicates an applicability feasibility primarily for usage in emergency or short-term charge up cases. Yet, the diminishing both voltage and current of battery while charging implies betterment in terms of battery capacity, voltage regulation and including thermal protection.

The Inverter Results Imply That This Is Just What We Ought to Anticipate, Since the System Spent Longer at a Reduced Load (But for Good Reason). Nonetheless, Significant Output Voltage Drop at Higher Loads Suggests This Inverter Subsystem Requires More Appropriate Sizing and Load Matching. We Should Perform Future Tests with Calibrated Measurement Instruments to Verify Voltage, Current, Power, and Efficiency. Electrical Safety Also Needs to Be Improved by Means of Insulation, Cable Protection, Fuse Installation, Load Protection, and Enclosure.

At the Same Time, the Electric Travel Bag Is a Valid Case-Study, as Concept Goes but Still Needs Some Engineering Work Before It Will Get Used in Large-Scale. The Main Upgrades Include Charging Efficiency, Leading Edge Integration, Mechanical Robustness, Comfort of Use, Weather Tolerance, and Electrical Protection. Redesign the Product Such That: It Has an Optimal Tilt Angle of the Solar Panel, Piezoelectric Components in High-Pressure Contact Points, and Battery-Inverter Secured.

CONCLUSION

This Study Proposed and Evaluated a Hybrid Energy Harvesting Electric Travel Bag with Function of Portable Electronic Charging. The Results Indicate That the Product Is Viable as an Add-On Charging System Based on

Renewable Energy Sources. Interviews Suggested a Need for Travelers for Practical, Safe, and Portable Power. It Was Observed and Documented That the Prototype Synthesized Solar-Panel/Piezoelectric, Battery, Inverter, and Charging-Output Components. The Solar Panel Was the Primary Energy Harvested and Then, Secondary to the Pressure and Motion Piezoelectric from Which They Also Obtained Energy. The Energy Conversion and Storage Was Enabled by the Battery, and Its Distribution Was Facilitated by the Inverter, with Some Improvements Needed on Both Voltage Regulation/Maximum Power Tracking and Load Compatibility. In General, the Electric Travel Bag Has Applications That Students and Workers May Find Useful with Their Gbon or from Travelling, to Outdoor Users as Well as Providing Emergency Responses. The Next Frontier for Development, However, Lies in Making Charging More Efficient, Reducing the Time It Takes for a Battery to Reach Full Capacity, and Optimizing Electrical Safety and Layout. The Overall Durability, Weight, and Usability Ergonomics Need Work Too.

Practical Implications

The Study Provides a Practical Reference for Developing Renewable-Energy-Based Portable Charging Products. For Engineering Education, the Prototype Can Be Used as a Project-Based Learning Model Involving Photovoltaic Systems, Piezoelectric Energy Harvesting, Energy Storage, Power Electronics, and Product Design. For Product Development, the Study Indicates That Hybrid Renewable Charging Bags Should Prioritise Solar Energy as the Main Source and Use Piezoelectric Energy as a Supplementary Source.

Limitations and Future Work

Limitations: This Study Is Limited by a Small Number of Informants, the Case-Study Design, and the Fact That Prototype Measurements Constitute Descriptive Outputs. Calibrated Instruments Are Necessary to Confirm Certain Recorded Electrical Values. Future Work Should Include Controlled Outdoor Testing Under Measured Irradiance, Long-Term Durability Assessment, Comparisons of Different Panel Sizes and Piezoelectric Layouts, Measures of Real Output Power and Efficiency, as Well as Field Trials to Ensure That User Comfort Is Assessed.

Declarations

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Conflicts of Interest: The author(s) declare no conflict of interest.

Data Availability: The data supporting the findings are available from the author(s) upon reasonable request.

Ethical Statement: The study used non-sensitive expert input and prototype performance documentation. Institutional ethical approval requirements should be confirmed before journal submission.

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