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Development of Optimized Stationary Solar Charging Stationat Saint Francis of Assisi College – Las Piñas

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Abstract:

The Development of Optimized Stationary Solar Charging Station is intended to provide a sustainable, convenient, and eco-friendly solution, as well as dependable charging options for students and faculty members who use various devices on campus, such as mobile phones, laptops, and tablets. To maximize energy generation, the design incorporated solar panels with reflective mirrors, a battery storage system, and multiple charging ports. It served as an educational tool to enable students to comprehend the significance of sustainability and the environmental impact of energy consumption, given that the station was entirely powered by solar energy. The study assessed the output voltage and current of solar panels to determine their suitability for powering a stationary solar charging station. This station was designed to provide charging facilities for common school devices such as laptops and smartphones. To analyze the collected data, the researchers used quantitative method, specifically descriptive statistics. By comparing computed results to actual measurements from the developed system, the study assessed the solar charging station's effectiveness and potential benefits to the educational institution. The research indicated that the highest voltage outputs were recorded at angles of 0 degrees and 45 degrees, with average solar output voltages of 20.75 V and 20.60 V, respectively. Factors like the prototype's location, shadings, application of mirrors, different times of the day, and varying weather conditions were found to affect energy collection, resulting in fluctuations from high to low energy accumulation.

Key Terms: ***Solar panel, Charging station, Solar shading, Solar irradiation, Solar charging station, Solar energy, Photovoltaic panels, Technology, School devices***

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I. INTRODUCTION

As technology evolves rapidly, new ideas, products, and services emerge, driven by innovation's pivotal role in shaping our society and profoundly impacting daily life. Innovation harnesses emerging technologies to address community needs sustainably and efficiently. Innovations, while undoubtedly transformative, are not devoid of drawbacks. Certain innovative products contributed to environmental issues. In some cases, the development of new technologies has had an adverse effect on the environment, resulting in air and water pollution as well as the depletion of natural resources worldwide. The use of fossil fuels to generate energy has significantly increased air pollution and contributed to the phenomenon of global warming. As a result, there is a vital demand to transition to alternative energy sources in order to address these environmental concerns. Solar power appears as an essential solution in the matter, as it is one of the largest, most efficient, and environmentally friendly sources of renewable energy used for the production of electricity (Dixit, 2020).

The efficiency rate of your solar panels can be affected by several things. Keeping track of these variables can help you better understand how these gadgets operate and how they can help you. Solar shading and dusts are some of the factors that can affect the efficiency rate of the solar panels by blocking of radiant energy by solid things such as trees, roofs, and other buildings is shading. When a solar panel receives insufficient sunlight, its overall production suffers. Additionally, if a portion of the panel remains in the shade, this can reduce its longevity, solar irradiation affects the solar panels since it uses the amount of sunlight rather than the heat from the sun to work. The solar panels' efficiency increases as the amount of light falling on them increase (Gavagsaz-Ghoachani, 2022).

According to Jim Neal (2021), Charging stations in educational institutions such as schools and colleges are becoming increasingly prevalent among students. While it is common to observe that many people rely heavily on their smartphones, college students stand out as a particularly invested user base. As a result, the need for longer battery life becomes critical. The availability of cell phone charging stations has become essential because it allows for continuous connectivity, punctual attendance in classes, and effective handling of various unforeseen circumstances that may arise.

This study focused primarily on determining the amount of output voltage and current produced by solar panels, conducted at Saint Francis of Assisi College – Las Piñas Campus. The researchers will use the mirror reflector optimization technique. First, to obtain the maximum output voltage of the solar panels. And second, to address the factors affecting its efficiency like Solar Shading, Time, and Solar Irradiation which can lessen the efficiency of the solar panel. Mirrors will be a big help to the solar panel by reflecting all the light falling on it. Tests and observations will be done to collect data. Secondarily, this study will also focus on installing different types of charging in the form of wireless, cables, ports, and outlets.

At Saint Francis of Assisi College - Las Piñas Campus, it is a common sight to see all college students equipped with mobile phones as they attend school. The diversity in their choice of devices necessitates a variety of charging solutions. Accordingly, the charging station is designed to cater to this diversity, featuring dedicated charging ports for Type C, Micro USB, and iOS devices. Recognizing the growing trend towards wireless technology, the stationary solar charging station further accommodates both Android and iOS phones with a wireless charging capability.

Recognizing that students also bring their laptops to school, the station is equipped to provide charging solutions for various laptop models, ensuring that students can conveniently power their devices. A standout feature of this charging station is its energy storage solution - a 12V 20Ah Lead Acid Battery. This allows the charging station to remain operational even in the absence of sunlight, provided it has a stored voltage of more than 10.8V. This feature ensures that students can rely on the charging station at any time of the day, making it a highly valuable resource on campus.

II.METHODOLOGY

The researchers employed quantitative data collection methods, emphasizing the gathering of numerical data to generalize across groups or describe specific occurrences. They utilized descriptive quantitative to compile, illustrate, and describe the obtained data, employing tables and figures to present the results from both experimentation and assessment of the project's optimization performance, as well as data collected through survey questionnaires that was conducted at Saint Francis of Assisi College – Las Piñas Main Campus.

An evaluation metric was utilized to gauge the optimization performance of the developed stationary solar charging station, with specific objectives outlined based on key considerations. The target for solar output voltage was established at six volts to align with the system's operation on a twelve-volt basis, adjusted to half to accommodate the maximum voltage capacity of 50%. The usage duration was aimed at six hours, mirroring the observational period used by researchers to identify factors impacting solar panel efficiency, and coinciding with typical school hours. Finally, the cost objective was set at PHP 35,000, taking into account the prevailing online market price range of PHP 25,000 to PHP 45,000, factoring in the exchange rate between the dollar and the peso.

Table 1.0 Evaluation Metrics

CRITERIA	OBJECTIVES	METRICS	SCALE	
Solar Output Voltage	To be able to use voltage not less than 6 V.	Measured by using a tool known as a multimeter.	10 V and above	Outstanding
			8 – 9.9 V	Very Satisfactory
			6 – 7.9 V	Satisfactory
			4 – 5.9 V	Unsatisfactory
			Below 4 V	Poor
Hours of Usage	The developed project can be used for 6 hours.	Measured by testing and observing the total number of hours that the project can be used during school working hours.	Above 7 hours	Outstanding
			6 hours and 1 second – 7 hours	Very Satisfactory
			5 hours and 1 second – 6 hours	Satisfactory
			4 hours and 1 second – 5 hours	Unsatisfactory
			Below 4 hours	Poor
Number of devices that can be charged	The number of devices that can be charged in a day should not be less than 8.	Measured by testing and observing the total number of devices that can be charged on the project in a day.	Above 13	Outstanding
			11 – 13	Very Satisfactory
			8 – 10	Satisfactory
			5 – 7	Unsatisfactory
			Below 5	Poor
Overall Cost	The overall cost of the project should not be more than Php 20,000.	Measured by considering the total cost of materials used in building the project.	Below Php 15,000	Outstanding
			15,000 – 17,999	Very Satisfactory
			18,000 – 20,999	Satisfactory
			21,000 – 23,999	Unsatisfactory
			Php 24,000 and above	Poor

Firstly, the Solar Output Voltage should not fall below 6 volts, with measurements conducted using a multimeter. Achieving 10 volts or more is deemed outstanding, while below 4 volts is considered poor. Secondly, the Hours of Usage should meet or exceed 6 hours during school working hours. More than 7 hours is rated outstanding, while less than 4 hours is considered poor. Thirdly, the Number of devices that can be charged should be no less than 8 per day, with over 13 devices being outstanding and fewer than 5 being poor. Finally, the Overall Cost of the project should not exceed Php 20,000, with lower costs being rated more favorably. Falling below Php 15,000 is outstanding, while exceeding Php 24,000 is considered poor. These criteria provide clear benchmarks for assessing the project's performance and cost-effectiveness.

To construct the prototype of the stationary solar charging station, a photovoltaic panel was incorporated, as depicted in the technical diagram of the prototype (Figure 1 and figure 1.1) along with its corresponding legend (Table 2).

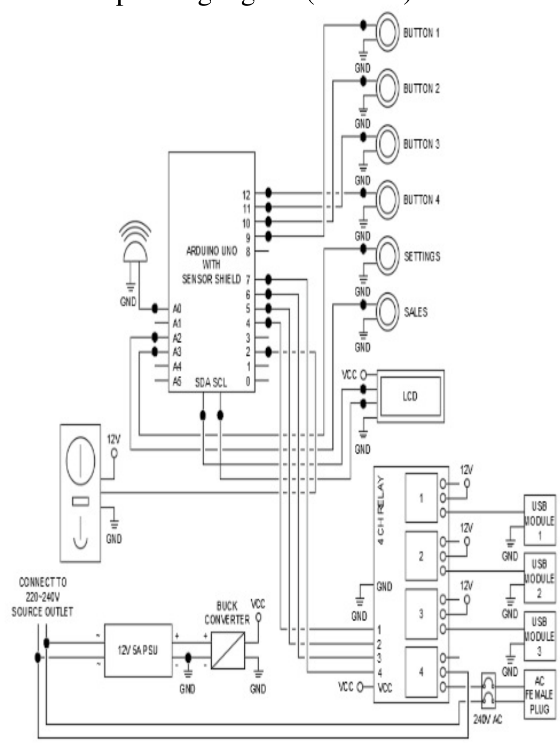

Figure 1.0 Technical Diagram

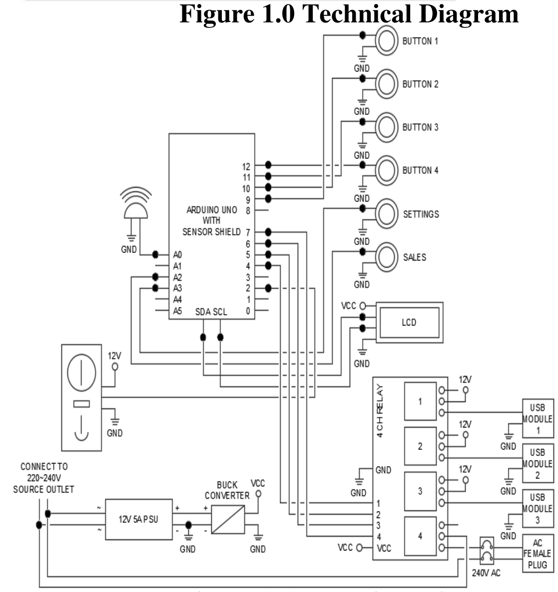

Figure 1.1 Technical Diagram

	12V 10W SOLAR PANEL
	10A PWM SOLAR CHARGE CONTROLLER
	12V-20AH LEAD ACID BATTERY
	100W SOLAR INVERTER 12V DC TO 220~240V AC
	10A SOLID STATE RELAY MODULE
	AC/DC MINIATURE CIRCUIT BREAKER
	ARDUINO UNO WITH ARDUINO SENSOR SHIELD V5.0
	5V FOUR-CHANNEL RELAY MODULE
12V 5A PSU	12V 5A SWITCHING POWER SUPPLY
	UNIVERSAL COIN SLOT SELECTOR
	BUCK CONVERTER
LCD	LCD DISPLAY
	PUSH BUTTON
	6-12V BUZZER
GND	TO ARDUINO GND PIN
VCC	TO ARDUINO 5V PIN
12V	TO 12V POSITIVE LINE

Table 2.0 Legend

Battery Needed:
Type: 12V Lead Acid Battery

Battery DOD: 50% Depth of Discharge

Total Wh: (Total energy consumption + System Loss) x2

(105Wh + 30%) x 2

273 Watt-hour

Total Ah: I = PV
273Wh / 12V
22.8 Amp-hour

Use: 1 – 12V-20Ah Lead Acid Battery

Solar Panel Needed:
Battery Wh: Watts = Voltage x Amperes
12V x 20Ah
240 Watt-hour

At 50% DOD: Battery Wh x 50%
120 Watt-hour

At 3.5 Sun hours: Total Battery Wh /3.5Hrs.
34.3 Watts

Use: 4 – 12V-10W Solar Panel

Solar Charge Controller Needed:
Type: Pulse Width Modulation (PWM) Solar Charge Controller

PV Nominal Voltage: 12V

Solar Panel Isc: 0.59A

No. of String: 4

Total Ampere: Isc x No. of String in Parallel x 125% Safety Factor

0.59A x 4 x 1.25

2.95 Amperes

Use:1 – 10A PWM Solar Charge Controller

Solar Inverter Needed:
Total Watts: 65W (Laptop charger)

Plus 20% Efficiency: 65W + 20%
78 Watts

USE: 100W SOLAR INVERTER 12V DC TO 220~240V AC

Charging Time of a Mobile Phone:
E.g.: Battery Capacity: 5000mAh

Input current: 2.0A

Time (t) = Capacity (C) / Discharge Current (I)

Discharging Time: 5.0Ah / 2.0A
2.5 hours

Battery Charging Calculations:

Method 1:
Solar Panel Current (A):
PV Watts / PV Voltage = Ampere

40W / 12V
3.33 Amperes

Battery Charging Time:
Battery Amp-hour / PV Ampere
20Ah / 3.33A
6 Hours

Charging Time for Lead Acid Battery:
Charging Time x Battery Depth ofDischarge
6 Hours x 50%
3 Hours

Method 2:
Battery Capacity:
Battery Voltage x Battery Amp-hour

12V x 20Ah
240Wh

Discharged Battery Capacity:
Battery Watt-hour x Battery Depth of Discharge
240Wh x 50%
120 Watt-hour

Solar Output:
PV Wattage x PWM Controller Efficiency
40W x 75%
30 Watts

Charge Time:
Discharged Battery Capacity (Wh) / Solar Output (W)
120Wh / 30W
4 Hours

Formula for Average:

$$Mean = \frac{sum\ of\ the\ terms}{number\ of\ terms}$$

Formula for Percentage:

$$Percent = \frac{sum\ of\ the\ terms}{number\ of\ terms} \times 100$$

To ensure the attainment of cost objectives, a comprehensive list of materials along with their associated costs was meticulously compiled. This bill of materials provides a detailed breakdown, encompassing both the quantity and expenses incurred for the materials utilized throughout the study. The total costs of developing the prototype amount to Php 13,560. This encompasses Php 11,870.00 allocated for materials procurement, Php 500.00 attributed to labor costs, and Php 590.00 designated for shipping fees spent during the material acquisition. Additionally, a monthly maintenance fee of Php 600.00 is allocated for the maintenance of the Stationary Solar Charging Station.

Quantity	Unit	Description	Unit Price	Price
1	pc.	¾” Plyboard	1215	1215
2	pcs.	2” x 2” x 10” Wood	195	390
6	pcs.	½” x 1” x 8” Wood	60	360
½	kilo	2” Nails	110	55
3	pcs.	100 grit Sandpaper	18	54
1	pack	Stickwel	55	55
1	pc.	1 ½” Brush	35	35
1	pc.	Clear Sealant	195	195
1	liter	Sanding Sealer	250	250
1	liter	Clear Gloss Lacquer	250	250
1	pc.	1/8” x 1” x 21” Silver Flat Bar	290	290
2	pcs.	8” x 10” 1/8 Flat Mirror	60	120
2	pcs.	6” x 10” 1/8 Flat Mirror	70	140
1	pc.	60cm x 20 cm 1/8 Flat Mirror	240	240
3	pcs.	Foot Rubber Cup	15	45
1	pc.	Safety Hasp Lock	45	45
1	pc.	Best guard Padlock	190	190
6	pcs.	Push Buttons	22	132
1	pc.	Arduino Uno Board	475	475
1	pc.	Arduino Uno Sensor Shield	146	146
4	pcs.	Board Spacer (L Spacer)	7	28
1	pc.	AC Female Plug	25	25
1	pc.	DC Male Adapter Plug	15	15
1	pc.	20 x 4 LCD with i2c	199	199
1	pc.	5V 4-way relay module	159	159

1	pc.	Buck Converter	95	95
3	pcs.	Charging Module	48	144
10	pcs.	(3 pins) Dupont female wires	6.1	61
1	pc.	(6 pins) Dupont female wires	10	10
1	pc.	Mini Buzzer	39	39
1	pc.	Coin Slot	420	420
1	meter	#14 Stranded Wire	25	25
1	meter	#12 Solid Wire	25	25
2	meters	#22 Stranded Wire	9	18
1	pack	Cable Tie	35	35
1	pc.	Adhesive Tape	39	39
1	pack	Screws	30	30
1	pack	Cable Clamp	17	17
2	meter	Soldering Lead	7	14
1	pc.	Electrical Tape	24	24
1	pc.	Masking Tape	26	26
1	pc.	10A AC Circuit Breaker	130	130
2	pcs.	10A DC Circuit Breaker	115	230
1	pc.	15W Wireless Charger	269	269
1	pc.	USB Male to Female Extension	35	35
1	pc.	3-in-1 Fast Charge Cable	89	89
1	pc.	10A PWM Charge Controller	235	235
1	pc.	12V 20Ah Lead Acid Battery	950	950
1	pc.	OTG Type – C Adapter	29	29
1	pc.	Solid State Relay	129	129
1	pc.	200W Inverter	644	644
4	pcs.	10W Solar Panels	750	3000
TOTAL				**Php 11,870**

Table 3.0 Prototype Cost

Considering that the prototype was used at full capacity of six hours per day and all slots were fully occupied. The price of charging a single device in a solar charging station was 30 pesos per hour multiplied by 4 because all slots were working then it was equal to 180. Thus, the cost for 6 hours was Php 720. Assuming it will be used from Monday through Friday, 720 times 5 equals 7,200, which was the income per week, or 14,400 a month. However, 600 will be deducted for maintenance, leaving us with a net income of 13,800. Therefore, it will take 0.98 months to return all the expenses.

III.RESULTS AND DISCUSSIONS

The researchers meticulously documented the daily voltage obtained from four solar panels positioned at varying angles. Notably, the highest voltage outputs were recorded at angles of 0 degrees and 45 degrees, yielding average solar output voltages of 20.75 V and 20.60 V, respectively.

Day	**Angle**			
	0°	**30°**	**45°**	**60°**
Day 1	20.00 V	19.57 V	19.73 V	19.57 V
Day 2	20.33 V	19.70 V	20.03 V	19.50 V
Day 3	22.05 V	21.28 V	22.13 V	21.38 V
Day 4	20.63 V	20.15 V	20.50 V	20.13 V
Average	20.75 V	20.18 V	20.60 V	20.15 V

Table 4.0 Average solar output voltage from different angles.

The solar charging station draws a total of 105 Watt-hours per day from the solar energyharvested by the PV panels, distributing this energy across its four distinct outlets.

Appliances	**Watts**	**Quantity**	**Hours**	**Wh/day**
Laptop charger	65	1	1	65
Wireless charger	10	1	1	10
Wired charger	5	1	3	15
Wired charger	5	1	3	15
Total:				**105**

Table 5.0 Total energy consumption per day.

Total Watts per day: 85W
Total Hours per day: 8Hrs.
Total Watt-hour per day: 105Wh
Estimated System Loss: 30%

Total Energy Consumption:
Formula:
Total energy consumption + System Loss
105Wh + 30%
137 Watt-hour
Days of Autonomy: 1 day

Number of slot/s that have been used at the same time	Average number of devices
one slot	9 devices
two slots	14 devices
three slots	25 devices
all four slots	24 devices

Table 6.0 Average number of devices charged with various slot counts.

The charging slot usage patterns revealed significant trends: on average, nine (9) devices were charged using a single slot, while fourteen (14) devices were accommodated with two slots. Furthermore, three slots facilitated the charging of an average of twenty-four (24) devices, whereas four slots concurrently serviced an average of twenty-five (25) devices. Additionally, the study noted an average difference of 0.92 in solar output voltage utilization. This figure was originally derived from two devices, leading researchers to divide it in half to determine the average voltage consumption per device during a 20-minute charging session, resulting in an adjusted figure of 0.46. Interestingly, despite the seemingly uniform charging interval of every 20 minutes for two (2) devices, discrepancies arose in voltage consumption due to different variety and classifications of devices.

Location	Day						Time	Average solar output voltage without mirror	Average solar output voltage with mirror	Difference
	Mon	Tue	Wed	Thu	Fri	Avg.				
Lower Ground Parking Lot	20.4 V	20.6 V	20.5 V	19.0 V	20.8 V	20.3 V	9 am	18.08 V	18.26 V	0.18 V
Besides School's Chapel	19.1 V	20.4 V	20.5 V	20.2 V	19.8 V	20.0 V	11 am	18.20 V	18.73 V	0.53 V
School Garden	20.8 V	21.4 V	21.9 V	20.0 V	21.5 V	21.1 V	1 pm	19.98 V	20.35 V	0.37 V
SFAC Main Gate	20.7 V	20.2 V	21.0 V	18.9 V	20.4 V	20.2 V	3 pm	14.70 V	14.89 V	0.19 V

Table 7.0 The average solar output voltage from four different areas, time, and difference in solar output voltage when a mirror is used.

The school garden emerged as the optimal location for solar energy collection, boasting an impressive average solar output voltage of 21.1 V. Recognizing its potential, the researchers conduct an experiment in this area to investigate the efficacy of mirrors in enhancing solar panel voltage production. The results revealed notable differences: at 9 a.m., the average solar output registered 18.08 V without a mirror, increasing to 18.26 V with the addition of a mirror. Similarly, by 11 a.m., the solar output rose from 18.20 V without a mirror to 18.73 V with one. Subsequently, at 1 p.m., the solar output sans mirror reached 19.98 V, while with a mirror, it surged to 20.5 V. Finally, at 3 p.m., the average solar output voltage stood at 14.70 V without a mirror, escalating to 14.89 V with the inclusion of a mirror.

The researchers meticulously documented the solar panel's energy collection at various times of day, in different locations, with and without mirrors, atdifferent angles, and in different weather conditions. These comprehensive observations revealed numerous factors influencing solar energy collection. Factors such as the prototype's location, mirror usage, time of day, and weather conditions were identified as critical in determining energy collection efficiency, resulting in energy accumulation ranging from high to low. Taking these factors into account, the researchers determined the best location for the charging station, aiming to maximize efficiency and effectiveness.

Number of slot/s that have been used at the same time	Average number of devices
one slot	10 devices
two slots	36 devices
three slots	42 devices
all four slots	46 devices

Table 8.0 Average number of devices charged with various slot counts.

The utilization of charging slots exhibited distinct patterns: 10 devices were charged using a single slot, followed by 36 devices utilizing two slots, 42 devices making use of three slots, and finally, 46 devices simultaneously charging through all four slots.

Battery's voltage	Battery's voltage after an hour of storing	Difference
12.00 V	12.35 V	0.35 V
12.35 V	12.53 V	0.18 V
12.53 V	12.73 V	0.20 V
12.73 V	12.87 V	0.14 V
12.87 V	13.01 V	0.14 V
Total		1.01 V

Table 9.0 The increase in battery voltage after storing.

The researchers took thorough steps to ensure that the battery had reached its lowest voltage level before measuring,effectively discharging it. Prior to beginning the storage process, the battery voltage was measured at 12 V. Subsequent hourly assessments revealed a gradual increase in voltage: after one hour, it rose to 12.35 V, then 12.53 V after two hours, and 12.73 V after three hours. Continuing the storage process, the voltage gradually increased to 12.87 V after four hours, eventually peaking at 13.01 V after five hours. This steady ascent resulted in a total storage of 1.01 V, which represented the battery's full capacity.

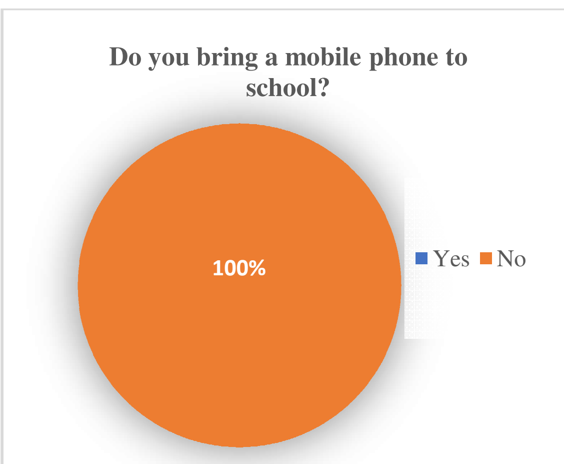

Figure 2.0

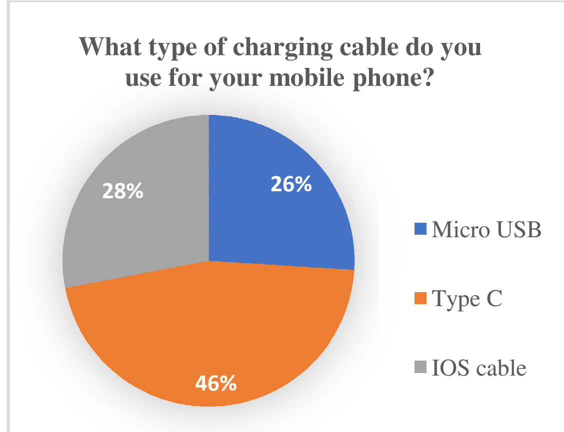

Figure 3.0

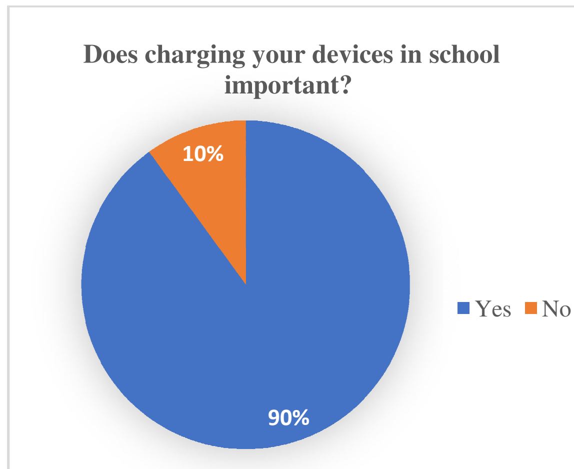

Figure 4.0

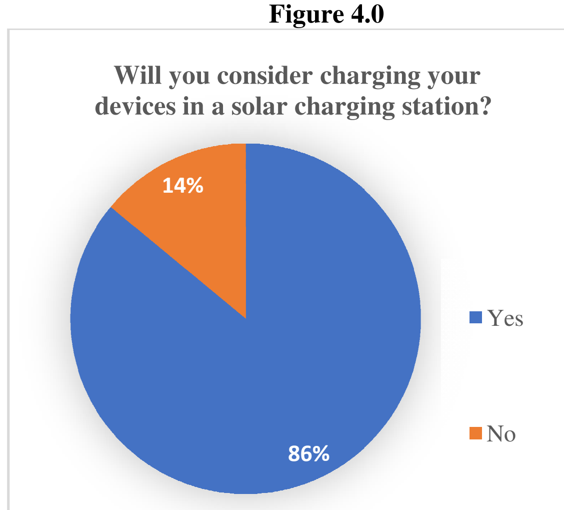

Figure 5.0

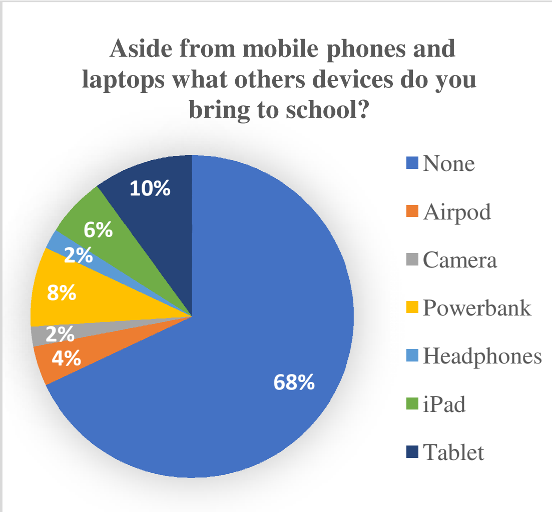

Figure 6.0

The survey conducted at Saint Francis of Assisi College – Las Piñas Campus provided insightful data on students' device usage and charging preferences. Notably, the survey revealed that every student, constituting 100% of the respondents, brings their mobile phones to school. This demonstrates the widespread use of smartphones in today's educational environment. The majority of students (68%) primarily carry smartphones and laptops, showcasing the critical role of these devices in academic environments. However, a significant portion of students also bring supplementary devices including tablets (10%), power banks (8%), iPads (6%), AirPods (4%), cameras (2%), and headphones (2%). The importance of charging facilities within school premises was highlighted by a vast majority of respondents (90%), emphasizing the essential role of charging stations in facilitating students' connectivity and productivity during the school day.

A diverse array of charging cable preferences among students. While 46% favored Type C cables, 28% opted for iOS cables, and 26% relied on Micro-USB cables. This diversity highlights the importance for charging stations that accommodate various cable types to cater to students' preferences.Furthermore, a significant number of students (86%) expressed an interest in using solar charging stations, indicating a growing awareness and preference for renewable energy sources. However, it is worth noting that 14% of respondents did not see solar charging stations as viable options for device charging. The survey found that students at Saint Francis of Assisi College - Las Piñas Campus have diverse device usage patterns and charging preferences. This highlights the need for versatile and sustainable charging solutions to meet their changing needs.

IV. CONCLUSIONS AND RECOMMENDATIONS

The popularity of smartphones among college students was evident, followed by laptops, tablets, and power banks, indicating high device usage. The study's findings had a profound impact on smartphone and laptop users among students, particularly in the context of blended learning becoming the norm. While the majority expressed the need for charging stations at school, solar charging stations were particularly preferred due to their eco-friendly nature. The solar charging station proved to be remarkably practical, accessible, and user-friendly, while its utilization of renewable energy made it environmentally friendly, benefiting both individuals and the environment. The effectiveness of solar charging stations depends on several factors, including location, weather conditions, and equipment efficiency. One significant variable affecting energy collection was shading, primarily influenced by the solar panel's location. Varying energy collection across different locations, emphasizing the importance of locating the solar charging station in areas with direct sunlight exposure and minimal shading. The inclusion of mirror reflectors enhanced power reception and solar cell output, while the solar panel's angle and placement played a crucial role in energy absorption. Nevertheless, they offer an efficient means of providing renewable energy for device charging and powering small equipment, contributing to the campus's carbon footprint reduction and promoting environmental sustainability. Furthermore, the adoption of renewable energy sources like solar power presents opportunities for educational and research endeavors on sustainable energy and technology, benefiting both students and faculty.

Based on the conclusions drawn, several recommendations are proposed, future researchers and innovators should focus on enhancing the stationary solar charging station by refining equipment, design, performance, security, and stability. Additionally, investing in research and development to advance the technology and reduce costs is advised. Policymaking and incentive programs should be developed to foster the adoption of stationary solar charging stations. Replicating optimized designs in various contexts and locations can further promote sustainable energy practices. School administrators are encouraged to collaborate with local organizations and businesses to advocate for the use of stationary solar charging stations, hosting seminars or webinars for engineering students on alternative energy resources and their environmental impact. Promoting sustainable behaviors among college students can reduce dependency on non-renewable energy sources, contributing to long-term environmental conservation. Lastly, both researchers and institutions should explore the potential of utilizing stationary solar charging stations for disaster preparedness and response, offering a reliable energy source for communication devices in times of emergencies or natural disasters.

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