

Design and implementation of portable renewable energy booths for generating electricity and solar heat

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Abstract:
The purpose of designing and building a multi-purpose portable energy booth is to educate, empower, and promote the culture of using renewable energy among citizens and secondly to provide welfare and support services on special days and occasions. The shed and equipment were designed, supplied, and built based on the following policy. The booths should have an educational and exhibition mode so that it is ready to be visited by people, students, and other environmental enthusiasts. Booths can be moved to different parts of the country on days and occasions to provide services. Due to the limitation of the roof of the booths and also the equipment that consumes electricity in the booths, the construction of an off-grid solar power plant with 6 panels of 545 watts and 8 batteries of 100 ampere 12 volts and also a solar water heater of 250 liters to provide hot water for the bathroom inside the booths It was planned. The sum of the total consumption of the electrical equipment including Lamps, misting fan, freezer, 32-inch LED TV, water purifier Standing split, and Laptop in the booths during the day and night is equal to 9404 watts throughout the day and night (784 Ah per day). This amount is supplied by batteries. After the design and installation of the equipment to familiarize the people and also for the use of the residents in the conditions where there was no access to the water, electricity, and gas network, the condo was tested for 10 days and its defects were also fixed. The costs of fuel transportation and electricity transmission are much higher than the use of solar energy in the garage. Students are also taught about renewable energy from this facility.

Keywords: *portable booths, renewable energy, solar heat and electricity, cultivation*

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1. Introduction

Nowadays, city planners and authorities around the world have been promoting principles to achieve a sustainable city. In this regard, Policy agendas have increasingly focused on how developing renewable energy as a clean energy can help to have integrated sustainable urban development. (1)
One of the ways to develop clean energies is to educate and promote the culture of using them. House-shaped canopies, as one of the portable and cost-effective solutions for housing, have received much attention in recent years. These structures have become an attractive option for people looking for a temporary or even permanent home due to ease of transportation and installation, lower costs than traditional constructions, and flexibility in design and use. House canopies are made from a variety of materials, including metal, wood, plastic, and even recycled materials. This variety of structural materials makes the condos show good resistance in different weather conditions and can meet the different needs of users. For example, sheds made of rust- and corrosion-resistant metals are suitable for areas with high humidity, while wooden sheds are more commonly used in areas with dry climates.
One of the outstanding features of the house cabins is their easy portability. These sheds are designed to be easily moved by trucks and trailers and installed at the new location in the shortest possible time. This feature is especially important for people who are looking for a temporary home or those who need to relocate frequently.

The interior design of house cabins is also very diverse and adjustable, and these cabins can be designed according to the different needs of people, from open and modern spaces to small and practical spaces. Interior facilities such as heating and cooling systems, bathrooms, kitchens, and even separate bedrooms can all be adjusted to the taste and needs of users.

2. Project History

One of projects is about for design of portable mini solar panel combined with micro hydropower system for power generation written by Awang et al. The objective of this project is to design and construct a portable power production system that uses renewable energy. The research also aims to determine the maximum and sufficient power consumption from solar energy and micro-hydropower systems to provide adequate energy for the space in the event of a power failure. The results of the test reveal that the portable power production based on renewable energy has enough capacity to create electricity during a power failure as well as provide adequate loads such as LED lights, mini fans, and phone chargers. (2)

Another research titled Designing a Portable and Low-Cost Home Energy Management Toolkit was written by Keyson et al. This paper describes the design of a home energy and comfort management system. The system has three components such as a smart plug with a wireless module, a residential gateway, and a mobile app. The combined system is called a home energy management and comfort toolkit. The design is inspired by the fact that making energy visible and able to control it will help to conserve energy. One of the key goals is to create an extendable platform based on the needs of the end users. Our proposed system is expected to help end users control and manage residential energy. (3)

Another article that was reviewed was Portable Multi-Inputs Renewable Energy System for Small Scale Remote Application that is written by Ibrahim Al-Bahadly The specific aim of the work is to design a compact, stand-alone, product that can be easily transported by people across uneven terrain. It can generate power from wind, solar, and hydroenergy sources. In this work, a new non-isolated multiport DC-DC converter topology for a hybrid energy system in low-power applications is proposed. The new topology assimilates multiple renewable energy sources and powers up multiple loads with different output levels. A complete Solid Works model and FEA analysis, on required components, is completed. The scope of the work encompasses both the electrical and mechanical design of the system. (4)

H C Leindecker and D R Kugfarth have also conducted research in Austria titled Mobile Tiny Houses – Sustainable and Affordable. The aim here was the development of an innovative, high-quality, and inexpensive modular system that does not exclude increased ecological standards. As part of an interdisciplinary project, a group of students developed an energy-self-sufficient cabin for almost every kind of application. Based on extensive research on existing building systems, a variety of topics were examined. The focus here was on mobility, modular assembly, ecological materials, self-sufficiency, energy efficiency, and the water cycle. In the end, a single-family house, which considers most of the aforementioned aspects, was built. (5)

Another project was based on the design and manufacturing of a foldable and portable solar PV system for domestic purposes written by Pankaj G Takale et al. The primary goal of this project is to reduce its size and make it more user-friendly and portable. This system has automatic foldable panels, and to increase the efficiency of the system, Maximum Power Point Tracking (MPPT) is used. The system has caster wheels for free movement, and it is lightweight compared to conventional types. (6)

Smita Joshi and Neha Upadhyaya have written another paper named DESIGN OF SMALL SCALE SOLAR POWERED HOUSE. This paper is about the abstract Electrical Load calculation of a small size solar powered house that has been done and the components of the solar electrical supply like solar panels, charge controller, battery backup, and load have been explained briefly. The load, for a small family, consists of lights, fans, television, refrigerator, and air conditioner. 3kVA invertor was required considering its efficiency as 80%. The battery backup of 96V and 300Ah was sufficient to run the load. To charge these batteries 16 solar modules each of capacity 250W are required for which 8m2 roof area is required. (7)

Portable Solar Power for Nomadic Herders was down by the word Bank Group in 2008. The Renewable Energy and Rural Electricity Access Project (REAP) helped the Government of Mongolia complete its National 100,000 Solar Ger Electrification Program, which provided over half a million nomadic herders with access to electricity through portable solar home systems. The project also helped fund improvements in soum (district) electrification, including rehabilitating mini-grids and installing renewable energy technology hybrid systems to power them. (8)

Design, fabrication, and performance assessment of a novel portable solar-based poly-generation system paper was written by Milad Soltani et al. In the current paper, a novel portable solar-based poly-generation system is proposed and it is experimentally investigated. The system consists of photovoltaic panels, an evacuated solar collector, vapor compression refrigeration, and a desalination section. The total power consumption of the cooling cycle, heating cycle, HDH desalination cycle, and RO desalination cycle is measured as equal to 330 W, 70 W, 36 W, and, 36W, respectively. Photovoltaic panels could supply 471 W of electricity and the compressor uses the most produced power. 16.5 L distilled water per hour could be supplied by the system, also. Excess electricity and heat are stored during the day to guarantee the continued operation of the system. Unique electronic boards are applied in the facility and several sensors are used to evaluate the operation of different sub-systems. Wireless sensor data acquisition and control monitoring are used according to the energy demand. (9)

N.H. Ramly et al. wrote a paper that named emergency portable solar power supply. This paper proposes an emergency portable solar power supply (EPSPS) by using a renewable energy source. The proposed EPSPS can be used in contingency conditions or a rural area with non-electric power sources. The system architecture is similar to the existing photovoltaic (PV) system with a portable and user-friendly design. EPSPS comprises a solar panel, battery, charge controller, inverter, sensors, relays, and Arduino Uno with Bluetooth module. The output voltage of EPSPS is 12 V and operates for 2 days without charging. The battery has required a minimum of 6 hours of charging. Based on the obtained results, the system supplied a maximum of up to 100 W of DC/AC power load. (10)

Solar Powered Portable Charging Unit as Emergency Response for Disaster Prone Areas is another paper written by Olly Roy Chowdhury et al. This paper presents a solar-powered battery charging unit that can be carried anywhere and electric power can be fetched during the daytime and after dark for charging and powering up our essential electronic appliances like mobile, Wi-Fi routers, powered fans, lights, etc. Here we have developed and tested solar-powered portable charging units or emergency electric power provider units for domestic use as well as for disaster-prone areas for emergency response. (11)

A portable renewable solar energy-powered cooling system based on wireless power transfer for a vehicle cabin is another related paper. This paper was written by Hongye Pan et al., it developed a novel portable, renewable, solar energy-powered cooling system with wireless power transfer (WPT) and supercapacitors to cool the vehicle cabin. The proposed system consists of a solar collector mechanism, an energy conduit, and a temperature control and cooling module. First, consisting of folding solar photovoltaic (PV) panels, the solar collector mechanism makes the proposed system portable. Once collected, the solar energy is converted into electricity and stored in the supercapacitors through wireless power transfer without breaching the vehicle body. Automatic temperature regulation is achieved with the cooling device via the temperature control and cooling module. The experimental results indicate that a maximum output power of 2.181 W and a maximum WPT efficiency of 60.3% are achieved when the prototype is loaded with 3 Ω and 5 Ω respectively. Meanwhile, the simulation shows the temperature inside the cabin is reduced by as much as 4.2 °C on average, demonstrating that the proposed solar energy-powered cooling system is effective and feasible in cooling a hot vehicle cabin. (12)

The article was written by John Kimsfer Gozano et al., about the design of a solar-based portable power supply with a modular battery system for the Dumagat Tribe in Norzagaray Bulacan. This paper aims to develop a portable power supply with a modular battery pack that is charged through a solar panel and controller that can provide the Dumagat Tribe in Norzagaray, Bulacan access to basic electric needs. Their needs were calculated using a schedule of loads and the system was designed by PEC Article 6.09 (Solar PV Systems). Data was assessed by monitoring voltage levels using Arduino and statistical treatment was used to determine any significant differences in charging and discharging rates. The system is equipped with the following major components: an inverter, a 12V battery pack with a battery management system (BMS), a rectifier circuit, a portable solar panel, a solar charger controller, and a 3D-printed enclosure. Interpretation of the data shows that the charging and discharging rates of the battery during the 3-day duration of testing are fairly consistent. Hence, the following objectives were achieved: determine the energy requirements of the main outpost area of the Dumagat tribe located in Norzagaray, Bulacan, to develop a portable power supply system that will satisfy the aforementioned demands, to measure the effectiveness of the system in delivering energy to the tribe through quantitative means and provide renewable energy for lighting and basic electric purposes. The following recommendations are suggested: 1) To further improve the battery pack by using higher quality (higher capacity) 18650 battery cells to prolong usage duration, 2) To utilize a much more powerful solar panel that is preferably much more compact than the one used in this study, and 3) To try different types of batteries, such as Li-Po. (13)

Ana Georginana Lupo et al. wrote a SWOT analysis of the renewable energy sources in Romania. SWOT analysis of solar energy sources presents the state-of-the-art, potential, and prospects for the development of renewable energy in Romania. The analysis concluded that the development of the solar energy sector in Romania depends largely on the viability of the legislative framework on renewable energy sources, increased subsidies for solar R&D, simplified methodology of green certificates, and educating the public, investors, developers, and decision-makers. (14)

The SWOT analysis of solar energy in Ethiopia directs to conclude as the following was written by Anteneh Belog. Legal regulation (for investors, contractors, sellers, and users), actual financial support for investors, tax waiving and starting a national certificate agency for solar energy equipment, educating the public, investors, contractors, and decision-makers in the field of solar energy development sector are useful. Even though people prefer to use solar energy, the SWOT analyses identify some gaps in solar energy development. That should be solved for easy market penetration and promotion and utilization of this energy. (15)

3. Subject Plan

The portable renewable energy shelter for generating electricity and heat from the sun was designed and built for the first time in Iran. The purpose of designing and building a multi-purpose portable energy booth is to educate, empower, and promote the culture of using renewable energy among citizens and secondly to provide welfare and support services on special days and occasions. The design of the shed and equipment were designed, supplied, and built based on the following policy. The booths should have an educational and exhibition mode so that it is ready to be visited by people, students, and other environmental enthusiasts. Booths can be moved to different parts of the country on days and occasions to provide services. In this paper, various aspects of this project are discussed, including the design and construction of the energy booths.

4. The steps of designing, building and equipping the portable energy booth

Step 1: design

According to the mentioned goals and in compliance with all the issues related to the strength, safety, and beauty of the booth, it was decided to design and build two booths with the standard dimensions of the kennel (6 x 2.40 meters). The outline of the booths is shown in the figure below.

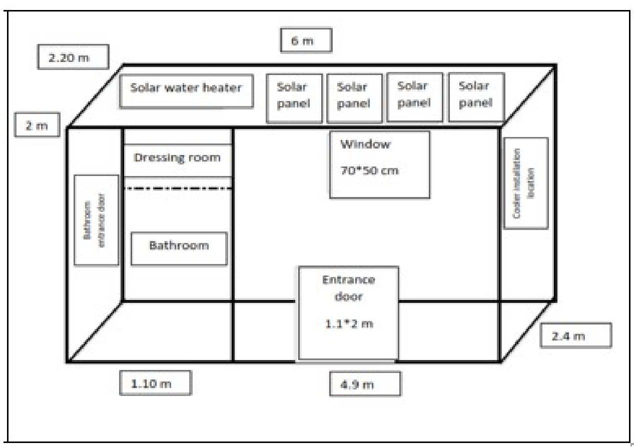

Figure 1. Schematic shape and size of different parts of portable energy booths

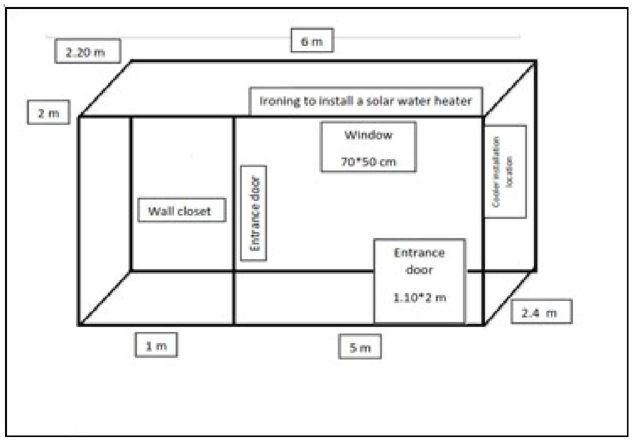

Figure 2: Schematic shape and size of different parts of office room

Step 2: construction

Technical specifications of the booths:

- ✓ **Dimensions: 2.4 * 12 (two devices 2.40 * 6) Total area: 28.8 square meters**
- ✓ **Booth height: from the ground to its highest part: 225 cm**
- ✓ **Number of windows: 3 sliding aluminum UPVC windows**
- ✓ **Number of doors: one aluminum for each booth**
- ✓ **Booth skeleton: 40x40 profile with a thickness of 1.15 mm**
- ✓ **Floor: chipboard or MDF with a diameter of 16 mm with felt parquet flooring**
- ✓ **External body: No. 30 galvanized sheet with electrostatic paint**
- ✓ **Internal wall covering material: shiny white PVC that can be washed**
- ✓ **Insulation of the walls of the booths: 4 cm thick polystyrene**

Figure 3: booths construction Structure

Figure 4: booths construction stages

Step3: installation of equipment

- **Installation of solar power plant**

In the design and construction of the solar power plant, the biggest limitation is related to the size of the portable energy enclosure. The design of the power plant should be in such a way that, firstly, the maximum use of the roof of the building is made by considering the construction of a solar water heater.
Secondly, all climatic conditions should be taken into account in the placement of panels on the carport, including observing the strength of the carport in storms with a speed of over 100 km.
The best suggestion was to build a box on the roof of the booth and place the panels in the box and give a height of 25 cm to the roof of the booth, and the maximum number of panels that could be placed in the box was 6 panels of 545- watts, and practically a 3 kilowatt off- grid power plant in The agenda was set.
Technical specifications of the solar power plant
Number of 6 panels 545 watt mono crystal model

1 3000W 24V solar inverter
8 deep cycle gel batteries, 100 Am 12 volts
A switchboard device with dimensions of 30x30 cm2
Photovoltaic panel base and structure made of 40*40 (mm2) profile

Figure 5: solar power plant installation

- **Construction of a solar water heater on the booths**

Due to the existence of a bathroom in the portable energy kennel, a 250-liter solar water heater with a vacuum tube made of steel and 24 collector glass tubes was prepared, and supplied, and installed on the booths.

Figure 6: solar water heater installation

- **Other equipment**

To equip the concourse with comfort equipment and services, including a monitoring system, providing a cooling and heating system, the following equipment support system was also installed inside the booths:

500-liter chest freezer for supplying cool water and storing perishable materials, a misting fan, a 32-inch TV for power plant monitoring, a Water purifier for drinking water, a 6 kW diesel generator for a backup system, a 50-watt projector to provide illumination of the area in the number of 2 installed outside the building, 4 SMD (20 watts) lamps that are installed inside the buildings to provide lighting, 15 watt SMD lamp inside the bathroom, 240-watt misting fan to provide comfortable air in the summer season, Water purifier with 18-watt consumption, 7000 standing split with 747-watt power consumption, Laptop device with 40-watt consumption and Solar equipment including phone chargers.

The total power consumption of electrical equipment inside the concourse is equal to 1804 watts. That is, if all the electrical equipment inside the building is turned on, the production power of 1804 watts per hour is required. And 43,296 watt hours or 43 kilowatt hours of electricity is needed during the day and night.

According to the type of electrical equipment in the booths, rarely or never all the equipment is turned on at the same time. The misting fan is used during the summer season and the day, and the projectors are used only at night to provide lighting. Perhaps the only device that is used throughout the year is the chest freezer, and the rest of the equipment is used on certain days and hours. On an average day and night, the consumption of electrical equipment inside the compound is as follows.

2 projectors of 50 watts were installed outside the building to produce lighting at night for a maximum of 10 hours and total consumption of 1000 watts per day. 2 SMD (20-watt) lamps installed inside the office building and on the roof of the building with an average consumption of 12 hours a day and total consumption of 480 watts per day. 2 SMD (20 watts) lamps installed inside the energy booth and on the roof of the booth with an average consumption of 6 hours a day and total consumption of 240 watts per day. A 15-watt lamp was installed in the bathroom and a maximum of 3 hours of consumption per day and 45 watts of total consumption. Misting fan with a consumption of 240 watts per hour and with an average consumption of 5 hours per day and in summer and hot seasons with a total consumption of 1200 watts per day. Chest freezer with a capacity of 500 liters and consumption of 550 watts, with an average active consumption of 6 hours per day and a total consumption of 3300 watts per day, with an adjustable temperature level. 32-inch LED TV with 24-watt-hour consumption and with an average consumption of 4 hours per day with a total consumption of 96 watts per day. Water purifier with 18 watts of power and an average consumption of 5 hours per day with a total consumption of 90 watts per day. Standing split 7000 with a consumption power of 747-watt hours with an average consumption of 6 hours per day and a total consumption of 4482-watt hours

The sum of the total consumption of the electrical equipment in the building during the day and night is equal to 10987 watts throughout day and night (915 amp hours of electricity are needed day and night)

The amount of production power of the solar power plant:

There are 6 545-watt solar panels on the roof of the building. These panels transmit the generated electricity to the batteries through a 3 kW solar inverter and the electricity is stored in the batteries.

There are 8 batteries of 100 amp hour 12-volt deep cycle with a special design for solar power systems with a high number of charging times and a high pressure, with a long life and without the need for maintenance and care during operation. They act on electricity storage. The amount of storage in batteries is calculated as follows.

6*100*8=4800 Ah per day

The amount of energy drained from the battery =800*60%= 480 Ah

Time required to fully charge the batteries: 6 hours

The total amount of production per day: 9600Wh (watt-hour)

Considering that it is possible to consume 9600-watt hours at most during the day and night, the use of electrical equipment is suggested as follows:

2 projectors of 50 watts were installed outside the building to produce lighting at night for a maximum of 10 hours and a total consumption of 1000 watts per day.

2 SMD 20-watt lamps installed inside the energy booth and on the roof of the booth with an average consumption of 6 hours a day and a total consumption of 240 watts per day. 2 SMD 20-watt lamps installed inside the office building and on the roof of the building with an average consumption of 10 hours a day and a total consumption of 400 watts per day

A 15-watt lamp was installed in the bathroom and a maximum of 3 hours of consumption per day and 45 watts of total consumption. Misting fan with a consumption of 240 watts per hour and with an average consumption of 5 hours per day and in summer and hot seasons with a total consumption of 1200 watts per day. Chest freezer with a capacity of 500 liters and consumption of 550 watts, with an average active consumption of 6 hours per day and a total consumption of 3300 watts per day, with an adjustable temperature level. 32-inch LED TV with 24-watt hour consumption and with an average consumption of 4 hours per day with a total consumption of 96 watts per day. Water purifier with 18 watts of power and an average consumption of 4 hours per day with a total consumption of 72 watts per day. Standing split 7000 with a power consumption of 747 watt-hours with an average consumption of 4 hours per day and a total consumption of 2988 watt-hours. Laptop device with LED screen and with 30-watt power consumption and average consumption of 3 hours per day and total consumption of 90-watt hours per day.

The sum of the total consumption of the electrical equipment in the building during the day and night is equal to 9404 watts throughout the day and night (784 Ah per day). This amount is supplied by batteries

Figure 7: others Equipment

5. How to operate and maintain the portable energy booth:

The solar water heater is installed in the form of bolts and nuts on the roof of the booth so that all the parts of the water heater can be opened and collected during the transfer, and after the booth is stabilized in the desired place, they can be installed again on the booth. The principles of maintaining the solar water heater during transportation are: If there is dust and debris on the collector glasses, the glasses should be washed with water and approved. Due to the increase and decrease of water pressure as well as the presence of seasonal changes, the float in the expansion source may be out of adjustment, which can be easily adjusted, by opening the small door of the expansion source and adjusting the float inside it. If the collectors are broken for any reason, the valves are installed next to the expansion source and, if possible, the water heater valve inside the valve should be closed and a technical expert will be present to replace the collector. In case of moving and transporting the booth, first close the main valve installed in the corner of the area. Then close the water heater inlet valve. Separate the tube that is in the form of a nut and open all the parts that are in the form of bolts and nuts. When moving, the only breakable parts of the water heater are the collector glass pipes, put them in the storage section of the office building, and secure the glass with foam.

4 panels are placed on the roof of the office building and 2 panels are placed on the roof of the energy (equipment) building. The panels are strong despite the frame and because they are on the roof of the booth (the slope was considered for the kennel itself), they are almost solid, but due to the high price of the panels and also the large shaking of the load during moving and long distance, it is recommended The panels should be returned and after reaching the destination, they will be closed again on the frames with bolts and nuts. The best place to store the panels is when moving the floor of the resting place and separating them with foam panels. Considering the size of the width of the booths with the length of the panel, if the panels are placed in the width of the concourse, it will not be possible for the panels to shake and move. When opening and closing the panels, care must be taken in how to install the cables and avoid being hit and damaged. At the time of use, we must place the solar panel in a place where there is no shadow on it; Because by creating a shadow, that part of the panel that is under the shadow will turn off and become a consumer, and if the diode does not have a bypass, there will be a possibility of a hot spot phenomenon and physical damage to the panel. Even if the panel has a bypass diode, the part that is in the shadow does not generate electricity and the efficiency of the panel decreases. Another point is solar panel connections. Another point is solar panel connections. We must choose the right cable according to the current of the panel, the voltage, and the distance between the equipment so that the solar panel can do its job properly. Finally, we should have reasonable consumption of the solar panel. If you use the panel that is designed and intended for the lighting of a refrigerator and air conditioner, for example, for the operation of the pump, the life of the battery will be reduced and the panel will not be able to charge the battery well, and its life will also be reduced.

The batteries are inside the box, and the MDF cabinet is also designed on it. During moving, no special work should be done for the batteries, only the following things are necessary for protecting the battery and not connecting the systems. If there is no need to use the solar power plant for a long time, it is suggested to disconnect the ends of the wires connected to the solar generator or turn off the solar generator.

When moving and even not using the power plant, it is better to turn off the inverter and disconnect the cables from the panels. The solar heater is installed on the wall of the cabin and no special operation is required when moving.

Figure 8: The interior and exterior of the portable energy booths

6 - Conclusion:

The portable booth is a pre-made structure whose body and roof are made of sandwich panels with steel or aluminum sheets in the factory in different dimensions and designs, assembled and then sent to the market. Portable sheds can be used for various applications, while the price of sheds is cheap compared to other construction materials, however, its application is very wide and in any place, even coastal lands that are loose or mountains that have hard ground. It is easy to carry and use.

The Portable Energy booths were designed and built for the first time to create culture and teach the use of renewable energy among citizens and secondly provide welfare and support services on special days and various occasions.

The energy booth includes a 3 kW solar power plant disconnected from the grid to supply the equipment in the booth, a 250-liter solar water heater, a 6 kW electric motor, a 500-liter freezer, 2 misting fans, a water purifier, an air conditioner. 32-inch portable TV and solar lighting equipment including lamps and projectors.

The sum of the total consumption of the electrical equipment in the building during the day and night is equal to 9404 watts throughout the day and night (784 Ah per day). This amount is supplied by batteries.

After the design and installation of the equipment to familiarize the people and also for the use of the residents in the conditions where there was no access to the water, electricity, and gas network, the condo was tested for 10 days and its defects were also fixed. The costs of fuel transportation and electricity transmission are much higher than the use of solar energy in the garage. Students are also taught about renewable energy from this facility.

In the end, it is suggested that due to the increase in environmental problems, the increase in population, and the lack of land, the design and construction of such condominiums to reduce environmental pollution and reduce costs should be supported by government institutions.

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