Research Article

Green Management for Disasters Using an Inflatable Tent Prototype with a Solar Power Plant

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Abstract.
Given the ever-increasing number of natural disasters, disaster management must be understood and implemented by all parties in a manner that includes green management and technology. This research begins with the problem of disaster preparedness management which currently uses less environmentally friendly facilities and infrastructure, including using tents with conventional structures and technological systems that are less flexible and require electricity with a gasoline-fueled generator. The aim of this research is to create a green technology-based disaster response facility in the form of an inflatable tent prototype for disaster preparedness using solar electricity. The method used in this study is experimental, designing and manufacturing prototype inflatable tents that use solar power plants. Tests are carried out on several variables: strength of tarpaulins, speed in construction and disassembly, comfort of air temperature, and performance of solar power generation. The results are of the experimental method are: the design and application of two prototype inflatable tents dimensions 6x9 square meters with a capacity of 20 patients, a 3,600 WP power plant using solar power, and a VRLA battery with a voltage capacity of 48 volts and a current of 200 Ah that is capable storing 4,800 watts of electricity. Thus, these devices meet electricity needs for air conditioning, lighting, and medical equipment in inflatable tents without using electricity from the state electricity company or gasoline generators.

Keywords: disaster, inflatable tent, solar power generation

1. Introduction

In responding to disasters whose frequency continues to increase every year in Indonesia, ideas regarding disaster management must be understood and implemented by all parties comprehensively towards green strategic management and technology in disasters, namely management activities that produce positive solutions by committing to the principles of environmental sustainability [1,2], strive to use renewable resources, and try to minimize negative impacts on the environment. This article is the result of research to deal with the problems of residents in disaster cases who need emergency facilities. Natural disasters that often occur throughout Indonesia require concepts and strategies in their mitigation in the context of disaster preparedness and response quickly [3,4]. A national institution dealing with disaster issues in Indonesia has published a technical guideline to deal with health aspects in disasters. Roswati et al. [5] and guidelines in minimizing the impact of disasters through the use of adequate equipment in disaster management so as to minimize the impact of disasters through several effective prevention, recovery and rehabilitation measures.. Disaster posts are a form of disaster response facilities that are indispensable as a first step in disaster management so that victims affected by disasters can be immediately accommodated comfortably [6,7].

Many disaster events occur in Indonesia, including major natural disasters. Disaster management to accommodate disaster affected residents usually uses tent facilities or emergency buildings with conventional structures, including using steel frame tents. It takes a long time to build conventional tents. Durumunda in his article stated that the field hospital's emergency facilities are at least in the form of rooms or tents that can accommodate a minimum of 10 patient beds, one operating room and one clinical laboratory [8]. Meanwhile, Bakowski proposed an alternative disaster response health facility in the form of an alternative to disaster emergency tents in the form of "mobile hospitals" [9], Where health facilities for emergencies use container trucks that have been converted into emergency hospitals. In the process of sheltering people affected by disasters, it is necessary to prepare disaster emergency posts that use fast-build structures so that they can be used immediately, one of which is to use an inflatable structure system whose frame is in the form of membrane material inflated by air. The membrane structure materials are sheets of coated tarpaulin, rubber, plastic, etc., but these materials have been made to withstand weather so that they can be reused for more than 10 years. This inflatable tent structure uses lightweight materials, easy to disassemble and can be installed in narrow areas that are easily accessible by small vehicles [10].

Some articles related to the preparation of facilities for disaster-affected residents in the form of health clinic posts that are quick and easy to dismantle and easily transported to the disaster site include: First, Bakowski [9] write that disaster emergency health posts must function properly when used to accommodate people affected by disasters. It can be ascertained that the health post guarantees health conditions or avoids the danger of life. For this reason, the criteria for establishing a health emergency post not only lie in technical solutions related to the problem of building health emergency post units, but also consider the aspect of modularity (ability to pack the functions of emergency health facilities into cubic containers) and mobility (ease of building construction systems that can be transported from one place to another). Second, Bitterman and Zimmer [11] In their article about portable health post facilities in disaster areas, they divide the category into two, namely permanent portable health facilities and temporary portable buildings.

Some articles about inflatable tent structures which are one of the solutions for disaster response post facilities. First, an article from Muhammad Iqbal about disaster emergency health facilities that use inflatable tent structures explains that tent structures are membrane structure systems that can stand without rigid frames such as aluminum or steel poles. The specialty of the inflatable tent structure is that the structure can stand and support the tent cover due to the difference in air pressure inside the structure frame and air pressure outside the structure [10]. Secondly, Hery Budiyanto has conducted several studies and written several articles on the application of inflatable tent structures. He stated that the pressure difference in the inflatable tent structure will cause a pulling force on the membrane so that the structure can stand stably [12,13].

Green disaster management requires the use of natural resources in overcoming disasters. Regarding the policy of power outages in disaster areas due to damage to electrical infrastructure, most of the solutions are to use electric generators which produce air pollution. For this reason, environmentally friendly alternative power plants are needed, one of which is solar power plants [14,15]. Some articles include: First, Kabir, E. et al. [16], In the article on the potential and future prospects of solar energy states that new technologies are used to generate electricity from energy derived from sunlight. This approach has been proven and widely practiced around the world as an alternative to renewable energy. Secondly, Razykov in his article The current status and future prospects of solar photovoltaic electricity states that PV electricity is one of the best options to meet the world's sustainable future energy needs. Currently, the PV market is growing rapidly at an annual rate of 35-40%, with PV production of about 10.66 GW [17].

How is the performance of the prototype of emergency health posts for COVID-19 isolation and posyandu in disaster areas? is the problem formulated in this study. Meanwhile, the purpose of the study was to assess the ability of inflatable tents of health posts as isolation facilities for Covid-19 patients and shelters for people affected by disasters.

2. Methods

This research includes diverse approaches with the use of experimental methods, action research, and qualitative and quantitative mix-methods [18-20]. 1). Experimental Methods: Testing the speed of construction and dismantling of PVC coated tarpaulin membrane inflatable tents In this test, experiments were conducted to compare various factors that affect the speed of construction and demolition of the tent. Independent variables such as construction techniques or differences in tent design can be manipulated, while construction and demolition speed becomes the dependent variable measured. 2). Action Research: Material testing and effectiveness of solar photovoltaic power supply systems are part of an action research approach. In this case, research is carried out in the field with the aim of understanding and improving the performance of such photovoltaic power supply systems. Researchers can plan, implement, and evaluate changes in these power supply systems to improve their effectiveness. 3) Qualitative and Quantitative Mix-method: Prototyping and field trials involve a combination of qualitative and quantitative approaches. Qualitative research is used to gain an in-depth understanding of user experiences, preferences, or problems that arise during field trials. Meanwhile, quantitative approaches are used to numerically measure the performance and effectiveness of prototypes, such as testing construction speeds or measuring photovoltaic energy output.

2.1. Collection of data

The data collection method involved observation and interaction with the objects involved in the study, namely an inflatable tent and a solar power plant unit. Here's a breakdown of the components: 1) two pieces of inflatable tents measuring 6x9 square meters; Possible features: quick construction and disassembly, portability, durability and weather resistance; Data collection with observations focusing on ease of construction and disassembly, overall functionality, structural integrity, and user experience. 2) Solar Power Generation Unit: The component consists of 4 pieces of monocrystalline solar panels, each with a capacity of 540 watt peak (WP); 1 piece of MPPT (Maximum Power Point Tracking); 60A solar charge controller; 4 VRLA (Valve Regulated Lead Acid) batteries, possibly with a voltage of 200 volts. 1 piece of 3,000 watt inverter. Purpose: To provide independent energy supply to the inflatable tent. Data collection: Likely focused on the performance and efficiency of the solar panels in converting sunlight into electricity, the functionality of the charge controller and batteries in storing and managing the generated power, and the overall reliability and sustainability of the energy system.

The data collection process involved direct interaction with these objects, likely conducted over a period of time to assess their performance under various conditions. The completion date of the "Inflatable Tent Model Design for Disaster Emergency with Photovoltaic Independent Energy" project is provided as June 6, 2023, indicating when the design phase concluded. Subsequent data collection likely occurred during field testing and usage scenarios to evaluate the real-world effectiveness of the design, as shown in Figure 1 and Figure 2.

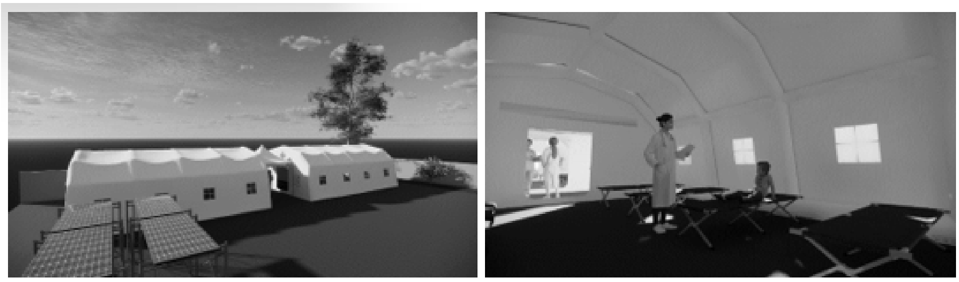

Figure 1: Isometric design of an inflatable tent for a health facility.

Figure 2: Construction of an inflatable tent with photovoltaic power plant.

2.2. Analysis of data

The data analysis for this study involved both qualitative and quantitative methods. Here's how each method was applied:

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2.2.1. Qualitative data analysis

Observation of the design process: Qualitative analysis involves examining the nuances, insights, and challenges observed during the prototype design process of inflatable tents and solar power plants, covering factors such as design iteration, material selection, and user feedback.

Installation and disassembly process: The qualitative analysis here involves capturing subjective experience, ease of use, and any issues encountered during the installation and dismantling of inflatable tents and solar power plants, including feedback from users or technicians involved in this process.

2.2.2. Quantitative data analysis

Air pressure in an inflatable tent tube: Quantitative analysis includes the measurement and analysis of numerical data related to the air pressure inside the inflatable tent tube. This can include average pressure values, fluctuations over time, and comparisons between different conditions.

Temperature inside and outside the inflatable tent: Quantitative analysis includes measuring the temperature using sensors inside and outside the tent and analyzing the data quantitatively. The data analyzed includes calculating averages, maximums, minimums, and trends over time.

Tarpaulin fabric strength: Quantitative analysis will involve performing strength tests on tarpaulin fabric samples and measuring tensile strength parameters

Current and voltage strength of a solar power plant: Quantitative analysis will involve measuring the current and voltage output of solar power plant components, such as solar panels, charge controllers, batteries, and inverters. This data will be analyzed to assess performance, efficiency, and stability under different conditions.

Using qualitative and quantitative data analysis methods, this study was able to gain a comprehensive understanding of the design, performance, and usability aspects of inflatable tents and solar power generation systems.

3. Results of Analysis and Discussion

3.1. Speed in the construction and dismantling process

The time needed to build/install an inflatable tent is 45 minutes (Figure 4), while to install a solar photovoltaic electric generator which includes 4 photovoltaic panels placed on 4 portable brackets only takes 20 minutes.

3.2. Pressure test in inflatable tent tube

See Figure 3 bellow.

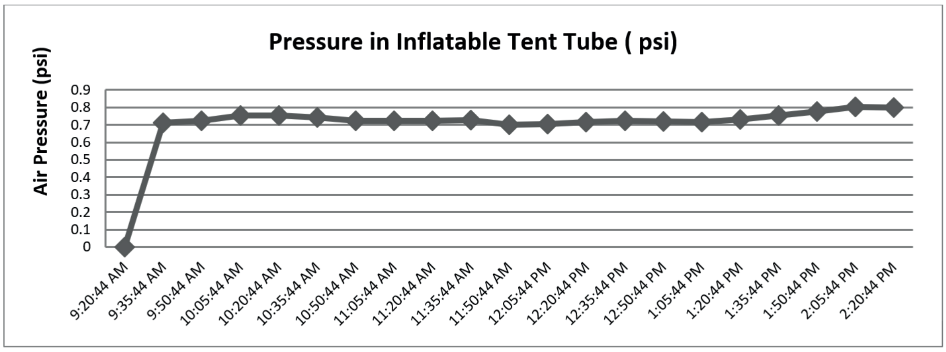

Figure 3: Air pressure in inflatable tent tube structure.

Minimum Air Pressure for Installation: 0.7 psi.

Time to Achieve Minimum Air Pressure: Within 25 minutes of the start of inflation.

The air pressure in the inflatable tube may fluctuate due to external factors such as temperature changes. Warmer temperatures can cause the air inside the tube to expand, increasing pressure, while colder temperatures can cause air to contract, reducing pressure. These fluctuations can have an impact on the stability and integrity of the inflatable tent structure.

To ensure the functionality and safety of the inflatable tent, it is necessary to monitor and regulate air pressure, especially during periods of temperature variations. This could involve implementing control mechanisms or using materials that can withstand changes in pressure and temperature effectively.

3.3. Analyzing thermal conditions inside and outside the inflatable tent

The trial conducted on August 29, 2023, involved temperature measurements for two types of tents, one equipped with air conditioning (Tent I) and one without air conditioning (Tent II), along with measurements of the outside air temperature. Four variables were measured during the trial:

Sky Light (lux): This variable likely refers to the intensity of natural light entering the tents from the sky. Lux is the unit of measurement for illuminance, which represents the amount of light per unit area.

Temperature Inside the Tent with Air Conditioning (Temp-AC): This variable represents the temperature inside Tent I, which is equipped with air conditioning. The temperature is measured in degrees Celsius.

Temperature Inside the Tent without Air Conditioning (Temp-Non AC): This variable represents the temperature inside Tent II, which does not have air conditioning. Similar to Temp-AC, the temperature is measured in degrees Celsius.

Temperature Outside the Inflatable Tent: This variable refers to the ambient temperature outside both tents. It represents the temperature of the surrounding environment and is also measured in degrees Celsius. See table 1 and Figure 4 below.

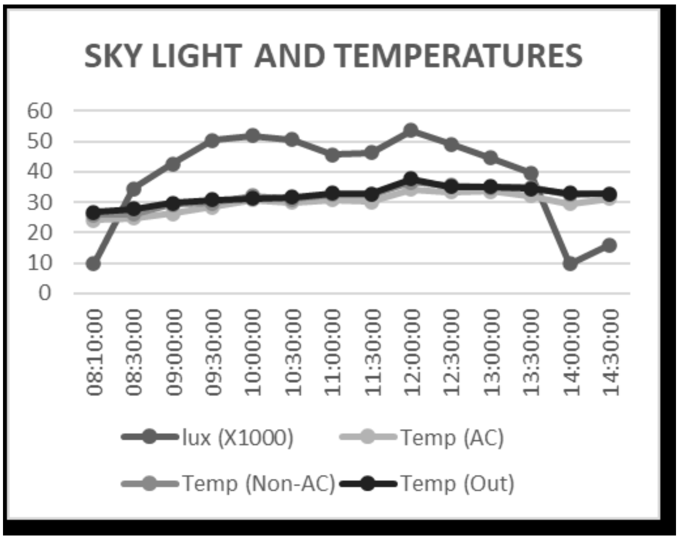

Figure 4: Graph of the temperature inside and outside the inflatable tent.

Based on the data provided, here's a summary of the results of air temperature measurements:

1. Comparison of Average Temperatures:

TABLE 1: Sky light and temperatures.

Time	lux (X1000)	Temp (AC)	Temp (Non-AC)	Temp (Out)
08:10:00	9,7	24,2	25,8	26,7
08:30:00	34,4	24,7	26,1	27,7
09:00:00	42,7	26,3	29,2	29,7
09:30:00	50,3	28,4	29,7	30,7
10:00:00	51,8	30,7	32	31,2
10:30:00	50,5	30	31	31,7
11:00:00	45,7	30,8	32,6	32,9
11:30:00	46,3	30,1	32,5	32,8
12:00:00	53,6	34,2	36,6	37,7
12:30:00	49,1	33,3	35,6	35,1
13:00:00	44,5	33,5	34,8	35
13:30:00	39,7	32	34,8	34,4
14:00:00	9,7	29,6	32,4	32,9
14:30:00	15,9	31,2	32,8	32,8
Average	38,85	29,9	31,8	32,2

- In inflatable tents equipped with air conditioning: The average temperature is 2.3 degrees Celsius below the outside temperature.

- In inflatable tents without air conditioning: The average temperature is reduced by 0.4 degrees Celsius compared to the outside temperature.

2. Morning Temperature Trends (09.05 to 12.05):

- During the morning hours, from 09.05 to 12.05, the air temperature inside the inflatable tents is consistently lower than the outside temperature.

3. Difference in Temperature Inside and Outside:

- There is a range of temperature differences observed between the inside and outside of the inflatable tents, ranging from -4.9 degrees Celsius to 3.8 degrees Celsius. This indicates fluctuations in thermal conditions and the effectiveness of temperature regulation mechanisms.

- These findings suggest that air conditioning has a more significant impact on reducing temperatures inside inflatable tents compared to natural ventilation alone. However, even in tents without air conditioning, there is still a slight reduction in temperature compared to the outside environment.

The observed temperature differences highlight the importance of effective thermal management strategies in inflatable tents, especially during periods of extreme temperatures or prolonged occupancy. Further analysis and interpretation of the data could provide insights into optimizing thermal comfort and energy efficiency in such shelters.

3.4. Test the strength of the inflatable tent tube terpaulin fabric

See Figure 5 below.

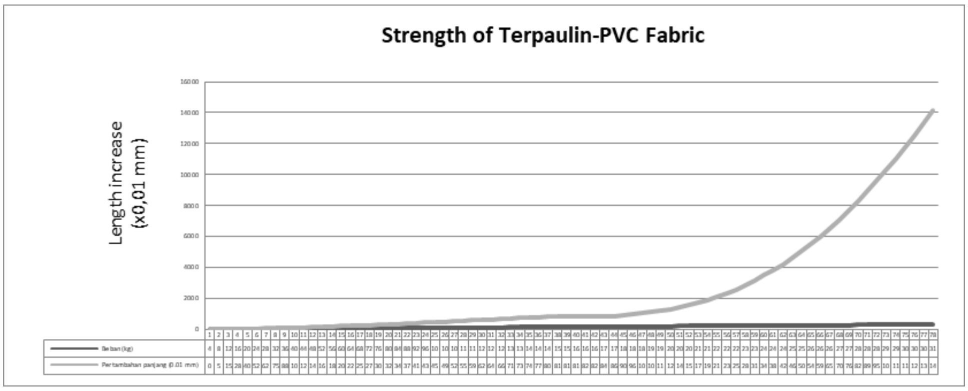

Figure 5: Graph of the strength test of PVC terpaulin fabrics.

The maximum strength of the PVC coated tarpaulin membrane you've described is achieved when it bears a load of 312 kg per square centimeter (cm2) of surface area. This information is crucial for understanding the structural capabilities and limitations of the material, particularly in applications such as constructing inflatable tents for disaster response.

With a thickness of 0.9 mm, the PVC coated tarpaulin membrane demonstrates significant load-bearing capacity. However, it's important to note that this strength may vary depending on factors such as environmental conditions (e.g., temperature, humidity) and the duration of the load application.

Understanding the maximum strength of the material allows for informed decisions during the design and engineering processes, ensuring that the inflatable tents can withstand expected loads and provide adequate protection for refugees or occupants in disaster areas. Additionally, it facilitates the selection of appropriate materials and construction techniques to enhance durability and resilience in challenging conditions.

3.5. Testing of photovoltaic energy performance

The test results of solar photovoltaic power plants using 4 pieces of monocrystalline solar panels of 540 wp each, with 4 batteries each having a capacity of 200 Ah, which are burdened by 2 pieces of air condition, then the performance is table 2 and Figure 6 follows:

TABLE 2: Currents and load test.

Time	lux (X1000)	Current MPPT to batt (A)	Current batt (V)	Current PV	Load (W)	Kind of Load
08:10:00	9,7	3	51	1,4	Without load	
08:30:00	34,4	8	49,2	6,73	1207	AC 2
09:00:00	42,7	20	50,51	14,95	1018	AC 2
09:30:00	50,3	26	51	20,5	1492	AC 2
10:00:00	51,8	29	49,1	22,44	2506	AC 2 blower 2
10:30:00	50,5	30	48,8	20,23	1744	AC 2
11:00:00	45,7	29	48,6	20,55	1685	AC 2
11:30:00	46,3	29	48,5	20,24	1832	AC 2
12:00:00	53,6	31	48,6	21,25	1776	AC 2
12:30:00	49,1	30	48,7	22,3	1593	AC 2
13:00:00	44,5	27	48,3	20,12	1624	AC 2
13:30:00	39,7	27	48,9	19,35	1654	AC 2
14:00:00	9,7	5	49,5	2,6	1497	AC 2
14:30:00	15,9	15	49,7	6,41	1011	AC 2
Average	38,85	22,07143	49,315	15,64786	1587,6	

The information provided offers insights into the generation and utilization of electrical energy from solar panels for meeting the electricity needs of inflatable tents, particularly for air conditioning and medical equipment. Here's a breakdown of the key points:

- Solar Panel Configuration: Four solar panels with a power output of 540 Watts Peak (WP) each are used to generate electricity. The total power output of the solar panel configuration is 2160 WP.

- Photovoltaic (PV) Current: The average PV current generated by the solar panels is 15.6 Amperes. This current is produced based on the strength of the light in the sky, with greater brightness leading to increased current production.

- Solar Control MPPT to Battery Current: An average current of 22.1 Amperes flows from the Solar Control Maximum Power Point Tracking (MPPT) system to the battery. The

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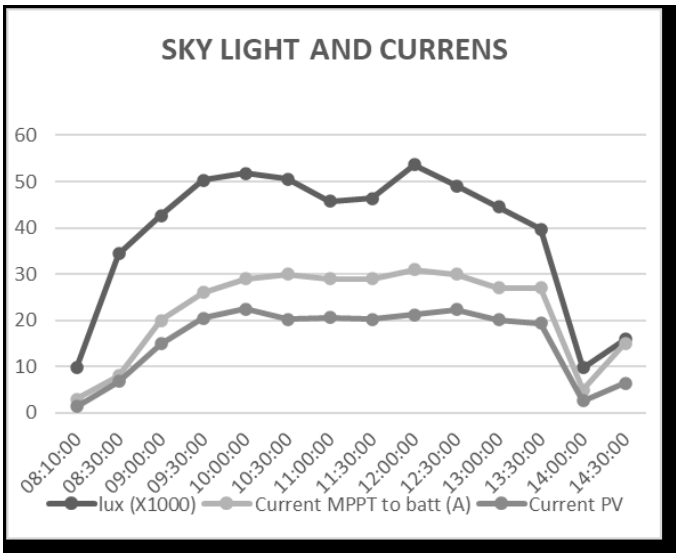

Figure 6: Graph of sky light and electrical currents.

MPPT system optimizes the power output from the solar panels to charge the battery efficiently.

- Battery to Inverter Current: The average current from the battery to the inverter is -49.2 Amperes. This indicates that power is being drawn from the battery to supply the electrical load connected to the inverter, such as air conditioning and medical equipment.

- Battery Capacity and Charging: Each of the four batteries has a capacity of 200 Ampere-hours (Ah) and operates at 12 Volts. In sunny weather conditions, the batteries can store a total of 4800 Watt-hours (Wh) of electrical energy when fully charged within 15 minutes.

- Electricity Usage: The stored electrical energy from the batteries can be utilized to meet the electricity needs of air conditioning and medical equipment in the inflatable tents.

Overall, the system efficiently harnesses solar energy to provide electricity for essential services in disaster response scenarios, contributing to sustainability and resilience in emergency situations.

4. Conclusion

Using green management principles in disaster response efforts is crucial for sustainability and efficiency. The prototype design of inflatable tents for accommodating refugees in disaster areas seems promising, especially with its quick setup and dismantling time compared to conventional tents. The prototype design consists of 2 inflatable tents, each with dimensions of 6x9 m2, capable of accommodating 20 patients. This design ensures a relatively large capacity while maintaining portability. One of the notable advantages of inflatable tents is their rapid deployment and dismantling. It takes only 45 minutes to set up and 30 minutes to dismantle each tent, significantly faster than conventional tents. This efficiency is crucial in emergency situations where time is of the essence. The setup process requires a minimum air pressure of 0.7 Psi, achievable within 25 minutes. This requirement ensures the structural integrity of the inflatable tent while keeping the setup time relatively short. Inflatable tents have the additional benefit of reducing outside air temperature by 2.3 degrees Celsius. This feature can improve the comfort of refugees, especially in hot climates or during heatwaves. Additionally, using pollution-free solar power plants for electricity needs aligns with green management principles. Solar power is renewable and environmentally friendly, making it suitable for disaster response efforts without further exacerbating environmental challenges.

The research presents valuable insights into the design and implementation of innovative solutions for disaster response, such as inflatable tents and solar power plants. However, it also identifies some shortcomings and provides recommendations for further research. Lack of Air Pump with Pressure Regulation: The absence of an air pump capable of regulating air pressure is a significant limitation. Such a feature is essential for maintaining the structural integrity of the inflatable tents and ensuring they meet safety standards. Without this capability, there may be difficulties in consistently achieving and maintaining the required air pressure. Limited Capacity of Inflatable Tents: While the prototype inflatable tents accommodate 20 patients, there is a recognized need to increase capacity to accommodate 50 patients. This limitation could potentially hinder the effectiveness of the disaster response efforts, especially in scenarios where large numbers of people require shelter and medical assistance.

Recommendations for Further Research: Increase Capacity of Inflatable Tents: Expanding the capacity of the inflatable tents to accommodate 50 patients, as suggested, is a critical area for further research and development. This could involve redesigning the tents to be larger or potentially connecting multiple tents in a modular fashion to create a larger shelter space. Monitoring and Regulation of Air Pressure: Implementing a system to monitor and regulate air pressure within the inflatable tent tubes is essential. This system should include an automatic pump capable of adjusting air pressure to ensure it remains within the desired range. This would enhance the safety, stability, and longevity of the inflatable tents, contributing to more reliable disaster response operations.

By addressing these shortcomings and implementing the recommended improvements, future research can further enhance the effectiveness, sustainability, and resilience of disaster response efforts, ultimately benefiting both refugees and the environment.

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