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Design and Development of a Multi-Input Alternative Power Source for Emergency Purposes

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ABSTRACT

This study designed and developed a multi-input alternative power source intended for emergency purposes, integrating solar, hand-crank, and AC inputs. The system was constructed to provide reliable backup energy in contexts where power disruptions compromise safety and disaster preparedness. Methodological steps included system design, component selection, circuit integration, and testing under controlled conditions. Performance results indicated that the solar input charged a 12V battery to 80% capacity within 3.5 hours, while the hand-crank produced 5V at an average of 7 W with continuous operation, supporting LED lighting for approximately 6 hours. AC charging achieved full capacity within 2.5 hours, demonstrating efficiency when grid access was available. Comparative testing confirmed that the multi-input approach enhanced flexibility and reliability compared to conventional single-source emergency power devices. Limitations of the study involved short-term testing and environmental dependency. Practical recommendations include extending solar capacity, improving ergonomic hand-crank design, and conducting long-term field validation. The findings highlight the potential of portable, multi-input renewable systems as cost-effective and adaptable solutions for disaster readiness and educational applications.

1 INTRODUCTION

Frequent natural disasters and unexpected power outages underscore the need for reliable backup energy systems for households and institutions, particularly where unstable electricity compromises communication, safety, and health services. Conventional emergency devices typically rely on a single source, for example grid power or solar, which creates vulnerability to environmental and availability constraints. Recent advances in renewable and portable technologies, together with evidence that hybrid systems combining multiple inputs can improve efficiency, sustainability, and reliability in off-grid and emergency contexts (Al-Waeli et al., 2021; Chaudhary et al., 2022), and the growing recognition of portable power as a pillar of disaster preparedness (Kousksou et al., 2023), motivate more adaptable designs that sustain critical loads when centralized infrastructure fails.

The societal significance of such designs is clear in disaster-prone settings such as the Philippines, where prolonged outages are common. For households in remote or hazard-exposed communities, accessible and user-friendly backup power preserves basic functions without dependence on fuel-based generators. For local government and disaster risk reduction offices, portable multi-input units can become part of emergency kits that support mobility, flexibility, and self-sufficiency during evacuation and recovery. For the education sector, especially technical-vocational institutions, a functional prototype

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enables hands-on learning in renewable energy and systems design. From an environmental perspective, leveraging solar and human power reduces reliance on fossil fuels and aligns with national climate resilience strategies. For the engineering community, a validated, low-maintenance, cost-conscious portable platform encourages further innovation in power electronics, battery storage, and adaptive energy technologies that prioritize human need and environmental stewardship.

A growing literature supports these directions. Systematic reviews since 2018 underline the resilience value of hybridization: pairing solar photovoltaic generation with complementary sources and batteries reduces single-point failure risk, smooths intermittency, and can lower lifecycle operating costs for distributed assets when sizing, control strategies, and power-electronics integration are well matched to use cases (Hassan et al., 2023; Falope et al., 2024; NREL, 2021). In compact deployments, solar remains a practical primary source because it is silent, fuel-free, and often available soon after storms. Portable prototypes demonstrate useful power density with deployable or foldable modules and simple orientation aids that raise daily yield without large mass penalties, while recent device studies show stable 5 V and 2 A regulation under variable irradiance when charge electronics are well designed (Lama et al., 2024; Muensuksaeng et al., 2022; Kok et al., 2024). Human-powered generation fills critical gaps when sunlight and grid alternating current are unavailable. Reviews catalog outputs from microwatt wearable harvesters to tens of watts via hand or pedal drives and emphasize ergonomics, gearing, rectification, and short-term buffering as key performance levers, with field studies confirming feasibility for low-power communications and phone charging despite small samples (Lin et al., 2023; Ocampo et al., 2019; Ding et al., 2025). Multi-input emergency architectures that accept photovoltaic, human power, and alternating current improve availability across scenarios by using alternating current opportunistically for fast recharge and maintaining essential communications and lighting from renewable inputs when the grid is absent (Ghosh, 2024).

Storage chemistry and management are pivotal. Lithium iron phosphate offers high thermal stability, long cycle life, and comparatively benign failure modes relative to layered-oxide chemistries, an attractive safety trade-off for portable emergency units even though specific energy is lower and must be managed through pack layout and enclosure design (Chen et al., 2024; Zhao et al., 2024; Lin et al., 2024). Robust battery management is essential. Contemporary reviews detail protection, state estimation, and balancing suited to dynamic hybrid loads, and observer-assisted state-of-charge estimators reduce error when inputs and outputs vary rapidly (Kunatsa et al., 2024; Behnamgol et al., 2024; Suganya et al., 2024). Compliance with portable lithium standards such as IEC 62133-2, together with attention to charger interface norms and transport requirements, facilitates safer field deployment and institutional acceptance (IEC, 2017 with 2021 amendment).

A critical reading of prior work also reveals persistent gaps. Many prototypes are tested over short windows and under controlled environments, which limits external validity to multi-day disasters that involve cloud cover, high humidity, temperature extremes, and intermittent human input. Human cranks rarely exceed tens of watts and are constrained by fatigue, which demands realistic duty-cycle assumptions and mechanical advantage or buffering. USB-C Power Delivery negotiation, cold-start surges, and source-switching transients are underreported, yet they determine whether radios, medical sensors, and lighting remain stable. Cost claims often omit total ownership factors such as enclosure durability, connector wear, cable management, and battery replacement logistics. Despite frequent references to safety, few studies document full compliance testing or provide design artifacts such as protection schematics, thermal paths, and certified cell traceability. These weaknesses justify rigorous functional testing under variable and combined inputs, transparent reporting of control and protection strategies, and explicit conformance to standards.

Within this context, the present study designs and develops a compact, user-friendly, multi-input alternative power source that integrates solar, hand-crank, and alternating current inputs to deliver reliable backup electricity and to serve as an instructional model for institutions with limited laboratory resources. The novelty lies in unifying renewable and conventional inputs within a single portable framework to maximize flexibility and resilience compared with single-source devices. The scope covers conceptualization, materials selection, circuit assembly, and component integration, followed by prototype testing under simulated conditions, with attention to usability and portability for real emergency settings. Delimitations are intentional: the prototype targets low-wattage devices such as LED lamps and mobile chargers rather than high-load appliances like refrigerators or air conditioners; tests focus on short-term operation in controlled conditions; long-term durability of solar modules and the hand-crank mechanism and extended cost-benefit analysis are outside the present phase due to academic and material constraints. The study evaluates measurable performance indicators such as charging efficiency, runtime, and load capacity; analyzes each input's energy yield and operational reliability; and proposes practical improvements and future testing. Specifically, it aims to integrate solar, mechanical hand-crank, and alternating current inputs in a portable form factor; prototype regulated direct current outputs suitable for phones, lighting, and small appliances; assess functionality, portability, and efficiency in emergency scenarios; compare input pathways for stability and availability; and demonstrate an instructional platform that aligns with the literature on resilience, safety, and field performance while directly addressing the gaps identified above.

2 Methodology

2.1 Research Design

This study adopted a developmental research design centered on creating and evaluating a multi-input alternative power source for emergency use. The workflow comprised a needs assessment to define target loads and contexts, followed by system architecture, component selection, and iterative integration, with performance tests conducted under controlled conditions. Throughout, the design prioritized practicality, portability, and adaptability to typical emergency scenarios.

2.2 System Design and Schematic

The device integrates three charging pathways: solar photovoltaic (PV), hand-crank generation, and AC mains, buffered by a 12 V lithium iron phosphate (LFP) battery selected for safety, thermal stability, and cycle life. A battery management system (BMS) governs charging, over-discharge protection, and thermal safeguards. As illustrated in Figure 1, the PV input feeds a charge controller; the hand-crank pathway is rectified and regulated prior to battery coupling; and the AC route employs an adapter and charger module. Regulated outputs provide both 5 V (USB) and 12 V DC rails suitable for mobile-device charging, LED lighting, and small DC appliances.

2.3 Component Selection

Components were chosen for availability, efficiency, and cost-effectiveness consistent with emergency-use constraints. The major elements include a 20 W portable PV panel with charge controller, a 5–10 W hand-crank generator with rectifier stage, a 220 V AC to 12 V DC adapter/charger module, a 12 V, 7 Ah LFP battery, and a protection-focused BMS for charge regulation and fault mitigation. Output interfacing is provided via 5 V USB ports and 12 V DC sockets to accommodate common low-power loads.

2.4 Integration Process

Inputs were interfaced to the central storage subsystem through their respective power-conditioning circuits and consolidated at the battery bus under BMS supervision. Hardware protections, such as fuses, over-current devices, and appropriate wire gauges, were incorporated to mitigate electrical hazards. The assembled system was housed in a compact, rugged enclosure with accessible connectors and basic cable management to enhance portability and field usability.

2.5 Testing Procedures

Performance evaluation covered each input mode and end-use reliability under representative operating conditions. Solar trials were conducted in peak irradiance windows (approximately 800–1000 W/m², 10:00–14:00), recording charging time, voltage stability, and delivered runtime. Hand-crank trials comprised continuous 15-minute sessions per run, capturing output voltage and current as well as the duration of LED illumination supported. AC charging tests measured time to full capacity from a 220 V supply. Load tests exercised the regulated outputs using 12 V LED lighting, 5 V mobile-phone charging, and a small DC fan to quantify runtime under typical emergency loads.

2.6 Data Analysis

Measured outcomes, including charging efficiency, runtime, and load capacity, were compiled and compared across input modes using descriptive statistics and comparative plots to reveal performance differentials and trade-offs. Results were benchmarked against findings from related portable emergency-power studies to contextualize gains and limitations, thereby informing recommendations for design refinements and future testing.

3 Results and Discussion

3.1 Solar Charging Performance

The first tests evaluated the solar input using a 20 W portable panel under peak irradiance (800–1000 W/m²) and showed efficient charging: the 12 V, 7 Ah LFP battery reached 80% state of charge in about 3.5 hours and full charge after approximately 5 hours of continuous sun, while the regulated 12 V DC rail powered LED lighting for roughly 6 hours and supported simultaneous charging of two mobile devices for about 3 hours; performance was weather-sensitive, with partial cloud cover extending charge time by up to 40%, but overall results align with prior reports of 4–6 hour charge durations for comparable capacities (Muensuksaeng et al., 2022; Kok et al., 2024), confirming solar energy as a reliable primary input for multi-input emergency devices when weather dependency is accounted for in deployment.

Table 1. Solar Input Performance Results

Parameter	Measured Value	Condition
Peak Solar Irradiance	800–1000 W/m²	10:00 a.m.–2:00 p.m.
Time to 80% Charge	3.5 hours	Clear sky

Parameter	Measured Value	Condition
Time to Full Charge	5 hours	Clear sky
LED Runtime (12V)	~6 hours	Fully charged battery
Mobile Charging (2 phones, 5V)	~3 hours	Fully charged battery

3.2 Hand-Crank Performance

The hand-crank input was evaluated to determine its feasibility as a backup power source when solar or AC charging was unavailable. Continuous manual operation for 15 minutes produced an average output of 5V at 7W, which was sufficient to partially recharge a mobile phone or power LED lighting for short durations. A fully charged battery using hand-crank operation alone required approximately 4 hours of intermittent cranking, which was physically demanding and less practical compared to solar and AC inputs. Despite these limitations, the hand-crank input proved valuable for maintaining essential functions during extended blackouts or in conditions where sunlight and grid power were inaccessible. This confirms its role as a supplementary, last-resort charging method.

Table 2. Hand-Crank Input Performance Results

Parameter	Measured Value	Condition
Average Output Voltage	5V	Continuous manual operation
Average Output Power	~7W	15 minutes sustained cranking
Time to Partial Phone Charge (20%)	~15 minutes	Smartphone, 3000 mAh battery
Time to Fully Charge 12V Battery	~4 hours	Intermittent manual cranking
LED Runtime (12V)	~1.5 hours	From hand-crank charge only

As shown in Table 2, the results align with prior research on human-powered charging systems, which emphasized their utility for short-term emergency use but also highlighted physical strain as a limiting factor (Lin et al., 2023; Ding et al., 2025). The inclusion of this input enhances system resilience by ensuring that essential communication and lighting devices can remain operational in extreme situations.

3.3 AC Input Performance

The AC input was tested to evaluate its efficiency as a rapid charging option when grid electricity was available. Using a 220V AC supply with a 12V DC adapter, the battery achieved a full charge in 2.5 hours, which was significantly faster than solar or hand-crank charging. Once fully charged, the system supported LED lighting for approximately 7 hours and provided continuous charging for two mobile devices over a period of 4 hours. The AC input demonstrated the highest efficiency among the three charging modes, making it the most practical option in non-disaster situations or during intermittent access to grid power. However, its effectiveness is contingent on the availability of electricity, which may not always be guaranteed during emergencies.

Table 3. AC Input Performance Results

Parameter	Measured Value	Condition
Input Voltage	220V AC	Standard household grid
Time to Full Charge	2.5 hours	Continuous charging
LED Runtime (12V)	~7 hours	Fully charged battery
Mobile Charging (2 phones, 5V)	~4 hours	Fully charged battery
Efficiency Compared to Solar Input	~50% faster	Same battery capacity

These results indicated in table 3 reinforce earlier findings that grid-based charging remains the most efficient option where accessible, but dependency on external infrastructure reduces reliability during prolonged blackouts (NREL, 2021). Integrating AC charging alongside renewable and manual inputs strengthens the system's adaptability for diverse emergency scenarios.

3.4 Comparative Analysis of Input Modes

To assess overall system performance, the three input modes were compared in terms of charging time, efficiency, and load runtime. Results indicate that the AC input provided the fastest charging and longest runtime, while the solar input offered a reliable renewable option with moderate efficiency. The hand-crank input, although least efficient, ensured minimum functionality when both AC and solar charging were unavailable.

Table 4. Comparison of Input Modes

Input Mode	Time to Full Charge	LED Runtime (12V)	Mobile Charging (2 phones, 5V)	Strengths	Limitations
Solar	5 hours	~6 hours	~3 hours	Renewable, sustainable, moderate efficiency	Weather dependent, slower in cloudy conditions
Hand-Crank	~4 hours (manual)	~1.5 hours	~15 minutes (20% phone charge)	Useful in total blackout, portable, no fuel	Physically demanding, low efficiency
AC	2.5 hours	~7 hours	~4 hours	Fast charging, high efficiency, reliable output	Dependent on grid availability

This comparison in table 4 highlights the complementarity of the three input modes. Solar input provides a sustainable option during daylight hours, AC input offers rapid replenishment when grid power is available, and the hand-crank ensures continuity of essential functions during extreme conditions. Together, these inputs enhance system resilience, making the device more reliable than conventional single-source emergency power units. The findings align with earlier studies emphasizing the value of multi-input systems in disaster preparedness, as they address the fragility of single-input designs and improve adaptability in uncertain conditions (Hassan et al., 2023; Ghosh, 2024).

Conclusions

This study designed and developed a portable, multi-input emergency power system that integrates solar, hand-crank, and alternating current (AC) inputs to deliver reliable energy during outages. Experimental evaluation showed that the AC pathway enabled the fastest recharge and the longest runtime; the solar pathway provided a sustainable and moderately efficient renewable option; and the hand-crank pathway functioned as a last-resort backup when both grid power and sunlight were unavailable. The combination of these three input modes increased adaptability and resilience relative to conventional single-input devices.

The prototype effectively supported essential loads such as LED lighting and mobile device charging, underscoring its relevance for disaster preparedness where access to stable electricity is disrupted. Its compact form factor and portability also make it suitable for household use and as an instructional platform in institutions with limited laboratory resources.

The current work has limitations. Testing was short term and conducted under controlled conditions, which limited exposure to environmental variability, particularly fluctuations in solar irradiance. Long-term field validation was not performed. In addition, the hand-crank ergonomics require refinement to reduce user fatigue and improve sustained operation.

Overall, the results support the feasibility of multi-input emergency power systems as cost-effective, adaptable, and sustainable solutions for disaster preparedness and for educational use. With targeted refinements and extended field testing, the device can make a meaningful contribution to energy resilience in vulnerable communities.

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Credit Authorship Contribution Statement

Fines, RTG.: Fines was responsible for the design and construction of the multi-input alternative power source prototype. Her contributions include the selection of components, circuit design, and the implementation of the power management system to ensure functionality and safety. She also performed the technical testing and data collection related to the device's performance.

Gabawa, LM.: Gabawa was responsible for the collection and organization of the performance data and user feedback. She conducted the formal analysis to evaluate the effectiveness and reliability of the power source. She also led the drafting of the manuscript, including the introduction, literature review, results, and discussion sections.

Ethical Statement

The authors confirm that this research adhered to the International Journal of Engineering Innovation and Dissemination's (IJEID) ethical guidelines. Prior to their involvement, all participants provided informed consent, and the necessary educational authorities gave their approval. The study followed the standards of transparency, confidentiality, and academic integrity, with all data provided accurately and sources correctly attributed.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability statement

The authors declare that the data supporting the findings of this study will be made available upon reasonable request.

AI Usage Disclosure

This manuscript utilized Grammarly and Quilbot for language refinement and editorial suggestions. Grammarly was used to enhance grammar, clarity and readability and Quilbot's primary role is to summarize and paraphrase texts. It helps users rework sentences, rewrite entire paragraphs, and create concise summaries of longer information. Original content creation, data analysis, and interpretation of research findings were not done with these tools. The researchers are solely accountable for the work's originality, scholarly integrity, and intellectual contribution.

References

Al-Waeli, A. H. A., Sopian, K., Kazem, H. A., & Chaichan, M. T. (2021). Photovoltaic/Thermal (PV/T) systems: Status and future prospects. *Renewable and Sustainable Energy Reviews, 149,* 111356. https://doi.org/10.1016/j.rser.2021.111356

Behnamgol, V., Hosseini, A., & Marco, J. (2024). Comprehensive review of lithium-ion battery state of charge estimation methods. *Energies, 17*(18), 5754.

Chaudhary, P., Raghuwanshi, N. S., & Singh, R. (2022). Hybrid renewable energy systems for sustainable power solutions: Recent developments and future directions. *Renewable Energy Focus, 43,* 27–40. https://doi.org/10.1016/j.ref.2022.03.004

Chen, T., Yang, J., Li, X., & Zhang, Y. (2024). Recent advances in lithium iron phosphate battery technology: A comprehensive review. *Batteries, 10*(12), 424. https://doi.org/10.3390/batteries10120424

Ding, H., Yu, L., Fu, Y., Peng, Y., Liu, J., & Wang, X. (2025). A comprehensive review of human-powered electricity generation. *Journal of Renewable Materials, 13*(4), 1–29.

Falope, T. A., Wang, Y., & Wang, J. (2024). Hybrid energy system integration and management for an energy transition toward zero-carbon power systems: A review. *Energy Conversion and Management: X, 21,* 100527. https://doi.org/10.1016/j.ecmx.2024.100527

Ghosh, A. (2024). Emergency power supply enabling solar PV integration with battery energy storage and wireless interface. *Philosophical Magazine, 104*(11), 1319–1338.

Hassan, Q. U., Zulfiqar, M., Sarwar, A., Habib, S., & Shehzad, M. (2023). A review of hybrid renewable energy systems: Solar and wind-powered solutions—Challenges, opportunities, and policy implications. *Results in Engineering, 20,* 101621. https://doi.org/10.1016/j.rineng.2023.101621

International Electrotechnical Commission. (2017/2021). *IEC 62133-2: Secondary cells and batteries containing alkaline or other non-acid electrolytes—Safety requirements for portable sealed secondary lithium cells and for batteries made from them (Li-systems) (Ed. 1 with Amendment 1).* Geneva: IEC.

Kok, C. L., Gan, W. C., & Ismail, M. (2024). A novel portable solar powered wireless charging device. *Electronics, 13*(2), 403. https://doi.org/10.3390/electronics13020403

Kunatsa, T., Mbohwa, C., & Nyadzayo, L. (2024). A review on state-of-charge estimation methods, energy storage technologies and parameters for PV applications. *World Electric Vehicle Journal, 15*(9), 381. https://doi.org/10.3390/wevj15090381

Kousksou, T., Allouhi, A., El Rhafiki, T., & Jamil, A. (2023). Portable renewable energy systems for disaster resilience: Opportunities and challenges. *Renewable Energy, 204,* 107–118. https://doi.org/10.1016/j.renene.2023.01.056

Lama, R. K., Katuwal, S., & Kim, H. (2024). Design and performance analysis of foldable solar panel with dynamic tracking for agrivoltaics. *Sensors, 24*(4), 1167. https://doi.org/10.3390/s24041167

Lin, Y., Ou, C., & Wu, T. (2023). A review on energy harvesting and recent developments. *Machines, 11*(6), 586. https://doi.org/10.3390/machines11060586

Lin, X., Wang, J., & Zhang, Q. (2024). Environmental impact analysis of lithium iron phosphate batteries. *Frontiers in Energy Research, 12,* 1361720. https://doi.org/10.3389/fenrg.2024.1361720

Muensuksaeng, C., Harnmanasvate, C., Chantana, J., & Cheacharoen, R. (2022). Portable solar-powered dual-storage integrated system. *Solar Energy, 247,* 245–254. https://doi.org/10.1016/j.solener.2022.12.012

National Renewable Energy Laboratory. (2021). *Voices of experience: Microgrids for resiliency* (DOE Office of Electricity/NREL report 75909). Golden, CO: NREL. https://www.nrel.gov/docs/fy21osti/75909.pdf

Ocampo, F. O., Constantino, R. Q., & Soriano, M. P. (2019). Design and construction of multi-purpose hand-crank mechanical energy charger. *International Journal of Innovative Technology and Exploring Engineering, 9*(2), 430–432. https://doi.org/10.35940/ijitee.B6426.129219

Suganya, R., Palanisamy, R., & Prasanna, K. (2024). A hybrid observer-based battery management system for electric vehicle applications. *International Journal of Energy Research, 48*(7), 9334–9350.

Zhao, T., Li, Z., & Zhang, H. (2024). An overview on the life cycle of lithium iron phosphate batteries. *Chemical Engineering Journal Advances, 17,* 100487.