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Project Report of Demonstration and Promotion of Energy Resilience Tool based on Solar-Powered Emergency Shelter Solutions (SPESS) for Natural Disaster in APEC

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Executive Summary

This literature survey informs APEC forum Energy Working Group (EWG), specifically its sub-forum of Energy Resilience Task Force (ER-TF).

The Asia-Pacific region, which comprises 52% of the Earth's surface area and 59% of the world's population, experiences more than 70% of the earth's natural catastrophes. Scientists expect that the severity and frequency of natural catastrophes in the Asia-Pacific area will continue to grow over the next few decades, a trend that will be worsened by unplanned development, poor land-use management, global warming, and climate change. Solar-powered emergency shelters (SPES) could address secondary damage caused by insufficient power and energy supply, as well as resettlement of impacted individuals and a location for non-professional medical treatment after a natural catastrophe.

This project aims to promote solar-powered emergency shelters (SPES) that are energy-efficient, environmentally friendly, and sustainable. Based on the major challenges and feasible technical solutions from renewable energy specialists, government officials, and corporate technicians (in the field of construction and solar technology), offered for the demonstration of solar-powered emergency shelter solutions (SPESS) as an energy resilience tool in APEC disaster-prone regions, and the technical review of emergency shelters in the APEC region, this report examines the viability of implementing solar-power emergency shelter solutions (SPESS). Here are the key points:

- **Enhancing humanitarian innovation**
- **Assessing the performance of physical products**
- **Open up avenues for multi-scenario applications**
- **Embrace investments and partnerships**

This report examines the design theory of solar-powered emergency shelters from five different vantage points: terrain and climate, time urgency, transportation, implementation ability of construction, and structural system. Additionally, application scenarios involving medical cabins, catastrophe relocation, and rural tourism are studied. Based on the theoretical foundation, form creation, and concrete construction for the demonstration project were completed. Due to the diversity of climatic conditions in the APEC region, the performance of single and double-roof solar shelters were tested onsite and computer-simulated to ensure their applicability. Insulation performance, natural ventilation, mechanical ventilation, and photovoltaic systems were also evaluated in disaster-prone APEC areas in order to develop a regional optimization strategy for project promotion. The report concludes by analyzing the promotion route of energy resilience tools from potential partners, key factors in the promotion process, and the commercial path. The following is the report's outline:

- **Design Methodology of Solar-Powered Emergency Shelter**
- **Application Scenarios for Solar-Powered Emergency Shelter**
- **Assessment of Climate Adaptation: Solar-Powered Emergency Shelter in Cold Climate**
- **Assessment of Climate Adaptation: Solar-Powered Emergency Shelter in Tropical Rainforest Climate**
- **Promotion Path of Solar-Powered Emergency Shelter**

The SPESS project draws on the latest technologies in emergency relief shelters to provide a theoretical basis for the design and to develop products adapted to APEC to rebuild communities and improve people's quality of life by providing shelter and energy.

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Project Description and Background

With just 52% of the world's surface area and 40% of its population, the Asia-Pacific region is home to more than 70% of all natural catastrophes. Disaster-related losses have exceeded $100 billion over the last decade. Such as Sep. 2018 earthquake in Sulawesi, Indonesia; Nov. 2013 Super Typhoon "Haiyan" hitting the eastern Philippines; the 2012 Super Storm Sandy in the US; May 2008 earthquake in Sichuan province, China, etc. Improvements in shelters are essential for the post-disaster communities to rebuild.

Energy is in high demand when people are displaced or when the grid fails after a disaster. It is imperative to investigate the current technological development of solar-powered emergency shelters (SPES) in actual disaster locations, address the difficulties in applying solar technology in disaster relief and discuss possible solutions.

Project Objectives

This project will support the application and demonstration of a holistic solution for energy supply and a pleasant interior environment for ERS (Emergency Relief Shelter), based on SPES solution, stressing people-oriented features, encouraging the application of sustainable, high-energy efficiency and environmental protection, and responding to APEC's idea of "cooperation, safety, security, efficiency, green technology, and comprehensive development". This project aims to solve the critical problems faced by disaster victims in the Asia-Pacific region, such as the energy supply and the primary living guarantee. This project will carry out the outcome of the SPESS open innovation competition (EWG 22 2015A) and provide an opportunity to explore potential cooperation among APEC economies about establishing a technical guideline for solar emergency shelters in post-disaster recovery, especially in susceptible economics to natural disasters.

Aims and Objectives

The project report included examples of solar emergency shelters from different APEC economies. In addition, a technological evaluation was conducted to investigate the most recent advancements in solar energy resilience technologies. Suitable solar technologies and products for SPESS were studied and analyzed from a technological and economic standpoint. Furthermore, ways to increase overall energy efficiency and interior settings were considered. The project report includes a summary of all findings.

Chapter 1 Design Methodology of Solar-Powered Emergency Shelter

A solar-powered emergency shelter (SPES) is a means to integrate art and technology on a smaller scale, not only for aesthetic appeal, ease of construction, and practical application but also for the use of green and clean energy, as well as active and passive technologies. "Green" and "health" are the two most important design principles. Low-tech solutions like solar energy, facility recycling and reuse, and locally suited design are all factors impacting the green design of SPES. Indoor environmental conditioning, active and passive ventilation techniques and "human-centered" belong to the health design. The key influencing factors in SPES design include terrain and climate, time urgency, transportation, construction implement ability, and structural system.

Moreover, two main categories of realization methods of SPES for disaster resettlement and post-disaster reconstruction were also explicitly described. One approach is for local governments to provide significant funding and technical guidance and for residents to repair and reinforce or reconstruct their original homes independently, known as "bottom-up." The other approach is for the government to provide temporary housing directly to disaster survivors, known as the "top-down" approach.

1.1 Design basis

Solar-powered emergency shelter (SPES) is a way to combine art and technology on a smaller scale, not only for aesthetic appeal, simplicity of building, and practical application but also for the use of green and clean energy, as well as active and passive technologies.

At the level of green and healthy technical design, while comprehensive green and healthy design standards exist at home and abroad, for the new field of emergency and disaster relief buildings, the foundation of design, the key influencing elements, and the entire life cycle operation mode are different, so the previous green and healthy design standards cannot be used directly as the design and testing standards, but only as a partial reference, from which the available information may be derived.

In the selection of technology, researchers utilize a combination of active and passive technology and the design principle "passive is the major emphasis, and active is supplemental" to lower the energy demand of the shelter and increase the use of "low-tech" technology, so that the shelter may accomplish the environmental effect under all climatic circumstances with the least amount of adjustment. The structure can be easily changed to the surrounding environment and climate[1]. Regarding design guidelines for functional structures, "timeliness" is always the primary factor in the design of emergency disaster relief buildings, which are intended to solve the problem of disaster victims as quickly as possible. A series of design points brought about by timeliness, such as the convenience of building transportation, the ease of understanding and operation of structures, and the efficiency of construction, are all issues that cannot be compromised. The absence of each connection will result in a significant loss of timeliness.

The structure of the building should also have an assembled modular design, which is conducive to mass production and the individual replacement of building components later through the simple modification and replacement of materials and structural modules to achieve adaptability to different site requirements and climates, and the modular splicing also provides more opportunities for the functional expansion and transformation of the building afterward.

Factors influencing the green design of solar-powered emergency relief buildings include low-tech strategies such as solar energy, recycling and reuse of buildings, and geographically adapted the design of buildings.

- **With the development of technology, using both active and passive solar energy is**

[1] Song Yehao, Wang Jialiang, Zhu Ning. Pondering over the Passive Design Strategy for Native Green Buildings of China[J]. Architectural Journal,2013(07):94-99.

an overall low-tech strategy from the energy use perspective.

Active solar technology is mainly a technology that stores solar energy and converts it into other energy sources for use. Passive solar energy utilization technology is mainly used to increase the use of daylight in buildings through the orientation of the building, the selection of building materials and components, the layout of the internal space, and the treatment of the external environment. In addition, emergency shelters can integrate other simple low-tech strategies, such as small water collection and purification devices to provide essential drinking and domestic water for disaster victims in case of water supply shortage; built-in small biofuel generators can also provide electricity for the building in case of power shortage. Many more low-tech strategies suitable for wilderness emergencies can be appropriately integrated into the building.

- **Although emergency structures are only utilized for a short time following a disaster, environmental concerns should nevertheless be given special consideration.**

New environmentally friendly materials made of "straw house," the walls are made of straw and mud through a unique process of mixing, insulation effect is excellent, and after special treatment, can be fire and moisture[2]. The University of Nevada has also helped Pakistan, which was hit by the earthquake, to build similar straw houses, helping the local people to solve the plight of displacement while also solving the problem of large amounts of straw that could not be disposed of[3]. Existing relief board houses are less comfortable transforming into permanent housing due to structural and material limitations, are not economically viable, and generate much pollution when cleaned and recycled[4]. After the Wenchuan earthquake, architect Liu Jiakun made a new type of recycled brick by processing waste construction materials and adding some straw and other aggregates, which solved the problem of disposal of waste materials and facilitated the self-

[2] Zhu Pei, Wu Tong, Li Yongquan. Zhu Pei:Low-tech strategy eco-housing-"straw house"[J]. Urban Environment Design,2009(02):156-157.

[3] Fan Quanwu,Li Jiahua. Present Situation and Thinking of Temporary Housing after Earthquake[J]. Huazhong Architecture,2009,27(11):5-6.

[4] Department of Science and Technology, Department of Housing and Urban-Rural Development of Sichuan Province, Research on recycling of slab materials in earthquake-stricken areas[J]. Construction Science and Technology,2010(09):61-63.

build of residents.

- **Emergency disaster relief buildings should take into account regional adaptation of the building design in order to meet the demand for speedy construction at the same time.**

The geographic adaptability of the building not only ensures the physical comfort of the suffering population but also repairs the trauma of the victims psychologically. The regional adaptation design of the building necessitates the designer taking into account more possibilities corresponding to different regions prone to different disasters. Furthermore, the ambient temperature around the site, the amount of rainfall, and the geographical characteristics of the erection site all influence specific disaster relief decisions and serve as the foundation for architectural design solutions, with modular adaptation to different climatic conditions being one of the characteristics that buildings should have[5].

Factors influencing the health design of solar emergency response buildings include indoor environmental conditioning, active and passive ventilation techniques, and "human-centered" design.

- **Emergency disaster relief buildings should take into account regional adaptation of the building design in order to meet the demand for speedy construction at the same time.**

Temporary housing in the aftermath of a natural disaster is typically disaster relief tents, primarily made of canvas and waterproof fabric. However, the insulation performance and breathability of these tents are poor, making it easy for heat to build up in the room, and the inability of the fabric to disperse water vapor will result in high indoor humidity, making the situation even more intolerable. The phenomena of a poor interior thermal environment in disaster relief throughout the summer are exceedingly prevalent and the most unbearable issue for those who reside

[5] Hu Bin, Zhang Mingzi, Lv Yuan. STUDY ON THE INTEGATED STRATEGY OF DISASTER PREVENTION IN THE PUBLIC SPACE OFCOMMUNITY[J]. Architectural Journal,2013(S1):46-50.

there[6]. In the Wenchuan earthquake in China, local victims added a layer of fabric on top of the tents for a simple transformation to increase the shading of the building; the outermost layer was covered with a black insulation net to reduce the solar radiation heat entering the room[7]. A single-roof tent transformed into a double-roof tent can also block most of the solar radiation and improve the indoor temperature; the air layer in the middle of the double roof can make the heat transfer thermal resistance of the inner and outer surface of the top bigger, reducing the heat entering the tent through conduction and convection; when there is wind outside, it can also take away the heat between the double roofs, and the heat insulation effect is better[8]. This series of improvement measures gives the temporary house a noticeable heat insulation effect and effectively improves the internal thermal environment.

- **Active and passive ventilation is an essential technical means. Natural ventilation is mainly divided into wind-pressure ventilation and thermal-pressure ventilation.**

Wind pressure ventilation mainly relies on convection between indoor and outdoor air to form the effect of ventilation and cooling, while thermal pressure ventilation drives air flow through temperature differences. If the design or site factors and other conditions ultimately still cannot meet the comfort requirements, active ventilation, and cooling technology can be added appropriately. Active equipment should try to choose portable and easy to integrate into the building equipment and minimize the consumption of external supply energy to achieve green requirements.

- **If architecture is compared to a living organism, health should be reflected in the body and mind.**

This dichotomy reflects the characteristics of integrating technology and art in architecture[9]. According to the World Health Organization and related

[6] Huang Luhong,Long Enshen. Investigation on Livability of Portable Dwellings in Post-disaster Transitional Settlement Areas afterWenchuan EarthquakeAnalysis Based on the Questionnaire in Dujiangyan[J]. Building Science,2012,28(06):61-65.

[7] Wang Tao, Long Enshen, Yuan Qi, Chen Hongqing. Discussion on the mprovement of Living Environment in Relief Tent in Terms of "Improvement by Indigenous Method"---Taking M8.0 Wenchuan Earthquake as an Example[J].Journal of Catastrophology, 2010,25(01):139-143.

[8] WANG Tao,LONG Enshen,YUAN Qi,CHEN Hongqing. Research on Thermal Insulation Effect of Double-roof Tent[J]. Building Science,2010,26(12):59-63.

[9] Zhou Min. GREEN AND HEALTHY BUILDING DEVELOPMENT AND CASE ANALYSIS[J].Architecture Technology,2018,49(01):11-14.

scholars, the psychological impact of natural disasters on people is severe[10]. "Human-centered" is the future development trend of emergency shelter buildings for natural disasters[11] [12]. The functional arrangement and specifics of the interior space should be optimized from the viewpoint of the users themselves, with full consideration given to the extension of the interior space and the fluidity of the optimized interior space[13]. At the same time, the ergonomic design should be present even in simple emergency relief buildings[14]. Although the form of the building is not the primary limiting constraint, the design of the shape should aim to match the broader vision and usage demands, notably the way of life and aesthetic preferences of the locals, and avoid making too many abrupt design decisions. Traditional disaster relief tents are mainly in military green and dark blue, with a single color, lacking the care for regional cultural characteristics and the hearts of the victims. Soft fabrics, cotton materials, light-colored wood, and other materials that can easily evoke a warm feeling in people are among the indoor decorative materials that should be used in addition to the main structure of the building's hard furnishing materials. Indoor decorative materials should also be long-lasting and recyclable. In particular, the texture and process of the material part closest to the human body can, to a certain extent, strongly influence the user's psychology.

1.2 Design influencing factors

An in-depth study of the relevant parts of emergency disaster relief architectural design research was undertaken, summarize and conclude the architectural design principles according to the needs of different attributes of buildings in diverse surroundings, and ultimately refine the general influencing factors for the design level, which are easy to understand, simple to manage, and efficient.

[10] Shi Kan. Disaster Psychology [M]. Science Press,2010.

[11] Ning Weiwei, Xu Jian. Post-disaster psychological reconstruction and psychological education[J]. Journal of Southwest Jiaotong University(Social Sciences),2008(04):1-4+14.

[12] Zhang Wei. Confronting Disaster - Architectural Concept Exploration and Modeling for Disaster Relief Temporary Shelter[J]. The Architect, 2009(03):99-105.

[13] Zhou Yang. The Mobility of container-type residence and indoor spaces[J]. Architecture & Culture,2015(04):174-175.

[14] Yu Fan, Nancy Chen. Bionic Plastic Design [M]. Huazhong University of Science and Technology Press,2005.

The most important feature of solar emergency buildings is still the word "emergency," which means that the "immediacy" of such buildings is the first factor that should be put into the design. Otherwise, nothing can be done. After a natural disaster, when everything around is destroyed, and materials are most scarce, the emergency shelter starts to play its value. The key to the design is to use the shortest time and rely on the fastest speed in complex situations, small groups or individuals independently, to complete the construction of simple shelters so that the victims have a temporary shelter while providing space for the injured people to heal and recuperate. Not only to survive but also to stabilize the victims' emotions and strengthen their will to live.

The type of local natural disasters, the local climate, and the natural landscape are the basis for the design. The construction level insists on the premise that the building is easy to transport and quickly erected while ensuring comfortable living and energy conservation, and environmental protection. Hence, the choice of materials also reflects the originality and integrity of the overall design. In contrast, the design for different sites requires shelters with solid versatility and applicability[15].

(1) Terrain and climate

After the disaster, many external factors disturbed the affected area's terrain. The situation is more complicated, so it cannot guarantee the conditions to open a large-scale flat open space for post-disaster resettlement, so the architectural design should be prepared to adapt to a variety of complex terrain, for example, the height-adjustable pedestal foot setting, in the uneven terrain can be appropriate to ensure the flatness of the interior through the height adjustment of different pedestal feet, or suspension The design can make the bottom surface of the building out of the ground, increase the surface air flow, but also avoid a lot of heat loss in the body of the people resting indoors. At the same time, according to different climatic conditions, the building envelope structure and thermal environment improvement methods to make targeted adjustments is also a part of the site adaptation design cannot be ignored; for example, by changing the building envelope materials to adjust the building for cold or hot areas, such as insulation performance, waterproof and breathable performance.

For example, when changing the living space of the emergency relief building to medical use, firstly, the scale of the building should be able to be used as temporary wards, consultation rooms, and operating rooms. The building structure components should be

[15] Wanming Zhang. THE RESEARCH OF INSTANT FACILITIES DESIGN[D]. Tianjin University of Science and Technology, 2015.

replaced to accommodate the larger scale of the medical space. The scale of the movable beds, the height of the surgical shadowless lights, and the space for storing medical equipment should all be fully considered. Secondly, the accessibility of each function should be considered, including not having too much threshold rise and fall, and the doors should be widened to ensure the passage of medical equipment and mobile beds.

(2) Time urgency

If the best time is missed, the disaster relief and the resettlement of the victims will lose their original role and meaning. The rapid emergency relief building for natural disasters is designed on the premise of rapid arrangement, with "efficiency" as the most critical factor influencing the success or failure of the architectural design. It is quickly transported to the disaster site to effectively carry out the resettlement and relief work to meet the needs of the victims of emergency shelter to the greatest extent.

(3) Transportation

In the design of such buildings, not only to save time and effort in the construction, but the transportation method is also a link that cannot be ignored in the rapid response, which directly determines whether it can be quickly transported to the disaster area and play a fundamental role in emergency resettlement.

In order to transport more relief buildings to the disaster area, the building units or structural components should be modular and integrated into the unopened and unassembled stage as much as possible to save space and ensure maximum transportation. However, the road system is usually blocked or even damaged after a disaster. In addition to land transportation, other transportation methods should be considered for disaster relief buildings, such as water or air transportation, to ensure efficient transportation and placement even when roads are interrupted. However, the modularity, integration, and lightness of the buildings are more demanding.

(4) Implementation ability of construction

Ease of operation requires the design to avoid overly complex spatial structures and building components and to use as many standard connection components and construction tools as possible in the market. Using the exact specification of connecting parts reduces the mix of different tools; even without tools, only the use of bayonet connection or folding ready-to-use design and construction method reduces the delay in installing buildings on site. When the affected people first get the building or building parts, they only need a small amount of time to learn the building skills and complete the proper installation and arrangement of the whole building.

(5) Structural system

In recent years, with the improvement of production technology level and the scale of production, light modular buildings have shown large-scale development, and such buildings are widely used in civil, military, disaster relief, and other fields, with good prospects for development.

The most significant advantage of modular construction technology is that it can realize parallel construction. A large number of structural parts processing work is completed in the manufacturing plant, significantly reducing the amount of work in the field construction, thus shortening the time cycle of the complete disaster relief in disaster resettlement. Not only does it reduce the difficulty of construction, better ensure the quality of construction and increase productivity, but it also reduces the cost of use by recycling building materials or repairing, reinforcing, and renovating the building after use and putting it into use again.

Modular building design and construction are based on the following concepts: first, it applies to a variety of building types, and the construction process can meet diverse architectural and structural solutions; second, the space module consists of two-dimensional flat components and all two-dimensional components can be assembled into a space module, which is easy to transport and flexible to build. Third, it can reduce construction waste and repeated investment and is green. Fourth, it can reduce the amount of on-site construction and save a lot of workforces.

Due to its light weight, modular construction, quick erection and disassembly, convenient transportation, and other features, its application areas are not only for civilian use; it also has a unique advantage in emergency relief and disaster relief, as well as in field barracks, field hospitals, and other specialized areas of application. Whether in terms of rapid erection and disassembly, functional use, residential comfort, or other aspects, it is better than traditional military and civilian tents.

The modularity of the structure serves as the foundation for the premise behind the conversion and expansion of building functions. The complex situation of the disaster area requires not only the building for the victims' residence, medical and health care, waste disposal, and even a short period for the placement of the corpses requires building space. In the case of damaged buildings after the disaster, the emergency building will be changed through the replacement of building parts and the combination of multiple buildings to change the space area. The building is adapted to the new function by adding different equipment.

1.3 Realization method

Although emergency architecture is a relatively new research topic, its prototype design is not new. However, it has been gradually generated in the long history of humanity, probably dating back to the most primitive shacks. It is only after modern times that emergency architecture has been divided into a new research field. In the "Ferry - International Emergency Architecture Design Exhibition" on 12 May 2009, the new professional term of emergency architecture was detached from temporary buildings, transitional dwellings, and simple houses and indicated its flag[16].

There are currently two main categories of emergency relief buildings for disaster resettlement and post-disaster reconstruction. One approach is for local governments to provide significant funding and technical guidance and for residents to repair and reinforce or reconstruct their original homes on their own, an approach known as "bottom-up". The "bottom-up" approach to housing, in which communities and users play a significant role in decision-making and management, is ideal for developing culturally, economically, and ecologically appropriate solutions to the local living environment. However, the comfort and overall construction quality of the home will vary depending on the design of the plan, the quality of the building materials, and the skill of the artisans. Such differences lead to more significant variability in the living patterns and comfort of local people, which is not conducive to overall control.

The other approach is for the government to provide temporary housing directly to disaster survivors, known as the "top-down" approach. In a disaster environment, the top-down approach also places more emphasis on standardization and the application of design and technology, resulting in a higher degree of design completion, easier control of building quality and occupancy comfort, pre-set and standardized elements that meet the

[16] Pan Qing. Building for Hope and Happiness: An Overview of the Watanabe International Emergency Architecture Exhibition[J]. ZHUANGSHI,2009(07):46-51.

government's predetermined fixed design and fire codes, and faster construction and disassembly than the "bottom-up" approach. The speed of construction and disassembly is also much faster than the "bottom-up" approach, and the recycling rate is also higher, further reducing the single-use cost of this type of building, which only requires maintenance or minor renovation of individual damaged buildings to be put back into use, reducing the government's investment costs later[17].

The "bottom-up" model pays more attention to local conditions and culture, and the post-disaster construction led by the township government is more participatory and active and follows the residents' lifestyle to build on their own. At the same time, it can avoid the dispute of interests brought about by the government's uniform construction.

- Due to their geography, long-term fixed living patterns, and other factors, residents are generally reluctant to leave their hometowns and rebuild off-site after a disaster. Most of them will choose to structurally strengthen and repair their original houses after the disaster, and the people will participate in the construction spontaneously.

One of the more valuable references is the Sandbag Shelter designed by an Iranian architect, praised by Omar Bach, head of the United Nations Development Program, for its practicality. The design of woven bags to build houses is cheap, earthquake resistant, efficient, and has better thermal performance; 15 m^2 temporary housing costs less than 200 U.S. dollars, and five people can be completed in a day and used for three years[18]. There are also examples of designs based on traditional crafts, such as origami art, which are easy to fold, transport, and set up quickly on-site[19].

[17] Adham Hany Abulnour. The post-disaster temporary dwelling: fundamentals of provision, design and construction[J]. HBRC Journal,2014,10(1).

[18] Liu Xiaohu, Liu Han, Li Baofeng. Bamboo Structure, Claybag, Straw Roof Experiment on Emergency Shelter of Low-cost Rural Material[J]. Time + Architecture,2009(01):89-91.

[19] Quaglia C P , Dascanio A J , Thrall A P . Bascule shelters: A novel erection strategy for origami-inspired deployable structures[J]. Engineering Structures, 2014, 75:276-287.

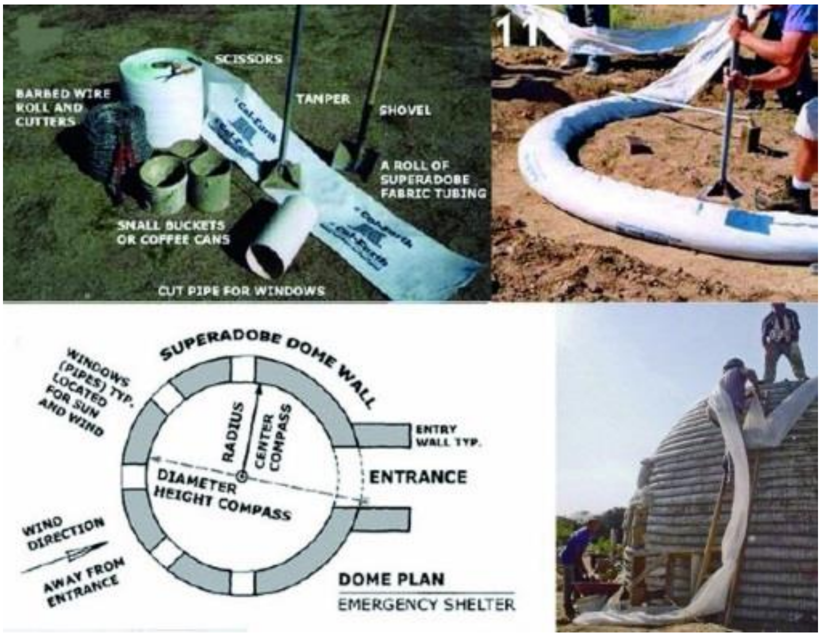


Fig. 1.1 Paving process of flexible thin film photovoltaic

(Source: Bamboo Structure, Claybag, Straw Roof Experiment on Emergency Shelter of Low-cost Rural Material)

In 1995, the Japanese government set up small and medium-sized organizations in the Hanshin earthquake-affected areas, mainly for the victims, and worked with residents to formulate reconstruction plans and measures and participate in the reconstruction work. During this period, the government only dispatched experts to evaluate and certify the intermediate plans and provide technical guidance during the reconstruction process, which became a model of "bottom-up" reconstruction[20]. However, in many cases, the "top-down" model, which the government controls, cannot truly understand the local people's actual feelings. Although the starting point is good, the results often go in the wrong direction, and the locally affected people are not the ones who benefit in the end. This may even lead to unclear work direction, interspersed and stacked work, resulting in waste of labor and destruction of resources and environment, thus affecting the promotion of the whole reconstruction work. With the accumulation of experience, people began to realize the importance of people's independent participation in the reconstruction work, combining the

[20] Li Lianqi. The New Opinion of Housing Rebuilding Policies after Disaster[J]. Journal of Xihua University(Philosophy & Social Sciences), 2008,27(5):16-18,27.

strength of the majority.

However, the "bottom-up" construction method often lacks professional guidance and construction supervision in the post-disaster emergency evacuation stage and is influenced by geographical conditions, so the building form, living comfort, and structural safety cannot be better guaranteed. Therefore, in China, this construction method is mainly seen in post-disaster reconstruction with the intervention of professional instructors and is primarily seen in the construction of permanent houses or the repair and reinforcement of original houses, which takes more time.

One of the most critical conditions for emergency shelter buildings is the immediacy of the building. The 72-hour golden rescue time is still the most influential period for such buildings, so the "top-down" construction method is more appropriate for the emergency relief stage.

Since one of the essential elements of emergency relief construction is to complete the construction in the shortest possible time and the most labor- and material-efficient manner, this paper focuses on the "top-down" model.

- This model is broadly divided into two types: one is produced in the factory, assembled, and then put into use quickly with a simple arrangement on the cleared site, similar to the "factory prefabrication" model of traditional construction. The other type is to make the components needed for building assembly in the factory and then transport the different components to the site and build the whole assembly, similar to the "on-site assembly" mode of traditional construction. These two types of construction have more solutions in practice, and the advantages and disadvantages of these two types of construction will be reviewed next.

The "factory prefabricated" type of emergency relief building is assembled in the factory and has a high degree of completion and integration at the time of delivery. The interior of the building can be integrated with more technical living facilities, and the safety and comfort of living are relatively high. The disadvantages are that the building cannot be folded or compressed, is large and not easily transportable, has a relatively low ability to cope with different kinds of geographical conditions, and the high degree of completion increases the difficulty of functional expansion and adaptive reuse.

- **Ex-Container project**

Fig. 1.2 Ex-Container container housing

(Source: http://bbs.zhulong.com/101010_group_201801/detail10048023)

In order to provide emergency shelter for victims of tsunami and earthquake disasters, Yasutaka Yoshimura & Associates has been working with Nowhere Resort on the research and development of a new type of box house - Ex-Container. Ex-Container is a modular box that uses standard. The modular box design is easy to transport and offers the possibility of moving it worldwide. All processes of Ex-Container are produced and assembled in the processing plant, and all components and internal equipment are highly integrated, which saves much work on site, as well as time and the use of non-essential fuel and heavy tools. The permanent building is made from a 20ft x 20ft uniform-size container, with a functional interior that integrates a series of basic living spaces such as bedrooms, bathrooms, kitchens, etc., with an area of 60 square meters at the cost of 60,000 yen. In addition, the architects further derived a two-story variant that accommodates a smaller base area and maintains the sensitivity of communication between communities. Yasutaka Yoshimura then applied these modular container houses to the "bayside marina hotel" project, which is more complete and includes a full range of prefabricated interior equipment and exterior finishes. Usually, the most common use of temporary container houses is two years. However, the designer modified the Ex-container appropriately to break the short-term nature of emergency construction and transform the temporary container house into a permanent, economical, safe, and comfortable residence.

- **Living Shelter by WY-TO**

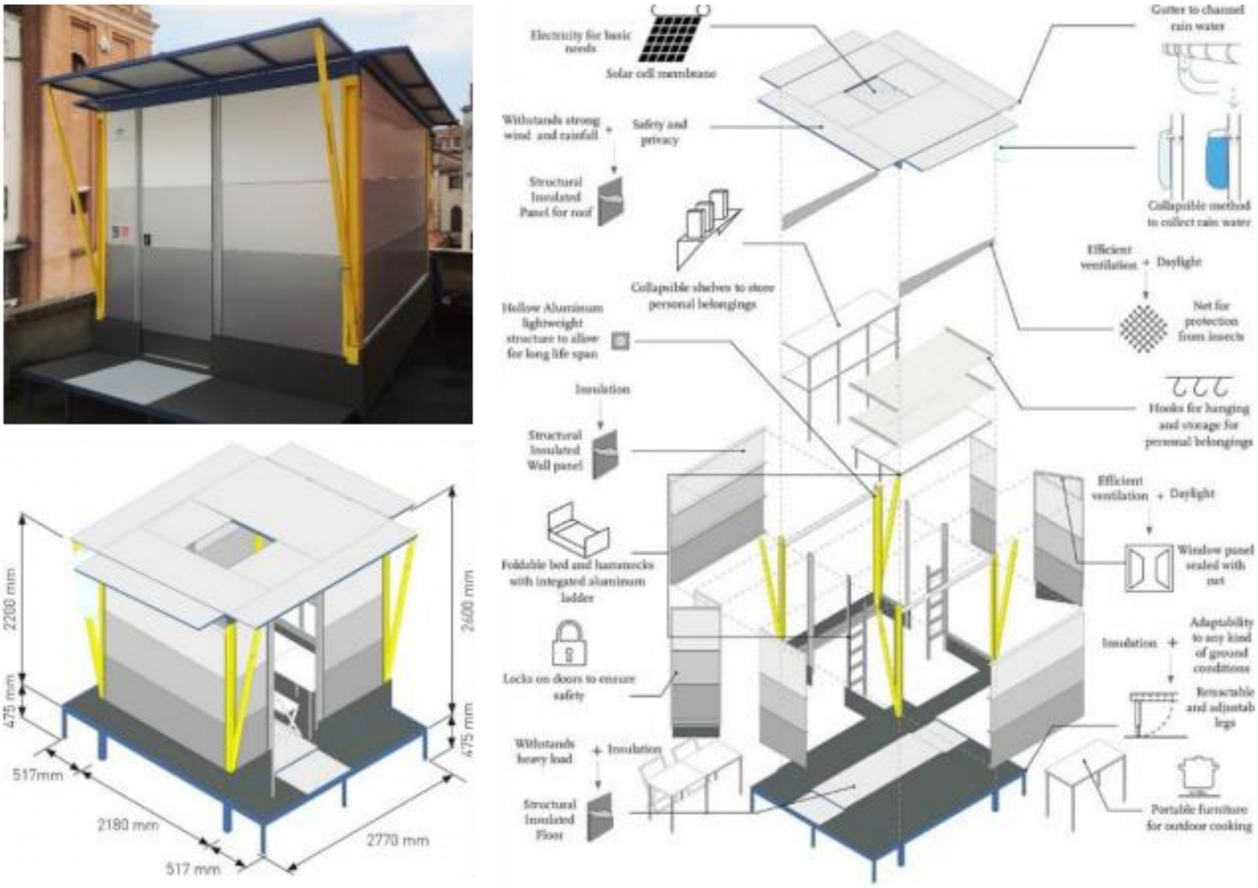


Fig. 1.3 Living Shelter by WY-TO

(Source: https://www.gooood.cn/living-shelter-by-wy-to.htm?lang=en_US)

The Asia-Pacific region is prone to natural disasters. WY-TO Architects in Singapore used its geographical advantage and architectural expertise to design an emergency shelter, Living Shelter, adapted to

Southeast Asia's climate, topography, and living habits to support the lives of people in the affected areas.

The building is modeled after the typical "kampong house" in Southeast Asia, emphasizing natural ventilation inside the building to provide shelter for people in the aftermath of a disaster. The unique base design allows it to be built on uneven sites, and all of its components and systems can be urgently disassembled, reassembled, and individually reused in new construction, facilitating maintenance and repair of the building while extending the life of the building components. The new folding mechanism developed by the design team allows novices to complete the shelter installation with simple training and without the use of tools. The shelter meets basic living needs and provides security and privacy. The hut's exterior is equipped with water bags for water collection and solar panels embedded in the roof to provide electricity for cell phones and lighting; inside the house, in addition to folding beds and shelves and other fixed home for people to use freely mobile furniture. All these components are packed in a flat box, easy to transport to the affected areas, and centralized placement. The team then continued to develop new technologies, such as 3D printing and lightweight composite materials for interior furniture, to enhance the overall stability of the building while not adding weight. The architectural design and interior equipment systems are ergonomically focused on providing convenience for the users.

- **FLEXHOME-emergency shelter**

FLEXHOME-emergency shelter is inspired by tent camping and mobile homes. It is a folding modular design that is quick to assemble, lightweight, and easy to transport and carry. It can be quickly unfolded as an emergency shelter in case of an emergency. The construction material comprises 75% fabric and 25% aluminum, polycarbonate, and particle board. The folding part of the house is composed of fabric modules attached to an aluminum frame that can allow horizontal folding, pulling on both sides, and easy handling, avoiding the use of any specialized tools and large machinery.

Fig. 1.4 FLEXHOME-emergency shelter

(Source: http://www.ikuku.cn/post/80424)

The lightweight and simple structural design makes it easy to transport and requires only 1 or 2 people to assemble the house in less than 10 minutes. The wheels at the bottom of the building are not only for the convenience of consignment but also allow the central part of the building to be raised off the ground, allowing air to circulate underneath, insulating it from humidity and avoiding problems such as human illness caused by massive heat dissipation. The most basic function of the building unit is designed as a temporary family shelter. However, in the future design, due to its modular and flexible characteristics, the building space can have multiple functional expansions. It can serve as a hospital, school, or other function during disaster relief and post-disaster reconstruction. In the non-disaster period, FLEXHOME can also be used as a mobile multi-functional family shelter, which has the lightness of a camping tent and the functionality of an RV, making it the best choice for family camping for short-distance travel trips.

- **Paper tube construction**

Fig. 1.5 Rwandan refugees set up plastic tents with paper tube support material

(Source: Temporary housing after a disaster in an ecological perspective)

Fig. 1.6 Paper Loghouse

(Source: https://www.archdaily.com/489255/the-humanitarian-works-of-shigeru-ban/)

As an architect and senior advisor to UNHCR, Shigeru Ban's high sense of design responsibility has led him to hope that everyone, including the poorest, can enjoy the best things. He has actively participated in the relief work after many disasters in recent years, gradually establishing the construction form and style of using paper tubes as building materials and structures through continuous exploration. Over the years, many simple temporary buildings, including post-disaster temporary shelters and public buildings, have been built using paper tubes, with lightweight structures and innovative forms, and have been called minimalist and experimental architects by many critics[21].

In 1994, the civil war in Rwanda, Africa, led to many people losing their homes and becoming refugees. Initially, the United Nations provided plastic tents to the victims, which not only had poor results but the support structure was made of wood leading to massive deforestation and severe damage to ecological resources and the environment. Finally, in 1995, the United Nations adopted the Banmo paper tube support structure solution, which solved the waste of resources and environmental damage caused by a large number of trees being cut down in the area, and made an appropriate solution to the massive influx of refugees and gave them a temporary stable home[22].

“Paper Loghouse”, a shelter after the 1995 Great Hanshin Earthquake in Japan, is one of Shigeru Ban's most famous works. The foundation of the house consists of beer boxes filled with sandbags to prevent the adverse effects of moisture on the ground. The walls of the building are made of neatly arranged paper tubes, and the roof is covered by tent cloth, which can be opened and closed flexibly according to the weather conditions to enhance indoor ventilation and ensure the temperature and freshness of the air inside. In addition to the cost, difficulty, and speed of construction, these sheds are easier to recycle after use. They are more assembled than other forms of temporary housing, easy to make and construct, inexpensive, comfortable to live in, and able to adapt to changes in climate.

After Typhoon Haiyan struck the Philippines in 2013, Shigeru Ban brought a new and improved "Paper Loghouse" to the disaster area, which continued the characteristics of the first generation and changed the structure to a frame structure. The roof was also replaced by heat

[21] Li Chengyi,Tang Hao. A practical path with paper tube material as the core of design - Banmao's design concept of post-disaster resettlement housing[J]. China Construction,2015(09):106-107.

[22] Wang Di,Zhang Tianyu. The Exploration of New Environment-friendly Materials in a Temporary Building[J].Huazhong Architecture,2010,28(05):37-39.

insulation panels with better thermal insulation performance, making the interior of the building have better thermal performance and further highlighting the importance of paper log houses to the disaster area[23].

In addition, with the help of Sakamo's design team, the Hua Lin Primary School building and Miao Miao Paper Tube Kindergarten were built after the Wenchuan earthquake in 2008 and the Lushan earthquake in Ya'an, Sichuan in 2013, respectively, and were adapted and upgraded in many aspects, such as building layout, foundation, structural system, maintenance system, and node structure, which is another extended reflection of Sakamo Paper Tube's transitional architecture[24] [25].

Fig. 1.7 Paper Tube Transitional School Building of Hualin Elementary School, Chengdu

(Source: Start from Transition: From Paper-tube School-building by Shigeru Ban to the Issue of Transitional Architecture)

- **MCEDO School in Kenya**

[23] Hou Lin. Research on the construction of post-disastershelters for transitional purpose -Starting from the studies on the Shigeru Ban paper tube in transitional construction[D].Southwest Jiaotong University, 2010.

[24] Qiu Jian,Deng Jing,Yin Hong. A Study on Paper-Pined Buildings in Earthquake Disaster Areas --- Shigeru Ban's Two Buildings in Wenchuan and Lushan[J].Architectural Journal,2014(12):50-55.

[25] Yin Hong, Deng Jing. Start from Transition From Paper-tube School-building by Shigeru Ban to the Issue of Transitional Architecture[J].Time + Architecture, 2009(01):72-77.

Fig. 1.8 MCEDO School in Kenya

(Source: Folding Structure The Structure Design and Construction of MCEDO School Project in Kenya)

In September 2014, a new light steel school building was constructed in the "Masare Valley" community in the northeastern suburbs of Nairobi, Kenya, as the MCEDO School (Masare Children's Education and Development Organization), co-designed by Zhu Jingxiang's team from the Chinese University of Hong Kong, and sponsored by the China Business Council of Kenya. This project is the first school designed and built by an independent team of Chinese architects in a slum on the African continent, bringing "Chinese design" to one of the poorest places in the world[26]. The building is a lightweight prefabricated structure that is flexible and lightweight. Two two-story classrooms are arranged side-by-side, forming an inner courtyard in the center, with removable sunshade louvers on the west elevation. The building stands discreetly on the edge of the neighborhood known as the "slum," bright but unobtrusive, providing space for approximately 600 slum children to learn and play at a low cost. The top and bottom floors of the building

[26] Huang Zhengli. Reinventing Slum Architecture"[J].Time + Architecture,2015(02):54-58.

are supported by four innovatively designed Y-shaped pillars that when folded, allow the building to be slapped flat for modular packaging[27]. Since transportation relies on container shipping, the investigation and analysis of container size parameters and transportation costs helped determine the size of the structural unit: the width of the structural unit is determined by the net width of the container of 2.35 meters minus the tolerance, the length direction is 6 meters, the length direction of the 40-foot container can hold two pieces, and the structural unit can be packed in layers to nearly fill the net height of the container. Furthermore, Zhu Jingxiang's team's study and reflection on light structure indicate another purpose of the light building system - its planning and construction capabilities should also be the beginning of a series of follow-up activities: to deliver hope and enlightenment on a human scale, as well as contemplation and communication, beyond solving practical difficulties[28].

- **Duffy Shelter**

Because emergency shelter buildings and equipment are usually designed to be inexpensive, easy to transport, and quick to build, a London studio called Duffy London has spent a year and a half designing a disaster relief shelter that can be assembled within an hour - the Duffy Shelter. The design of the shelter is based on the idea of a trailer caravan produced in the US This self-assembled multi-purpose mobile shelter can be used for disaster relief, emergency shelter, wilderness adventure, or camping accommodation, combining practicality, usability, and functionality. The construction consists of walls, floors, support legs, roofs, windows, hatches, and hinges - all components that can be assembled quickly and easily to form a comfortable room.

[27] Wu Chenghui, Zhu Jingxiang. Folding Structure---The Structure Design and Construction of MCEDO School Project in Kenya[J]. Time + Architecture,2015(02):48-53.
[28] Zhu Jingxiang. Possibilities of Light-weight Building Systems[J]. Time + Architecture,2015(02):59-63.

Fig. 1.9 Duffy Shelter

(Source: http://w.huanqiu.com/r/MV8wXzI4NDgxODhfMTgxMF8xNDc2NDI2OTYw#p=1)

The dimensions of the shelter are 185 cm x 125 cm x 142 cm for two adults. The company uses a more precise CNC cutting machine to cut FSC-certified wood to make, and the processed panels can be assembled simply to form the body of the building, with few building accessories and no tedious installation steps or large installation tools, and can be assembled with just a screwdriver. In terms of transportability, the unassembled building exists in the form of cut and finished flat panels, and an ordinary truck can carry 35 sets of flat-packed Duffy Shelter. the building can also be suitably modified later to become a living space for a trailer RV with the addition of tires, and its strong potential for transformation makes its application scope further expanded.

Chapter 2 Application Scenarios for Solar-Powered Emergency Shelter

Solar-Powered Emergency Shelters (SPES) are primarily utilized for disaster resettlement. Therefore, the discussion focuses on economies that are vulnerable to disasters, the climate resources that are accessible, and waste disposal. Taking prompt action to treat the victims' injuries after the disaster is crucial. The medical cabin is another application scenario for SPES. The medical module, as the most basic unit, is an essential part of the composition of the module hospital. It can be used alone to form a separate rapid-response medical unit and through the organic combination of different functional modules to form a whole module hospital. Regarding the military, the cabin hospital is an essential component of the army logistics medical security force. Inflatable, light frame and metal folding "quick" support structure are also, in recent years, the world's military in the field barracks, field hospitals, emergency disaster relief, and other aspects of structural exploration. Additionally, rural tourism is a possible application scenario to boost the large-scale growth of SPES since it can supply both rest space and power.

2.1 Medical cabin

(1) Introduction

In the 1960s, the research of square cabin hospitals began to be on the agenda, the first application was for the US Army in Viet Nam to treat the sick and wounded, and later, the British, the US, German, French, and other domestic armies developed and equipped with protective field hospitals.

The medical module, as the most basic unit, is an essential part of the composition of the module hospital. It can be used alone to form a separate rapid response medical unit, but also through the organic combination of different functional modules to form a whole module hospital, such as a standardized field psychological protection module, blood refrigeration module, sterilization module, etc. After the composition of the field cabin hospital can form a comprehensive wartime medical configuration suitable for field rescue and disaster relief in treating the wounded and sick.

(2) Military medical cabin

In the Wenchuan and Yushu earthquakes, the comprehensive square module hospital, composed of medical square modules, was sent to the disaster area to carry out rescue tasks. Many wounded patients received timely and comprehensive treatment. At the same time, the Chinese and foreign joint military exercises, with the field forces carrying out joint training tasks of security, also appeared many times. The figure of the square cabin hospital became an essential component of the army logistics medical security force. However, the actual use of the process also revealed some problems, such as limited mobility, functional imperfections, and high requirements for the development of the regional conditions of the square hospital problems, which need to be assessed and improved, and ready to play a more powerful and more influential role. Nowadays, economies worldwide are constantly developing and updating their square cabin hospitals. Various developed areas have been equipped with a variety of field medical rescue systems, and the current medical square cabin existing in foreign armies is divided into two types, extended and non-extended, from the structural point of view. The future square cabin hospital develops toward standardization, systematization, modularization, information technology, and other aspects[29].

(3) Case study

Most of the existing square cabin hospitals in China use standard containers for transformation, loading, and transportation by truck. Part of the mechanical or hydraulic devices can achieve the extension function. However, often the proportion of extension is low. After the "Tenth Five-Year" research and development of the second generation of square cabin hospital, hydraulic drivers and automatic adjustment of the level of the addition of advanced technology to make the square cabin technology has been dramatically enhanced, and in the late "Eleventh Five-Year", based on the second

[29] Wang Zhimin. Exploration on the functional improvement of carbin hospital from earthquake rescue and military exercises[J]. Chinese Journal of Disaster Medicine,2016,4(09):511-513.

generation of research out of the third generation of square cabin Hospital, the new structure and constantly improve the level of information technology, to achieve the gradual improvement of the field medical equipment system.

In 2012, the Chinese Armed Police developed the first generation of security and medical treatment platform, based on the second generation of square cabin hospital, using the modular design concept, the functional module consists of five parts: critical care disposal vehicle, surgical disposal vehicle, comprehensive disposal vehicle, medical comprehensive security vehicle, and communication command vehicle, each part is connected by a channel tent to become a complete square cabin hospital, with the reasonable functional arrangement and shorten the casualty treatment time. Each medical module is transported and expanded by a carrier car without loading and unloading. About five people can quickly unfold the car and complete the assembly, which significantly improves the efficiency of the layout of the hospital. The total area after all the unfolding and assembling reaches 16m^2, which can provide sufficient space for medical treatment[30].

The large-scale expansion of the square cabin is the focus of research on the square cabin hospital at home and abroad. An expanded square cabin medical space is several times the traditional square cabin, significantly reducing the number of square cabin transport and layout assembly time to meet the demand for space for medical treatment to ensure that medical personnel in the shortest possible time into the emergency treatment. In addition, inflatable, light frame, and metal folding "quick" support structure is also, in recent years, the world's military in the field barracks, field hospitals, emergency disaster relief, and other aspects of structural exploration[31].

2.2 Disaster resettlement

(1) Disaster-prone economies

According to statistics, the five most severely affected economies were the United States, Japan, the Philippines, Indonesia, and China. The severity of the damage in China and the United States is mainly due to the large size of the economy and the complex weather

[30] Meng Xiaodong, Zheng Jingchen, et al. Development of intelligent expandable vehicle-mounted shelter hospital of PAP[J]. Chinese Medical Equipment Journal,2015,36(10):27-29.
[31] Jiang Chen, Shi Xuyan. 'Quick-creat"Architecture:The Research Mainly about Tent A Kind of Quick-build Architecture [J]. Huazhong Architecture,2010,28(10):69-72.

conditions.

- **United States**

The climate of the United States varies due to changes in latitude and a range of geographic features, including mountains and deserts. Generally, on the mainland, the climate of the US becomes warmer the further south one travels and drier the further west until one reaches the West Coast. West of 100°W, much of the US has a cold semi-arid climate in the interior upper western states (Idaho to the Dakotas), to warm to the hot desert and semi-arid climates in the southwestern US East of 100°W, the climate is humid continental in northern areas (locations roughly above 40°N, Northern Plains, Midwest, Great Lakes, New England), transitioning into a humid temperate climate from the Southern Plains and lower Midwest east to the Middle Atlantic states (Virginia to southern Connecticut).

The Gulf of Alaska is the origin of many storms entering the United States. Such "North Pacific lows" enter the US through the Pacific Northwest, then move eastward across the northern Rocky Mountains, northern Great Plains, upper Midwest, Great Lakes, and New England states. Across the central states from late fall to spring, "Panhandle hook" storms move from the central Rockies into the Oklahoma/Texas panhandle areas, then northeast toward the Great Lakes. They generate considerable temperature contrasts and often bring copious Gulf moisture northward, sometimes resulting in cold conditions and possibly heavy snow or ice north and west of the storm track, warm conditions, heavy rains, and potentially-severe thunderstorms south and east of the storm track-often simultaneously.

- **Japan**

The climate of Japan is predominantly temperate but varies significantly from north to south. The northernmost region, Hokkaido, has a humid continental climate with long, cold winters and very warm to cool summers. Precipitation is not heavy, but the islands usually develop deep snowbanks in the winter.

In the Sea of Japan region on Honshu's west coast, northwest winter winds bring heavy snowfall during winter. The region sometimes experiences sweltering temperatures in the summer because of the foehn. The Central Highland has a typical inland humid continental climate, with significant temperature differences between summer and winter. The mountains of the Chūgoku and Shikoku regions shelter the Seto Inland Sea from seasonal winds, bringing mild weather year-round.

The Pacific coast features a humid subtropical climate that experiences milder winters with occasional snowfall and hot, humid summers because of the southeast seasonal wind. The Ryukyu and Nanpō Islands have a subtropical climate, with warm winters and summers. Precipitation is very heavy, especially during the rainy season. The primary rainy season begins in early May in Okinawa, and the rain front gradually moves north. In late summer and early autumn, typhoons often bring heavy rain. According to the Environment Ministry, heavy rainfall and increasing temperatures have caused problems in the agricultural industry and elsewhere. The highest temperature ever measured in Japan, 41.1 ℃ (106.0 ℉), was recorded on 23 July 2018, and repeated on 17 August 2020.

- **The Philippines**

The Philippines has a tropical maritime climate that is usually hot and humid. There are three seasons: a hot, dry season or summer from March to May; a rainy season from June to November; and a cool, dry season from December to February. The southwest monsoon lasts from May to October and the northeast monsoon from November to April. Temperatures usually range from 21 ℃ (70 ℉) to 32 ℃ (90 ℉). The coolest month is January; the warmest is May.

The average yearly temperature is around 26.6 ℃ (79.9 ℉). In considering temperature, location in terms of longitude is not a significant factor, and temperatures at sea level tend to be in the same range. Altitude usually has more of an impact. The average annual temperature of Baguio at an elevation of 1,500 meters (4,900 ft) above sea level is 18.3 ℃ (64.9 ℉), making it a popular destination during hot summers. Annual rainfall measures as much as 5,000 millimeters (200 in) in the mountainous east coast section but less than 1,000 millimeters (39 in) in some of the sheltered valleys.

Sitting astride the typhoon belt, the islands experience 15-20 typhoons annually from July to October, with around nineteen typhoons entering the Philippine area of responsibility in a typical year and eight or nine making landfall. The wettest recorded typhoon to hit the Philippines dropped 2,210 millimeters (87 in) in Baguio from July 14 to 18, 1911. The Philippines is highly exposed to climate change and is among the world's ten economies that are most vulnerable to climate change risks.

- **Indonesia**

Indonesia lies along the equator, and its climate tends to be relatively even year-round. Indonesia has two seasons, a wet and a dry season, with no extremes of summer or winter. For most of Indonesia, the dry season falls between May and October, with the wet season between November and April. Indonesia's climate is almost entirely tropical, dominated by the tropical rainforest climate found on every large island of Indonesia. More cooling climate types exist in mountainous regions that are 1,300 to 1,500 meters (4,300 to 4,900 feet) above sea level. The oceanic climate (Köppen Cfb) prevails in highland areas adjacent to rainforest climates, with reasonably uniform precipitation year-round. In highland areas near the tropical monsoon and tropical savanna climates, the subtropical highland climate (Köppen Cwb) is prevalent with a more pronounced dry season.

Some regions, such as Kalimantan and Sumatra, experience only slight differences in rainfall and temperature between the seasons, whereas others, such as Nusa Tenggara, experience far more pronounced differences with droughts in the dry season and floods in the wet. Rainfall varies across regions, with more in western Sumatra, Java, and the interiors of Kalimantan and Papua and less in areas closer to Australia, such as Nusa Tenggara, which tends to be dry. The almost uniformly warm waters that constitute 81% of Indonesia's area ensure that land temperatures remain relatively constant. Humidity is quite high, at between 70% and 90%. Winds are moderate and generally predictable, with monsoons usually blowing in from the south and east in June through October and from the northwest in November through March. Typhoons and large-scale storms pose little hazard to mariners; significant dangers come from swift currents in channels such as the Lombok and Sape straits.

- **China**

Eastern China has a monsoon climate (which can also be divided into subtropical monsoon climate, temperate monsoon climate, and tropical monsoon climate), northwestern China has a temperate continental climate, and the Qinghai-Tibet Plateau has an alpine climate. From the temperature zone division, there are tropical, subtropical, warm temperate, middle temperate, cold temperate, and Qinghai-Tibet Plateau zones. From the division of dry and wet areas, there are humid, semi-humid, semi-arid, and arid areas. Moreover, the same temperature zone can contain different wet and dry areas; the same wet and dry area contains different temperature zones. Therefore, within the same climate type, there are also differences in the degree of heat and wet and dry. The complexity and diversity of the terrain also add to the complexity and diversity of the climate. It is the most severely affected economy.

(2) Available climatic resources

For the particular application area of emergency disaster relief building, the building type is more complex than traditional building in the design of technology integration, simple, practical, lightweight, and other restrictions become a vital reference and influence basis when screening technology.

After the 1970s, the problem of water scarcity brought on by global urbanization became increasingly severe, and European economies and Japan began to pay attention to water conservation-related research, and many advanced technologies and mature measures were proposed for water conservation in buildings and rainwater resource conversion programs began to be focused. Since 1980, the International Rainwater Harvesting Systems Association (IRCSA) has been established, and rainwater utilization has developed towards multi-objective and comprehensive technologies. At present, the world organizations related to rainwater utilization research and technology are relatively loose, among them the Water and Sanitation Health Program in the United States, the National Center for Rainwater Harvesting and Sanitation in The Hague, the Intermediate Technology Development Organization in the United Kingdom, and more recently the International Rainwater Harvesting Systems Application Consortium have publications promoting the development of rainwater harvesting systems applications, and the International Rainwater Harvesting and Utilization Congress has conducted many studies on rainwater utilization and water in buildings[32].

Areas with abundant rainwater can use small water collection and purification devices to provide the victims with the necessary drinking and living water. Through the multi-functional rainwater storage facilities upstream and downstream equipment and facilities integration optimization, reasonable collocation, each other to take a more appropriate structure form combined, the formation of a reasonable element composition, mutual advantage complementary, mutual matching organic whole, to produce a more critical role. Germany is the global urban rainwater utilization technology developed one economy in 1989 on the introduction of rainwater utilization facilities standards. In the early 2000s, in Germany, in terms of integrated equipment, finished products could complete rainwater interception, storage, filtration, infiltration, lifting, etc. As a large number of complete sets of rainwater utilization equipment in the market achieved good environmental and social benefits the rainwater system has been well-controlled and used.

In today's society, especially in rescue and disaster relief and post-disaster resettlement, whether it is a rescue, communication tools, or construction and maintenance of mechanical equipment, the power supply system is one of the indispensable "lifelines". The traditional field emergency power supply system relies on oil generators to generate electricity, which not only consumes a lot and pollutes seriously, but also has complicated conditions in disaster areas and inevitably obstructed roads. Therefore, in designing disaster relief shelters and related products, it is imperative to incorporate technologies that can supply sufficient and stable electricity at all times in the shelter itself. Photovoltaic technology can be utilized in areas with abundant solar energy resources. Solar photovoltaic technology, whether it is to create a site near the rescue point to centralize the arrangement of photovoltaic systems or the integration of power generation systems to the

[32] Che Wu, Li Junqi. The current situation and trend of urban rainwater utilization from the 10th International Conference on Rainwater Utilization[J]. Water & Wastewater Engineering,2002(03):12-14.

roof of a single shelter, can be more convenient for the occupants of the unit and the region to solve the problem of electricity, especially thin film photovoltaic power generation technology in the outdoor cloudy day under the low light environment can still have good power generation efficiency, so its application areas and scenarios are more extensive.

(3) Waste disposal

To remove construction waste in earthquake-affected areas should be classified and transported. Domestic garbage in damaged buildings, biological pollutants, infectious pollution sources, toxic and hazardous dangerous chemicals, and other particular garbage should be separated and then diverted with the cooperation of relevant departments and transferred and treated separately promptly according to relevant regulations and standards. For construction waste containing or suspected of infectious biological pollutants, infectious sources of pollution, difficult to separate, should determine the regional scope, disinfection treatment under the guidance of health epidemic prevention personnel, be sent to the sanitary landfill zoning disposal. Damaged ancient buildings and traditional dwellings and other remnants of conservation value should be in cooperation with the competent administrative departments of cultural relics, according to the authenticity of the value carried, integrity, and reusability of the classification of cleanup, as far as possible to retain and protect the reusable, carrying traditional material characteristics and traditional craft information components. When cleaning up construction waste, it is appropriate to sort and ship slag, waste brick and tile, waste concrete, waste wood, waste steel, etc., and sort and pile them up after transporting them to the disposal site. For mixed shipments of construction waste, after unloading to the disposal site, can be sorted by the relevant departments as needed.

2.3 Other applicable scenarios

Rural tourism has long been a novel form of travel in developed economies in Europe and the United States. The modern industrial revolution has made cities lively and noisy and life flat and fast, so people have chosen to travel to the emerging rural area and undertake rural tourism. The development of transportation facilities improved the transparency between cities and towns, and European economies and the United States became early regions for rural tourism. At the end of the last century, British scholar Lawn B (1994) argued that rural tourism is based on a pleasant and beautiful natural landscape with traditional, rustic, and natural characteristics. Lane (1994) argued that pure rural tourism has the following characteristics: (1) tourist activities are located in the rural area, with an open view, closely related to nature, and activities with local cultural traditions of the rural area; (2) both in the activity area and accommodation, the scale is rural; (3) social structure and culture change slowly, rich in tradition, rural tourism is mainly under local control; (4) the complexity and diversity of the rural economy and the geographical environment in which the rural area is located, as well as the rural area has a history and culture, making rural tourism has different types. Inskeep (2004) has a different opinion on the classification of rural tourism. He believes there is no difference between agritourism, rural tourism, and leisure tourism, and that they are substitutes for each other. In summary, due to the complexity and diversity of rural tourism, foreign scholars and experts do not define the concept of rural tourism in the same way. However, they agree that rurality is a cultural characteristic. The region's rurality is an essential basis for attracting tourists to rural tourism and a meaningful way to distinguish rural tourism from other tourism. Compared to the lifestyle, culture, etc. that people in big cities are frequently exposed to, rural tourism has a different cultural milieu.

Japan's rapid development of rural tourism has attracted much attention. Japan was an early adopter of rural tourism, starting in the 1960s. With the economic take-off, affected by the fast-paced work pressure in the city, the Japanese people who work at all times are in dire need of a soothing environment to relax and cultivate their emotions, and it is in this context that Japanese rural tourism arose. Early Japanese rural tourism in the form of a B&B business model open to snow slide tourists, this period of rural tourism in a single mode, later in the 1960s to 1970s Japan's rapid economic development in the decade, domestic income continued to increase, people are no longer satisfied with a single ski tourism B&B model, with the paving of the road, many farmers in the rural area will be their land into Golf courses, ski resorts and other models to attract more tourists, and in 1970 the suburban farm tourism close to 2,800. By October 1973, the complex international situation and Japan's domestic financial bubble ended Japan's rapid economic development, urban and rural residents' incomes continued to expand, and the rural economy faced a decline and weakening, at this time the Japanese government through policy to guide and encourage the development of domestic rural tourism. In 1971, the Ministry of Agriculture, Forestry and Water Resources launched the "Nature Leisure Village" campaign to promote rural tourism, and from 1980 to 1990, Japan's domestic land development boom spread from the cities to the rural area with rural residents expressing rural products directly to the cities and urbanites farming in the rural area to bring them a cultural experience different from that of the cities. In 1992, the Japanese Ministry of Agriculture, Forestry and Water Resources published a report on "Green Travel", which translates into Chinese as green tourism, a way for urban residents to travel deeper into the rural area to experience natural scenery and humanistic landscapes at a slower pace. This report is the first time the Japanese government formally proposed the concept of green tourism, marking a new chapter in Japanese rural tourism. Based on the above, we can see the development of rural tourism in Japan, and we can also see that the development of rural tourism is inseparable from the scientific and benign guidance of the Japanese government. The government has formulated various policies for the benefit of the people, which can effectively promote the exchange between urban and rural areas and between tourism practitioners and rural areas.

China's rural tourism was born in 1950 and has developed rapidly since 1998, when the National Tourism Administration launched the "98 China Rural and Urban Tour". There are many perspectives on rural tourism in China. According to He (2001), rural tourism is the sum of phenomena and relationships arising from tourism consumption behavior, and it is based on all the tourism resources that attract tourists in rural areas to meet various tourism needs, such as tourism, leisure, vacation, learning and shopping. Wang Xi (2006) considers rural tourism as a tourism activity covering rural areas whose tourist destinations are the natural environment and man-made objects of the rural area. Zhang Zuqun (2014) argues that the rural area is natural, productive, and fragile and that the culture of the rural area can have a significant impact on tourists' choices and meet the experiences that people need in rural tourism, which is the main reason for generating rural tourism. The intrinsic essence of rural tourism is the folk culture of the rural area. Attention should be paid to strengthening a strong rural culture in rural tourism development, not simply rural economic development and rambling rural culture, but rural culture on the rural economy.

Chapter 3 Assessment of Climate Adaptation: Solar-Powered Emergency Shelter in Cold Climate

The winning design of the Solar Emergency Shelter Solutions Competition (EWG 22 2015A), which incorporates cutting-edge thin-film photovoltaic technology into the modular design of the shelter, is evaluated in this chapter for its climate adaptation while taking into account the need for transportation, erection, and living comfort. The findings demonstrate two ways to improve interior comfort: one is to raise the enclosure's tightness through thermal insulation. Particularly in the area where the ventilator is attached to the room, the fan seeks to remove more hot air, improving the efficiency of indoor ventilation. The other is to increase the interior ventilation rate adequately. Attention is given to opening windows to enable passive technologies such as natural convection between internal and exterior spaces. Active ventilation technology is introduced when the criteria cannot be reached. Moreover, reducing the influence between components, reducing loss, lowering the temperature, and avoiding occlusion are the key focuses of optimizing solar capacity characteristics.

3.1 Geometrical model of Solar-Powered Emergency Shelter

Design concept: the scheme is created for rapid unfolding and folding design, comparable to a book, and can be folded, assembled, and carried swiftly. Folded transportation ensures batch and quick transit efficiency while saving space. When arriving at the destination, it may be swiftly carried out and installed with little need for the site other than what is necessary to guarantee the proper operation of the solar system and minimal technical requirements for people and material resources. Fig.3.1 depicts the folding process.

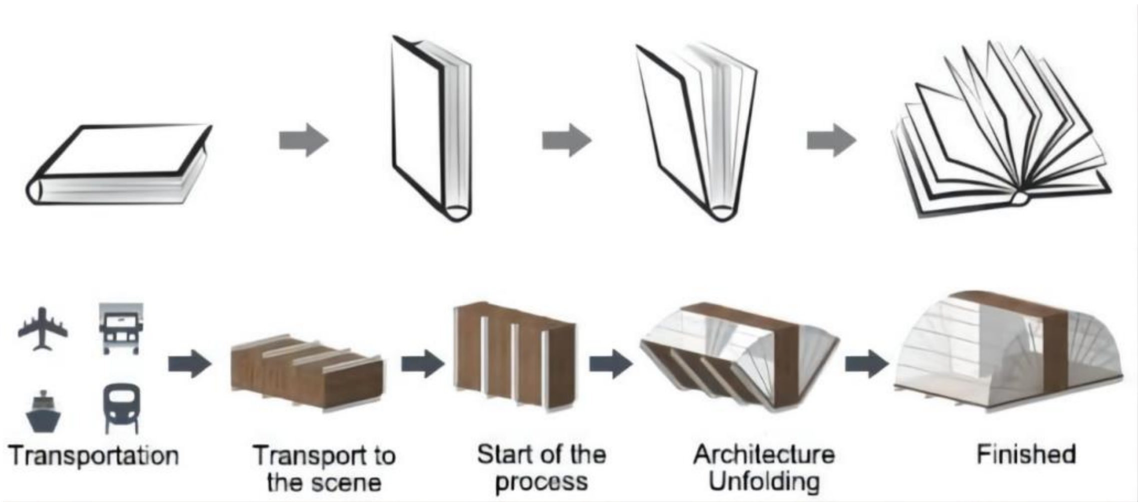


Fig.3.1 Generation of shelter space

(Source: APSEC)

Space size: the space can basically guarantee the residence of four people. The design size is 6m × 4m × 2.4m after opening and 4m × 1m × 2.4m after folding. Based on this, a 2:1 scale model is built, and the size is 3m × 2m × 1.2m after opening and 2m × 0.5m × 1.2m after folding.

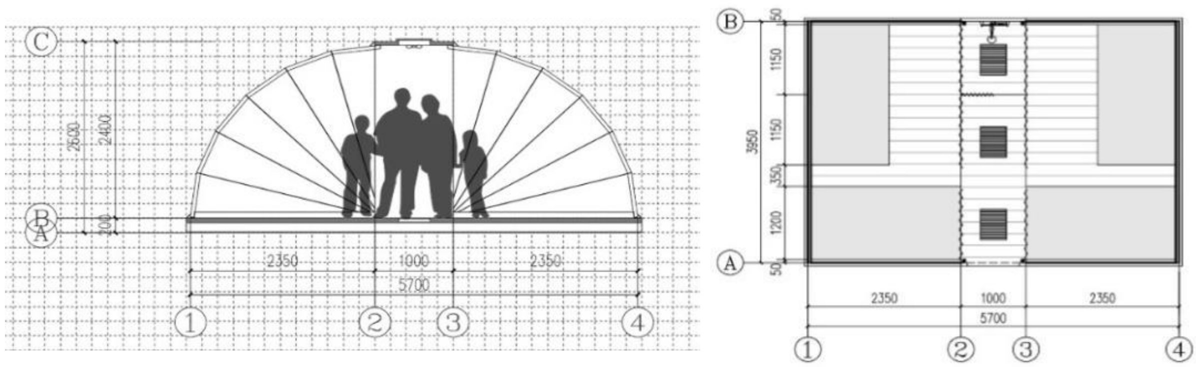


Fig.3.2 Dimensional drawings of small-scale shelters

(Source: APSEC)

Material and construction: The chosen panels are sandwiched insulation panels that are 50mm thick, consisting of two layers of 0.5mm color steel plates and a center layer of 50mm thick polystyrene foam. At the factory, the panels were created and cut in accordance with the design specifications. The finished products consist of two pieces measuring 2000mm × 590mm × 50mm for the top and bottom of the shelter, two pieces measuring 1100mm × 590mm × 50mm for the building's wall, one of which has a cutout for a doorway measuring 900mm × 400mm, and two pieces measuring 2000mm × 1150mm × 50mm for the shelter's opening and closing surface, which is unfolded for the floor of the shelter and it closes to form a complete box. Finally, 50# C-type aluminum was added to the panels' perimeter to increase their structural integrity.

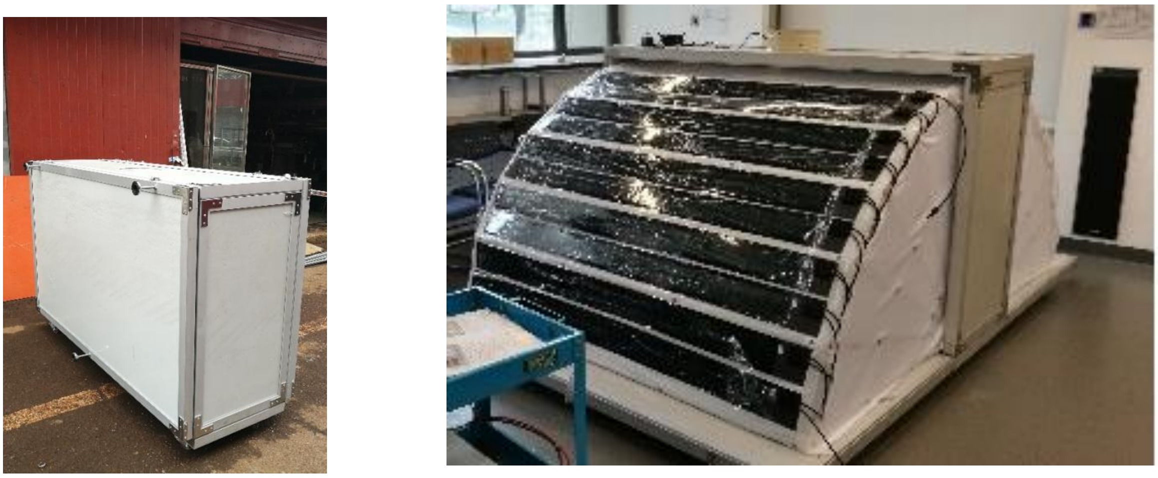


Fig.3.3 Paving process of flexible thin film photovoltaic

(Source: APSEC)

Fig. 3.4 Experimental test platform

(Source: APSEC)

3.2 Indoor comfort related to ventilation

From 14:00 to 17:00 on September 3, SPES was placed in Tianjin, China, and its indoor comfort was tested. The DT-172 temperature tester is placed at a height of about 10 cm at the middle and bottom of the building. After the internal temperature of the building is stable, the air exchange rate experiment begins at 15:00. The air exchange port of the fan is a round mouth with a diameter of 265 mm, and the air exchange rate is from 0.1 m^3/s to the maximum 0.7 m^3/s. The corresponding wind speeds at the fan outlet are 1.814 m/s, 3.628 m/s, 5.442 m/s, 7.256 m/s, 9.070 m/s, 10.884 m/s, and 12.698 m/s, respectively. The interval between each change of wind speed is 15 minutes. After the indoor temperature is stable, the wind speed data and motor power are recorded, and the next wind speed is adjusted.

At the air exchange rate of 0.5 m^3/s, the wind speed is 0.39~0.62 m/s at the indoor elevation of 0.2 m in the middle of the building, 0.53~0.90 m/s at the elevation of 0.5 m, 1.25~1.40 m/s at the elevation 1 m; the wind speed is 0.03~0.09 m/s at the indoor elevation 0.2 m in the middle of both sides of the building, 0.15~0.24 m/s at the elevation 0.5 m, and 0.06~0.15 m/s at the elevation 1 m. According to the summer comfort air conditioning, indoor wind speed should not be greater than 0.25 m/s. Under the summer comfort air conditioning, indoor wind speed should not be greater than 0.25 m/s. The highest wind speed in the living space on both sides of the building is 0.24 m/s to meet the comfort requirements.

Based on the experimental data, the simulation under more representative weather conditions is carried out by software. According to the Design Code for Heating, Ventilation and Air Conditioning in Civil Buildings GB50736-2016, the minimum fresh air volume for living space in public buildings is 30 m^3/(h-people), so the minimum ventilation rate of the building is set at 0.0083 m^3/s in the ventilation option to ensure that it is consistent with the minimum infiltration fresh air volume entering through building gaps, etc. in practice.

The natural fan ventilation method chooses the fan to exhaust air to the outside to ensure that the incoming air direction comes from the openings and gaps around the building to avoid the occurrence of highly concentrated wind speed in certain areas caused by the fan's incoming air and to ensure the freshness of indoor air and the comfort of the wind environment. The ventilation rate of the fan ranges from 0 m^3/s to 0.7 m^3/s, with an equal progression in the interval of 0.1 m^3/s. Because the role of the fan is to ventilate and dissipate heat indoors in a hot climate, the simulation is carried out by selecting the climate data of the two days of the summer solstice and autumn equinox, which are more representative of the Tianjin area, respectively. At a fan ventilation rate of 0 m^3/s, the time of the day with the most significant difference between indoor and outdoor temperatures was selected to simulate the effect of different ventilation rates on indoor temperature changes.

In the case of a fan ventilation rate of 0 m^3/s, according to the simulation results, the maximum ambient temperature of the site on the summer solstice is 16:00, the temperature is 31.94 ℃, and the maximum temperature difference between indoor and outdoor is 28.61 ℃ and 34.73 ℃ at 13:00, the temperature difference is 6.12 ℃; the maximum ambient temperature of the site on the autumn equinox is also 16:00, the temperature is 31.03 ℃, and the maximum temperature difference between indoor and outdoor is 25.09 ℃ and 31.90 ℃ at noon, the temperature difference is 6.81 ℃. Noon indoor and outdoor temperature difference reached the maximum outdoor 25.09 ℃, indoor 31.90 ℃, the temperature difference of 6.81 ℃. Next, the optimal air exchange rate was obtained by simulating the time point with the maximum temperature difference between the two days.

The ventilation rate of the fan changes from 0 m/s to 0.7 m/s and progresses with an equal difference in the range of 0.1 m/s. Through the comparison of several groups of simulation data, it can be seen that the temperature change of the two solar terms tends to be stable when the ventilation rate is 0.5 m^3/s, and the daily temperature difference is 0.45 ℃ for the Summer Solstice and 0.50 ℃ for the Autumn Equinox. At this time, according to the rated operating power of the actual fan 50 W, the air exchange rate of 0.5 m^3/s is about 72% of that of 0.69 m^3/s under full load, and the operating power is about 36 W, and the power consumption of the next day is 0.86 kWh. Plus two 8 W LED lights, assuming that a day is used only at night for a total of 6 hours, the daily power consumption is 0.096 kWh, with a total consumption of 0.960 kWh.

3.3 Thermal environment of Solar-Powered Emergency Shelter

On September 8, the indoor thermal environment of SPES was experimentally tested. Eleven thermocouples are suspended and arranged indoors to detect whether the indoor temperature distribution is uniform. The detection position is divided into three parts: the south area with flexible thin-film photovoltaic, the north area without photovoltaic, and the middle area of the box part. The height of the measuring point is 0.2 m at rest, 0.5 m in a sitting position, and 0.8 m at the top of the building. Because the entrance door is arranged on one side in the middle area of the box part, the measuring points are set at the height of 0.6 m at the near door and the far door, respectively. Thermocouples choose materials with low thermal conductivity to avoid temperature data errors caused by heat transfer.

Fig. 3.5 Schematic diagram of measuring point layout

(Source: APSEC)

The indoor fan ventilation rate will be 0.5 m^3/s, and the testing times will be from 5:00 to 19:00 for the meteorological data, 5:30 for sunrise, and 18:30 for sunset, respectively. The testing times will also be from 6:00 to 18:00 for the PV surface temperature and the indoor temperature distribution.

During the test, the solar radiation detection instrument was placed horizontally. The PV side of SPES was facing south. The outdoor ambient temperature was 21.7~30.6 ℃ , reaching a maximum at 13:05, and the irradiance reached a maximum of 926 W/m^2 at 12:50. Cloudy weather appeared from 13:00 onwards, with large fluctuations in irradiance values due to occasional cloud shading. As the flexible thin film photovoltaic is irradiated by sunlight and heat is generated in the power generation process, the heat is transferred directly to the room through the connected polytetrafluoroethylene (PTFE) film.

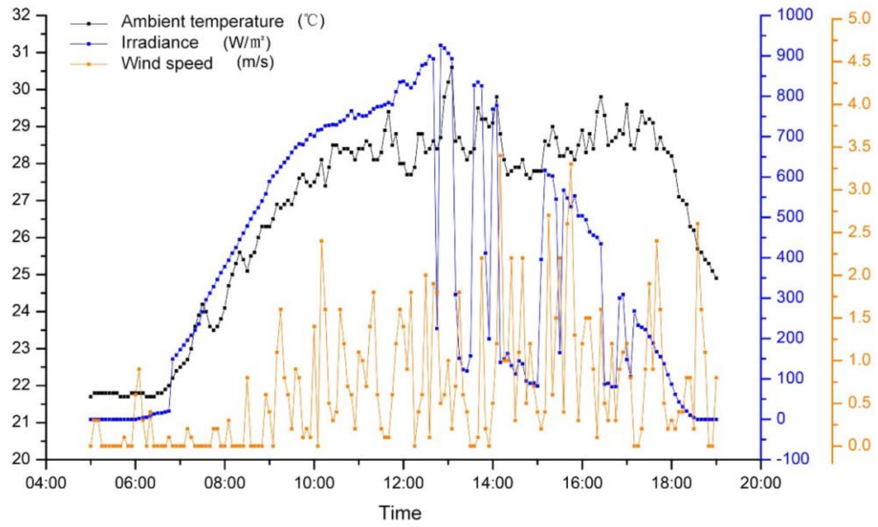


Fig. 3.6 Meteorological conditions on the day of the experiment

(Source: APSEC)

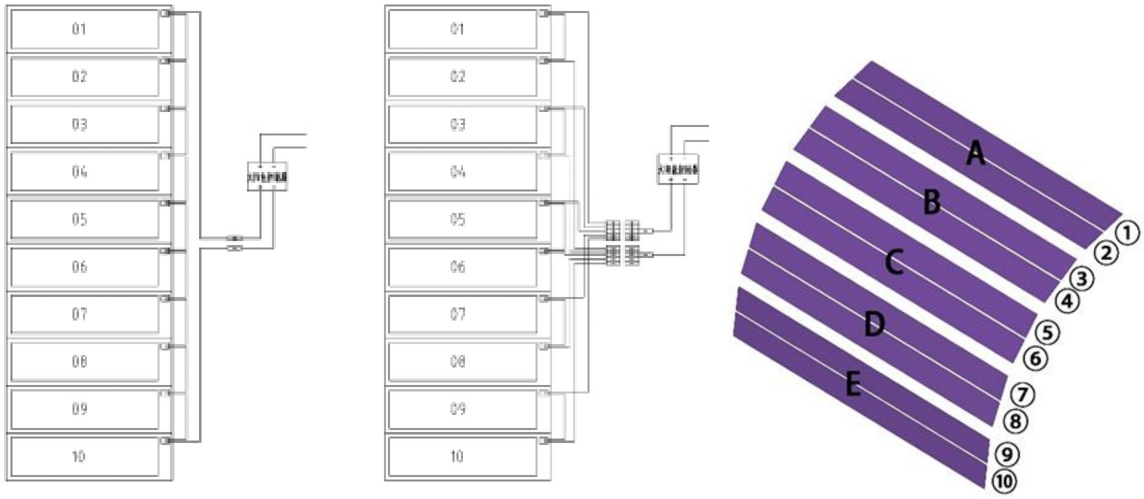
During the experiment, the temperature of the indoor side surface and the front and back sheets of flexible photovoltaic were measured. In the beginning, the temperature values of the three are close. However, the overall temperature increases gradually with exposure to sunlight and the process of photovoltaic power generation. However, the overall temperature of the backplane, indoor surface, and panel are high to low. Photovoltaic backplane affixed directly to the outer surface of SPES leads to no effective heat dissipation, which makes the heat generated by power generation be transmitted directly to the indoor surface of the building and further radiate to the indoor air, resulting in a rise in indoor temperature.

Through the distribution of the temperature detection points, it can be seen that the temperature distribution on the south side of the building is uneven due to the ample solar radiation in the south and the heat input in the process of photovoltaic power generation. The overall temperature of the three temperature measurement points on the south side is higher than that of the three on the north side. Due to the rise of hot air flow, the temperature trend at both ends increases with the height of the temperature measuring point. The temperature difference between the 0.8m temperature measurement point in the south and the 0.2m in the north reaches the maximum at 8:30 and 13:00, respectively. The temperatures of the two-time points are 27.5 ℃, 24.0 ℃ (0.8m) and 34.1 ℃, 30.5 ℃ (0.2m), respectively, and the temperature differences are 3.5 ℃ and 3.6 ℃, respectively. However, the temperature data in the middle area are different. Because the ventilator is located directly above the middle area, there is no apparent increase in temperature with height at the beginning, and the temperature in the lower part is occasionally higher than at the top. However, as the temperature increases, the hot air on both sides converges upward. The temperature value of the temperature measuring point at the height of 1 m and 0.6 m is higher than that at 0.2 m. However, the ventilator makes the middle of the fan's wind speed quicker; thus, the temperature at 1 and 0.6 meters is always in a relative value condition. Due to the need for additional ventilation on the side of the middle area, the door is always open. The temperature difference between the 0.6 m measuring points on both sides of the near and far door changes obviously during the one-day test. At 12:30, the maximum temperature difference between the two is 3.6 ℃, the temperature near the door is 29.2 ℃, and the temperature at the far side is 32.8 ℃.

3.4 PV system performance

For the power generation characteristics, experiments on the power generation characteristics of PV modules were also conducted on September 8 and September 9. The overall power generation characteristics and total power generation of PV modules under series connection conditions were tested on September 8, and the comparison of PV power generation efficiency and the photoelectric conversion efficiency and I-V curves of five groups of flexible thin film PVs with different angles were tested on September 9 under both series and parallel connection methods.

According to the test results from September 8, the sun rose at around 5:30, the flexible thin-film PV began to produce electricity, the morning was clear, and the PV power generation increased with the sun's irradiance; at around 13:00 and 14:00, however, there was a slight fluctuation because of cloud cover shading, and at around 15:00 there was an increase in clouds and a longer period of shading, which resulted in a significant drop in the PV power generation efficiency. According to calculations, PV generates roughly 0.811 kWh of electricity per day. If the afternoon cloud cover were excluded, the theoretical power generation would be higher than the detection data.



Series connection Parallel connection

Fig. 3.7 Schematic diagram of flexible thin film PV grouping

(Source: APSEC)

In the test on September 9, every two PV modules with the same tilt angle were combined into one group, divided into five groups for the experiment, and tested the PV power generation power of ten modules connected in series and five groups of modules connected in parallel, the test time was from 9:00 to 15:00, every hour, and finally, by comparing the results of different moments, it can be seen that in the morning and afternoon when the solar irradiance is low, the PV power generation power of series-parallel connection is significantly greater than that of series connection, and the greatest increase in the test was at 9:00, reaching 18.2%; while around noon when the solar irradiance is high, the difference between the PV power generated by series and the parallel connection is reduced, but still, the parallel connection is greater than the series connection, and the minimum increase after changing the method is 11:00, increasing by 1.5%. The reason for this result is that the solar irradiance in the morning and evening is low, and the resistance of PV increases with the reduction of light intensity, resulting in a larger resistance of flexible thin film PV by irradiance, the resistance change of one module in series connection will have a greater impact on the overall power generation, and the impact under parallel connection is much smaller than the series connection.

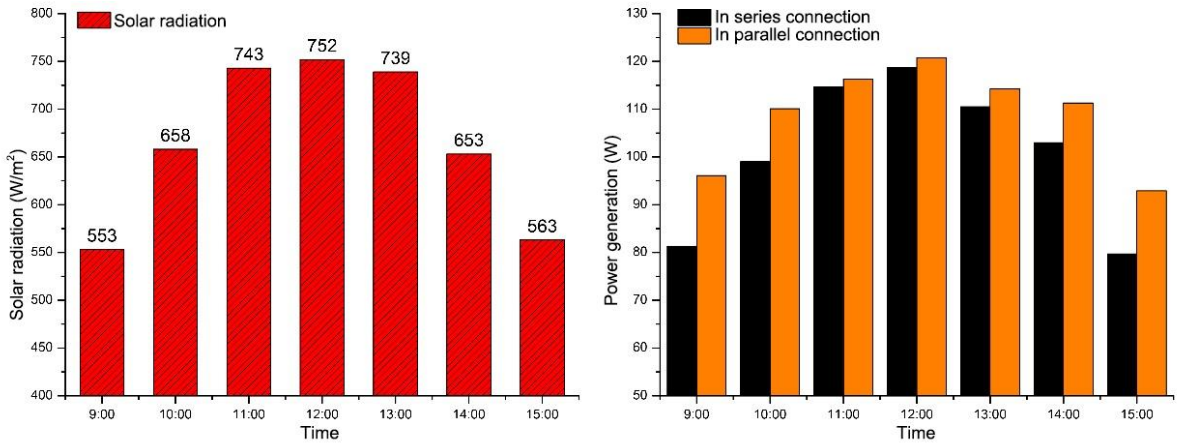


Fig.3.8 Comparison diagram of solar irradiance and series and parallel power

(Source: APSEC)

This conclusion can also be learned from the I-V curve test results of the two connection methods. Taking the noon solar radiation as an example, due to the different radiance of the flexible thin-film PV on the unfolded surface, the series connection method has an unsmooth curve due to the large influence between the modules, while the parallel connection method has less influence, so the I-V curve is smoother.

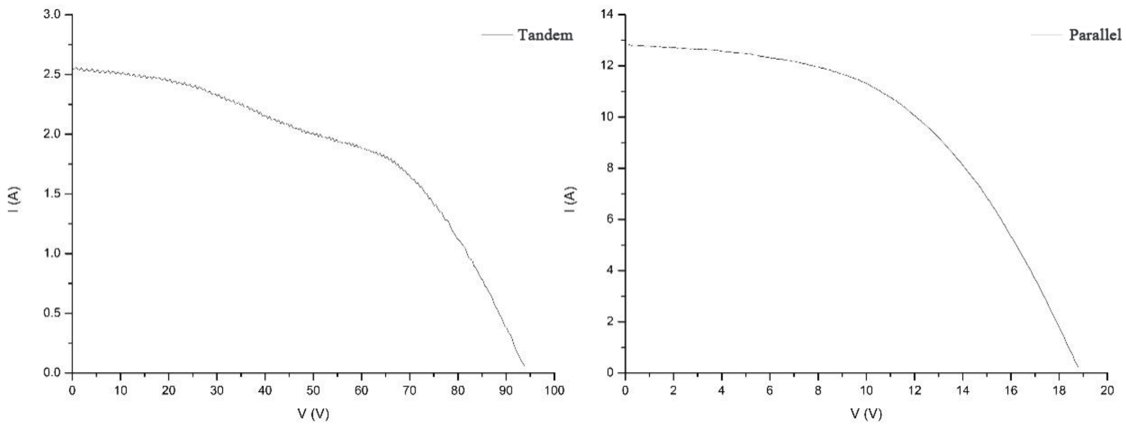


Fig.3.9 Series and parallel I-V curve test diagram

(Source: APSEC)

The experimental test of photovoltaic conversion efficiency, also with the more stable solar radiation at noon, for example, the five groups of photovoltaic modules were disassembled for separate testing while detecting the temperature of each group of module panels and back sheets, according to the official material data provided by Hanergy shows that the photovoltaic conversion efficiency of its flexible thin-film photovoltaic modules is 15%. While the actual test results show that, although the photovoltaic power generation is also greater with the enhancement of solar radiation, the photoelectric conversion efficiency is affected by the temperature, plus the energy loss on the wire, the actual measured maximum is 10.7%.

3.5 Energy performance

The energy end of the SPES is relatively simple, in addition to the fan used for indoor ventilation, in the rescue situation necessary for lighting lamps at night, the fan with the best ventilation rate is 28.58 W, assuming that in hotter climates for the whole day operation, then the power consumed a day is 0.69 kWh, in addition to two 8 W energy-saving lamps for night lighting, the open time is about 6 h, then the power consumption of a day is 0.096 kWh, a total of 0.786 kWh, according to the climate conditions of September 8 the power generation is 0.811 kWh, the remaining 0.025 kWh, to meet the demand of energy self-sufficiency.

3.6 Discussion

Through the comparison between the experimental and simulation results, we can see that, first of all, in terms of temperature, the software simulation result is the average indoor temperature in the ideal condition. In the case of simulation, the tightness and heat transfer coefficient are better than the actual situation, so both the ventilation efficiency and the thermal insulation performance are higher than the actual situation. Due to the difference between the design size and the actual size of the building components in the model construction, the gap in each part of the building is large. In particular, the tightness between the fan and the expanded components is poor, and the indoor hot air is not fully discharged to the outside, resulting in a decline in the ventilation efficiency of the indoor fan. The operating power of the fan will decrease after running for a long time. In addition, the thermal bridge effect of metal bars and parts is also a factor leading to indoor temperature rise. The optimization scheme of indoor living comfort can be carried out from two aspects:

- **Thermal insulation increases the tightness of the building.**

  In particular, the part where the ventilator is connected to the room ensures that the fan takes away more hot air and improves indoor ventilation efficiency. Change the outer protective material with lower thermal conductivity to reduce the indoor and outdoor thermal bridge and prevent a large amount of radiant heat from the sun from entering the room. The upper part of the opening and closing bar is covered with a double-layer film structure, and the middle air layer is connected with the outside so that the natural circulation of air can be used to take away part of the radiant heat passing through the first layer of the film and reduce the heat transferred into the room.

- **Ventilation-appropriately increase the indoor ventilation rate.**

  Priority is given to opening windows to enable passive technologies such as internal and external natural convection, and active ventilation technology is added when the requirements cannot be met. While increasing the air exchange rate of the fan, there will be a specific output power requirement for the power supply system. At the same time, it will bring some problems, such as an increase in energy consumption, the excessive speed of indoor air circulation, the increase in fan noise, and so on. Therefore, more experiments should be conducted to compare various ventilation methods to increase ventilation and finally choose a more appropriate scheme.

In terms of energy consumption balance, because the laying of flexible thin film photovoltaic in the design is not all at the same angle, the solar radiation received by photovoltaic modules from different angles is different, resulting in different power generation. The series mode of ten components used in the experiment significantly influences the whole under the condition of low light. The findings of the experiment and the simulation differ slightly because, in the simulation, each component is treated as a single individual for the photovoltaic configuration, meaning that the ten components are linked individually and have no influence on one another. During the experiment, the photoelectric conversion efficiency decreased due to the increase in the temperature of the photovoltaic module, which did not reach 15% of the theoretical value under laboratory conditions, which had an impact on the total amount of photovoltaic power generation. The interference of clouds and shielding is also a factor that cannot be ignored. The appearance of a large area of clouds in the afternoon has a noticeable impact on the total power generation in the experiment. The optimization of photovoltaic capacity characteristics is mainly carried out from four aspects:

- **Reduce the impact between components.**

  In the experiment, by changing the series-parallel connection mode between the components, the total generating power of the components increased by 18.2% after changing the series mode to the parallel mode. If all ten components can be connected to the battery separately, the total power generation will be increased accordingly without being affected by the series-parallel connection between the components.

- **Reduce loss.**

  Not only the connection mode but also the wire's length, the material of the wire, the adapter, etc., will produce corresponding losses in the power transmission process, affecting the final total amount of power generation. When connecting, we should select wires with low resistivity, simplify wires and adapters, etc., to reduce energy loss.

- **Reduce the temperature.**

  The temperature of flexible thin film photovoltaic is one of the factors that affect the photovoltaic conversion efficiency, so attention should be paid to the effect of heat accumulation on the power generation characteristics of the module in the design process. The design of the double-layer film structure enables the air interlayer to take away part of the solar radiation heat absorbed by the photovoltaic module and the heat generated by power generation and can also increase the heat dissipation effect of the module in the back, such as heat sink or water cooling device.

- **Avoid occlusion.**

  In the process of experiment and layout, the open outdoor site should be selected as far as possible, and the side with photovoltaic facing the sun should be placed. In addition to irresistible weather factors such as cloud cover, photovoltaic modules should be avoided from reducing power generation caused by trees and buildings.

Chapter 4 Assessment of Climate Adaptation: Solar-Powered Emergency Shelter in Tropical Rainforest Climate

This chapter examines the thermal and electrical performance of solar-powered emergency shelters (SPES) in the city named Poso with tropical rain forest climate, which is located in Sulawesi Province in Indonesia. The results show that, although the double roof can isolate part of the heat from the top, it improves the indoor thermal environment to a certain extent. However, because the hot air in the interlayer cannot be discharged effectively, the accumulated hot air will still exchange heat with the indoor, so the overall indoor temperature is still high. Ventilation is an efficient method of lowering room temperature. Rapidly lowering the inside temperature can be accomplished by simultaneously opening side windows and doors. Mechanical ventilation can more effectively remove heat from the interlayer, resulting in a decrease in interior temperature. Additionally, evaporative chillers might lower the temperature of the incoming air and improve heat exchange between the photovoltaic system and the air.

Indonesia's climate is a typical tropical rainforest climate. There is no difference between the four seasons, the climatic conditions are stable, and the annual variation is slight. Affected by the monsoon, the rainfall is abundant. The meteorological data file of this chapter comes from the Epw Map meteorological database and uses the meteorological data of Poso in Sulawesi Province for simulation analysis. The annual meteorological conditions are shown in the following figure. It can be seen that the temperature is relatively stable throughout the year, and the monthly temperature fluctuation is slight; the monthly irradiance fluctuates slightly, but the overall change is small.

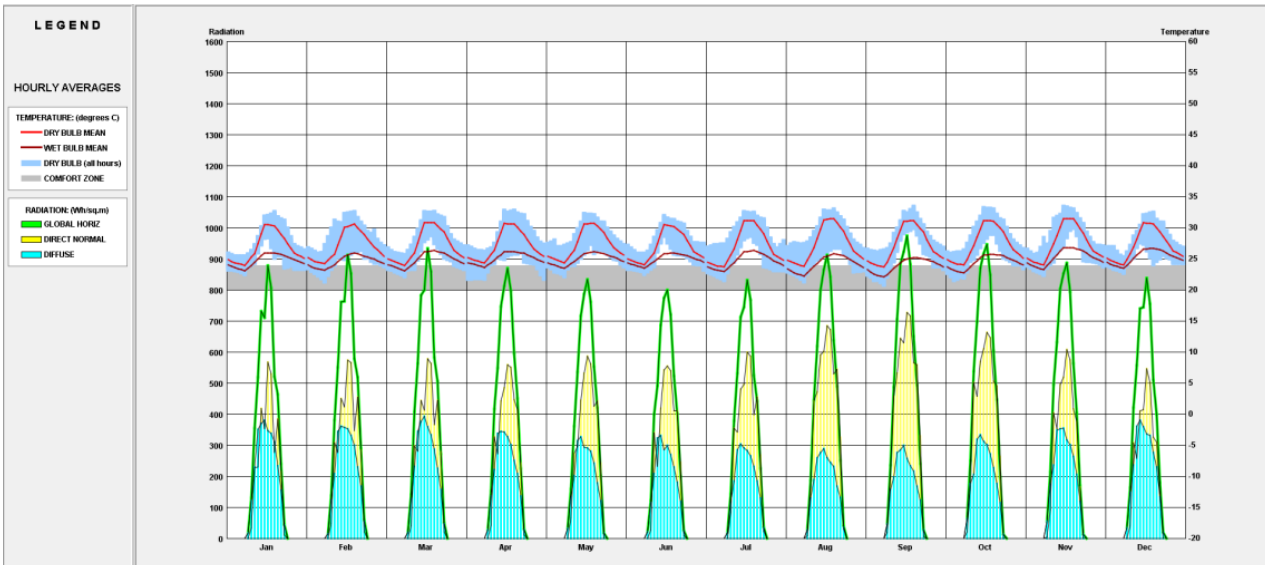


Fig.4.1 Annual meteorological data of Poso

(Source: APSEC)

The subsequent simulations were based on the time-by-time curves of the parameters during one day of the summer meteorological design day in Poso. As shown in Fig.4.1, the temperature range is 22.6-31.2 ℃ during the day, and the temperature increases gradually with the increase of solar irradiance at 6:00, the maximum temperature is 31.2 ℃ at noon, and the temperature decreases gradually after 18:00, the minimum temperature is 22.6 ℃ at 06:00; the solar irradiance range is 0-857 W/m², the maximum irradiance occurs at 12:00, 857 W/m²: The range of solar irradiance was 0-857 W/m², and the maximum irradiance occurred at noon; the range of wind speed was 0-3.6 m/s, with fluctuating wind speed during the day and stable wind speed at night.

4.1 Insulation performance

The indoor temperature monitoring points are shown in Fig.4.2. The simulation results in this chapter mainly monitor 11 indoor point locations. The detection locations are divided into three parts: the south area with flexible film PV attached, the north area without PV attached, and the middle area of the box section. With heights of 0.2 m when a person is resting (south, north, and middle point locations are indicated by s0.2, n0.2, and m0.2). The sitting height is 0.6 meters at three locations: south (s0.6), north (n0.6), and middle point (m0.6). The standing height is 1.7 meters at three locations: south (s1.7), north (n1.7), and middle point (m1.7). Additionally, there are two points located at a height of 0.6 meters on the east (e0.6) and west (w0.6) sides.

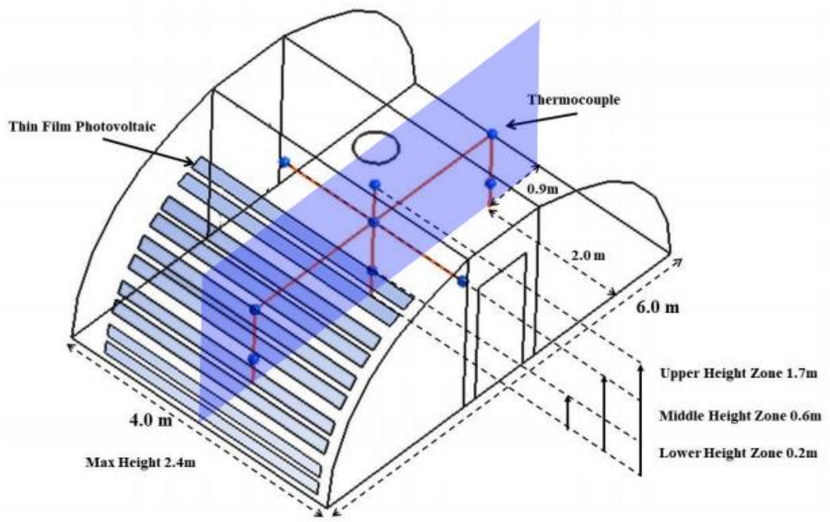


Fig. 4.2 Diagram of monitoring points

(Source: APSEC)

(1) Single-roof

In the closed state, the air temperature inside the SPES model decreases from top to bottom, the shelter's top temperature is up to 64.1 ℃, and the temperature near the ground is 34.2 ℃. This is because the temperature of the inner surface of the model rises rapidly under the action of solar radiation and heat production of the photovoltaic system. Especially on the inner surface of the tent roof on the south side, the temperature is higher than that on the north side, and the heat is transferred from south to north and from top to bottom, which leads to uneven temperature distribution and stratification between the north and the south. The position of the cross-section in the temperature cloud picture is shown in the picture above.

The internal temperature of the single-top model increases gradually with the increase in height, and the temperature in the south and middle is slightly higher than that in the north at the same height. At the height of 0.2 m, the temperatures of the south, middle, and north are 40.7 ℃, 40.6 ℃, and 40.3 ℃, respectively, at 0.6 m, 40.9 ℃, 40.8 ℃, and 40.8 ℃, respectively, and at 1.7 m, the temperatures of the south, middle and north are 45.7 ℃, 45.4 ℃, and 45.0 ℃, respectively. It can be seen that there is little difference in the temperature between the height of 0.2 m and 0.6 m. When the height rises to 1.7 m, the temperature increases more, with an average increase of 4.5 ℃ at each point. At the same time, the ground temperature is 34.2 ℃. Compared with the height of 1.7 m, the average temperature difference of each point is 12.5 ℃, which is equivalent to the head and foot temperature difference of 12.5 ℃ when the human body with a height of 1.7 m stands indoors, which will significantly increase the discomfort of the human body. Overall, under completely closed conditions, the indoor temperature is higher as a whole.

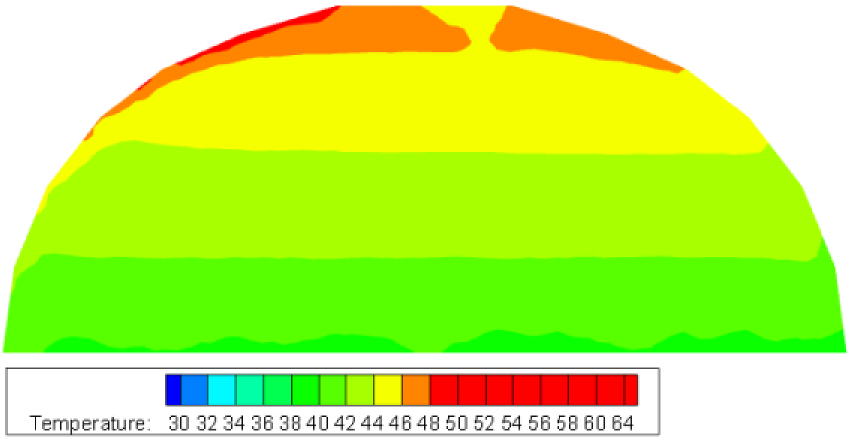


Fig. 4.3 Indoor temperature distribution of single-roof model under the closed condition

(Source: APSEC)

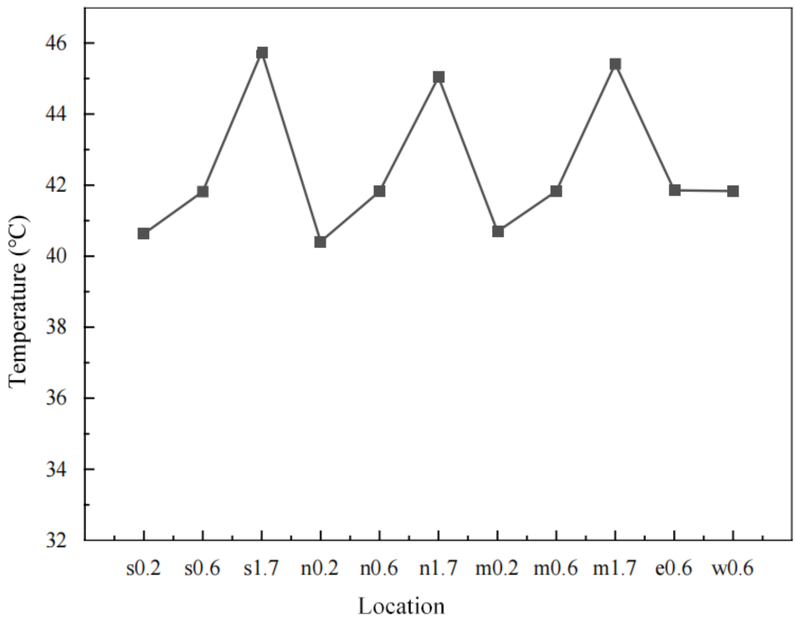


Fig. 4.4 Indoor temperature of single-top model in closed state

(Source: APSEC)

(2) Double-roof

Compared with the single-top model, the green area of the indoor temperature distribution map of the double-top model is enlarged, and the red and yellow areas with higher temperatures are concentrated in the double-top interlayer. This is because the heat from the direct solar radiation and the spontaneous heat generated by the photovoltaic system is isolated in the bimodal interlayer, thus reducing the indoor temperature.

The temperature of the measuring point at the height of 0.2m, 0.6m, and 1.7m of the double-top model decreased by 2.1 ℃, 3.2 ℃, and 5.8 ℃, respectively, compared with the single-top model. The temperature decreased by 3.4 ℃ at the height of 0.6 m in the west and 3.3 ℃ in the east. The average temperatures at 0.2 m, 0.6 m, and 1.7 m are 38.3 ℃, 38.5 ℃, and 39.7 ℃, respectively. Although the double roof can isolate part of the heat from the top, it improves the indoor thermal environment to a certain extent. However, because the hot air in the interlayer cannot be discharged effectively, the accumulated hot air will still exchange heat with the indoor, so the overall indoor temperature is still high.

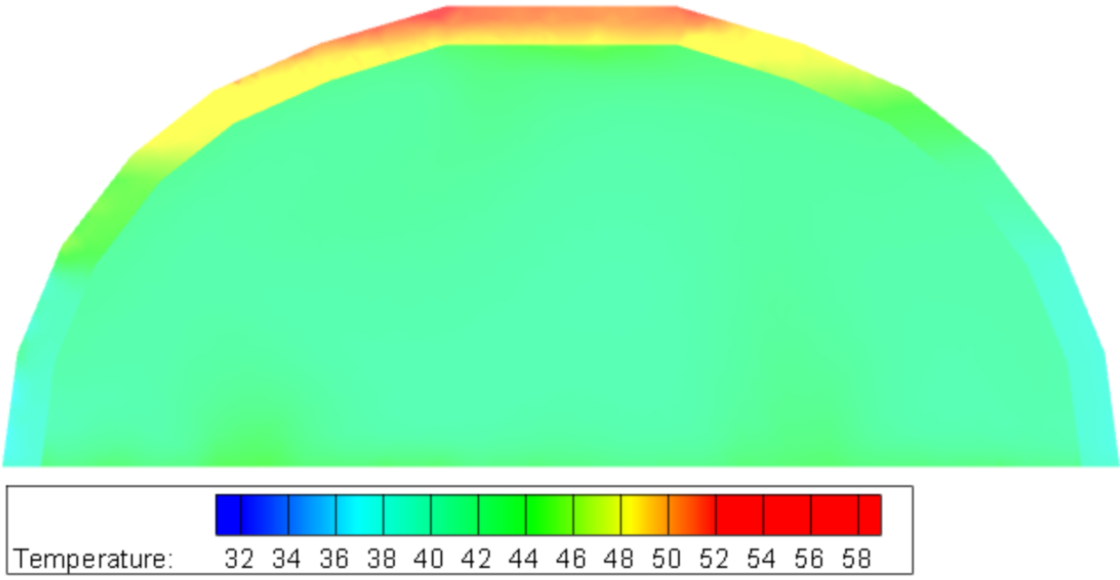


Fig. 4.5 Indoor temperature clouds of double-roof model under closed condition

(Source: APSEC)

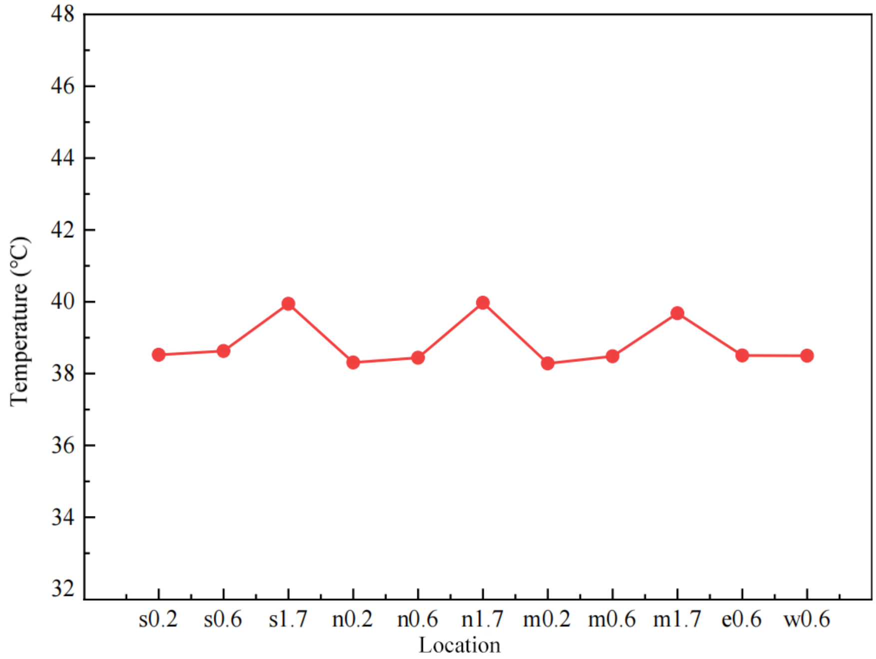


Fig. 4.6 Indoor temperature of double-top model in closed state

(Source: APSEC)

4.2 Natural ventilation

Natural ventilation mainly includes wind pressure ventilation and hot pressure ventilation, both of which can be optimized and improved by improving window conditions. The influence of side windows on the indoor thermal environment is not considered in the original design scheme, which is not conducive to normal indoor ventilation and heat dissipation. The high window is opened on the door's opposite side in the optimization design, and the window-to-surface ratio is set at 0.1. The window position is shown in Fig. 4.7. After opening the window on the opposite side, the single roof model carries on the natural ventilation simulation and opens the door, the top, and the side window. The natural wind enters from the door, the hot air is discharged from the top and side windows, and the instantaneous wind speed is 0.2 m/s. Compare the effect of natural ventilation on indoor temperature before and after opening the side window.

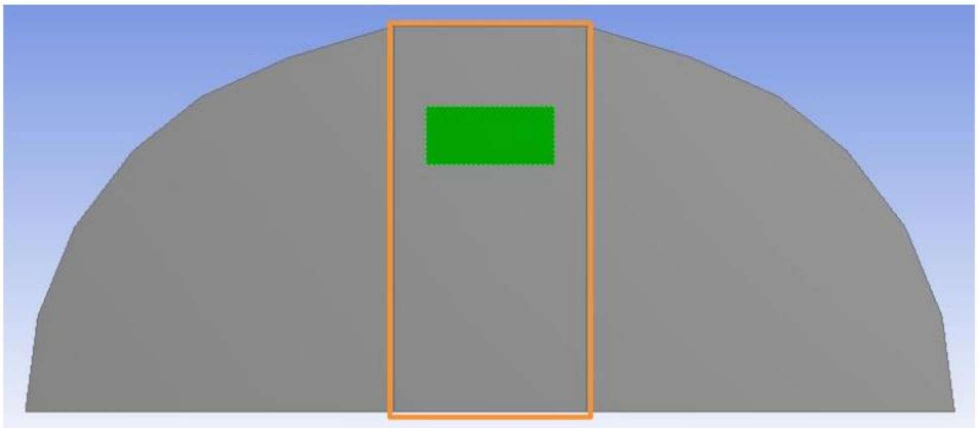


Fig. 4.7 Sketch diagram of the position of the side window

(Source: APSEC)

After opening the window on the opposite side, the indoor temperature at each point decreased significantly compared with that before the opening of the window. This is because, after opening the window on the opposite side, a "through-the-hall wind" is formed between the doors and windows, which made the indoor hot air better discharged and the temperature drop as a whole. The average temperatures at the heights of 0.2 m, 0.6 m and 1.7 m are 32.2 ℃, 32.4 ℃ and 34.5 ℃, respectively. After opening the side window, compared with that in front of the open side window, the three height measuring points decreased by 2.1 ℃, 2.3 ℃ and 3.1 ℃, respectively. The temperature decreased by 1.9 ℃ at the height of 0.6 m in the west and 2.0 ℃ in the east.

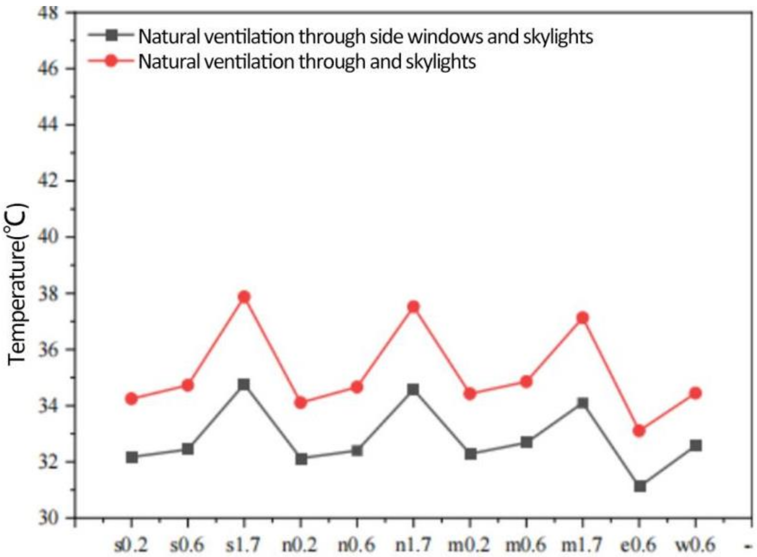


Fig. 4.8 Comparison of indoor temperature at each point of the single-roof model under different natural ventilation modes

(Source: APSEC)

4.3 Mechanical ventilation

The heat accumulation in the double parietal interlayer leads to higher heat in the interlayer. Double-layer ventilation can efficiently remove the heat from the interlayer and subsequently lower the inside temperature, however, natural ventilation's impact varies depending on the outside climate. The fluctuation is significant, and the improvement effect is limited. The top fan is utilized to drive the heat from the interlayer to be released while performing active ventilation. The temperature environment within is then contrasted and examined before and after active ventilation. The top fan, whose exhaust air volume is 0.1 m^3/s, is pushed to discharge the natural wind, which comes through the bottom air entrance of the interlayer of the enclosure construction.

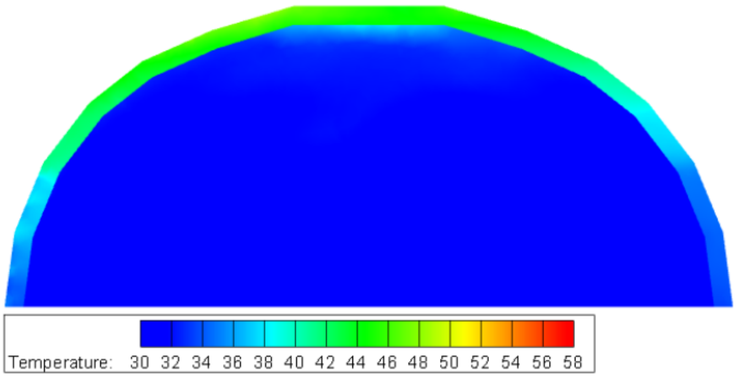
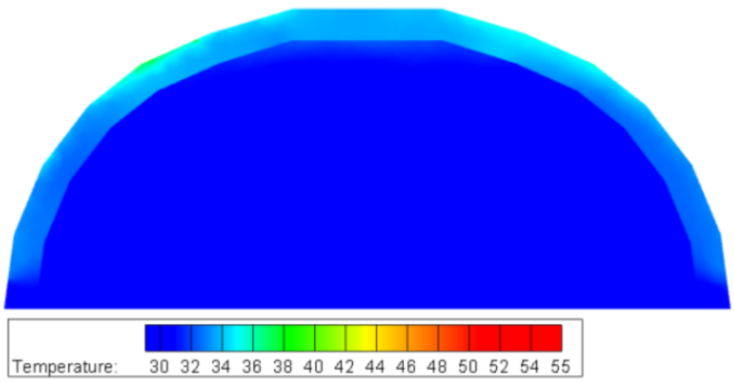


Fig. 4.9 Indoor temperature clouds of the double-roof model under interlayer closure

(Source: APSEC)



4.10 Indoor temperature clouds of the double-roof model under mechanical ventilation mode

(Source: APSEC)

Compared with the model without forced ventilation, the double-top interlayer temperature decreases significantly under mechanical ventilation. The yellowish green area disappears, showing light blue, and the temperature is relatively low. This is because, through interlayer ventilation, the lower outdoor air is replaced with the hot air in the interlayer, which removes the hot air accumulated in the interlayer, thus significantly reducing the air temperature in the interlayer. At the same time, the lower interlayer air temperature carries on the heat exchange with the indoor, which further reduces the indoor air temperature and improves the overall temperature.

The indoor temperature of each point fell overall under the double-roof interlayer mechanical ventilation condition as compared to the interlayer closed state. The average temperature of three places at 0.2 m, 0.6 m, and 1.7 m heights was reduced by 1.8 ℃, 2.6 ℃, and 2.3 ℃, respectively, under mechanical ventilation. At 0.6 m in the west and east, the temperature dropped by 2.0 ℃ and 2.7 ℃, respectively. The average temperatures are 32.6 ℃, 32.7 ℃, and 33.2 ℃ at heights of 0.2 m, 0.6 m, and 1.7 m, and the temperature difference between indoor and outdoor is further diminished. The internal thermal climate can be improved more using double-roof interlayer mechanical ventilation.

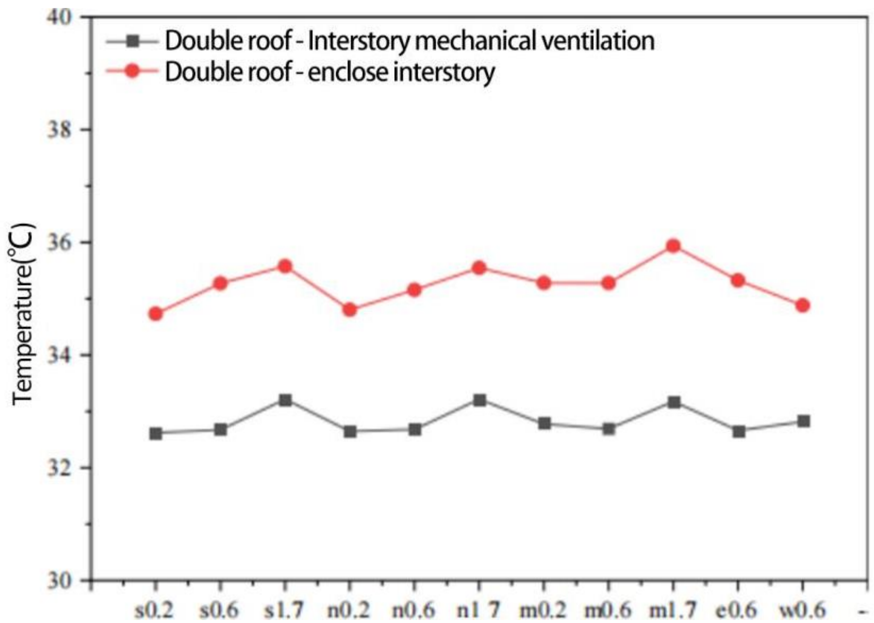


Fig.4.11 Comparison of temperature at various points in the model room under mechanical ventilation and closed conditions in the interlayer

(Source: APSEC)

The temperature inside the shelter can only fall close to the ambient temperature and cannot be further decreased without the use of an external cold source, and the internal thermal environment is significantly influenced by the outer environment. When employed in conjunction with the spontaneous power production capabilities of solar emergency disaster relief structures, external cold sources may be used to cool when the outside temperature is high, ensuring that the internal temperature is kept in a low condition. There are two types of evaporative cooling technology: direct and indirect. The more popular evaporative air conditioners on the market primarily employ direct evaporative cooling technology to treat the input air such that the temperature of the exit air is the same as that of a wet bulb. Then the lower exit air temperature is then used to conduct the interior heat exchange.

The evaporative air conditioner is utilized for active ventilation via the air inlet at the bottom of the interlayer; the input air temperature is 24.5 ℃, and the exhaust air volume of the top fan is 0.5 m^3/s. According to the statistics, the average interior temperature has decreased. After using an evaporative air conditioner, the temperature dropped by 5.6 ℃, 5.1 ℃, and 5.1 ℃, respectively, at three locations at 0.2 m, 0.6 m, and 1.7 m height. At 0.6 m height, the west side's temperature decreased by 5.2 ℃ while the east side had a 5.1 ℃ decrease. Average temperatures are 27.0 ℃, 27.5 ℃, and 28.1 ℃, respectively, at heights of 0.2 m, 0.6 m, and 1.7 m, while the corresponding temperature differences from the outside environment are 4.1 ℃, 3.7 ℃, and 3.1 ℃, respectively. By employing evaporative air conditioners, the inside temperature may be reduced to be lower than the dry bulb temperature outside, and the cooling effect is improved.

4.4 Photovoltaic system

As shown in Fig.4.12, the temperature clouds of the PV system before and after the model optimization at noon moment of the summer meteorological design day, it can be seen that the average temperature of each PV group decreased after the active and passive optimization. This is due to the use of exhaust fans to speed up the airflow in the double inter-ceiling layer, thus enhancing the convective heat exchange between the PV system and the air and better carrying away the heat generated by the PV system. Meanwhile, evaporative chillers reduce the inlet air temperature and further enhance the heat exchange between the PV system and the air. The photovoltaic temperatures of the five groups were reduced by 14.5 ℃, 16.3 ℃, 15.7 ℃, 14.1 ℃, and 12.2 ℃, respectively. According to the research, the power temperature coefficient of thin-film photovoltaics made of copper, indium, gallium, and selenium ranges between -0.3% and 0.36%[33]. The photovoltaic system power of each group before and after optimization is raised by about 4.4%, 4.9%, 4.7%, 4.3%, and 3.6%, respectively, if the power temperature coefficient is set to-0.3%, and the total power is increased by around 4.4% on average.

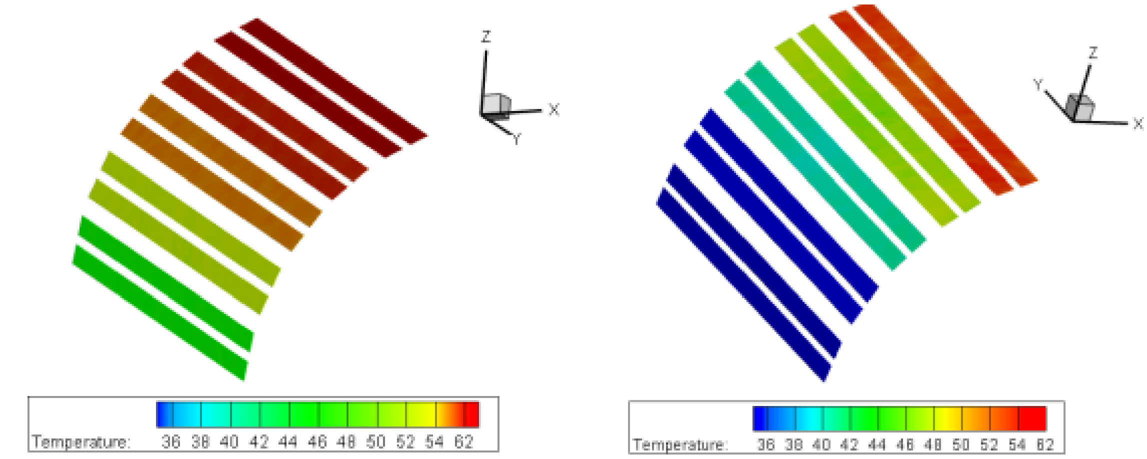


Fig.4.12 Comparison of PV system temperature clouds before (left) and after (right) optimization

(Source: APSEC)

[33] Zhang Chuansheng. Research on the performance ratio of CIGS PV power plants[J]. Renewable Energy Resources, 2017, 35(008): 1176-1180.

Chapter 5 Promotion Path of Solar-Powered Emergency Shelter

The promotion path of a solar-powered emergency shelter (SPES) is principally examined in this chapter from three perspectives: potential partners, key factors in the promotion process, and commercial promotion path. The International Emergency Relief Center (IERC), the United Nations Disaster Assessment and Coordination Team (UNDAC), international rescue teams of different economies, and military cooperation were introduced. Product applicability, funding and policy support are key factors in the promotion process. The source of funds for SPES, which can be broadly divided into three channels, is crucial in the process from the landing of theory to the large-scale application as an innovative topic to support the development of public welfare undertakings. Based on the characteristic of SPES, target group, and business environment analysis, the end of this chapter, four recommendations are made in order to encourage the large-scale growth of SPES projects in the APEC region: legislative support, technological advancement, financial sources, and promotion of energy accessibility.

5.1 Potential partner

(1) United Nations Disaster Assessment and Coordination Team (UNDAC)

The UNDAC/United Nations Disaster Assessment Coordination (UNDAC) is a professional force selected, trained, dispatched, and supervised by the UN OCHA/Office for the Coordination of Humanitarian Affairs (OCHA). The UNDAC/United Nations Disaster Assessment Coordination (UNDAC) is a professional force selected, trained, dispatched, and supervised by the UN OCHA/Office for the Coordination of Humanitarian Affairs. The team comprises experts from all over the world with professional backgrounds in disaster emergency management, response, and coordination, who have passed UNDAC's induction training and completed the relevant administrative procedures for registration. When an affected economy sends a request for assistance to the UN, the UN Office for the Coordination of Humanitarian Affairs (OCHA) will select the appropriate team members from among those who are able and volunteer and appoint a team leader and deputy team leader to form a UNDAC team that meets the mission requirements to carry out humanitarian support in the affected economy. As of December 2015, UNDAC has conducted 255 humanitarian support missions worldwide, with 1,378 UNADC team members deployed to more than 100 economies.

UNDAC's critical work systems and methods are built on the four foundations of Core Value, Disaster Management, Humanitarian Principle, and Leadership. "UNDAC's primary work system and methods are built on the four foundations of Core Values, Disaster Management, Humanitarian Principle, and Leadership.

The core values include Equitable, Accountable, Competent, Flexible, Inclusive, Hands-on, and Supportive; Disaster Management refers to being rooted in disaster management but also influenced by humanitarian coordination and connecting these channels; Humanitarian Principles include: Humanity, Neutrality, Impartiality, and Independence, which are the fundamental principles of the UNDAC system; Leadership refers to UNDAC's ability to provide or support leadership at the hands-on and tactical levels while providing or supporting leadership at the strategic level. A standard UNDAC team consists of the positions and responsibilities listed in Table 5.1.

Table 5.1 Positions and responsibilities of UNDAC

Jobs	*Main Responsibilities*
Captain	*Action plans and updates;* *Assigning or tracking the physical location of the team member;* *Liaise directly with RC/HC, HCT, affected governments, other partners, and Cluster;* *OCHA regional offices or headquarters;* *Strategic Plan;* *Ensuring the cohesiveness of the team;* *The contact person for security matters.*
Vice Captain	*Full acting captain when needed;* *Liaison with the detachment;* *Day-to-day operations and OSOCC management;* *The safety and security plan for the team;* *Execute mission handover and exit strategies to later teams, state agencies, OCHA, etc;* *Task software workspace;* *Review of reports and information management;* *Intra-team communication;*

	Approve or implement media policies.
Team Logistics Support Management	*Logistical coordination;* *Provide support for internal agency implementation assessments;* *Management team resources and technical support staff;* *Organization of accommodation, transportation, local support, translation, etc;* *Establish and enhance document management systems;* *Funding management.*
Information to hang you	*Intra-team information flow management;* *Task Software Workspace;* *Reporting and Information Management;* *Intra-team communication;* *Proposing and developing media policies.*
Disaster Management and Coordination	*Optimizing the use of available resources and prioritizing response activities;* *Coordination of international teams;* *Provide support for the coordination of needs assessments;* *Reporting and information management, including affected groups and institutions;* *Infusing information for safety and security management;* *Liaison, including the establishment of population protection and UN or international response mechanisms;* *Managing the UNDAC support team;* *Injecting public information initiatives;* *Task transfer/exit strategy to long-term OCHA teams.*
Humanitarian Response and Coordination	*Coordination of humanitarian partners;* *Create responsible support for the UN, Red Cross, Red Crescent, and NGOs humanitarian structures, actors, and standards to provide protection and support;* *Provide advice on humanitarian sectors, organizations, and funding mechanisms;* *Provide support for the coordination of needs assessments;* *Reporting and information management, including affected groups and institutions;* *Infusing information for safety and security management;* *Provide support (but not full responsibility) for funding needs;* *Provide support to long-term OCHA teams in tasking/exit strategies.*
Coordinated Needs Assessment	*Providing professional assessment methods (e.g. MIRA);* *Development, agreement and application of shared assessment capabilities and methodologies;* *Coordinated assessment;* *Analysis of assessment information, including formal analysis;* *Feedback to key decision makers, both leading and operating organizations;* *Preparing assessment information for release to the public;* *The responsibility for ensuring that the information released by the assessment is used correctly;* *With responsible humanitarian structures and actions for ongoing assessment, monitoring impact, development interventions agencies, and coordinators to maintain close collaboration.*
Additional areas (potentially assigned by OCHA)	*Environmental Response, Urban Search and Rescue, Cluster Specialist, Civilian and Military Coordination, and Media and public information.*

Source: Li Li. The UN Disaster Assessment and Coordination team (UNDAC)'s working system and training methods[J].

China Emergency Rescue, 2016(04): 57-59.

When UNDAC carries out its mission, International Humanitarian Partners (IHP), Asia-Pacific Humanitarian Partners (APHP), Americas Support Team (AST), European Union (EU), Map Action, Assessment Capability Project (ACAPS), etc., will provide technical equipment, information, and personnel support as relevant resources.

(2) International Emergency Relief Center (IERC)

The International Emergency Relief Center (IERC) was founded by the NGO International Information Development Organization as an international organization for global emergency relief, providing emergency assistance-related business and industrial development services under the framework of the United Nations Millennium Development Goals and the 2030 Sustainable Development Goals, with several relief centers and industrial development centers worldwide.

The Center is dedicated to aiding in the implementation of the United Nations 2030 Agenda for Sustainable Development, improving global comprehensive capacity for disaster prevention, mitigation, and relief, emergency relief to deal with various calamities effectively, and participating in non-profit social emergency relief service operations within the present international rescue system, as an essential supplement to the government rescue business. It offers the entire world information, resources, scientific research, seminars, and services for personnel training in emergency assistance.

The center coordinates and integrates global emergency rescue resources to advance the development and improvement of the international emergency rescue market system, thoroughly investigates and makes use of market resources to advance the development and advancement of the worldwide emergency rescue market system, and depends on scientific and technical advancement to advance the general level of emergency rescue personnel, information, and equipment. IERC's primary functions are as follows:

- To promote the innovative development of the international community's emergency rescue industry through emergency rescue industry research, technology development, international industry standards, the coalescence of social capital, and the formation of production and marketing capabilities for emergency rescue products, technologies, and services.
- Training emergency rescue commanders and rescue operators,

publicizing and popularizing emergency rescue knowledge, and enhancing the level of emergency rescue knowledge and practical rescue skills of the entire community.

- Research emergency rescue theory, policy, system, legal system, and operation strengthen academic exchanges and promote the construction of international emergency rescue theory, policy, and regulatory system.
- Collecting and reflecting on global emergency rescue information and situation, studying market rules, formulating and identifying effective emergency rescue plans, cooperating with the disposal of relevant major emergency rescue matters, cooperating and exchanging global emergency rescue business, etc.

(3) International rescue teams of different economies

- **China International Search and Rescue Team**

The China International Search and Rescue Team (CISAR) was established on 27 April 2001, as a team of military officers, soldiers, earthquake experts, and medical rescuers. CISAR consists of search, rescue, medical, technical, and security teams, staff, and technical and security groups, and is a professional earthquake disaster emergency rescue team that has reached the standard of the United Nations heavy rescue team.

CISAR has participated in significant domestic and international disaster rescue in Xinjiang Gash, Batu, Yunnan Dayao, Algeria, Iran, Haiti, etc. Algeria earthquake rescue operation, the first time to participate in international rescue operations of the Chinese international rescue team relying on advanced technology, successfully searched and rescued a survivor, digging out the four victims. Only two survivors recovered among the thirty-eight rescue teams involved in the rescue. The Chinese international rescue team was the second team to successfully search for survivors in the earthquake zone after the French rescue team. Officials from the UN Office for Humanitarian Coordination had this to say about the China International Rescue Team: "The China International Rescue Team has become a valuable force in the international search and rescue arena."

- **American Rescue Team International**

American Rescue Team International (ARTI) was founded in 1985 with 15 rescue teams from several economies. Like the British International Rescue Team, ARTI is entirely non-profit and has no purpose or intention other than to save lives; ARTI has little to no budget and may only need a few thousand dollars a year to operate. ARTI has thousands of members and is constantly expanding its team through cooperative agreements to attract more rescuers from around the world. ARTI organizes its members into teams stationed in various locations worldwide to guarantee that we can respond as soon as a crisis strikes and that we are always the first to reach the site.

In the more than 20 years since ARTI was founded, it has survived significant tests such as the 1985 Mexico earthquake, the 1986 Greece earthquake, the 1986 El Salvador earthquake, the 1991 Costa Rica earthquake, the 1995 Tokyo and Osaka earthquakes, the September 11 attacks, and many others. Tens of thousands of people have been saved so far.

ARTI has some of the most sophisticated equipment in the world. They claim their equipment is more than ten years ahead of other rescue teams. Moreover, many inventors in ARTI will develop their rescue equipment. This advanced equipment can help ARTI to find the dead and injured by various means, such as hair, smell, etc.

- **Japan Disaster Rescue Team**

The Japanese government established the Japanese Disaster Rescue Team (JDRT) in June 1987. Its task is to quickly collect helpful information on major domestic and urban natural and technological disasters, report it to the Japanese Bureau of International Cooperation of the Ministry of Foreign Affairs after specialized treatment, and report to the Bureau of Economic Cooperation for decision-making. It undertakes international disaster relief tasks through legal channels with first-class technical equipment, first-class technical skills, and foreign language skills.

JDRT is built according to the standards of the international rescue team, which mainly includes: a search and rescue team, a professional rescue team, a medical team, a self-sufficient management team, an efficient liaison team, and education teams trained according to international rescue training materials. Following the regulations, the team is equipped with more than 100 tons of equipment and tools, including transport and communication vehicles, ships and small helicopters, various lifting, digging and loading and unloading tools, search and rescue equipment, personal appliances, daily supply and storage equipment, power generation equipment and so on.

JDRT expanded from 400 people to 1540 people in 2002. This search and rescue personnel are from the Japan Police, Japan Coast Guard, and fire management agencies, of which 614 are registered as medical personnel, 201 are doctors, 261 are nursing staff, 21 are pharmacists, 31 are medical coordinators, and 100 are logisticians. The annual financial budget of the Japan Disaster Response Team between 1999 and 2001 was about $48.5 million (including 1/2 of the salaries of all staff), of which $3 million was for the purchase of equipment and instruments, $5 million for annual training exercises, and about $800,000 for assistance available in case of emergency needs.

- **United Kingdom International Search and Rescue Team (UK-ISAR)**

On behalf of the UK government, the United Kingdom International Search and Rescue Team (UK-ISAR) is a search and rescue organization based in the United Kingdom. According to the International Search and Rescue Advisory Group (INSARAG) rules, the present team organization is categorized by the United Nations as a "Heavy USAR Team" (urban Search and Rescue). In accordance with UN regulations, the whole domestic team is prepared and waiting to be sent to a stricken nation within 10 hours following a formal request for aid. In addition to conducting search and rescue missions, UK-ISAR provides the UK Emergency Medical Team with logistical know-how for its deployed facilities.

In 1993, UK-ISAR was established. The team has completed operations in Iraq, Turkey, Algeria, Pakistan, India, Iran, Mozambique, Indonesia, Haiti, New Zealand, Japan, Bosnia, and Nepal during the past 25 years. Members have also participated in several foreign training exercises in Poland, Italy, the United States, and Germany.

(4) Military cooperation

In the 1960s, the research of square cabin hospital began to be on the agenda. The first application was for the US Army in Viet Nam's battlefield treatment of the sick and wounded. Later, the British, the US, German, French, and other armies developed and equipped protective field hospitals. As the most basic unit, the medical module is an essential part of the hospital, which can be put into use alone to form a separate rapid response medical unit, but also through the organic combination of different functional modules to form a whole module hospital, such as standardized field psychological protection module, blood refrigeration module, sterilization module, etc. After the formation of the field cabin hospital can form a wartime-integrated medical configuration suitable for field rescue and disaster relief in treating the wounded and sick. More communication with the military of each economy can promote the implementation of this project in a large area.

Climate adaptability testing of square cabin hospital is crucial, especially for temperature and humidity. Temperature is an important indicator affecting indoor living comfort, and air humidity affects the evaporation of water in human sweat, when the humidity is too high sweat will always be on the body's surface and cannot evaporate into the air, affecting the human body temperature decline and energy balance, as the square cabin hospital in the disaster area is generally directly erected on the ground and slightly less breathable, the evaporation of water vapor from the surface leads to high indoor air humidity, further reducing the human Comfortable living[34] [35]. Heavy summertime rainfall is the most significant contributor to the indoor humidity issue in the tropics and subtropics. After a rain, square cabin hospitals materials like asbestos roofing, untreated plywood, and massive core walls will be sopped in a broad area of water and, in difficult situations, will leak, allowing moisture to travel through the enclosure structure. Additionally, water entering the wall causes the wall's ability to provide thermal insulation to decline, which worsens indoor air quality. In order to prevent exterior water vapor intrusion and damage to the insulation and durability of wall components, the wall should have a waterproof covering (such as colored steel plate, tarp, etc.) on the outside of it. It is highly possible that inadequate drainage systems around Square Cabin Hospital would result in standing

[34] Zhao Erqing, Di Yuhui, et al. Analysis of thermal environment in tents and improvement measures[J]. Low Temperature Architecture Technology,2015,37(04):152-154.
[35] Zhao Erqing. Study on thermal environmentand improvement measure of the military tent[D]. Xi'an Polytechnic University,2016.

water or even pouring it inside, making the interior wetter. This will also damage the comfort and hygienic conditions of the interior.

5.2 Key factors in the promotion process

(1) Product applicability

As a solar-powered design, the viability of SPES on a large scale depends heavily on how the market for photovoltaic products develops. Since 2011, China has dominated the manufacture and supply of solar photovoltaic cells and modules worldwide, from photovoltaic technology research to product manufacturing. This implies that the cost of batteries and other components in China significantly influences "international" prices for goods and project costs, which in turn impacts the output of other manufacturers and the profit margins of related projects. The total supply of solar photovoltaic cells and modules will reach 123.5 GW in 2019, with manufacturers in Asia, particularly China, accounting for the bulk of this production. Chinese businesses are thought to contribute more than 80% of the 78GW worth of solar cells and modules that the top 10 manufacturers of these products supply, with comparable market shares held by firms in Korea (Hanwha Q-Cells) and the United States (First Solar). Chinese enterprises make up seven of the top 10 manufacturers, including the top three. In part, the Chinese market's limits on the development of solar power plants in 2019 have resulted in an oversupply of photovoltaic cells and modules, which has lowered market prices. This circumstance has effectively sped up the growth of significant new international markets, balancing the slowdown in the expansion of installation capacity in the Chinese market. Some Chinese businesses have spent extensively since 2018 to boost production capacity and create plans for additional development while advancing technical innovation, despite decreasing subsidies and declining demand in China. All of these actively and successfully encourage a decrease in solar costs.

(2) Funding

The source of funds for SPESS, which can be broadly divided into three channels, is crucial in the process from the landing of theory to the large-scale application as an innovative topic to support the development of public welfare undertakings.

- **Totally government-funded**

Governments at all levels allot budgets for issues such as SPESS design optimization, manufacture, storage and maintenance, distribution and usage, recycling and maintenance, and others based on the actual state of each economy. This strategy is appropriate for governments in better economic circumstances. The advantage is that the SPES can be immediately delivered to the disaster site, ensuring the victims' resettlement and power usage. The drawback is that the government is required to make a fixed annual investment.

- **Joint investment between the government and businesses.**

This strategy not only significantly lessens the financial strain on the government but also ensures that SPES may be used to its fullest potential during the relief effort in the event of a disaster. However, in order to maximize enterprise economic benefits, SPES should be employed not just in typical disaster relief scenarios but also in other application scenarios. Business operations like product leasing can be conducted while SPES is not in use.

- **Full contribution by enterprises or various organizations.**

The development of photovoltaic technology and the maturity of modular technology will significantly reduce the cost of SPES. When SPES, as a commodity, has sufficient competitiveness and market, it will attract funds from enterprises and various organizations. The benefit of this strategy is that the performance of SPES will be significantly enhanced under market promotion, and the application situations tend to diversify gradually. The drawback is that SPES might not be able to reach the area in time due to the impact of market supply on disaster assistance. Additionally, uncertain capital investments are inappropriate for the SPESS project's initial development.

(3) Policy support

The development and implementation of relevant interventions is a complex and dynamic process that should aim to help the most promising energy innovations overcome bottlenecks in the promotion chain. The diffusion of innovations requires knowledge-sharing platforms, demand "pull" and adequate supply "push" mechanisms. Over the past decade, many economies have experimented with several policy tools, ranging from targeting and procurement policies to green labelling and tax and fiscal incentives. The potential policy alternatives at various stages to support the development and deployment of SPES are summarized in Table 5.2.

Table 5.2 Barriers to SPES technology and related support policies

	Technology development stage	*Technology demonstration stage*	*Technology commercialization stage*	
			Early Middle Period	*Maturity*
Major obstacles	• *Inadequate government funding for research and technology development*	• *The technology itself is not yet mature in the development stage and has certain risks* • *High capital costs of the project itself and limited government funding allocated to demonstration projects*	• *Uncertainty about technology maturity and cost reduction potential creates difficulties for project financing*	• *Deficiencies in the legal system and procedures related to project investment* • *The price of market-competitive technologies does not include externalities such as environmental impacts*
Policies related to the removal of barriers	• *To design economy-wide strategies for the advancement of research and technology.* • *Formulation of medium and long-term research priorities technology research developable directions* • *Increase direct public funding from the government* • *Develop corresponding mandatory technical standards*	• *Direct support for demonstration projects* • *Develop and effectively implement relevant tax incentives* • *Provide low-cost or guaranteed credit*	• *Develop and implement a temporary subsidy policy* • *Develop and effectively implement relevant tax incentives* • *Effective Government Procurement*	• *Create appropriate conditions to promote broad market competition* • *Develop and implement innovative retail financing and consumer credit programs*

Source: APEC Sustainable Energy Center. Study on Innovative Model of Renewable Energy Scale-up Development in APEC Region. 2020.

In summary, technology system innovation should be supported at every point along the entire chain of SPES development and utilization, including dedicating a greater proportion of public sector funding to R&D, supporting demonstration project establishment, and using effective public-private partnerships (PPPs) to actively purchase new technologies product in the early stages of development and commercialization to support cost reductions. In terms of financial and tax support, subsidizing certain aspects has proven to be one of the practical approaches. However, effective market mechanisms should be fully utilized in medium and long-term development to promote innovation and the adoption and widespread deployment of new technologies while continuously improving economic efficiency.

5.3 Commercial promotion path

(1) Target group description

The Target group of SPESS has two main characteristics, one is the severity of the disaster and the other is the willingness to invest in renewable energy. Combining the above characteristics, some economies are selected for description[36].

- **Viet Nam**

Viet Nam is one of the economies most affected by climate change and often suffers severe impacts from various natural disasters, especially typhoons, floods, landslides, seawater intrusion, and other climate-related disasters. Natural disasters have caused nearly 400 deaths and disappearances as well as economic losses of 1-1.5% of GDP every year for 30 years. At the same time, it also attaches great importance to the application of solar energy, and several solar power projects have been established.

- **Indonesia**

Indonesia is located at the intersection of the Pacific Rim seismic zone and the Mediterranean-Himalayan seismic zone. It is the most seismically active region in the world, with thousands of earthquakes of various sizes each year. Because Indonesia is prone to seismic hazards, it is more likely to induce tsunami hazards. Frequent natural disasters and abundant solar energy resources can significantly promote the large-scale application of

[36] APEC Sustainable Energy Center. Study on Innovative Model of Renewable Energy Scale-up Development in APEC Region.2020.

SPES in this region.

- **Mexico**

Mexico is located at the junction of three major plates of the earth, namely the North American plate, the Pacific plate, and the Cocos plate in the eastern Pacific Ocean. Earthquakes occur whenever plates rub or collide, which leads to frequent earthquakes, mudslides, landslides, and other disasters in Mexico. At the same time, Mexico is a coastal area, so it can cause disasters such as tsunamis. Mexico's power grid is in poor condition, and power lines across the economy need to be upgraded and expanded. This presents an opportunity for the SPESS project, particularly given that most of Mexico's wind and solar energy resources are dispersed throughout the economy and far from major population centers. SPESS can encourage the development of distributed energy systems in the area and guarantee the robustness of the electrical grid.

(2) Business environment analysis

Politics, law, economy, society, and technology are the four basic areas of business environment analysis.

- **Politically and legally**

All economies have attached great importance to disaster relief facilities and the resettlement of victims. Many economic documents have once again stressed that the protection of people's lives, property, and health should always be given top priority in emergency and disaster relief.

- **Economically**

Multi-channel sources of funding are also a feature of the emergency and disaster relief process. The gradual standardization and transparency of the channels for the use of relief funds have promoted the development of new post-disaster resettlement facilities to a great extent.

- **Socially**

With the continuous improvement of living standards, people pay more and more attention to the living environment and gradually realize the importance of post-disaster resettlement for the psychological and physical health of the victims.

- **Technically**

Photovoltaic technology is developing continuously and rapidly, and building modular production and assembly technology is also maturing, which provides technical support for the large-scale utilization of SPES.

(3) Analysis of promotion strategy

Four recommendations are made in order to encourage the large-scale growth of SPES projects in the APEC region: legislative support, technological advancement, financial sources, and promotion of energy accessibility.

- **Bolster policy backing**

Effective government policies are particularly crucial in overcoming institutional, technical, and economic barriers, and they significantly positively impact the growth of SPESS and programs. There is an urgent need for domestic policy assistance because of the uniqueness of SPES application scenarios. Different subsidies should be the focus of policies depending on the variance in catastrophe intensity, regional economic growth, and stakeholder diversity. Additionally, it is advised that in order to preserve the victims' physical and emotional health and fully execute the "people-oriented" policy, mandatory standards for emergency relief shelters should be created.

- **Encourage technical advancement and cost-cutting**

The development of photovoltaic technology and the drop in manufacturing costs are essential for the widespread use of SPESS. The considerable decrease in the cost of photovoltaic technology over the last decade may be attributed to the rapid growth of science and technology, increasingly affluent research and development expertise, large-scale advantages of technology implementation, suitable industrial chain, and supply chain competitiveness. While continuing to encourage the development of photovoltaic technology, it is advised that we pay attention to the assembly line of modular production and assembly of SPES and aim to minimize product costs.

- **Increase financial support**

SPES is distinguished from conventional emergency and disaster relief facilities by its relatively large initial investment, emphasis on inside comfort, and use of energy-efficient design. Some businesses may give up on establishing and investing in SPES due to the high funding threshold. In order to successfully encourage the large-scale development of SPESS, it is recommended that the relevant economies enhance their financial support for SPESS projects through the creation of funds for the development of renewable energy and R&D initiatives for emergency shelters.

- **Promoting energy accessibility through the SPESS program**

Although energy accessibility is no longer an issue for most APEC economies, there are still a significant number of people without power in some regions, particularly in distant, sparsely inhabited, and geographically deficient rural portions. The SPESS project's extension technology may create the right circumstances for enhancing the dependability and accessibility of the local energy supply. To make SPESS projects and its extension technologies successful and financially viable, it is recommended that relevant economies develop relevant support policies, modify key regulatory frameworks for relevant regional research, offer matching technical assistance and capacity-building for stakeholders, and investigate suitable business models. In post-disaster resettlement, SPESS is dedicated to finding solutions to space and energy issues, focusing on people. The APEC region contains a variety of economies, and the local resources, climate, and solar regulations in disaster-prone locations are all unique. It is recommended that APEC economies, particularly developing economies, should make use of successful examples of innovative ideas from other economies.

Chapter 6 Conclusion

Solar-powered emergency shelter (SPES) addresses the secondary damage caused by inadequate power and energy supply, poor resettlement of affected people, and unprofessional medical sites after a disaster. SPES has a precise application scenario, and the focus of the design is not only to meet the "emergency" requirements of ease of understanding, ease of operation, and efficiency but also to ensure the integrated modular design of the solar system. At the same time, it is closely related to the climatic conditions and envelope construction of the affected area, considering the habitat's health. This report aims to provide information on the potential applications and technologies related to SPESS within APEC.

Based on the key issues and feasible technical solutions that the renewable energy experts, government officials, and corporate technicians (in the field of building and solar technology) proposed, this report investigates strategies for the demonstration and promotion of energy resilience tools based on Solar-Powered Emergency Shelter Solutions (SPESS) for natural disasters in APEC region. Highlights are as follows:

- - Enhancing humanitarian innovation
- - Assessing the performance of physical products
- - Open up avenues for multi-scenario applications
- - Embrace investments and partnerships

This report first elaborated on the design methodology of Solar-powered emergency shelters (SPES) from three aspects: design basis, design Influencing factors, and realization method. Based on the theoretical basis, application scenarios for solar-powered emergency shelters were explored. This research then explores climate adaptation in two areas. One is Tianjin in China in the cold zone, and the other is Poso in Indonesia with a typical tropical rainforest climate. Finally, the solar-powered emergency shelter (SPES) promotion path was investigated as an energy resilience tool. The outline of the report is as follows:

- Design Methodology of Solar-Powered Emergency Shelter

- Application Scenarios for Solar-Powered Emergency Shelter
- Assessment of climate adaptation: Solar-Powered Emergency Shelter in a cold climate
- Assessment of climate adaptation: Solar-Powered Emergency Shelter in a tropical rainforest climate
- Promotion Path of Solar-Powered Emergency Shelter

The SPESS project draws on the latest technologies in emergency relief buildings to provide a theoretical basis for the design and to develop products adapted to APEC that will rebuild communities and improve people's quality of life by providing shelter and energy.