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Authors: Esra DEMİRHAN, Yasemin DAMAR ARİFOĞLU

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The Application of Rain Water and Solar Energy System on Green Roof One of The Building in Sakarya University

Yasemin Damar Arifoglu*[1], Esra Demirhan[1]

Abstract

In our present day, consuming water and energy sources at a rapid rate, losing green areas, air pollution which is caused by gas emissions, global warming and actions that damage the balance in the ecosystem have made it necessary to take precautions. In this perspective, using water and energy sources sufficiently, finding new energy sources and using ecofriendly roofs are crucial for the world's future. Green roof systems, built for the purpose of preventing global warming, and stopping climate change, are the eco-friendly systems that reduce the heat in a city, prevent air pollution, and eliminate too much water accumulation in the city's infrastructure by holding rain water. In this study, decreasing the climate change by holding carbon emissions with green roof, finding the solutions for problems of water scarcity by saving water with the rain harvest system, saving the electricity by lightening the street lamps with stocking the energy coming from the solar system have been aimed. It has been tried to decrease the negative effects of climate change to the environment. The appropriate building has been determined for the inclination and height of roof where a green roof can be built by analyzing some buildings' roofs in Sakarya University in the study. In the scope of experimental study, an extensive green roof system has been designed on the roof of boiler room building. By gathering the rain water on green roof, green places have been watered regularly. The garden has been lightened by producing electricity with solar energy. The contributions have been added to sustainability owing to these sensitive systems for environment.

Keywords: Green roof, water and energy resources, climate change, global warming

1. INTRODUCTION

In the world where water and energy resources are declining, 42% of water and 50% of energy are consumed in building construction. The most important issue on a global scale is due to global warming, 50% of greenhouse gases, 24% of air pollution, chlorofluorocarbon (CFC), 50% of hydro chlorofluorocarbon (HCFC) emissions are building related activities [2]. Green buildings and green roofs have been started to be designed due to the population increase, the use of the average half of the energy resources of the buildings, air pollution, the disappearance of nature and green areas over time [3].

* Corresponding author: ydamar@sakarya.edu.tr
[1] Sakarya University, Department of Environmental Engineering
E-mail: esraademirhann96@gmail.com
ORCID: https://orcid.org/0000-0003-1281-0847, https://orcid.org/0000-0002-5859-7271

While roofs are a building material that absorbs heat, green roofs have been designed and turned into a building material that contributes to the ecosystem with the development of technology and building materials. Green roofs are systems that improve the energy use of the building, air quality and city ecology and provide solutions to the problem of water scarcity by using rain water effectively. At the same time, green roofs provide green space that they can use as an activity. Therefore, the concept of green roof is very important ecologically and socially [1].

In recent studies, it has been observed that green roof shave serious ecological, technical and social benefits in buildings and cities. These benefits are the protection of environment and biodiversity, shelter in wildlife, reuse of water, reducing the impact of urban heat island, reducing electromagnetic radiation, helping exchange of carbon dioxide and oxygen, reducing noise pollution, impacting the lifetime of the roof membrane, filtering airborne particles, energy efficiency and cooling effect [1].

The rise in the world's population, climate changes, urbanization and industrialization have a negative impact on natural resources. In the case of increased water needs, the lack of water due to unconsciousness use and global warming has made water the first issue on the international agenda [4].

The rain water collected by pipes from the rooftops of buildings is filtered and collected in the tank and the water collected is used for needs such as garden irrigation, car washing, cleaning and pool filling. It is also used as drinking water when the collected rain water is purified. When the drinking water has reached its quality, it can also be used when taking a shower, cooking and washing dishes. The potential for rain water harvesting is proportional to the amount of rain and varies according to regions in Turkey. The potential savings in rain water collected from the green roofs are around 30 to 60% of a household's drinking water needs, depending on the area of water collection. The collection and storage of rain water and use for needs both protect water resources and save on the water bill. Thus, rain water collection systems play an important role in the creation of sustainable cities [5].

There are some examples of rain water harvesting technologies from green roofs in Turkey. For example, the Bursa Hilton Hotel is a Green Star concept that improves energy efficiency and is found in the category of environmentally conscious hotels. The Green Star concept includes the use of rain water or purified waste water in garden irrigation and toilet reservoirs. Designed with the green building concept, 20 m^3 of rain water is stored by collecting and filtering rain water on the terrace of the Bursagaz General Directorate building and drainage water around the structure, stored rain water is used in the watering of green areas and in toilet reservoirs [6]. One of the most useful and environmentally friendly energy sources in renewable energy sources is solar energy. Solar panels are elements that convert solar energy into electrical energy. There are also equipment such as charge control pen, accumulator, inverter that can work with solar panels in generating electricity from solar energy. It has benefits such as lighting and heating in buildings. Increasing environmental awareness has made this system widespread [7].

The purpose of this study is to stress the positive effects of green roofs to the environment, to annihilate the climate change problems that are caused by drought and greenhouse gas emissions by using natural sources effectively such as rain and sun. The use of tap water and fossil fuels will be in minimum level and decreasing the carbon footprint has been aimed.

2. MATERIAL, METHOD AND FINDINGS

2.1. Research Area

The research area is the roof of the boiler room building in Sakarya University Esentepe Campus (Figure 1). This building was chosen because the slope and height of the roof are suitable for designing a green roof system. The building is located in side area of Engineering Faculty Deanship and Engineering Faculty class block. It is one-storey and reinforced concrete building. Building height is 4,25 meter, roof area is 273 m², the inclination of roof is 8,5%. Shingle has been used for roof coating. Experiments, observations and measurements were made between 14 December 2020 and 14 July 2021 with a 1,5 m^2 green roof, rain water and solar energy system designed on a part of the roof of the boiler room building.

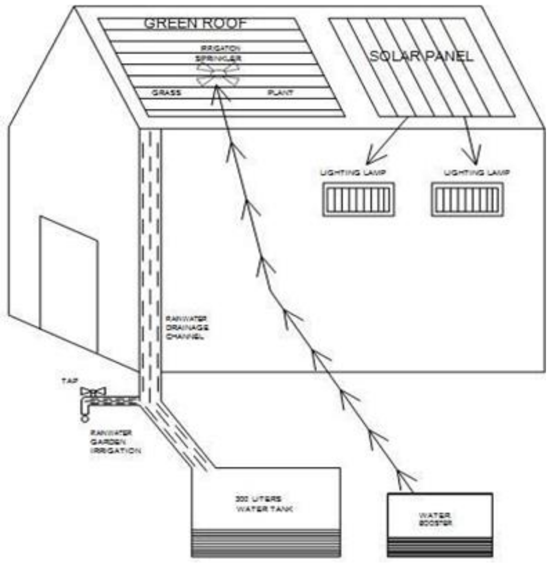

Figure 1 Research area

Approximately 2 and 6,2 mm rain fell in Sakarya/Serdivan where the research site was set between 14 December 2020 and 14 July 2021. This amount is approximately the same as the general average of Sakarya, which has a monthly average precipitation of 3,13 mm. When the monthly average temperature values are examined, it is seen that the monthly average air temperature of Serdivan is 13,78 °C, and the average monthly air temperature of Sakarya in general is 14,66 °C. Thus, it has been determined that the monthly average air temperature of Sakarya is 0,88°C higher. It was observed that the highest air temperature in the region where the research area is located in the 8 month study period was in July with 33,3 °C, and the lowest air temperature was in January with 1,5 °C. During the experimental period, 634.8 mm of precipitation fell in the region where the research area is located. A total of 52,4 mm of precipitation fell in the research area. The highest amount of precipitation falling at the location of the research area was in July with 50,1 mm, and the lowest amount of precipitation was in May, when 0 mm of precipitation was the highest. The longest consecutive rainy days were observed between 18 – 27 March 2021. The number of days without precipitation is 110. The longest consecutive days without precipitation were observed from 26 June to 3 July 2021. Drought, which occurs as a result of consecutive days without precipitation, negatively affects the growth of plants on the green roof. In this period, the plants on the green roof are irrigated with the rain water accumulated in the tank so that the plants can continue to develop. When the monthly total precipitation data measured throughout the study is examined, it can be concluded that the climates have begun to change since the highest precipitation was measured in July.

When the 8-month meteorological data taken from the General Directorate of Meteorology and covering the years 2020-2021 are examined, the region where the research area is located is normal humid with humidity rates varying between 53% - 58% for 3 months between December 2020 - February 2021, March 2021 - July 2021. It has high humidity according to the humidity rates varying between 65% and 81% in the 4-month period between Sakarya in general has high humidity in the 8-month period between December 2020 - July 2021.

2.2. Material

Within the scope of the research, first of all, interviews were held with companies working on green roof systems, solar energy systems and water installation systems and an agreement was reached. In the construction of the green roof; 3 egger osb for floor preparation for water proofing, 2 wooden pallets for mounting egger osb to the pallet, 2 weber polyurethane sealants to ensure sealing and adhesion at the joints of the wooden pallet, 3 polyfin agoc-plan ecb 1015 geomembranes for waterproofing, by creating an uninterrupted drainage channel, 2 florax balls were used to prevent ponding in the soil layer, 9 aluminum pressure bars to prevent water from flowing through the wall and passing between the wall and the membrane, and 3 geotextile felt moisture traps to protect the water and heat insulation materials on the roofs. 1 water tank of 300 liters to collect and store rain water, 1 pump to use the water in the tank for green roof and garden irrigation, 1 pipe to deliver the rain water from the green roof's gutter to the tank, 1 fittings for connecting the pipes and 1 valve used. 1 solar panels measuring 38 cm x 44 cm in 30 watts are used to absorb sunlight and convert it into electrical energy and power the gel battery. 1 gel batteries are used to store solar energy and use it as electrical energy. It is gel because sulfuric acid and silica are produced by homogeneous mixing. 1 charge control pens are used to regulate the voltage from the solar panel, prevent and compensate for high voltage. Two 7 watt lamps are used to provide garden lighting.

2.3. Method

An environmentally friendly green roof consisting of various layers has been designed on the roof of the boiler room building which is located at Sakarya University Esentepe Campus. Rain water coming from the pipe on the green roof was collected and stored in a 300 liter water tank. The rain water collected in this tank was used to irrigate the plants on the roof, the lawn and the garden. Generally, irrigation was done every 15 days, and once a week in the summer season when the weather was hot and dry. Solar panels and equipment placed on the roof helped plants and grass grow, and the garden was illuminated by generating electrical energy from the solar panel and placing two 7-watt lamps on the wall of the building. Rain water falling on the green roof and accumulating in the warehouse and the energy accumulated in the solar panel were observed monthly. The potential of the rain water to be collected in meeting the water requirement outside the building and the amount of savings achieved by generating electrical energy from the energy to be collected were investigated.

The following are the calculations for rain water to be collected from the roof surface [6].

Rain water yield = rain collection area x precipitation amount x roof coefficient x filter efficiency coefficient [6].

Rain collection area; total area of the roof [6].

Precipitation; total annual rainfall determined by the General Directorate of Meteorology [6].

Roof coefficient; this is the coefficient specified by German standards as 0,8 in DIN (1989). It states that all rain falling on the roof cannot be recycled [6].

Filter efficiency coefficient; this is the coefficient specified by German standards as 0,9 in DIN (1989). This coefficient is the efficiency coefficient of the first filter passed to separate rain water from solids from the roof. It is the coefficient given by calculating that some of the rain water cannot pass through here [6].

Roof rain water amount (m^3) = roof area (m^2) x 0,9 x 0,8 x rainfall amount (annual, mm) [6].

Figure 2 has a structure trait to hold humidity, it protects the below materials by being used on insulating plates owing to resistant to be unctured (Figure 2). Figure 3 is used for water proofing (Figure 3). Figure 4 protects the geomembranes from being punctured, being torn due to friction based and damages (Figure 4). Figure 5 has higher capacity of vertical drainages than holes (Figure 5). Therefore it blockes ponding on ground plate. It annihilates the weight on the filtration geotextile due to unidirectional bubble structure. It is furnished by making the bubbles get on each. It creates continuous drainage channel under the filtration plus by blocking the plates' moving. Figure 6 is used to protect the water isolation applications owing to the effect of spreading pressure (Figure 6).

Figure 2 Geotextile felt moisture trap

Figure 3 Ecb geomembrane

Figure 7; ground plate makes the rain water reach substratum by absorbing a little part of it (Figure 7). It meets the needs of nutrition of grass on green roof and plants. Grass creates habitat for animals and cleans the air. Figure 8's caring is simple because of rarely planted green roof and it doesn't weight on (Figure 8). Figure 9; pipes make the rain water coming from green roof reach water tank (Figure 9). Figure 10; the general view of green roof, rain and solar energy has been given (Figure 10). Figure 11; the energy which has been picked from sun by solar energy has been used to lighten the garden (Figure 11)

Figure 4 Second geotextile felt moisture trap placed on ecb geomembrane

Figure 5 Root holder plate

Figure 6 The third geotextile felt moisture trap placed on the root retaining layer

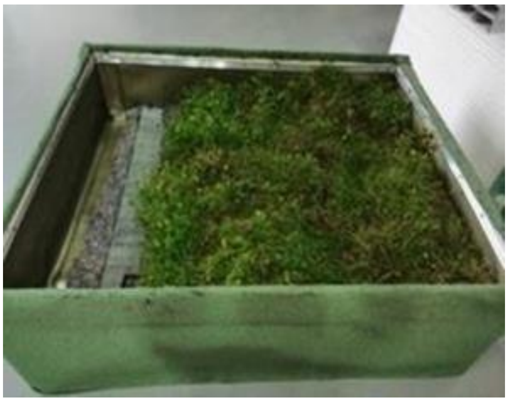

Figure 7 Soil and grass

Figure 8 Extensive green roof

Figure 9 Water tank and pipes

Figure 10 Green roof, rain water and solar energy system

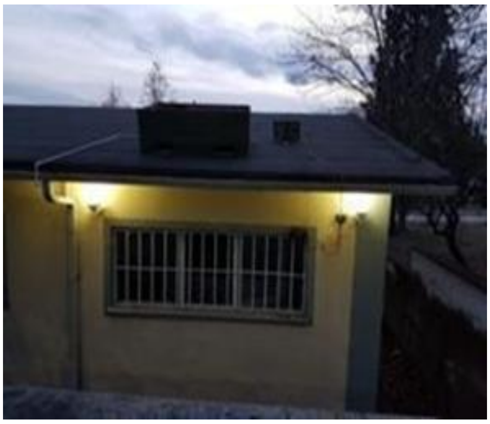

Figure 11 Green roof system, solar energy system and garden lighting

3. RESULTS

The amount of stored rain water falling on the green roof surface of the building and the amount of electricity generation from solar panels and equipment are given below:

3.1. December Rain Water, Solar And Electric Power Data

3.1.1. Stormwater data for December 14-31, 2020.

The amount of rain falling in Serdivan district of Sakarya between 14-31 December 2020: 52,2 mm = 0.0522 m

Between 14-31 December 2020, amount of rain water falling on the green roof of the boiler room at Sakarya University:

1,5 m^2 x 0,9 x 0,8 x (0,0522 m) = 0,056376 m^3 = 56,376 liter

Amount of rain accumulated in the water tank at Sakarya University between 14-31 December 2020: 55,37 liter = 0,05537 m^3

Rain water remaining in the tank for irrigation of the green roof for 1 minute: 58,337 liter – 15 liter = 40,37 liter = 0,04037 m^3

Amount of rain water remaining in the tank in garden irrigation for 1 minute: 40,37 liter − 20 liter = 20,37 liter = 0,02037 m^3

Solar energy data between 14-31 December 2020

In 1 day: 30 watts x 9 hours = 270 watts

In 10 days: 270 watts x 10 days = 2700 watts

10 days between 14-31 December 2020 are sunny.

Electricity data between 14-31 December 2020

A light bulb in the garden consumes 7 watts of energy in 5 days.

Over 1 night: (7 watts / 5) = 1.4 watts

1,4 watts x 2 = 2,8 watts

2.8 watts x 14 hours = 39,2 watts
At 18 nights: 39,2 watts x 18 nights = 705,6 watts

3.2. January Rain Water, Solar And Electric Power Data

3.2.1. Stormwater data for January 1-15, 2021.

The amount of rain falling in Serdivan district of Sakarya between 1-15 January 2021: 69,9 mm = 0,0689 m
Between 1-15 January 2021, amount of rain water falling on the green roof of the boiler room at Sakarya University:

1.5 m^2 x 0,9 x 0,8 x (0,0689 m) = 0,074412 m^3 = 74,412 liter

Amount of rain accumulated in the water tank at Sakarya University between 1-15 January 2021: 73,41 liter = 0,07341 m^3

The amount of rain water remaining in the water tank at Sakarya University between 14 – 31 December 2020 + the amount of rain water accumulated in the water tank at Sakarya University between 1-15 January 2021: 20,37 liter + 73,41 liter = 93,78 liter = 0,09378 m^3

Rain water remaining in the tank for irrigation of the green roof for 1 minute: 93,78 liter – 15 liter = 78,78 liter = 0,07878 m^3

Amount of rain water remaining in the tank in garden irrigation for 1 minute: 78,78 liter – 20 liter = 58,78 liter = 0,05878 m^3

Solar energy data between 1-15 January 2021

In 1 day: 30 watts x 9 hours = 270 watts

In 9 days: 270 watts x 9 days = 2430 watts

9 days between 1-15 January 2021

Electricity data between 1-15 January 2021

1,4 watts x 2 = 2,8 watts

2,8 watts x 14 hours = 39,2 watts

At 15 nights: 39,2 watts x 15 nights = 588 watts

3.2.2. Stormwater data for January 16-31, 2021.

The amount of rain falling in Serdivan district of Sakarya between 16-31 January 2021: 69,3 mm = 0,0693 m

Between 16-31 January 2021, month of rain water falling on the green roof of the boiler room at Sakarya University:

1,5 m^2 x 0,9 x 0,8 x (0,0693 m) = 0,074844 m^3 = 74,844 liter

Amount of rain accumulated in the water tank at Sakarya University between 16-31 January 2021: 73,84 liter = 0,07384 m^3

The amount of rain water remaining in the water tank at Sakarya University between 1-

15 January 2021 + the amount of rain water accumulated in the water tank at Sakarya University between 16-31 January 2021: 58,78 liter + 73,84 liter = 132,62 liter = 0,13262 m^3

Rain water remaining in the tank for irrigation of the green roof for 1 minute: 132,62 liter – 15 liter = 117,62 liter = 0,117562 m^3

Amount of rain water remaining in the tank in garden irrigation for 1 minute: 117,62 liter – 20 liter = 97,62 liter = 0,09762 m^3

Solar energy data between 16-31 January 2021

In 1 day: 30 watts x 9 hours = 270 watts

In 9 days: 270 watts x 9 days = 2430 watts

9 days between 16-31 January 2021

Electricity data between 16-31 January 2021

1,4 watts x 2 = 2,8 watts

2,8 watts x 14 hours = 39,2 watts

At 15 nights: 39,2 watts x 16 nights = 627,2 watts

3.3. February Rain Water, Solar And Electric Power Data

3.3.1. Stormwater data for February 1-14, 2021.

The amount of rain falling in Serdivan district of Sakarya between February 1-14, 2021: 7,3 mm = 0,0073 m

Between 1-14 February 2021, amount of rain water falling on the green roof of the boiler room at Sakarya University:

1,5 m^2 x 0,9 x 0,8 x (0,0073 m) = 7,884 x 10^{-3} m^3 = 7,884 liter

Amount of rain accumulated in the water tank at Sakarya University between 1-14 February 2021: 6,88 liter = 0,00688 m^3

The amount of rain water remaining in the water tank at Sakarya University between 16-31 January 2021 + the amount of rain water accumulated in the water tank at Sakarya University between 1-14 February 2021: 97,62 liter + 6,88 liter = 104,5 liter = 0,1045 m^3

Rain water remaining in the tank for irrigation of the green roof for 1 minute: 104,5 liter – 15 liter = 89,5 liter = 0,0895 m^3

Amount of rain water remaining in the tank in garden irrigation for 1 minute: 89,5 liter – 20 liter = 69,5 liter = 0,0695 m^3

Solar energy data between 1-14 February 2021

In 1 day: 30 watts x 10 hours = 300 watts

In 8 days: 300 watts x 8 days = 2400 watts

8 days between 1-14 February 2021

Electricity data between 1-14 February 2021

1,4 watts x 2 = 2,8 watts

2,8 watts x 13 hours = 36,4 watts

At 14 nights: 36,4 watts x 14 nights = 509,6 watts

3.3.2. Stormwater data for February 15-28, 2021.

The amount of rain falling in Serdivan district of Sakarya between February 15-28, 2021: 49,4 mm = 0,0494 m

Between 15-28 February 2021, amount of rain water falling on the green roof of the boiler room at Sakarya University: 1,5 m^2 x 0,9 x 0,8 x (0,0494 m) = 0,053352 m^3 =

53,352 liter

Amount of rain accumulated in the water tank at Sakarya University between 15-28 February 2021: 52,35 liter = 0,05235 m^3

The amount of rain water remaining in the water tank at Sakarya University between 1-14 February 2021 + the amount of rain water accumulated in the water tank at Sakarya University between 15-28 February 2021: 69,5 liter + 52,35 liter = 121,85 liter = 0,12185 m^3

Rain water remaining in the tank for irrigation of the green roof for 1 minute: 121,85 liter − 15 liter = 106,85 liter = 0,10685 m^3

Amount of rain water remaining in the tank in garden irrigation for 1 minute: 106,85 liter – 20 liter = 86,85 liter = 0,08685 m^3

Solar energy data between 15-28 February 2021

In 1 day: 30 watts x 10 hours = 300 watts

In 6 days: 300 watts x 6 days = 1800 watts
6 days between 15-28 February 2021

Electricity data between 15-28 February 2021

1,4 watts x 2 = 2,8 watts

2,8 watts x 11 hours = 30,8 watts

At 14 nights: 30,8 watts x 14 nights = 431,2 watts

In figure 12, the most rainfall was seen between 1-7 July 2021, the last rainfall was seen between 1-15 May 2021.

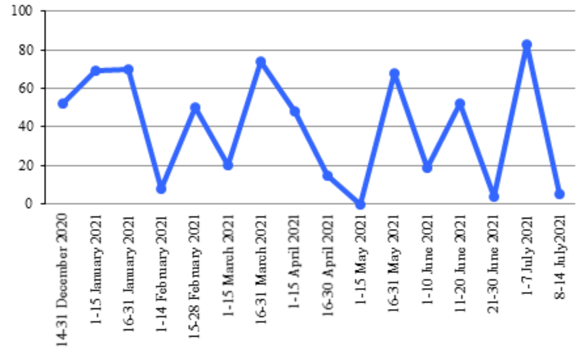

Figure 12 Amount of rain falling on Serdivan between 14 December 2020 – 14 July 2021

In figure 13, the most rainfall on green roof was seen between 1-7 July 2021, the least was seen between 1-15 May 2021.

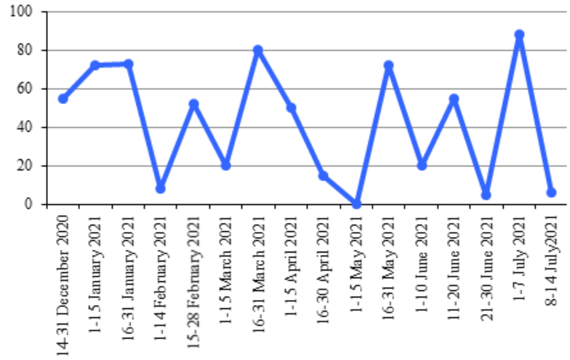

Figure 13 Amount of rain water falling on green roof between 14 December 2020 – 14 July 2021

In figure 14, the most save rain water in tank was between 1-7 July 2021, the least was between 1-15 May

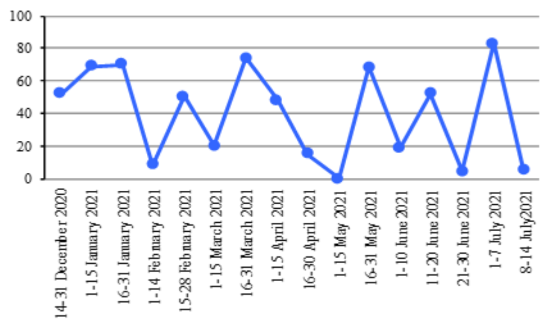

Figure 14 Amount of rain water accumulated in the water tank between 14 December 2020 – 14 July 2021

In figure 15, the most saved rain water in tank was seen between 21-30 July 2021 and 1-7 July 2021, the least was seen on 14-31 December 2020.

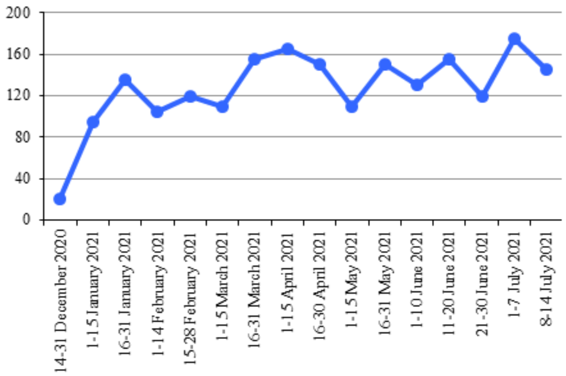

Figure 15 Amount of rain water remaining and accumulated in the water tank between 14 December 2020 – 14 July 2021

In figure 16, after watering the green roof and garden, the most saved rain water in tank was observed between 1-7 July 2021, the least was observed between 14-31 December 2020.

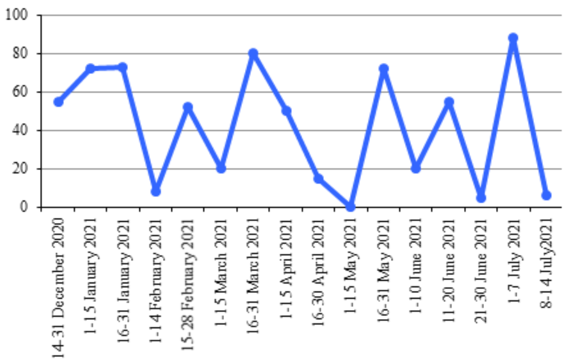

Figure 16 Amount of rain water remaining in the tank after watering the green roof and garden between 14 December 2020 – 14 July 2021

3.4. Comparison Of Monthly Water Amount In Rain Collection Tanks And Precipitation Amounts

The precipitation between 14-31 December 2020 is 52,2 mm. Supply of rainfall saved in tank is 56,376 liter.

The precipitation between 1-15 January 2021 is 68,9 mm. Supply of rainfall saved in tank is 73,41 liter. The precipitation between 16-31 January 2021 is 69,3 mm. Supply of rainfall saved in tank is 73,84 liter.

The precipitation between 1-14 February 2021 is 7,3 mm. Supply of rainfall saved in tank is 6,88 liter. The precipitation between 15-28 February 2021 is 49,4 mm. Supply of rainfall saved in tank is 52,35 liter.

The precipitation between 1-15 March 2021 is 19,8 mm. Supply of rainfall saved in tank is 20,38 liter. The precipitation between 16-31 March 2021 is 74,2 mm. Supply of rainfall saved in tank is 79,13 liter.

The precipitation between 1-15 April 2021 is 47,1 mm. Supply of rainfall saved in tank is 49,86 liter. The precipitation between 16-30 April 2021 is 15,5 mm. Supply of rainfall saved in tank is 15,74 liter.
The precipitation between 1-15 May 2021 is 1 mm. Supply of rain fall saved in tank is 0,08 liter. The precipitation between 16-31 May 2021 is 67,4 mm. Supply of rainfall saved in tank is 71,79 liter.

The precipitation between 1-10 June 2021 is 18,7 mm. Supply of rainfall saved in tank is 19,19 liter. The precipitation between is 11-20 June 2021 is 53 mm. Supply of rainfall saved in tank is 56,24 liter. The precipitation between 21-30 June 2021 is 4,2 mm. Supply of rainfall saved in tank is 3,53 liter.

The precipitation between 1 to 7 July 2021 is 81,86 mm. Supply of rainfall saved in tank is 87,12 liter. The precipitation between 8-14 July 2021 is 5,2 mm. Supply of rainfall saved in tank is 4,61 liter.

When the data is analyzed, it has been determined that monthly precipitation and supply of rainfall saved in tank are proportional.

In figure 17, the most saved solar energy was observed between 1-14 February 2021, the least was observed between 16-31 March

2021.

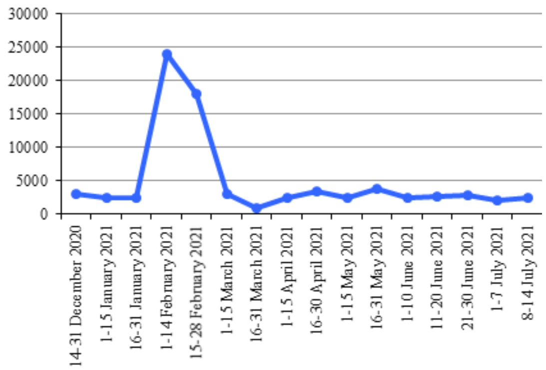

Figure 17 Solar energy data between 14 December 2020 – 14 July 2021

In figure 18, the most produced electricity was seen between 14-31 December 2020, the least was seen between 1-14 July.

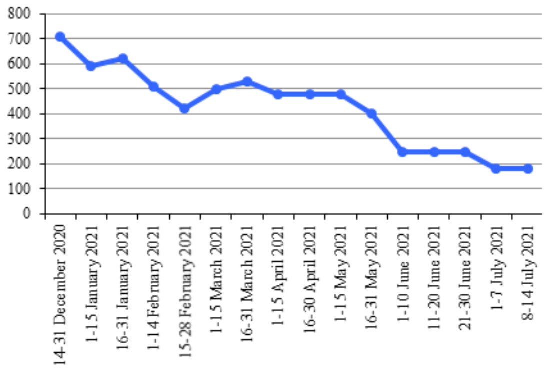

Figure 18 Data of electrical energy between 14 December 2020 – 14 July 2021

3.5. Comparison Of Solar Energy / Electric Energy Datas

Between 14-31 December 2020, 2700 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 18 nights. 705,6 watts of electrical energy was used.

Between 1-15 January 2021, 2430 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 15 nights. 588 watts of electrical energy was used. Between 16-31 January 2021, 2430 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 16 nights. 627,2 watts of electrical energy was used.

Between 1-14 February 2021, 2400 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 14 nights. 509,6 watts of electrical energy was used. Between 15-28 February 2021, 1800 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 14 nights. 431,2 watts of electrical energy was used.

Between 1-15 March 2021, 2640 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 15 nights. 504 watts of electrical energy was used. Between 16-31 March 2021, 990 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 16 nights. 537,6 watts of electrical energy was used.

1800 watts of energy was stored between 1-15 April 2021. The stored energy enabled 2 lamps to illuminate the garden for 15 nights. 462 watts of electrical energy was used. 2730 watts of energy was stored between 16-30 April 2021. The stored energy enabled 2 lamps to illuminate the garden for 15 nights. 462 watts of electrical energy was used.

Between 1-15 May 2021, 4320 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 15 nights. 462 watts of electrical energy was used. 3780 watts of energy was stored between 16-31 May 2021. The stored energy enabled 2 lamps to illuminate the garden for 16 nights. 403,2 watts of electrical energy was used.

1800 watts of energy was stored between 1-10 June 2021. The stored energy enabled 2 lamps to illuminate the garden for 10 nights. 252 watts of electrical energy was used. Between 11-20 June 2021, 2250 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 10 nights. 252 watts of electrical energy was used. Between 21-30 June 2021, 3150 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 10 nights. 252 watts of electrical energy was used.

1350 watts of energy was stored between 1-7 July 2021. The stored energy enabled 2 lamps to illuminate the garden for 7 nights. 176,4 watts of electrical energy was used. Between 8-14 July 2021, 2250 watts of energy was stored. The stored energy enabled 2 lamps to illuminate the garden for 7 nights. 176,4 watts of electrical energy was used.

Generally, the electrical energy used is directly proportional to the stored energy. However, this rate changes according to how many nights the garden lighting is in that month.

4. WATER AND ENERGY SAVİNG CALCULATİON

Water saving

Sakarya province Serdivan district 1 ton water unit price: 4,89 TL

Amounts of used rain water between December 14 2020 and July 14 2021

Amount of used rain water in December: 20 liter + 15 liter = 35 liter = 0,035 tons

Amount of used rain water in January: 35 liter x 2 = 70 liter = 0,07 tons

Amount of used rain water in February: 35 liter x 2 = 70 liter = 0,07 tons

Amount of used rain water in March: 35 liter x 2 = 70 liter = 0,07 tons

Amount of used rain water in April: 35 liter x 2 = 70 liter = 0,07 tons

Amount of used rain water in May: 35 liter x 2 = 70 liter = 0,07 tons

Amount of used rain water in June: 35 liter x 3 = 105 liter = 0,105 tons
Amount of used rain water in July: 35 liter x 2 = 70 liter = 0,07 tons

Amount of saved water between December 14 2020 and July 14 2021: 35 liter + 70 liter + 70 liter + 70 liter + 70 liter + 70 liter + 105 liter + 70 liter = 560 liter = 0,56 tons

Price of saved water between December 14 2020 and July 14 2021: 4,89 TL (SASKİ mains water price) x 0,56 tons = 2,7384 TL

The amount of water which is saved during the 7-month experimental period from December 14 2020 to July 14 2021 was calculated as 0,56 tons. The price of water that purchased from Sakarya Water and Sewerage Administration (SASKİ) is 4,89 TL. According to these analysis 2,7384 TL of water were saved in 7 months.

Energy saving

Sakarya province Serdivan district Electricity Unit Price: 0,4743 TL/kWh

Amounts of used electricity between December 14 2020 and July 14 2021

Amount of used electricity in December: 705,6 watt = 0,7056 kW

Amount of used electricity in January: 588 watt + 627,2 watt = 1215,2 watt = 1,2152 kW

Amount of used electricity in February: 509,6 watt + 431,2 watt = 940,8 watt = 0,9408 kW

Amount of used electricity in March: 504 watt + 537,6 watt = 1041,6 watt = 1,0416 kW

Amount of used electricity in April: 462 watt + 462 watt = 924 watt = 0,924 kW

Amount of used electricity in May: 462 watt

+ 403,2 watt = 865,2 watt = 0,8652 kW

Amount of used electricity in June: 252 watt + 252 watt + 252 watt = 756 watt = 0,756 kW

Amount of used electricity in July: 176,4 watt + 176,4 watt = 352,8 watt = 0,3528 kW

Amount of saved electricity between December 14 2020 and July 14 2021: 705,6 watt + 1215,2 watt + 940,8 watt + 1041,6 watt + 924 watt + 865,2 watt + 756 watt + 352,8 watt = 6801,2 watt = 6,8012 kW

Price of saved electricity between December 14 2020 and July 14 2021: 0,4743 TL/kWh x 6,8012 kW = 3,2258 TL
Working time of two 7 watt lamps between December 14 2020 and July 14 2021: W = P x t

6,8012 kW = 0,014 kW x t

t = 485,8 hours = ~ 20 days

Electricity amounts used from December to July were calculated monthly. The total electricity amounts used for 7-month were found. The saved electricity amount has been found by multiplying the electricity unit price taken from Sepaş by these found values.

5. EVALUATION AND DISCUSSION

During the experiment period from December to July, data was collected by making measurements and observations of 15 days, in some months, 10 days and 1 week. Rainfall data on the region where the pilot plant is located were obtained from Sakarya Meteorology Station Directorate. About 1% of the rainfalling on the green roof is absorbed, the rest is transferred to the warehouse. 15 liters of the water in the tank was used for 1 minute to irrigate the green roof, and 20 liters for garden irrigation. The maximum amount of water was collected between 1-7 July 2021 with 87,12 liters, and the minimum amount of water 0,08 liters between 1-15 May 2021. At the end of the experiment, 560 liters of water were saved. In addition, 2,7384 TL economic gain was obtained. During the experiment, the data of the number of sunny days in each month was collected. Accordingly, electricity is produced with the energy stored in the solar panel. Maximum solar energy was stored with 4320 watts between 1-15 May 2021, minimum solar energy was stored between 16-31 March 2021 with 990 watts. The maximum electricity was produced between 14-31 December 2020 with 705,6 watts, the minimum electricity was produced between 1-7 July 2021 and 8-14 July 2021 with 176,4 watts. At the end of the experiment, 6801,2 watts of electricity was saved. 3,2258 TL economic gain was achieved.

According to the literature, rain water collected from the roof; it can be used in car washing, cleaning, filling pools and toilets. It can also be used for washing dishes, showering and cooking if purified. In the experimental application, rain water collected from the green roof has been used to irrigate the grass, plants and garden on the roof. It was not used inside the building because it was not treated. Solar energy systems are used to meet the electricity needs in bus stops, agricultural irrigation, residences, park and garden lighting. Solar energy systems are used for both indoor and garden lighting in residences; they reduce emissions and save electricity. In the experimental application, the solar energy system designed on the roof of the building has been used in garden lighting, preventing greenhouse gas emissions and saving electricity.

5.1. Cost Analysis

5.1.1. Cost analysis of green roof, rain water, and solar energy system

Cost analysis; it includes equipment which is used in the construction of green roof, rain water and solar energy systems. These equipment; it is classified as consumables and machinery- equipment. According to the number of materials, the amount was determined at the unit price. The total cost is calculated as 9117,96 TL (Table 1).

Table 1 Cost Analysis

Budget Type	Name	Quantity	Unit Price	Cost
Consumables	Eggerosb	3	100,00 TL	300,00 TL
Consumables	Wooden pallet	2	100,00 TL	200,00 TL
Consumables	Weber polyurethane mastic poliyfin agoc-plan ecb 1015	2	80,00 TL	160,00 TL
Consumables	Gomembran	3	200,00 TL	600,00 TL
Consumables	Florax top	2	100,00 TL	200,00 TL
Consumables	Aliminium pressure bar	9	30,00 TL	270,00 TL
Consumables	Geotextile felt moisture trap	3	20,00 TL	60,00 TL
Machinery andequipment	Water tank (300 lt.)	1	750,00 TL	750,00 TL
Machinery andequipment	Hydrophore pump	1	1000,00 TL	1000,00 TL
Consumables	Pipe, fittings, valve	1	2000,00 TL	2000,00 TL
Machinery andequipment	Solar panel	1	1500,00 TL	1500,00 TL
Consumables	Small battery	1	600,00 TL	600,00 TL
Machinery andequipment	Power test light	1	350,00 TL	350,00 TL
Consumables	Grass, ivy plant, soil	1	600,00 TL	600,00 TL
Consumables	Garden light lamp	2	89,99 TL	179,98 TL
Consumables	Bulb	2	23,99 TL	47,98 TL
Machinery andequipment	Crane	1	300,00 TL	300,00 TL

6. CONCLUSION

Turkey is a country with a rapid growth potential and needs to meet its energy needs from natural resources. Measures that can save energy consumption are very important for the future of the country. Due to climate change, natural water resources are decreasing day by day. For this reason, ecological measures should be taken for the formation of sustainable and environmentally sensitive cities. In addition, non-ecological approaches will not be economical in the long run. Within the scope of these measures, green roofs are a positive option [8].

Green roof systems are spreading rapidly in the world as they provide environmental, ecological, social and economic benefits. Green roofs; biodiversity plays an important role as a pioneer of sustainability in terms of environmental and ecological reasons, such as being effective in accumulating rain water, reducing air pollution, reducing urban heat island effects, effecting carbon dioxide oxygen exchange, reducing noise pollution, increasing the amount of green space [1].

In researches on green roofed structures, it has been seen that energy savings of 24-50% and 13% savings in maintenance fees can be achieved compared to traditional roofed structures. Thanks to green roofs, it is possible to create an energy efficient and nature-friendly environment [1].

Thinks to do in order for the roof of the structure examined within the scope of the research to have a green roof feature was evaluated in terms of water, energy efficiency and ecological effects. By reconnoitering in the building, do’s to use rain water efficiently and save energy within the scope of water and energy efficiency was determined. The aim of the study is to protect and use natural resources efficiently.

The role of rain water which is harvested on the roof of the boiler room building in Sakarya University in meeting the outdoor water needs and the role of the solar energy system in providing outdoor lighting were investigated. For this purpose, the amount of rain water to be collected from the green roof of the building was calculated by using the monthly rainfall data of Serdivan district of Sakarya province. The water needs used to water the harvested rain water and plants in the roof, lawn and garden was calculated regularly by watering every month twice a month. The energy which is stored on sunny days has also been used on days and seasons when there is no sun. With this energy generates electricity and light the garden.

Thus, it has been determined that water and electricity will be saved thanks to the green roof, rain harvest and solar energy systems and will play an important role in reducing the effects of climate change.

Thanks to the acquired findings in the research, it can be said that a extensive green roof system is a sustainable option in the conditions of Sakarya province.

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Authors' Contribution
The authors contributed equally to the study.

The Declaration of Ethics Committee Approval
This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics
We declare that we comply with the scientific, ethical and citation rules of SAUJS in all processes of the article and that we do not falsify the collected data. In addition, we declare that Sakarya University Journal of Science and its editorial board have no responsibility for ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

REFERENCES

[1] E. Akpınar. Külekçi, “A research on green roof systems from past to present and determination of quality standards in green roofs,” ATA Journal of Planning and Design, vol. 1, no. 1, pp. 35-53, 2017.

[2] B. Kılıç. Turan, A. Gülten, “Analysis of the effect of green roofs on the heating and cooling load of buildings for different building forms and degree day regions,” Fırat University Journal of Engineering Sciences, vol. 32, no.1, pp. 105-118, Feb 2020.

[3] N. Şensy, A. Pakoğlu, R. Kara, “Evaluation of structural features of some roof gardens in Ankara,” Duzce University Faculty of Forestry Journal of Forestry, vol. 13, no. 2, pp. 58-74, Dec 2017.

[4] E. Kalıpcı, V. Başer, N. Genç, “Evaluation of rain water harvesting using geographic information system: Giresun University Campus Example,” Gaziosmanpasa Journal of Scientific Research, vol. 10, no. 1. pp. 49-58, Apr 2021.

[5] G. E. Üstün, T. Can, G. Küçük, “Rain water harvesting in the buildings,” Journal of Uludag University Faculty of Engineering, vol. 25, no. 3, pp. 1593-1610, Dec 2020.

[6] M. Yalılı. Kılıç, M. N. Abuş, “Rain water harvesting in a garden house sample,” International Journal of

Agricultural and Wildlife Science, vol. 4, no. 2, pp. 209-215, June 2018.

[7] S. Rüstemli, F. Dinçer, "Current situation and future of solar energy in electric power generation in van province," Journal Of The Institute of Natural and Applied Sciences, vol. 16, no. 1, pp. 22-33, June 2011.

[8] E. Yalçınalp, A. Öztürk, D. Bayrak, "Economical effects of green roof and grey water systems in housing scale," Turkish Journal of Agricultural and Natural Sciences, vol 5., no.1, pp. 71-80, Dec 2017.