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Research Paper

Energy Management of Disaster Shelter Centres Established in the Recent Earthquakes in Turkey

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Abstract: Natural disasters create disasters stop human activities, destroy homes, businesses and the environment. Such disasters occur without warning and deprive hundreds or even thousands of people of drinking water, heating, lighting, communications, and electricity services. Turkey has experienced the last three important disasters. 6702 buildings in the Erzincan earthquake, 48,666 in the Van earthquake, 3,200 in the Elazığ and Malatya earthquake, 90,813 buildings in the İzmir earthquake were destroyed or heavily damaged, and a long-term power outage was experienced in the city center, towns and villages. Post-disaster housing needs are the most important element of the improvement of the modern disaster management system. The importance of alternative energy to be used in lodging centers after a major disaster is enormous. Lodging centers following disasters are built in safe areas- far from the city centers. Shelter centers are insufficient to meet the needs of lighting, heating, and hot water due to reasons such as distance from city and transformer capacity, as well as infrastructure for electrical energy. In this study, a decision-making road map was drawn for the shelters planned to be built in the future by evaluating the data on the integration of the solar panels into the containers to be used in the shelter centers.

Keywords: *Disaster, lodging centers, alternative resource, renewable, solar energy*

Introduction

Turkey is a country that is often faced with natural disasters like floods, rock falls etc. landslides, especially earthquakes, due to its geological, tectonic, meteorological, seismic, topographic and climatic structure. Turkey is third in the world in terms of human loss in earthquakes and eighth in terms of number of people affected by the earthquake. On average, every year there is at least one earthquake with a magnitude of 5 to 6 (AFAD, 2018).

The disaster is defined as natural and anthropogenic events that incite economic, social and physical losses for human life, hindering human activity, or interrupting normal life (Ergunay, 1996). Most of the disaster types that affect people's lives, and their life quality are caused by nature. Cases that cause destruction, damage and damage are called disasters and multiple forms of calamity are called affaults. Disasters are the loss of many people and other living things. Although disaster species are generally known for risk management, it is not possible to prevent or cease to occur (Özcelik, 2020)

Disasters are divided into two groups: man-made and natural disasters. Natural disasters are natural phenomena, especially earthquakes, such as floods, fires, rock falls, hurricanes, typhoons, landslides. Human-borne disasters are human-caused disasters such as explosions, pollution, traffic accidents, and war-related immigration (Acerer, 1999).

Disaster types often follow each other as chains, not alone. For example, earthquakes are not the only damage caused by the destruction of ground movements and the damage it causes. Other natural disasters after the destruction follow fire, landslide, and flooding. In Turkey, natural disasters account for earthquakes, landslides, flooding, rock falls, fires, avalanches, storms, and the rise of groundwater (Ergunay, 1996).

Disasters affect public life, leading to loss of life and property. The first stage after a disaster is during disaster-affected victims, health care, food and shelters. Disasters directly affect society, business revenues, based on duration and status. This chain reaction is followed by a decline in family income and production of businesses. In the period after the disaster, it can lead to inequality in income

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distribution, inflation and increased epidemic diseases (Bazoglu, 1980). The effects of disasters are most directly seen in the housing sector (Sey & Tapan, 1987).

Urgent accommodation is the healthy provision of basic accommodation and hospitality for victims who have been exposed to disasters. To this end, tents or containers for areas such as hangars, gyms, dormitories are being provided to accommodate victims (AFAD, 2018). Temporary accommodation sites are accommodation sites (Maral, 2016) that have been pre-planned and provide the best living conditions for survivors of possible disasters to be temporarily housed and protected from natural conditions. In 25 different provinces after the earthquake disaster, Turkey has been given lodging for storage of tents and containers (AFAD, 2018). Given the statistics from natural disasters over the past seventy years, it is estimated that 60% of damage occurs because of earthquakes, 16% landslides, 13% flooding, 5% rock falls, 4% fires, and 2% avalanches, storms, etc. (Songur, 2000).

Earthquakes will continue from the past to the present and to the future through the movement of the Earth. Earthquakes are dangerous and measures should be known. To avoid the effects of the earthquake, people can go on living normal lives without being harmed by proper planning and risk management. In our history, the situation does not look very bright. Earthquakes are always a disaster for us. The absence of a catastrophe will only be the conscious individual and the society by providing earthquake-centric education, law, and coordination (Bayraktar v. 2019). Between 1966 and 2021, there were 34 earthquakes in Turkey, more than 6.0 magnitude (Table 1).

Table 1. 1966-2021 earthquakes in Turkey larger than Mag=6*(Source: http://www.koeri.boun.edu.tr,2022)*

Date	Occurrence Time	Location	Violence	Mag	Loss of Life	Damaged Building
19.08.1966	14.22	Varto (Muş)	IX	6.9	2396	20007
28.03.1970	23.02	Gediz (Kütahya)	IX	7.2	1086	19291
22.05.1971	18.43	Bingöl	VIII	6.8	878	9111
06.09.1975	12.20	Lice (Diyarbakır)	VIII	6.6	2385	8149
24.11.1976	14.22	Muradiye (Van)	IX	7.5	3840	9232
30.10.1983	07.12	Erzurum-Kars	VIII	6.9	1155	3241
13.03.1992	19.08	Erzincan	VIII	6.8	653	8057
01.101995	17.57	Dinar (Afyon)	VIII	6.1	90	14156
27.06.1998	16.55	Ceyhan (Adana)	VIII	6.2	146	31463
17.08.1999	03.01	Gölcük (Kocaeli)	X	7.8	17480	73342
12.11.1999	18.57	Düzce	IX	7.5	763	35519
19.08.1966	14.22	Varto (Muş)	IX	6.9	2396	20007
22.07.1967	18.56	Mudurnu (Adapazarı)	IX	6.8	89	7116
03.09.1968	10.19	Bartın (Zonguldak)	VIII	6.5	29	2478
28.03.1970	23.02	Gediz (Kütahya)	IX	7.2	1086	19291
22.05.1971	18.43	Bingöl	VIII	6.8	878	9111
06.09.1975	12.20	Lice (Diyarbakır)	VIII	6.6	2385	8149
24.11.1976	14.22	Muradiye (Van)	IX	7.5	3840	9232
28.03.1978	03.48	Alaşehir (Manisa)	VIII	6.5	53	3072
30.10.1983	07.12	Erzurum-Kars	VIII	6.9	1155	3241
13.03.1992	19.08	Erzincan	VIII	6.8	653	8057
01.101995	17.57	Dinar (Afyon)	VIII	6.1	90	14156
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12.11.1999	18.57	Düzce	IX	7.5	763	35519
3.2.2002	09:11	Çay - Sultandağı (AFYON)	VII	6.4	44	622
1.5.2003	03:27	BİNGÖL	VIII	6.4	176	6000
2.7.2004	01:30	Doğubayazıt (AĞRI)	VII	5.1	17	1000
23.10.2011	13:41	Van	VIII	7.2	644	17005
24.01.2020		Elazığ	VIII	6.8	41	18760
30.11.2020		İzmir	VII	6.6		2500

The Kandilli Observatory and Earthquake Research Institute of the University of Bogazici hold information on the history, times of earthquakes, places, violence, loss of life, and damaged buildings. The problems at lodging centers after natural and human-caused disasters require lighting, heating and hot water. In the event of a possible disaster, meeting humanitarian needs due to these problems may vary according to the nature and severity of the disaster. Disaster life containers (such as Ankara, Konya, Afyon, Antalya, Bursa) located in the Metropolitan area by the Ministry of Interior Disaster and Emergency Situations are shipped from these provinces to the disaster area and assembled in safe zones. Because the event, time, and location of the disaster are not known, the need for energy can be revealed. Economic analysis of solar system integration has been undertaken using an alternative solar source to the disaster life containers to avoid the need for energy in temporary accommodation centers to be built.

Material and Method

The study explored solar energy potential, total solar radiation, sunbathing times and average annual solar radiation in Turkey. The daily energy needs of the disaster-life containers in lodging centers have been calculated in case of a disaster. This research led to the design of the solar panel system for containers and the cost analysis of the solar panel system.

Solar Energy Potential in Turkey

The sun is a very important source of energy for the earth and its energy resources. Therefore, both heat production and electricity production share is large. As a result of its location, Turkey is located between 36-42° north parallel and 26-45° east meridian, so geographically sunbathing is more favorable to Germany, Italy, Spain and Belgium than other European countries. There is a constant reaction from the sun, and the energy is released. Electricity and heat production have been realized using this energy in different fields. In electricity generation, "solar cells" can be transformed into systems, transforming solar energy directly into electricity (Figure 1).

Figure 1. Solar cells *(Source: www.dunyaenerji.org.tr, 2022)*

Figure 2. Condensed solar energy *(Source: www.tespam.org, 2022)*

Turkey's annual solar power potential has been given an average annual sunbathing time (Figure 3). Our country has an average annual solar radiation of 1,304 kWh/m2 and an average sunbathing time of 2,640 hours. This is a total of 108 days of sunbathing, approximately 7.2 hours per day, to 3.57 kWh/m2 daily. The energy potential has 26.2 million TEPs (equivalent to 20 tons of oil). For 10 months in a year, technically 64% of the surface area and 16% of the entire year could benefit from solar energy. The location of the required investments should be considered with the solar potential (Figure 8). The Earth receives an energy of 170 million MW per second from the Sun. This energy is approximately 1,700 times Turkey's annual energy output.

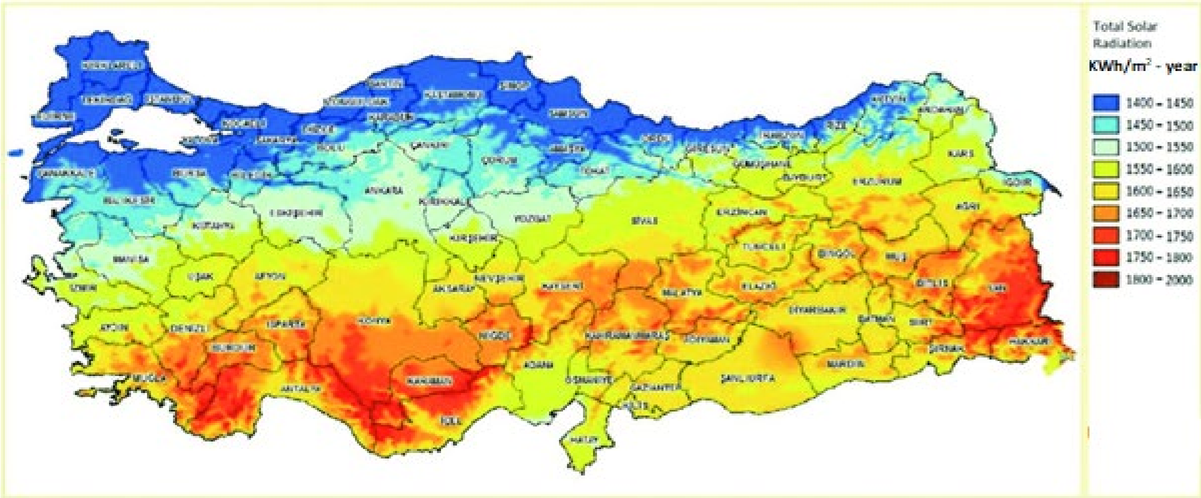

Figure 3.Total solar radiation *(Source: www.mgm.gov.tr,2022)*

Turkey's average sunbathing times from 1991 to 2020 were shown in Figure 1. The months with the highest sunbathing times are July, August and June. The lowest months were December, January, and February.

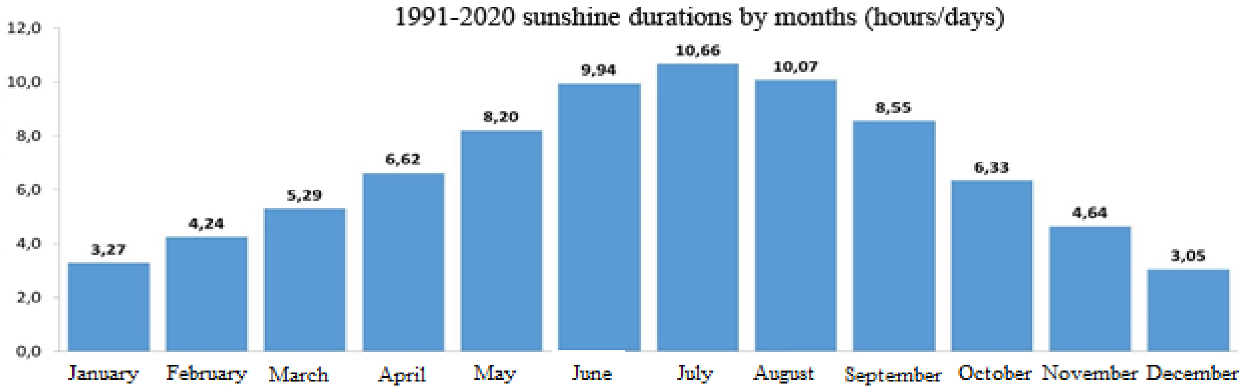

Figure 4. Turkey's sunbathing times by month (hours/days) *(Source: www.mgm.gov.tr,2022)*

According to the installed power report of TEIAS data from October 2021, the solar power plant is the primary source of energy with the number of plants. There are 8,212 solar power stations. The power produced by these plants has an estimated 7,658.6 MW. It is based in Turkey at 99,050.4 MW. The power generated by primary energy sources in Turkey is 99,050.4 MW.

Design of the Solar Panel System

The Solar Panel System (SPS) has several steps to be taken care of. The solar battery system consists of a solar panel, inverter (right current alternating current), charge regulator, and various electronic evenings. One of the things to look out for when selecting these electronic evenings is the efficiency of the electronic equipment that drives the system. The average solar panel yield (η_{pe}) is 80%, the battery yield ($\eta_{battery}$) is 80%, and the inverter yield (η_{inv}) is 90% (Alkan, 2014).

The first stage is the choice of solar panels; it is necessary to consider efficiency when doing panel calculations based on the amount of energy needed in the SPS.

The second stage battery selection is possible to be designed in two different ways as a grid-independent and network-dependent system. At times of daylight, batteries are needed when there is no need for batteries, while at times when there is no daylight. In battery selection, the battery is selected according to its economics and characteristics.

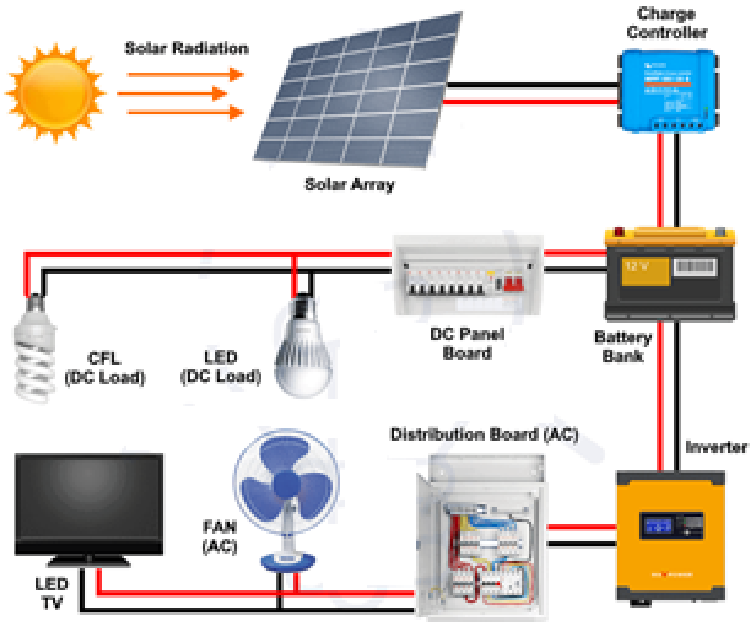

Figure 5. Exterior representation of the Solar Panel System (SPS) *(Source: www.electricaltechnology.org)*

The third stage charge regulator; once battery selections are made, charge regulators are needed to protect it from overcharging and electrical surges in the battery.

In the fourth and final stage, inverter is made according to the capacity of the solar system while Inverter is selected. The electronics and electrical goods we use in our daily lives are usually powered by 220 volts and 50 Hz electric current. And all of these electronics and electrical appliances that we use are consistent with alternating current. So, the solar energy that we're producing in solar cell systems is a 12-volt direct current. It is necessary to use inverter to convert the solar energy produced by solar cell systems into an alternative energy current.

Containers set up in temporary accommodation centers consist of 21 m², with 2 rooms, 1 toilet and bath (Figure 6). The main characteristic of the standard disaster life containers is easy to manufacture, fast shipping, and ready for use as soon as possible. Due to full fabrication production, it is readily available for use when downloading from the crane with a discrete installation capability in case of disaster and emergency. Containers are ready to use in minutes, with two people, as well as no other materials, due to its discrete capability and the availability of a next-generation system with bolts and phases. Table 2 provides the electricity requirement for a planned disaster life container set up in a post-disaster temporary shelter.

Table 2. Energy of daily devices used in containers

Electronic Device Name	t_k	P_h	P_t
Refrigerator A+	4 (hours/week)	1200W/day	4800
Washing Machine, A+	6 (hours/weeks)	1000Wh	6000
32-Screen TV	10 (hours/weeks)	50Wh	500
Lighting	15 (hours/weeks)	55 kilowatt-hours	825
Electric Thermophone	20 (hours/weeks)	6 kilowatt-hours	120
Air conditioning	5 (hours/week)	1600Wh	8000
Weekly Energy Total			**20250Wh**
Daily Energy Total			**2890Wh**

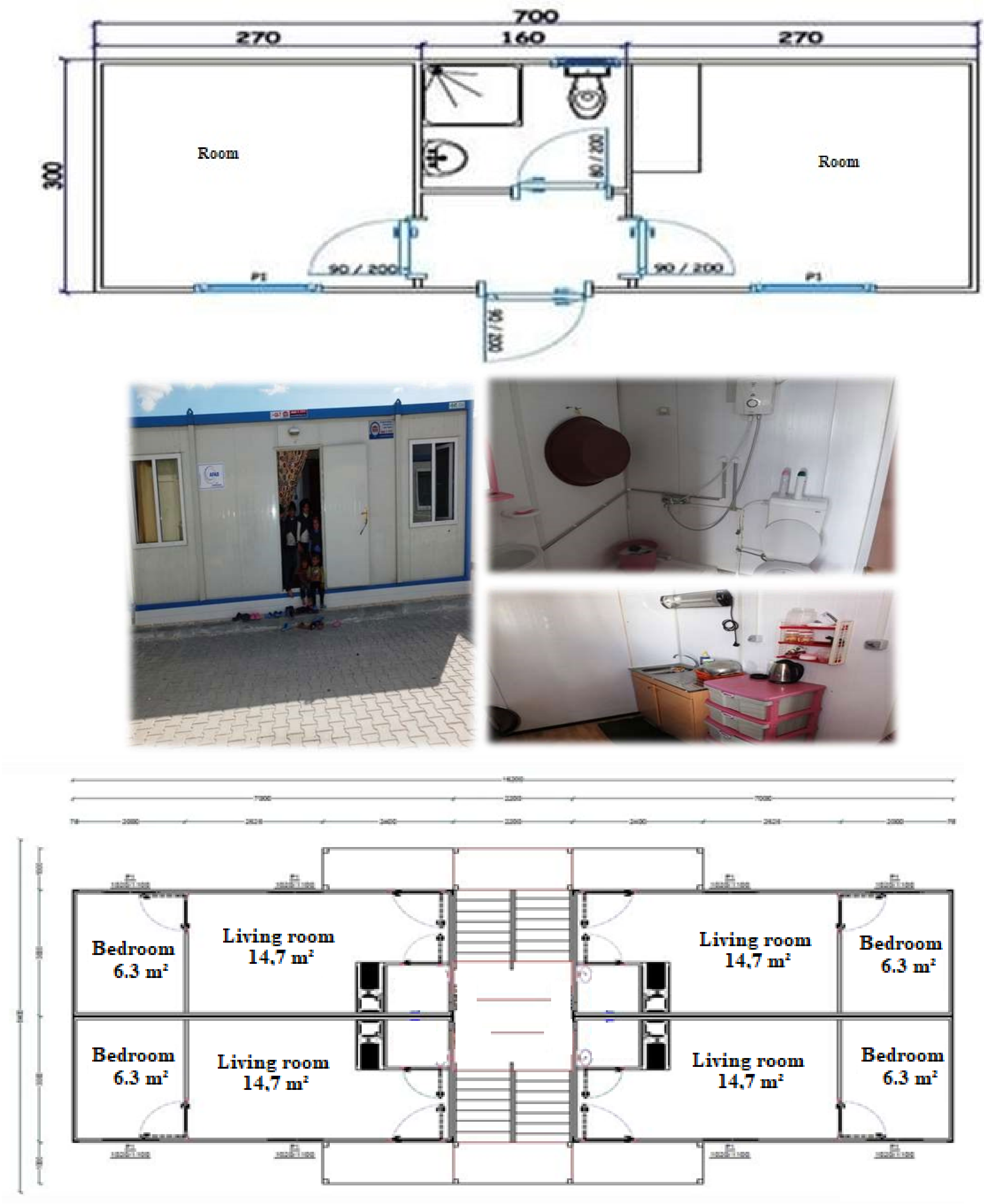

Figure 6. Disaster life container *(Source: www.afad.gov.tr,2022)*

The T320-72P solar panel is selected based on the energy needs of everyday devices for the solar panel system, which is designed for electrical generation in temporary accommodation centers, and the computed panel number, panel power, and panel efficiency. The maximum power of the T320 72P solar panel is 320Wp, the maximum voltage produced is 37.70V, and the maximum current is 8.49A (Table 3).

Table 3. Performance values of T320 solar panel

Panel Model	$P_{mak.}$	$V_{mak.}$	$I_{mak.}$	V_{oc}	I_{sc}
TT320 72P	320Wp	37,70 V	8,49 A	46,40 A	9,04 A

The solar panel has a 12-year manufacturer's guarantee. It guarantees 80% productivity over 10 years, 90% over 25 years. This GP is made from 72 156.75 mm x 156.75 mm silicon solar cells.

$$S.P.A : 1.959 \times 0.995 = 1{,}950\ m^2 \quad (1)$$

The equation for finding the solar panel field is calculated in 1.

$$P_{mak.} = I_{mak.} \times V_{mak.} \quad (2)$$

With equation 2, the maximum current ($I_{mak.}$) and voltage ($V_{mak.}$) of solar panels can be multiplied by the power of solar cells (Altas,1998).

$$\eta GP = \frac{Pmak.}{(SPA \times H)} \times 100 \quad (3)$$

The efficiency of the solar panel can be calculated in GP equation 3. In equation 3, the radiative value (H) is used because the region or state is not clear (H≅800 Wh/m^2). The maximum power ($P_{mak.}$) value of the panel (Kutlu,2002).

$$\eta sys = \eta SPx\eta batteryx\eta inv \quad (4)$$

In equation 4, the efficiency of the system is calculated by multiplying the solar panel, battery efficiency, and inverter yield values (Kutlu, 2002).

$$PS = \frac{D.E.Nx\eta sys}{(Pmax.xPPS)} \quad (5)$$

Calculating number of panels (PN) to be used in GPS in equation 5. The product of the inverter efficiency (η_{sis}) with the daily energy needs (D.E.N) is achieved by the product of the fog and maximum power of the panel (Pmax.) and by the product of the daily sunbathing time (PPS≅7.05) (Öztürk and Dursun, 2011).

$$AS = \frac{D.E.NxAk}{(VbxBc)} \quad (6)$$

In equation 6, the number of batteries (BN) is determined (Öztürk and Dursun, 2011). As is calculated by the battery voltage (V_b) and Battery capacity (Bc) values (Öztürk and Dursun, 2011).

$$\dot{I}C = \frac{D.E.Nx\dot{I}loss}{PPS} \quad (7)$$

After determining the number and of batteries we use for the solar panel system, the inverter capacity is calculated in equation 7. The translator capacity is estimated at 10% for losses incurred from the internet (Öztürk and Dursun, 2011).

$$CR = \frac{D.E.N}{PPS} \quad (8)$$

In equation 8, the charge regulator is derived from the daily sunbathing time portion of the daily energy need (Öztürk and Dursun, 2011).

Cost Analysis of the Solar Panel System

The cost of a solar battery system designed for integrating solar panel system of disaster life containers created or planned to occur in the aftermath of a disaster is an economically large part of the system being first investment cost, business and maintenance.

$$g = \frac{Ck + Cm + Cf}{E} = \frac{Ct}{E} \quad (9)$$

It is necessary to calculate the cost of energy generation achieved for the designed system. Therefore, system costs and Wh unit price are calculated in equation 9. Annual investment expenses or annual capital (C_k) refers to annual operating-maintenance costs (C_m), annual fuel costs (C_f), annual total expenditure (C_t), and annual electricity generation amounts (Keçeli, 2007).

$$C_k = I_{ac} \times a \quad (10)$$

In equation 10, to calculate annual investment expenses or annual capital costs; I_{ac} is achieved by the installation and assembly cost times the "a" depreciation factor (Köşker, 2007).

$$a = \frac{(1+i)^n i}{(1+i)^n - 1} \tag{11}$$

In equation 11, the depreciation "a" is calculated. Total life expectancy is "n", interest is "i (Kutlu, 2016).

$$E = I\,x\,A\,x\,\eta SP\,x\,\eta sys\,x\,365 \tag{12}$$

In equation 12, the average annual radiative value is shown as "I," the panel surface area is "A," and the panel yield is "η_{SP}" and the system yield is "η_{sys}". Based on these values, it is possible to calculate the total amount of energy that can be produced for a year. Solar panels are divided by the total annual amount of energy spent on system installation, which calculates the cost per power by units of "g" in equation 9 (Korkmaz,2001).

Results

A planned disaster life container for post-disaster temporary accommodation centers requires electrical energy for solar panel integration; the maximum power of the solar panel is 320Wp, panel efficiency is 18%, system efficiency is 90%. 2 batteries are required. The panel count is calculated from 4 T320 72P solar panels. Inverter capacity is 750VA inverter sufficient for 586.95 VA capacity. Charge regulator preferred charge regulator capacity of 750W for 450.8W power. Unit price amounts for equipment are shown in (Table 4).

Table 4. Economic analysis of GPS for containers

Equipment	Quantity	Unit Price	Amount ($)	Amount
Solar panel T320 72P	4	229$	916$	13576,4 TL
VRLA Battery	2	100$	200$	2964,28 TL
Solar Charge Regulator	1	190$	190$	2816,07 TL
Full Sine Inverter	1	230$	230$	3408,92 TL
Subtotal			1563$	23165,85 TL
Installation Cost (20%)	-	-	312,6$	4633,17 TL
Total			1875,6$	27799,02 TL

**The central bank has been calculated from 21.03.2022 (1$=14.82TL)*

Solar panels install cost 27799.02 TL; C_f has no fuel costs; C_f value is zero, C_m value (annual=100$) is 14812 TL, C_k is worth 2605 TL, and C_t valued at 3504.8 TL. Panel space is 1,950 m², with solar radiation not planned for any Turkish province, and an average efficiency of 90% panel yield 20%. If the system yield is 90%, then the equation 7 will produce an annual amount of energy of 13394.5 Wh. We can calculate that there are four solar panels in the solar panel system for the container, and that's 53578.2 Wh.

Because the life of the solar system is assumed to be 25 years old, the values of c_m, c_k, and c_t multiplied by 25. C_m= 370300 TL, C_k= 65125 TL, C_t= 87620 TL. The total annual energy output is 2227271.28 W. The unit electricity price is g=0.03835688 TL/Wh.

The EPDK (Enerji Piyasası Düzenleme Kurumu) approved 1 Kw of electricity for 2022 at 1.37 Tl/kWh for 150 kWh and 2.06 Tl/kWh for over 150 kWh for consumption. 2860WH per day energy consumption is 1043.9 kWh. This annual consumption energy quantity is 26097.5 kWh for 25 years. This 25-year consumption is 25 years of electricity costs by multiplying the power supply by the unit price of TEDAŞ grid electricity. The 25-year electricity bill that will be paid to the TEDAŞ institution is 26097.5 kWh × 1.37 TL/kWh=35753.58 TL (p). After 25 years, the interest rate account is $S=p(1+i)^{25}$ $S=35753.58(1+0.095)^{25}=345678.61$ TL. For the solar panel system designed for disaster containers, we will pay 27799.02 TL. The price difference is 317879.59 TL

Discussion

Turkey is dependent on foreign energy in terms of energy, such as Germany, the Netherlands, Portugal and Italy in Europe. The amount of energy consumed increases by 7% every year due to industrialization and population growth. However, fossil fuel reserves are decreasing. Since our country is a developing country, its energy needs are increasing day by day. While energy consumption was 220 billion kWh in 2012, it was 249 billion kWh in 2017. It is predicted that the consumption will be 460 billion kWh in 2023. Turkey is not a rich country in terms of natural gas and oil resources. In this context, alternative clean energy sources are important for depletion of fossil fuels and reducing dependence on foreign energy.

Solar energy, one of the renewable energy sources, has a high potential due to Turkey's geographical location. Although the sunshine duration of our country varies throughout the year, it is approximately 2,800 hours per year. In this study, feasibility studies of solar panels system for living containers to be established in temporary shelter centers created as a result of human and natural disasters in Turkey have been carried out and it is seen that profit is made. Since the technology of solar energy equipment is foreign-dependent, it is affected by the exchange rate. When a decrease is observed in the dollar exchange rate and the solar panel system has a life of 25 years, the difference is calculated as 317879.59 TL. According to the results of the economic analysis, it is thought that if electricity generation from the solar panels system is used in the accommodation centers, it will be profitable for the country's economy.

Containers used in disaster areas are preferred because of their low transportation and assembly costs. For this reason, with the solar panel system designed for containers, the basic needs of disaster victims such as shelter, heating/cooling, lighting and hot water will be met with the understanding of the social state in a 72-hour period. In addition, if the number of panels to be planned in the disaster area is increased and energy storage can be made because of R&D studies, the excess energy to be produced can be traded in case of demand.

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