Can It Power Your Life?: Investigating the Efficiency of a Solar-Powered Power Bank as an Alternative to Commercial Power Banks

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ABSTRACT

Amid growing concerns over e-waste and energy consumption, this study investigates the effectiveness of modified and repaired solar-powered power banks (SPPBs) as a long-term alternative to standard commercial power banks. In this study, solar-powered power banks that were previously non-functional or underperforming were carefully adjusted and rebuilt to restore functionality. By repurposing these devices, they were not only made usable again but also positioned as an environmentally responsible alternative to typical solutions. This experimental quantitative research explores the performance of these refurbished SPPBs by measuring their energy storage capacity in three hours and overall performance in an hour for comparison to commercial power banks. After thorough testing and experimentation with different formulations and measurements, the researchers found that all solar-powered power banks worked well in terms of storing energy and were able to charge smartphones for extended periods, though at a slower rate than commercial power banks. It was found that SPPB 3 consisting of 8,000 mAh had the highest energy storage and charging performance with an average of 21% and 13%, respectively. However, in the t-test made by researchers, their efficiency is still low as compared with the commercial power bank in terms of charging performance, averaging a large 44% battery added. These findings suggest that solar-powered power banks are a significant step toward the use of sustainable energy in commonplace devices, even though they may not yet equal the charging speed and convenience of conventional power banks. This research recommends further exploration of the materials, improving the overall durability, and creating a bigger battery capacitance (above 10,000 mAh) to improve the fast charging of the solar-powered power bank.

Keywords – solar-powered power bank; commercial power bank; environmentally friendly charging solution; renewable energy sources; portable charging

INTRODUCTION

Most of the communities in the Philippines have been addicted to the use of the gadgets to the point they sometimes leave it at a low battery percentage. According to Howe (2024), individuals aged 16 to 64 in the Philippines spend an average of 8 hours and 52 minutes online daily, with 5 hours and 20 minutes of this time via mobile phones and 3 hours and 32 minutes on tablets. According to Buctot et al. (2020), the prevalence rate of smartphone (mobile device) addiction among Filipino high school students was 62.6%, with males at 66.2% and females at 60.2%. In this number of statistics, mobile devices can have limited battery capacity due to overuse and limited charging time. Most Filipinos often forget to charge their mobile devices because of routine disruptions, faulty charging habits, and forgetfulness (Esco, 2024).

One of the solutions for alternative charging sources are the power banks. According to GoSun (2024), power banks are small devices that store electrical energy to charge a variety of electronic devices when required. They are especially valuable for scenarios when installed power points are missing, such as traveling, outdoor recreation, or power loss. They also allow you to charge your device while on the move by simply connecting the device to a power bank with a charging cable that is compatible with it.

Background of the Study

In today's world of media age, portable electronic devices have become essential in daily life, from smartphones and tablets to wireless earphones and smartwatches. As reliance on these gadgets increases, so does the demand for accessible and efficient charging solutions. Commercial power banks have addressed this need by providing portable energy sources. However, they are often limited by their dependence on traditional charging methods, which consume electricity and contribute to rising energy demands and carbon emissions. In this study, the researchers will be investigating how solar-powered rechargeable power banks will be useful for storing electricity. SPPB are cost-effective and can improve their own use for the people that had been experiencing low phone battery percentages and those people who forgot to charge their gadgets. However, as modern economies continue to move towards digitalization and adoption of technologies, part of the population still deals with the problem of charging, in which there are no charging outlets in public places.

As the solution for the problem, according to Solaric (n.d.), it can be helpful for them to use the solar-powered power bank since it is able to charge anywhere. The research aligns with SDG 7 (Affordable and Clean Energy) by promoting the use of solar energy through the development of a solar-powered power bank, which supports the transition to renewable energy. It improves energy efficiency by evaluating the storage capacity and charging time of the device, contributing to SDG 7's focus on increasing energy efficiency. Additionally, by offering an affordable and sustainable alternative to traditional power banks, the research enhances the accessibility and affordability of clean energy solutions, especially for mobile charging.

Review of Related Literature

A. Design and Technological Modification of Solar-Powered Power Banks

1.1 Applications of Power Banks

According to Garimella et al. (2023), power banks are becoming more popular because of their ability to prolong the use of mobile phones and other portable electronic devices that are a part of modern society. The onshore battery in a mobile phone can last for a few hours before gradually dying out. As a result, a power bank is required to prolong the use of electronic devices such as smartphones and tablets. However, employing unconventional energy sources, like solar panels, to charge electrical devices like power banks and cell phones will be useful in remote locations and environmentally friendly. A study by Stanlee et al. (2024) has developed a solar panel-based portable power bank, which is designed to convert solar energy into electrical power to charge the smartphones. The study shows the Laboratory-scale test showcasing that the SPPB can charge smartphones from 20% to 100% within four hours under the peak of sunlight, and 20% to 75% under lower sunlight. This study suggests increasing the energy storage capacity, improving its efficiency, and expanding its compatibility.

B. Evaluation of the Performance Efficiency of Solar-Powered Power Banks

2.1. Energy Storage Capability

According to the study titled *"Solar Powered Mobile Power Bank Systems"* by Sambandh et al. (2016), the energy storage capacity is discussed in the context of the battery integrated into the solar-powered power bank. The system uses a battery to store electrical energy converted from solar power, which can then be used to charge mobile devices. While the study explains the functionality and design of the system, specific numerical values for energy storage capacity are not explicitly mentioned in this research. However, this study by Neerav Jain et al. (2023). provides a detailed survey about the storage capacities of the solar power banks. 45% of the respondents were reported owning solar power banks with the capacity ranging from 10,000 mAh to 20,000 mAh, 15% of respondents had commercial power banks with the capacity of exceeding 20,000 mAh, and lastly smaller capacities 5,000 mAh were reported by only 11% of its respondents. This reflects the typical energy storage capacities for solar-powered power banks. To talk about the study of this research, it will be only ranging around 4,000 mAh to 6,000 mAh to determine if the electrical devices, specifically smartphones, can still be produced within a proper limited time.

2.2. Charging Time Efficiency of Mobile Phones

According to Ferreira et al. (2011), it takes about 2 hours to fully recharge a smartphone battery. Maintenance mode power, often known as the power consumed while the phone is completely charged but the charger remains plugged in, is 0.13 Watts. Salim Mudi in "Design and Construction of a Portable

Solar Mobile Charger" has constructed a solar charger that outputs voltage of 5V and an average of 800 mAh current, and with that capacity, it fully charges a mobile phone battery of 4800 mAh in about 4–5 hours under optimal sunlight conditions (Mudi, 2020). In another study of Chowdhury et al. (2021), a wearable solar cap embedded with 30 polycrystalline silicon cells demonstrated the ability to charge a 900 mAh mobile phone battery from 7% to 67% in 105 minutes under direct sunlight.

C. Comparison of Solar-powered Power Bank and Commercial Power Bank

3.1. Solar-powered Power Bank vs. Commercial Power Bank

The comparison between solar-powered power banks and traditional commercial power banks has been a subject of growing interest due to the increasing demand for portable energy solutions and environmental sustainability. Solar-powered power banks utilize photovoltaic panels to convert sunlight into electrical energy, which is stored in a battery for later use, making them an eco-friendly alternative to traditional power banks that rely on electricity from non-renewable sources. According to Jain et al. (2023), solar power banks present a sustainable option for charging mobile devices, particularly in areas with limited access to electricity. Their research highlights the environmental benefits of solar power banks. While commercial power banks are growing in popularity due to technological advancements, expanding applications across various industries, and a focus on sustainability (Global Power Bank Market Report, 2023). Their ability to meet the increasing energy demands of modern devices makes them an integral part of the portable electronics market.

D. Synthesis and Research Gap

There is a growing interest in integrating renewable energy sources, such as solar power, into portable devices, particularly power banks. Solar-powered power banks (SPPB) are seen as an eco-friendly alternative to conventional power banks, which typically rely on non-renewable sources for charging. This shift aligns with broader sustainability goals, aiming to reduce the environmental impact of portable charging solutions. However, despite the potential benefits, many studies focus on solar charging technologies in isolation, with fewer offering direct comparisons between solar-powered and commercial, branded power banks still the most widely used charging option. A comparison in terms of charging time, energy efficiency, and overall performance could provide valuable insights into the exchange between the environmental advantages of solar charging and the speed and convenience offered by traditional power banks. As interest in renewable energy grows, understanding these trade-offs becomes crucial in advancing the development of practical, user-friendly solar-powered solutions for everyday use (Irfan et al., 2023).

According to Mahmood et al. (2020), solar panels are more used, but weather factors affect their efficiency. In this study, some factors affecting the efficiency of solar cells were studied, in which a solar-powered rechargeable power bank may not be charged efficiently due to unpredictable weather conditions.

Research Objectives

The primary object of this research is to investigate the efficiency of solar-powered power banks as an alternative commercial power bank. The study specifically aims:

1. To modify and repair a solar-powered power bank (SPPB) that functions as an alternative energy source for mobile devices;
2. To evaluate the efficiency of the SPPB in terms of:
   2.1. Energy storage capability;
   2.2. Charging percentage added to smartphones in an hour;
3. To compare the charging performance of the SPPB with selected commercial power banks in terms of charging time.

Theoretical Framework

Technological Innovation and Diffusion Theory by Rogers, E.M. (1962)

This study is anchored with the Technological Innovation and Diffusion Theory by E.M. Rogers (1962). Diffusion of innovations, a theory about how new technology and other advances, are disseminated within and between societies and cultures, from introduction to widespread adoption. The diffusion of innovations theory aims to understand how and to some extent why ideas and practices were adopted (García-Avilés, 2020). According to Rogers, innovations are adopted through a process influenced by factors such as perceived advantages, compatibility with existing values and practices, simplicity and ease of use, trialability, and observable results.

In the context of this research, the solar-powered power bank represents an innovative alternative to conventional commercial power banks, offering potential advantages such as renewable energy sourcing, environmental sustainability, and portability. The study examines how the perceived efficiency, reliability, and practicality of solar-powered power banks influence their adoption among users. It also explores barriers to adoption, such as charging speed, weather dependency, and cost. Understanding these factors through the lens of the Diffusion of Innovations Theory will provide insights into the potential market acceptance of solar-powered power banks as a sustainable technological solution.

Conceptual Framework

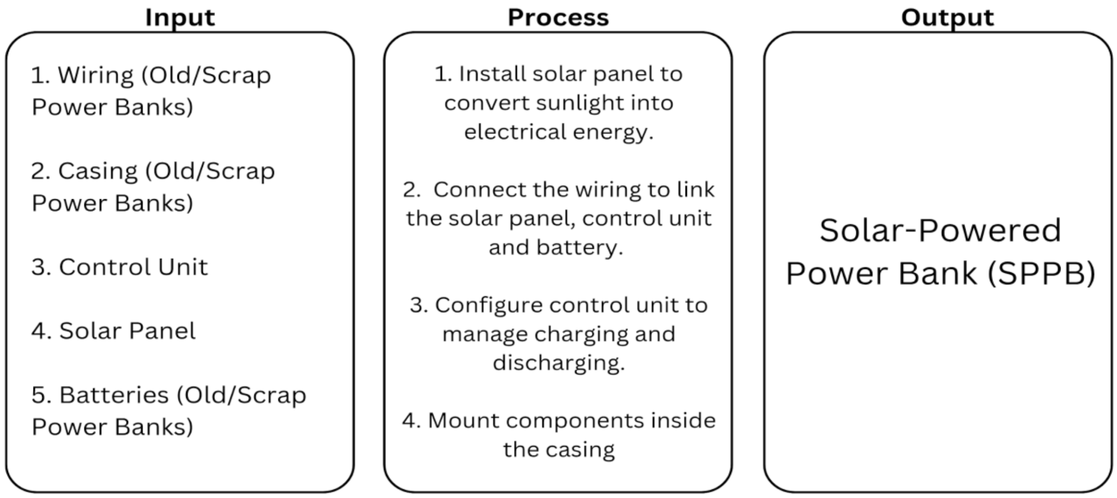

Figure 1. Conceptual Framework

The input stage involves the collection of key components such as wiring, casings, and batteries taken from old or non-functional power banks. These materials serve as the foundation for the modification and repair of existing SPPBs, aiming to enhance functionality and sustainability while minimizing e-waste. The process stage focuses on the careful assessment and repair of the SPPBs. This includes diagnosing and replacing faulty components, integrating or improving solar charging capabilities, reconfiguring the control unit to optimize charging and discharging, and ensuring proper assembly within the casing. Each modification is designed to restore or improve the device's performance relative to its original state and to commercial counterparts. The output is a fully functional, modified solar-powered power bank that is tested and evaluated against standard commercial power banks. The comparison focuses on key performance indicators such as energy storage capacity, charging speed, solar efficiency, and overall reliability.

This framework guided the researchers in conducting a structured investigation, enabling a comparative analysis through experimental testing and quantitative evaluation to determine the viability of modified SPPBs as sustainable and cost-effective alternatives to commercial models.

Significance of the Study

This study focuses on modifying and repairing solar-powered power banks (SPPBs) as a sustainable alternative to commercial power banks. By using recycled components, the study reduces e-waste and promotes eco-friendly technology. The performance of the modified SPPBs is compared to commercial models in terms of charging efficiency, energy storage, and reliability.

CONSUMERS. The study offers consumers an eco-friendly way to charge their devices, especially for those who care about the environment or live in places with unreliable electricity. SPPBs provide a renewable and cost-effective solution for charging on the go, making them a good choice for those who value sustainability.

COMMUNITIES. SPPBs can be especially helpful for communities in areas with limited or no access to electricity. During power outages, they provide a reliable charging option, keeping people connected and able to use their devices even when traditional power is unavailable. This helps improve communication and access to important services, even in remote areas.

TECHNOLOGY DEVELOPERS AND MANUFACTURERS. The findings of this study will give manufacturers and developers useful information about how SPPBs compare to regular ones. This can help them design better, more affordable, and efficient solar-powered devices. The study also encourages manufacturers to focus on creating sustainable products that meet the growing demand for eco-friendly solutions.

STUDENTS. This study can be a valuable resource for students learning about renewable energy, sustainable technology, or electronics. It can be used in classrooms to show how solar energy can be applied in everyday products. Students can also get hands-on experience in building and testing solar-powered devices, sparking their interest in green technologies and sustainability.

FUTURE RESEARCHERS. This study sets the stage for future research on SPPBs and other renewable energy solutions in consumer electronics. Future researchers can build on this work to improve energy storage, solar panel efficiency, and the development of better solar-powered devices. They may also find ways to make these products more affordable and accessible to a wider audience, helping promote the global use of renewable energy.

In short, this study provides valuable insights that can benefit consumers, communities, technology developers, students, and future researchers. By helping improve solar-powered power banks and similar technologies, it plays an important role in advancing the use of sustainable energy solutions.

METHODOLOGY

Research Design

This research employed experimental quantitative research to evaluate the efficiency and performance of a self-developed solar-powered power bank (SPPB). The experimental quantitative research applies a scientific and systematic approach to examining the cause-and-effect relationships between variables (Grand Canyon University, 2023). Specifically, the research aimed to determine how solar energy influences the efficiency of an SPPB in comparison to a commercial power bank. In this research, the independent variables were the type of power bank (solar-powered vs. commercial) and the energy source used (solar vs. electric charging). The dependent variables included the amount of energy stored, the mobile phone charging percentage per hour, and the total time required for charging. These variables were assessed through repeated testing and observation.

The research focused on repairing a malfunctioning SPPB and systematically observing its performance under real-world conditions. Following the principles of quantitative research, the study relied on numerical data to ensure objective evaluation. As Mohajan (2021) noted, quantitative research involves formulating focused questions, collecting quantifiable data, and using statistical or measurable outcomes to derive conclusions. The data were gathered using primary data collection methods, particularly through experimental procedures and observation. The researchers developed the SPPB prototype and conducted a series of tests to determine its performance. Various tools, such as voltmeters and timers, were used to record measurements accurately. A Likert scale-based evaluation was also designed for internal use to standardize performance assessment in terms of energy storage and charging effectiveness.

Research Site

The selected research sites for this study were located at two places: the first site was in the B12 L10 Redbud Street, Vista Verde in Mambog 3 and the last site was in the B22 L2 Ezra Street, St. Jude Homes in Molino VII. Both of them were chosen to take place with the research since it is the residence of two of the researchers.

The first site had been with all of the researchers to perform the experiment with the SPPB. It has a large open space with proper plain surface space to experiment. With its effective communication, the researchers can easily communicate with each other. The second site was the second option for the researchers to conduct. If the SPPBs are not complete or fixed, with the help of one of the researchers, they can continually be processed.

Respondents of the Study

This study did not involve any external respondents. Since the research focused on an experimental design, all data were obtained through direct observation and measurement conducted by the researchers (Zubair, 2023). The development and testing of the SPPB were carried out in a controlled setting, and the researchers utilized standardized observation tools and data collection sheets to measure energy storage and charging performance. This approach ensured consistency and accuracy in the gathered data without requiring subjective evaluations from outside participants.

Data Gathering Procedure

This study investigates the efficiency of a solar-powered power bank (SPPB) as an alternative energy source for mobile devices. The experiment involved testing the SPPB by determining its efficiency in terms of energy storage capability, charging smartphones, and comparing its performance with commercial power banks. The charging percentage added to smartphones in one hour was recorded. In each trial, smartphones were charged from a starting battery percentage of 15%. The total charging time for each was noted. Data were systematically recorded using observation tools, and the filtered results were analyzed to evaluate the efficiency of the SPPB in terms of energy storage, charging time, and percentage increase in battery life. testing the SPPB by charging smartphones and comparing its performance with commercial power banks.

Data Analysis Procedure

In this study, the efficiency of solar-powered power banks (SPPBs) was evaluated in terms of energy storage, charging percentage, and comparison with commercial power banks. Data collected from the experiments were analyzed using statistical methods to determine significant differences in performance.

The energy storage capability was assessed using a one-way Analysis of Variance (ANOVA) to compare the performance of three different SPPB prototypes with varying battery capacities (4,000 mAh, 6,000 mAh, and 8,000 mAh). The ANOVA results revealed significant differences in energy storage among the groups, with a p-value of 2.51847E-07, indicating that the differences were statistically significant. Each SPPB's performance was evaluated in terms of consistency over the testing period, with the SPPB 3 (8,000 mAh) showing the highest efficiency despite some variability.

To assess the charging effectiveness of the SPPBs compared to a commercial power bank, independent sample t-tests were performed. The results consistently revealed statistically significant differences between each SPPB model and the controlled variable. For SPPB 1 (4,000 mAh), SPPB 2 (6,000 mAh), and SPPB 3 (8,000 mAh), the computed t-values were -12.02, -11.07, and -9.03 respectively, all with p-values less than .05. In all comparisons, the commercial power bank exhibited substantially higher mean charging percentages (M = 44.29%) compared to the SPPBs (M = 3.14%, 6.29%, and 13.29% respectively). Although incremental improvements were observed as the SPPBs' capacities increased, their charging performance remained significantly inferior to that of the commercial power bank under identical experimental conditions. These findings highlight the current limitations of the SPPBs' efficiency and emphasize the need for further advancements in their design and energy storage capabilities to achieve practical competitiveness.

The data from both energy storage and charging percentages were recorded using structured observation sheets and Likert scale-based feedback from the researchers themselves, who assessed the efficiency of the devices based on predefined criteria. The findings from these analyses help support the conclusion that larger-capacity solar-powered power banks can provide more efficient energy storage and faster charging times.

Research Instrument

The researchers' study on the use of SPPB as an alternative to commercial power banks employed a researcher-made instrument to address the aspects of SPPB. In this study, the researchers used observation tools, specifically a structured observation sheet to evaluate the efficiency of SPPB in terms of energy storage capability and charging percentage added to mobile phones in an hour. The researchers planned to use a Likert scale-based questionnaire, which gives respondents the option to select one of five responses to a statement. This methodological tool is commonly used for data collection (Pescaroli et al., 2020). The questionnaire consisted of 10 questions in the form of a four-point Likert scale to obtain a clear and decisive feedback which ranges from highly efficient (4) to inefficient (1). Since this research did not involve any external respondents, the researchers themselves will be the respondents of the questionnaires. The researchers followed the standardized instructions and procedures to ensure that the respondents understood the questions and guidelines clearly. Data from all instruments were analyzed by the researchers to draw meaningful and reliable conclusions.

RESULTS AND DISCUSSION

Table 1.1
Energy Storage Test on SPPBs

Days (Trials)	SPPB 1 (4,000 mAh)	SPPB 2 (6,000 mAh)	SPPB 3 (8,000 mAh)
Day 1	10%	18%	24%
Day 2	13%	17%	22%
Day 3	13%	18%	18%
Day 4	12%	14%	19%
Day 5	13%	18%	22%
Day 6	12%	15%	21%
Day 7	13%	17%	18%
Average	12.29%	16.71%	20.57%

Legend. % = energy capacity added in SPPB.

Table 1.1 presents the results of testing for the energy stored in the different formulations of solar-powered power banks. The table of data is based on the observation sheet of the researchers to determine the efficiency of the SPPB through charging on the Sun. The test was charged within three (3) hours, starting from 1:00 PM to 4:00 PM. The SPPB starting battery percentage was around 15%. The ratings of Table 1.1 are based on the ratings, with "Highly Efficient" being the highest rating ranging from 15% and above, and "Inefficient" being the lowest rating ranging from 0% or almost none.

The first formulation, SPPB 1 (4,000 mAh), consistently but modestly performed throughout the seven-day trial. It started with a 10% energy gain on Day 1, increased slightly the next day, and maintained between 12% and 13% on the remaining days. It recorded an average energy storage of 12.29%, which indicates stable and consistent performance. This result corresponds to an "Efficient" rating.

The second formulation, SPPB 2 (6,000 mAh), performed better, with an average energy storage of 16.71%. While it maintained a relatively consistent energy gain, a slight dip was observed on Day 4, possibly due to lower solar intensity. Despite the temporary drop, the unit quickly recovered in the following days. This prototype received a "Highly Efficient (HE)" rating, indicating its strong performance under varying solar conditions.

The third formulation, SPPB 3 (8,000 mAh), achieved the highest energy storage performance with an average of 20.57%. It initially stored a high of 24% on Day 1 but showed a gradual decline in the next few days. Though it briefly rebounded on Day 5, the values dropped again on the last two days. While SPPB 3 was rated "Highly Efficient," the data suggests slightly more variability in its daily performance compared to the others.

The statistical analysis validates that the energy storage performance significantly varies across different SPPB battery capacities, with SPPB 3 emerging as the most efficient. This supports the idea that larger-capacity batteries can optimize energy retention when paired with solar charging components, likely due to enhanced regulation systems and reduced energy loss during conversion.

Table 1.2.1

Means and Standard Deviations for Energy Storage Capability of SPPBs

Variables	Trials	Average	Standard Deviation
SPPB 1 (4,000 mAh)	7	12.28571429	1.238095238
SPPB 2 (6,000 mAh)	7	16.71428571	2.571428571
SPPB 3 (8,000 mAh)	7	20.57142857	5.285714286

Table 1.2.2
Analysis of Variance (ANOVA) for Energy Storage Capability of SPPBs

Source	*SS*	*df*	*MS*	*f*	*P-value*	*F crit*
Between Groups	240.6666667	2	120.3333333	39.69109948	2.51847E-07	3.554557146
Within Groups	54.57142857	18	3.031746032			
Total	0.022870554					

Legend. The result is significant at $p<0.005$.

Table 1.2.1 presents the means and standard deviations of testing worked by the researchers on the Energy Storage Test. The next table, table 1.2.2, presents the results of the energy storage capability test using a one-way Analysis of Variance (ANOVA). This test was conducted to determine whether there are statistically significant differences in energy storage among the three groups of solar-powered power banks (SPPBs), each with different battery capacities and configurations. The ANOVA revealed a statistically significant difference, with an F-value of 39.69, which is greater than the critical F-value of 3.55, and a p-value of 2.51847E-07. These results indicate that the observed differences in energy storage among the three groups are unlikely due to chance or random variation alone.

Over a seven-day observation period, the average energy stored by each SPPB varied. SPPB 3 exhibited the highest mean energy storage at approximately 20.57 units with a standard deviation of 5.29. SPPB 2 demonstrated moderate average storage of around 16.71 units with a 2.57 standard deviation, while SPPB 1 recorded the lowest mean energy storage at approximately 12.29 units with a standard deviation of 1.24. This indicates that, on average, SPPB 3 was the most effective in storing energy during this period, followed by SPPB 2 and then SPPB 1.

The ANOVA results confirm that these differences were statistically significant, as the between-group variance (SS = 240.67) was much larger than the within-group variance (SS = 54.57). The p-value of 2.51E-07 (< 0.005) is extremely small, leading to the rejection of the null hypothesis (H_0), confirming that at least one SPPB formulation differs significantly in efficiency compared to the others.

These findings align with existing literature, such as the study by Neerav et al. (2023), which highlights the technical variability in solar-powered power banks. Their findings noted that most solar power banks typically range from 5,000 mAh to 20,000 mAh, with smaller models often limited by 5W solar panel outputs, resulting in slower charging rates. The performance of the SPPBs in this study reflects similar trends, where both battery capacity and solar panel capabilities influence efficiency.

Table 2.1
Battery Performance Test for the Smartphone

Source	*SPPB 1 (4,000 mAh)*	*SPPB 2 (6,000 mAh)*	*SPPB 3 (8,000 mAh)*	*Commercial Power Bank (10,000 mAh)*
Trial 1	3%	6%	14%	54%
Trial 2	3%	7%	12%	32%
Trial 3	2%	6%	14%	43%
Trial 4	3%	6%	12%	35%
Trial 5	3%	5%	14%	56%
Trial 6	4%	6%	13%	42%
Trial 7	4%	8%	14%	48%
Average	3.14%	6.29%	13.29%	44.29%

Legend. % = energy capacity added in the smartphone.

Table 2.1 presents the results of testing for the charging percentage in a smartphone. It contains different formulations of solar-powered power banks and a controlled variable, the commercial power bank (CPB), to compare its performance to a smartphone. The table of data is based on the observation sheet of the researchers and the test lasts one (1) hour. The smartphone used for testing had a 5,020 mAh battery and the starting battery percentage was around 15%. The ratings of Table 2.1 are based on the ratings, with “Highly Efficient” being the highest rating ranging from 30% and above, and “Inefficient” being the lowest rating ranging less than 5%.

The first formulation, SPPB 1 (4,000 mAh), records only a low battery percentage in a smartphone. It only shows around 2%-4% and it recorded a mean charging of 3% and a standard deviation of 0.69, which indicates very inefficient and it impractical for regular use. This result corresponds to an “Inefficient” ratings. The second formulation, SPPB 2 (6,000 mAh), records around 6%-8%. It has a decent battery with a recorded mean charging of 6.29% and a standard deviation of 0.95, which indicates slower and may not be ideal for quick, on-the-go charging. This result corresponds to a “Less Efficient (LE)” rating.

The third formulation, SPPB 3 (8,000 mAh), achieved the highest charging performance in the researchers’ product with an average of 13.29% and a standard deviation of 0.95, the same as the second formulation. The SPPB 3 was rated

"Moderately Efficient (ME)". The last is the controlled variable, the CPB (10,000 mAh), which achieved the highest energy storage performance with an average of 44.29% and a standard deviation of 9.03. It initially charge a high of 56% on an hour. The commercial bank achieved "Highly Efficient (HE)." Overall, the CPB had the biggest charging percentage in smartphones in an hour, suggesting that the SPPB in that state needs to create more volts for fast charging efficiency.

These findings align with the existing literature. According to Lobitas et al. (2023), tested the solar power banks with wireless charging cases and reported charging percentages increase and charging speeds under controlled conditions. The result of this study shows a normal temp. charging which can long for 6-8 hours to get the phone to be fully charged, in terms of recharging the SPPB it is estimated to take 4-6 hours before getting fully charged. This study highlights the variability in charging rates like device formulation and the support needed for comparative analysis like t-test to determine the significant difference between each group.

Table 2.2
t-test Results Comparing SPPB 1 and the Controlled Variable

	SPPB 1 (4,000 mAh)	*Commercial Power Bank (10,000 mAh)*
Mean	3.142857143	44.28571429
Variance	0.476190476	81.57142857
Observations	7	7
Pooled Variance	41.02380952	
Hypothesized Mean Difference	0	
df	12	
t Stat	-12.01739888	
P(T<=t) one-tail	2.37924E-08	
t Critical one-tail	1.782287556	
P(T<=t) two-tail	4.75848E-08	
t Critical two-tail	2.17881283	

Legend. The result is significant at $p<0.005$.

Table 2.2 performs an independent samples t-test to assess the difference in charging efficiency between an SPPB 1 (4,000 mAh) and a CPB (10,000 mAh). The results revealed a statistically significant difference between the two devices, $t(12) = -12.02$, $p = 4.36748E-08$ (<.005). SPPB 1 demonstrated a markedly lower mean charging efficiency (M = 3.14%, Variance = 0.48) compared to the CPB (M = 44.29%, Variance = 81.57).

The observed t-statistic far exceeded the critical values for both one-tailed and two-tailed tests, further supporting the rejection of the null hypothesis. This indicates that the charging capability of SPPB 1 is significantly inferior to that of the commercial alternative. The relatively low variance of SPPB 1 suggests a consistent, albeit poor, performance across trials, while the CPB showed greater variability but substantially higher average efficiency.

Overall, these findings suggest that, in its current form, SPPB 1 is impractical for standard smartphone charging needs, underscoring the necessity for enhanced design, improved energy conversion mechanisms, and increased storage capacity to render solar-powered power banks a viable alternative to conventional commercial models.

Table 2.3
t-test Results Comparing SPPB 2 and the Controlled Variable

	SPPB 2 (6,000 mAh)	*Commercial Power Bank (10,000 mAh)*
Mean	6.285714286	44.28571429
Variance	0.904761905	81.57142857
Observations	7	7
Pooled Variance	41.23809524	
Hypothesized Mean Difference	0	
df	12	
t Stat	-11.07052763	
P(T<=t) one-tail	5.90515E-08	
t Critical one-tail	1.782287556	
P(T<=t) two-tail	1.18103E-07	
t Critical two-tail	2.17881283	

Legend. The result is significant at p<0.005.

Table 2.3 performs an independent samples t-test to assess the difference in charging efficiency between an SPPB 2 (6,000 mAh) and a CPB (10,000 mAh). The analysis revealed a statistically significant difference, t(12) = -11.07, p = 1.18103E-07 (<.005). SPPB 2 exhibited a considerably lower mean charging efficiency (M = 6.29%, Variance = 0.90) compared to the Commercial Power Bank (M = 44.29%, Variance = 81.57). The magnitude of the t-statistic and the extremely low p-value provide strong evidence to reject the null hypothesis, confirming a substantial disparity in performance.

While SPPB 2 demonstrated slightly improved efficiency relative to SPPB 1, its charging capability remained markedly inferior to the commercial alternative. The low variance observed for SPPB 2 indicates consistent but limited performance across trials.

These findings suggest that, despite enhancements in storage capacity, SPPB 2 remains inadequate for quick and reliable smartphone charging, reinforcing the need for further technological improvements in solar-powered portable power banks to achieve commercial viability.

Table 2.4
t-test Results Comparing SPPB 3 and the Controlled Variable

	SPPB 3 (8,000 mAh)	*Commercial Power Bank (10,000 mAh)*
Mean	13.28571429	44.28571429
Variance	0.904761905	81.57142857
Observations	7	7
Pooled Variance	41.23809524	
Hypothesized Mean Difference	0	
df	12	
t Stat	-9.031219908	
P(T<=t) one-tail	5.32214E-07	
t Critical one-tail	1.782287556	
P(T<=t) two-tail	1.06443E-06	
t Critical two-tail	2.17881283	

Legend. The result is significant at p<0.005.

Table 2.4 presents an independent samples t-test conducted to assess the difference in charging efficiency between SPPB 3 (8,000 mAh) and the Commercial Power Bank (10,000 mAh). The results indicated a statistically significant difference, t(12) = -9.03, p = 1.06443E-06 (<.005). SPPB 3 exhibited a mean charging efficiency of 13.29% (Variance = 0.90), which was considerably lower than that of the Commercial Power Bank (M = 44.29%, Variance = 81.57).

The magnitude of the t-statistic and the very low p-value provided strong evidence against the null hypothesis, confirming a substantial disparity in charging performance. Although SPPB 3 demonstrated improved efficiency compared to its predecessors (SPPB 1 and SPPB 2), it still showed a notable performance gap relative to the commercial model.

These findings suggest that while SPPB 3 achieved moderate efficiency within the tested scale, it remains limited in delivering fast and consistent smartphone charging, highlighting areas for further development in solar-powered portable battery technologies.

CONCLUSION

To conclude the research, this study aimed to assess the effectiveness of solar-powered power banks (SPPBs) as a practical alternative to traditional commercial power banks, focusing on energy storage, charging speed, and overall performance. The results show that while SPPBs provide an eco-friendly and sustainable solution, they do have some drawbacks, such as slower charging times and reliance on weather conditions. Despite these limitations, using solar power for portable charging presents a great opportunity to reduce our dependence on traditional, non-renewable energy sources, especially in areas where electricity is not always available.

The SPPBs worked well in terms of storing energy and were able to charge smartphones for extended periods, though at a slower rate than commercial power banks. This highlights the potential for further improvement in both solar panel efficiency and battery capacity when reusing old or discarded components. The research also shows that solar-powered power banks are a promising tool for encouraging sustainability and contributing to the global movement toward renewable energy.

In the end, while solar-powered power banks may not yet match the charging speed and convenience of regular power banks, they represent an important step toward using sustainable energy in everyday electronics. With continued research and development, solar-powered power banks could play a key role in reducing environmental impact and improving access to energy around the world.

RECOMMENDATION

For Consumers:

- Consumers can consider using solar-powered power banks as a sustainable alternative to conventional power banks, especially in areas where electricity is limited or unreliable.

For Communities:

- Communities in remote or underserved areas may benefit from the introduction of solar-powered charging systems. Local initiatives can explore low-cost, solar-based energy solutions to promote energy access and support mobile communication, especially during emergencies or power outages.

For Technology Developers and Manufacturers:

- It is encouraged that technology innovators further improve the design and materials of solar-powered power banks to enhance their charging efficiency and energy storage capacity. Manufacturers can also explore integrating eco-friendly and recycled materials to promote sustainable production practices.

For Students

- This study may serve as a foundation for student researchers who wish to explore renewable energy solutions, product development, and applied electronics. Students are encouraged to pursue projects that blend innovation with sustainability to address real-world energy concerns.

For Future Researchers

- It is recommended for the future researchers to expand more on this study by testing the SPPB under different weather conditions, using different solar panel specifications, or integrating multiple output ports. They may also consider improving the prototype's charging speed, examining long-term durability, or involving more trials to validate findings across multiple devices.

Based on the results of Table 1, researchers recommend exploring and creating more binding agents to improve the efficiency of the SPPB. Even though the experiment was not a failure, the researchers still suggest adding more time rather than the researchers' goal which is 3 hours (1 PM to 4 PM specifically). Based on the results of Table 2, researchers recommend smartphones that have the same battery capacity which can be maintained to record and have no difference in the storage capacity. Many smartphones have a big capacitance battery that can take more time to charge.

Overall, this research can be improved more in future studies by changing the formulations of the SPPB, for instance, the researchers recommend creating a much bigger battery capacity (10,000 mAh above), improving the overall durability of the solar-powered power bank and also its fast-charging speed since most of the power banks nowadays have the fast-charging component to charge their devices quickly.

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