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Research Article

Mobile Solar Power Plant (*PLTS Mobile*) for BASARNAS Operational Area

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Abstract: Indonesia is a developing country located at the convergence of four tectonic plates, making it highly prone to natural disasters such as earthquakes, tsunamis, landslides, and volcanic eruptions. These frequent disasters highlight the critical need for reliable electricity during emergencies. However, disaster-affected areas often struggle to restore power due to accessibility issues. To address this, alternative energy sources are needed, and Solar Power Plants (PLTS) offer a practical solution. PLTS are easy to implement, depend only on sunlight, and provide clean energy with low carbon emissions. Under clear skies, solar radiation can reach 1,000 Watts per square meter, making it a powerful energy source. Additionally, PLTS systems are adaptable and can be deployed in various formats, including mobile units. This study focuses on designing a Mobile PLTS to support BASARNAS operations in disaster zones. Data collection was conducted using resources from BNPB, BMKG, BASARNAS, and NASA. The analysis includes the geographical characteristics of the site, solar radiation intensity, and the operational dimensions of the BASARNAS Mobile Truck. The study aims to determine the suitable system specifications and estimate the energy production capacity of the Mobile PLTS. The proposed design features 20 solar panels, each with a capacity of 300 Wp, producing an average of 27.70 kWh per day. It also includes 16 batteries for energy storage. The remaining space in the truck can be used for transporting logistics or essential tools, making it a multifunctional unit ideal for disaster response scenarios.

Keywords: Photovoltaic, Panel, Mobile Solar, Power System.

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1. Introduction

Indonesia is a developing country that is geographically located in a very tectonically active region, precisely at the confluence of four major world plates, namely the Indo-Australian, Eurasian, Pacific and Philippine Plates. This geological condition makes Indonesia very vulnerable to various natural disasters such as earthquakes, tsunamis and landslides. In addition, the presence of hundreds of active volcanoes spread across the main islands also increases the potential for other disasters such as volcanic eruptions and flash floods. With the high frequency of disasters, the need for energy sources, especially electricity for lighting, communication, and emergency assistance, is crucial in disaster management.

Unfortunately, electricity infrastructure often cannot be immediately restored in disaster-affected areas, especially in remote or access-connected areas. Therefore, there is a need for alternative energy solutions that are reliable, easy to transport, and quick to operate in the field. One potential solution is the use of mobile solar power plants, which can provide emergency power supply in a flexible and sustainable manner.

The utilization of solar energy is very relevant considering Indonesia's energy potential as a tropical country that receives sunlight throughout the year. In clear weather conditions, each square meter of the earth's surface receives about 1,000 Watts of solar energy. Based on

Saiful Manan's study (2009), the distribution of solar energy shows that less than 30% is reflected back into space, about 47% is converted into heat, and 23% is utilized in the process of circulating work on the earth's surface. The rest, only a small portion-about 0.25%-is stored in the form of wind energy, waves, or ocean currents, and even smaller is about 0.025% used in the process of photosynthesis by plants, which then becomes fossil energy reserves such as coal and petroleum.

Seeing the magnitude of solar energy potential and challenges in disaster management in Indonesia, the author is interested in studying the design and utilization of Mobile PLTS systems as a solution to providing electricity in the operational area of the National Search and Rescue Agency (BASARNAS). This research aims to design a Mobile PLTS system that can support electricity needs at disaster sites, and adapt it to geographical conditions, solar radiation intensity, and specifications of operational vehicles used by BASARNAS.

2. Literature Review

Solar Energy as a Renewable Energy Source

Solar energy is a form of renewable energy that comes from sunlight radiation and can be utilized through photovoltaic (PV) technology. Indonesia as a tropical country has enormous solar energy potential, with an average irradiation intensity reaching 4-6 kWh/m² per day. Under ideal conditions, the earth's surface can receive solar energy of about 1000 W/m² during the day (Saiful Manan, 2009). This potential makes solar energy one of the best alternatives in providing electricity, especially in disaster-affected areas.

Solar Power Plant (*Pembangkit Listrik Tenaga Surya* (*PLTS*)

PLTS is a power generation system that utilizes solar cells to convert light energy into electrical energy. It is divided into three main types: off-grid, on-grid, and hybrid (Gifson, Siregar, & Tesla, 2020).

- Off-grid systems are used in areas not covered by conventional power grids and rely on batteries for energy storage.
- On-grid systems are directly connected to the PLN power grid and are commonly used to reduce energy consumption from fossil sources.
- Hybrid systems combine solar PV with other generation (such as diesel or wind) to improve the reliability of energy supply.

PLTS Mobile

Mobile solar power plants (*PLTS Mobile*) are an innovative form of portable solar power plants designed to be mounted on vehicles, such as operational trucks, so that they can be easily moved to disaster-affected locations. This system is a practical solution for emergency power supply in areas that are difficult to access by conventional electricity networks. In the context of BASARNAS operations, mobile PLTS is very relevant given the urgent and unpredictable nature of energy needs in the field.

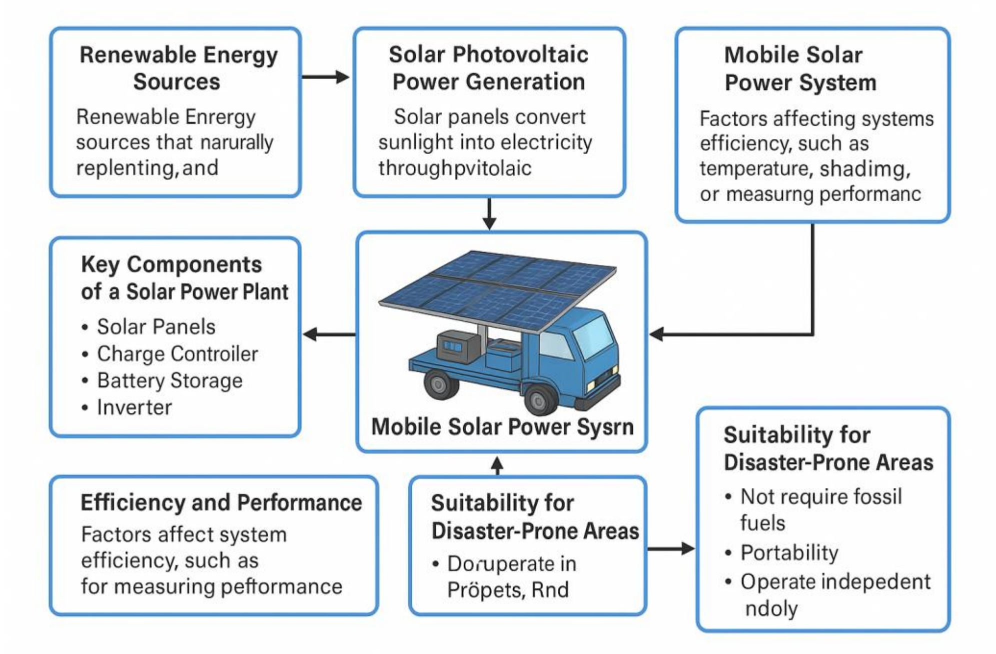

Figure 1. PLTS Mobile

Main Components of Solar Power Plant (*PLTS*)

Solar power plants consist of several important components that are integrated with each other, namely:

- Solar Panel (Photovoltaic Module): Converts sunlight energy into DC electrical energy.
- Solar Charge Controller (SCC): Regulates the charging process to the battery to keep it stable and safe.
- Battery: Stores electrical energy for use when light intensity is low or at night.
- Inverter: Converts DC current into AC so that it can be used for common electrical appliances.

Solar PV Efficiency and Performance (*PLTS*)

The efficiency of solar power plants is influenced by various factors, such as solar cell temperature, panel orientation towards the sun, shading, and the quality of system components. In calculating the performance of PLTS, parameters such as Final Yield (YF), Reference Yield (YR), and Performance Ratio (PR) are used. A high PR value (above 70%) indicates that the PLTS system is working optimally (IEC 61724).

Feasibility of Implementation in Disaster Areas

Mobile solar power plants (*PLTS Mobile*) are very suitable for use in disaster-prone areas because they do not require fossil fuels, are easy to move, and can be operated independently without an external power grid. Previous studies have shown that the combination of solar power systems with batteries can provide energy in refugee camps and isolated areas (Ramadhan, Nahkoda, & Agustini, 2020).

3. Proposed Mthod

This research was conducted through a data collection method that combines literature study and interview approaches. The literature study was conducted by reviewing various relevant literature sources such as books, scientific journals, papers, and previous research reports that have relevance to the topic under study. In addition, this research also uses a semi-structured interview approach, which is a question and answer technique that is flexible but still focused on the core issues that are the object of research, in order to obtain more in-depth and contextual data. All data obtained was then processed and analyzed in accordance with the research objectives.

In the process of preparing this final project, systematic and planned steps are needed so that the implementation of research can run effectively and efficiently. Therefore, to facilitate understanding of the research workflow, the stages of completing this final project are organized in the form of a flow chart that describes the research process in a coherent and structured manner.

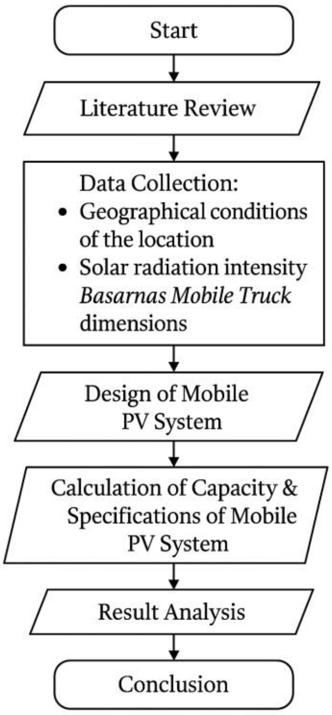

Figure 2. Research Flow Chart

4. Results and Discussion

Cilacap Regency is the largest region in Central Java Province, located at 7°43'40.7604'' south latitude and 109°0'21.2868" east longitude. Geographically, it borders the Indian Ocean to the south, Banyumas, Brebes and Kuningan Regencies (West Java Province) to the north, Kebumen Regency to the east, and Ciamis Regency and Banjar City (West Java Province) to the west.

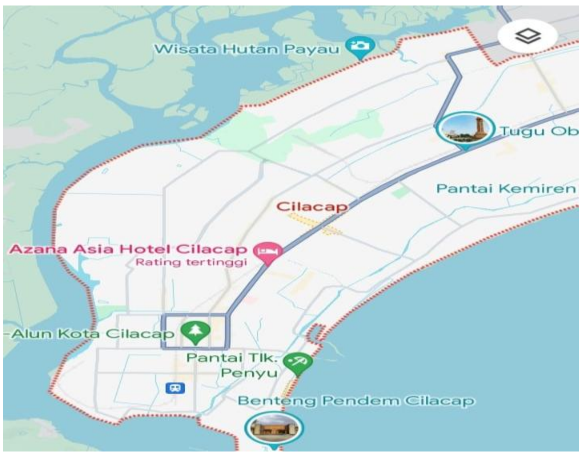

Figure 3. Research Location based on Google Maps

Throughout 2022, Cilacap Regency recorded 82 natural disaster events. The details of these events include 15 landslides, 25 floods, and 42 extreme weather incidents. Based on disaster recapitulation data from January to December 2022, these natural disasters affected 9,039 housing units, hundreds of public facilities, and 1,214 hectares of rice fields. When compared to 2021, the number of disaster events in 2022 has decreased, mainly because there was no drought that previously hit a number of villages in 2021 (bercahayafm.cilacap-kab.go.id, 2023).

In designing this Mobile PLTS, the irradian value obtained from NASA data is needed by entering the coordinate points according to the location of the research object.

Table 1. Iradian value at the location of the research object

Latitude -7,727989/ **Longitude** 109,005913			
Month	IRADIAN (*Wp/M²*)	TEMPERATURE (*˚C)*	
		Minimum	Maximum
January	4,42	20,11	32,10
February	4,62	19,78	29,15
March	4,56	21,21	31,02
April	5,57	18,92	28,97
May	4,87	20,91	29,49
June	4,65	19,98	30,02
July	5,87	19,32	28,71
August	5,39	19,59	30,99
September	5,54	20,21	31,98
October	5,67	18,76	33,09
November	4,53	20,54	29,96
December	4,65	20,85	31,71
Average	5,028	20,015	30,599

The figure below is the side view design of the Mobile Solar Power Plant design which can fit 3 pieces of solar panels measuring 1,134x1,290x35 mm.

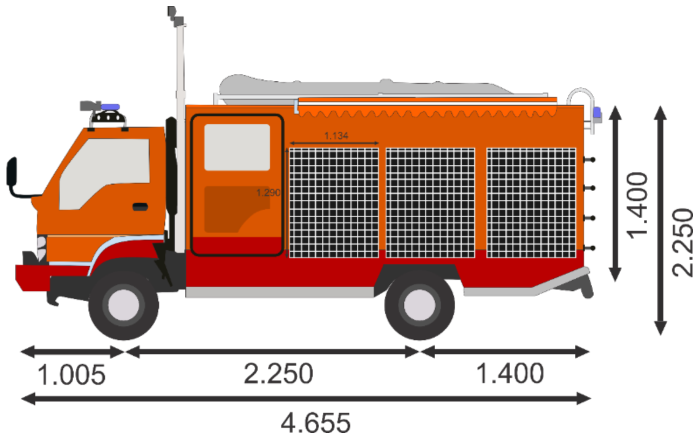

Figure 4. Side view design of PLTS Mobile

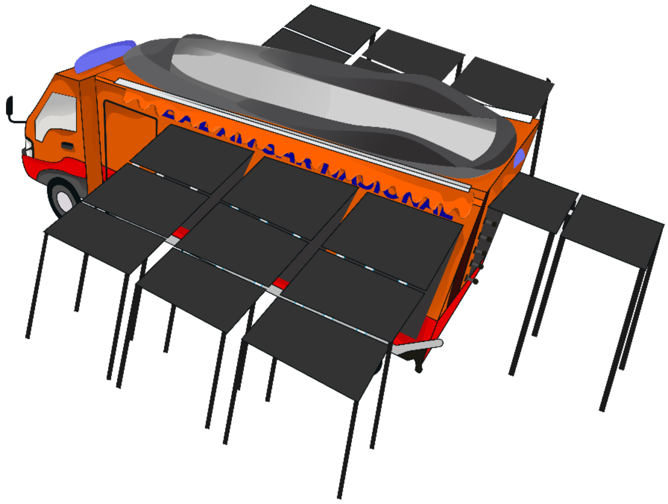

Figure 5. Top side view design of PLTS Mobile

Table 2. Model 182 Cell 12BB solar panel specifications

Specification	Description
Rated Maximum Power (Pm)	300 W
Tolerance	± 5%
Voltage at Pmax (Vmp)	34.20 V
Current at Pmax (Imp)	8.77 A
Maximum Input Current	10 A
Open-Circuit Voltage (Voc)	41.04 V
Short-Circuit Current (Isc)	9.38 A
Normal Operating Cell Temp (NOCT)	47 - /+2 C
Maximum System Voltage	1000 Vdc
Minimum System Voltage	80 Vdc
Operating Temperature	-40 to +85 C
Series Fuse Rating (A)	15
Application Class	Class A
Fire Safety Class	Class C
Cell Technology	Mono – Si
Dimension	1290x1134x35mm
Included	Connector and MC4 cable (attached to the back of the panel)

Determination of this circuit is done to determine the amount of power released by the solar panel as a whole, if to increase the current, the installation is done in parallel, and if you want to increase the voltage, it needs to be assembled in series (Naksabandi, 2018).

The calculation is as follows:

Known:

Open Circuit Voltage (Voc)	:	*41.04 V*
Maximum Power Voltage (Vmp)	:	*34.20 V*
Maximum Power Current (Imp)	:	*8.77 A*
Maximum System Voltage	:	*1000 Vdc*
Minimum System Voltage	:	*80 V*
Maimum Input Current	:	*10 A*

Series-parallel arrangement of solar panels

- In series at least

$$\boldsymbol{Min\ modul\ seri\ per\ string = \frac{80V}{41,04\ V} = 1.94 \approx 1\ panel}$$

- In series maximum

$$\boldsymbol{Max\ modul\ seri\ per\ string = \frac{360V}{34.20\ V} = 10.52 \sim 10\ panel}$$

- In parallel

$$\boldsymbol{Max\ Paralel = \frac{10\ A}{8.77A} = 1.14 \approx 1\ panel}$$

Thus, the maximum voltage and current that can be output from the array is:

10 x Vmax = 10 x 41.04
= 414 V

1 x Imax = 1 x 8.77
= 8.77 A

So, in this planning, two arrays/inverters will be made, 1 array for 10 solar panels, assembled 1 parallel and 10 in series.

From the calculations about series and parallel above, the inverter used is 2 pieces, because the solar module circuit is assembled with the provisions of the system value of the inverter, and the solar panels assembled in series are not more than 12 and less than 3, and the parallel circuit is not more than 1.

For more details about the installation of parallel series solar panels can be seen in the following figure:

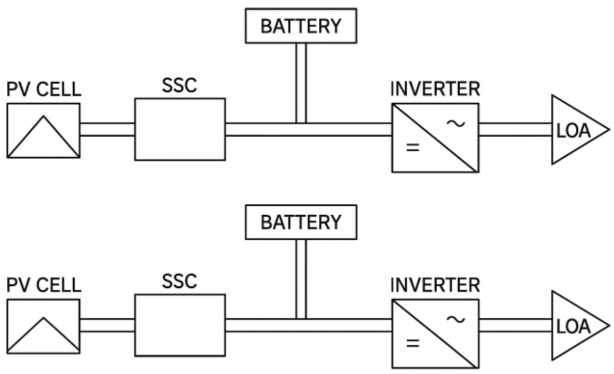

Figure 6. Block diagram off grid with 2 array

Table 3. Specification *Inverter*

Specification	Description
Input (DC)	
Max. PV array power	5000 Wp
Max. input voltage	600 V
MPP voltage range	260 V to 500 V
Rated input voltage	360 V
Min. input voltage / initial input voltage	50 V / 80 V
Max. usable input current (I_{Dcmax}) per string	10 A
Number of independent MPP inputs / strings per MPP input	1 / 1
Output (AC)	
Rated power (at 230 V, 50 Hz)	2500 W
Rated apparent power / max. apparent power	2500 VA / 2500 VA
Rated voltage / range	220 V / 230 V / 240 V
Nominal voltage range	180 V to 280 V
Grid frequency / range	50 Hz, 60 Hz / ± 5 Hz
Rated grid frequency / rated grid voltage	50 Hz / 230 V
Rated out8put current / max. output current	11 A / 11 A
Power factor at rated power	1
Adjustable displacement power factor	0,8 overexcited to 0,8 underexcited
Feed-in phases / connection phases	1 / 1
Efficiency	
Max. efficiency / Euro-eta	97,2 % / 96,7 %
Protective Devices	
DC side connection point	O
Ground fault monitoring / grid monitoring	O / O
DC reverse polarity protection / AC short circuit current capability / galvanically isolated	O / O / -
All-pole-sensitive residual-current monitoring unit	O
Protection class (according to IEC 61140) / surge category (according to IEC 60664-1)	I / III
Reverse current protection	Not required
General Data	
Dimensions	460 / 357 / 122 mm
Weight	9,2 kg (20,3 lbs)

Operating temperature range	-40 °C to +60 °C
Noise emission, typical	< 25 dB
Self-consumption (at night)	2,0 W
Topology	Transformerless
Cooling concept	Convection
Degree of protection (according to IEC 60529)	IP65
Climatic category (as per IEC 60721-3-4)	4K4H
Max. permissible value for relative humidity (non-condensing)	100 %
Features	
DC connection / AC connection	SUNCLIX / connector
Display via smartphone, tablet, laptop	O
Interfaces: WLAN / Ethernet	O / O
Communication protocols	Modbus (SMA, Sunspec), Webconnect
Integrated shade management SMA ShadeFix	O
Warranty: 5 / 10 / 15 years	O / O* / X
Cerfitificates and permits (more available upon request)	ABNT NBR 16149, AS4777

The assumption of losses of the PLTS system is considered 15% because all system components used are still new (Bien, Kasim, & Wibowo, 2008: 41 in his book Mark Hankins, 1991: 68), so that the amount of energy from the solar panel is reduced by the amount of losses as follows :

$$20\ solar\ panels\ \times 300\ Wp\ = 6000 \approx 6\ kWp$$

The result of reducing losses on solar panels based on the installed panel capacity is 5.1 kWp. The following will analyze the energy produced by solar modules related to the lowest and highest solar radiation data. If the data used is the lowest solar radiation of 4.42, the energy produced by the panel can be calculated as follows:

$$\boldsymbol{E_{out} = E_i \times Minimum\ Solar\ Radiation}$$
$$\boldsymbol{= 5,1\ kWp \times\ 4,42\ h}$$
$$\mathbf{= 22{,}542\ kWh}$$

So, the energy generated at the time of lowest solar radiation is 22,542 kWh.

If we use the highest solar radiation data of 5.87 then:

$$\boldsymbol{E_{out} = E_i \times Maximum\ Solar\ Radiation}$$
$$\boldsymbol{= 5,1\ kWp \times 5,87\ \ h}$$
$$= 29{,}93\ \mathrm{kWh}$$

So, the energy produced at the time of the highest solar radiation is 29.93 kWh.

If you want to calculate the energy produced on average per year, then the radiation data used is the average radiation, or called Peak Sun-Hour (PSH) with a value:

$$\boldsymbol{E_{out} = E_i \times PSH}$$
$$\boldsymbol{= 5,1\ kWp \times 5,028\ h}$$
$$\mathbf{= 27{,}70\ kWh}$$

$$Energy\ yield = energy\ output\ x\ 365\ days$$

$$Energy\ yield = 26{,}92\ kWh\ x\ 365\ days = 9.825{,}9\ kWh/year.$$

Table 4. Calculation results of solar radiation and *Energy Yield*

Lowest Solar Radiation (kWh)	Highest Solar Radiation (kWh)	Average Solar Radiation (kWh)	$\boldsymbol{Eyield}$ (kWh/year)
22,542	29,93	27,70	9.825,8

Performance Ratio (PR) is a measure of system quality in terms of the annual energy produced. If the system's PR value ranges from 70-90%, then the system can be said to be feasible. The following is the calculation to find the performance ratio value of this PLTS system:

$$PR = \frac{E\ yield}{E\ ideal},\ E\ ideal = P\ array\_STC \times H_{tilt}$$
$$H_{tilt} = PSH\ x\ 365 = \left(5{,}1\ h\ x \frac{1000\ W}{m2}\right) x\ 365\ days = 1861{,}5\ kWh/m2$$

$$Energy\ ideal = power\ solar\ module\ specification\ x\ number\ of\ module\ x\ H_{tilt}$$
$$Energy\ ideal = 300\ Wp\ x\ 20\ modules\ x\ 1861{,}5 \frac{h}{tahun} = 11169 \frac{kWh}{tahun}$$
$$Energy\ ideal = 11.169\ kWh/tahun$$

So that PR is obtained, equal to :

$$PR = \frac{E\ yield}{E\ ideal} = \quad PR = \frac{9.825{,}8\ kWh/year}{11.169\ kWh/year} = 0{,}87 \approx 87\%$$

5. Comparison

Compared to conventional power generation systems such as diesel generators, the Mobile Solar Power Plant (PLTS Mobile) offers several distinct advantages, especially in the context of disaster management. Diesel generators, while widely used, require a constant supply of fuel, which can be difficult to transport and store in remote or disaster-affected areas. In contrast, PLTS Mobile systems rely solely on sunlight, making them a more sustainable and logistically feasible solution. The mobility of the system allows it to be quickly deployed to areas where electricity infrastructure has been damaged or is inaccessible. Furthermore, PLTS Mobile produces clean energy with minimal environmental impact, unlike diesel generators which contribute to greenhouse gas emissions and noise pollution. While the initial investment in a PLTS Mobile system may be higher, it offers long-term cost savings due to the absence of fuel costs and lower maintenance requirements. Based on the research findings, the designed PLTS Mobile system, equipped with 20 solar panels and 16 batteries, is capable of producing an average of 27.70 kWh of energy daily, sufficient for emergency lighting, communication, and basic equipment operation. Therefore, when evaluated in terms of sustainability, operational efficiency, and environmental impact, PLTS Mobile proves to be a superior alternative to conventional power sources in disaster response operations, particularly for organizations such as BASARNAS.

6. Conclusions

In conclusion, the Mobile Solar Power Plant (PLTS) model has been successfully designed by modifying the existing BASARNAS operational vehicle, enabling it to serve not only as a means of evacuation but also as a reliable source of electrical energy in disaster-prone areas such as those affected by earthquakes and landslides. The system is equipped with 20 units of 182 Cell 12BB solar panels, two inverter units, and 16 batteries, arranged according to the specifications and configurations outlined in the study. Based on the calculation results, the system is capable of producing 22.542 kWh under minimum solar radiation and up to 29.93 kWh under maximum conditions, with a projected average annual energy production of 5,821 kWh. This indicates that the PLTS Mobile system offers a practical and sustainable solution for emergency power supply in field operations. However, further research is recommended to optimize the design, particularly in maximizing the use of available space within the vehicle, and to enhance the overall effectiveness of the Mobile PLTS system in real-world disaster response scenarios.

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Conflicts of Interest: The authors declare no conflict of interest.

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