Hindawi
Advances in Materials Science and Engineering
Volume 2020, Article ID 8167402, 16 pages
https://doi.org/10.1155/2020/8167402

Research Article

Evaluation of the Existing Solar Energy and Rainwater Potential in the Total Roof Area of Buildings: Izmit District Example

Mehmet Kaya

Department of Airframe and Powerplant Maintenance, Faculty of Aeronautics and Astronautics, Kocaeli University, Izmit, 41285 Kocaeli, Turkey

Correspondence should be addressed to Mehmet Kaya; mkaya24@gmail.com

Received 21 July 2020; Revised 28 October 2020; Accepted 30 October 2020; Published 16 November 2020

Academic Editor: Anna Richelli

In this research, an exemplary study has been conducted in order to draw attention to the importance of evaluating the existing potential on the roofs of buildings. This research offers an evaluation of the existing solar energy and rainwater potential on the total roof area of the buildings in the Izmit district, which is a central district of Kocaeli province, one of the busiest centers of industry in Turkey. The calculations in this study were carried out by using the data obtained from various institutions. As a result of these calculations, the ratio of electrical energy that can be provided with photovoltaic systems on roofs to meet the annual electricity consumption of the district was found to be 203.581%, and the annual solar energy utilization rate for a family of 4 to bring 240 liters of daily use water temperature to 60°C with an 8 m^2 collector area was calculated as 66%. In addition, the ratio of rainwater that can be collected from the total roof area of the existing buildings in the district to meet the domestic water consumed by the district was found to be 33.27%.

1. Introduction

Due to the development of technologies facilitating human life and increasing living standards and population growth as well, the need for energy is increasing day by day and energy continues to be one of the basic needs of life. Increasing energy demand is no longer an independent problem of a single country; energy provision has become a global issue. Also, the wars and occupations in the world today are a reflection of global energy problems to people. Energy, once a need just to meet the basic requirements of people, has now become a force in shaping international policies [1]. Human beings directed themselves to the sources with which they could produce energy more effectively in order to meet the increasing need for energy; thus, they started to use fossil fuels, which produce relatively more energy when burned, and they continue to use those fuels. Consumption of fossil fuels without using methods to prevent the negative effects of using fossil fuels has created serious problems regarding the ecological balance of the world. This situation, which has emerged in the last century, has caused global climate changes and become a threat to natural habitats and the health of living creatures. Today, with the observation of the negative effects of the use of fossil fuels in energy production in the world on the environment and living creatures, fossil fuel shortage and an increase in the production and supply costs of such fuels in the near future have led countries to consider different sources of energy in terms of energy supply. This situation has enabled renewable energy to be placed among the strategic sectors [2]. Fossil fuels not having a balanced distribution in the world and their concentration in some certain areas make the countries with fossil fuel shortages foreign dependent and put a great burden on their economies as well. Effective use of resources in every aspect is of great importance for sustainable growth in the global world. Energy should be provided from renewable resources rather than fossil fuels. The amount of energy to be provided from renewable resources for sustainable growth should be increased as time passes by. The lack of fossil fuels in Turkey imposes a burden on the country's budget and increases its foreign dependency [3, 4]. A significant portion of the foreign trade deficit of the country is made up of energy imports. In 2013, the utilization rate of imported resources in Turkey, which were comprised of natural gas, imported coal, and liquid fuels in electricity production, was 65.1%. However, in 2018, foreign dependency on the production of electricity dropped back to 51% thanks to some domestic investments. Several studies were conducted to show Turkey's renewable energy sources have enough potential to meet the energy needs of the country, and now the findings are accepted on a large scale. Today, in all available studies and assessments, it is emphasized that Turkey should give priority to renewable energy in order to provide the energy it needs. When the reports on the energy sources of Turkey are taken into consideration, it is seen that Turkey's one-year solar energy potential is equal to or more than the amount of energy corresponding to its total oil reserve [5, 6]. Today, efforts to utilize renewable energy resources continue with increasing momentum in many leading countries in the world. In the same way, Turkey is also trying to fulfill its responsibilities in terms of environment and public health for a clean and livable world. However, the steps taken and the investments made in renewable energy still fall short of expectations. For this, Turkey should rapidly carry out the necessary investments in the renewable energy field [7, 8].

1.1. Evaluation of Solar Energy as a Renewable Energy Source

1.1.1. Electric Energy. Major types of energy in terms of consumption can be stated as mechanical, thermal, and electrical energy. However, the facts that electric energy is eco-friendly, it is produced in great amounts and efficiently from various energy sources, it is transmitted and distributed over long distances and areas of utilization in great amounts with high efficiency and very rapidly, it is provided in the quality demanded uninterruptedly, it is an easily and efficiently used energy resource, and it is easily and efficiently transformed into various energy types such as heat, motion, and light make electric energy the most valuable type of energy when compared with the other energy types [9, 10].

Energy production sources can be generally classified as renewable energy sources such as direct solar energy, biomass energy, and wave, hydro, and wind energy depending on solar energy, and nonrenewable energy sources including nuclear fuels and fossil fuels such as petrol, coal, and natural gas [11]. Today, the majority of energy production including electric energy is provided by fossil fuels and nuclear energy sources. It is now widely accepted that fossil fuels have a limited lifespan and have started to run short and that fossil fuels will not suffice for energy production across the world. The harm that fossil fuel use causes to the environment and human health on a global scale in order to provide energy is now undeniable, and it will be inevitable that the cost to be paid by people in the near future will be too high. However, the negative effects of the use of fossil fuels that were observed and experienced worldwide were noticed, and a considerable number of countries started to use renewable resources more in energy production [12].

In determining the potential of a region to produce electricity from solar energy, the calculations made considering only climatic criteria are insufficient to reflect true values. To get more accurate results, local analysis studies should also be done which consider all the factors including not only climatic data such as temperature, sunshine duration, humidity, and radiation but also physical condition such as land use, slope, and aspect. These local analysis studies can be made using geographic information systems and some other programs [13, 14]. Accordingly, the potential of any region on Earth to generate electricity from solar energy is evaluated as geographical, technical, and economic potential. In the geographical potential calculations, the predicted values are higher than the true values only when parameters such as the time-averaged irradiance in unit area (W/m^2), the number of insolation hours in a year (h/y), and the available area for PV panel installation (km^2). Technical potential is calculated when the effect of parameters such as conversion efficiency of electricity generation from solar energy, environment, and module temperature is added to the values obtained by geographical potential. However, to get more reliable results, economic potential is determined by including the effect of the PV system and other related factor costs to the technical potential [15]. Considering that the electrical energy conversion efficiency from solar energy is 20%, Turkey's available economic potential of annual electricity production from solar energy is around 305 billion kWh/year. As of the end of July 2018, approximately 300 billion kWh/year of electric energy was consumed in Turkey. This calculation shows that solar energy potential in Turkey is higher than the electric energy consumed [16, 17]. With the use of renewable energy sources in Turkey, dependence on imported fuels will be reduced; priority will be given to domestic resources; employment will increase as a result of domestic production; sustainable economic growth and development will be provided; energy supply safety will increase; the safety used to meet the energy demand will have a positive effect on the sectors using energy and promote investments; stability will increase with the creation of an environment of trust both in production and consumption; and welfare and stability will increase in social and economic life [12].

Due to the many reasons mentioned above, Turkey should start to generate energy from more renewable energy sources. However, while Turkey attaches importance to renewable energy sources and makes the required investments for the country, it should not destroy agricultural soil, which is one of the basic needs of the agricultural sector. Future planning of a country must be holistic. Otherwise, while a problem is being fixed, it might give rise to bigger problems in another field. The possibility to expand agricultural lands in the world is quite limited. In this context, nonagricultural use of the agricultural lands should be limited in the country, and proper management of these lands should be provided. Yet, although it is a well-known fact that it can take up to 100 to 1000 years to form one centimeter of soil, soil is still used unconsciously. With the use of agricultural lands, which are impossible to recover, for agricultural purposes only, positive results will be observed in agriculture and environmental values will be preserved [18, 19].

Considering the vital importance of the preservation of agricultural lands, as the ones that will make use of renewable energy sources, particularly of solar energy, it is of crucial importance to benefit from the areas which are not used as agricultural lands anymore and which are specified to be used for building, parking lots, and roads. On this issue, the government should do the necessary facilitating arrangements and make investments, create plans and projects to set an example, and mobilize and promote society to realize these projects. One of the methods to collect solar energy in buildings is photovoltaic systems. Photovoltaic systems are the systems that produce electric energy directly from solar energy with the help of photovoltaic (PV) modules with an implementation efficiency rate of 15–20%. Photovoltaic systems are systems that have advantages such as they are simple to install, they have no mobile parts, and they have almost no operation and fuel cost and that the cost of eliminating the waste is low and renewal cost is low as a result of its economic lifespan [1].

In the world, particularly in the developed countries, a rapid increase is being seen in the installation of photovoltaic systems in buildings, parking lots, and roads. In order for Turkey to decrease its foreign energy dependence and not to have trouble meeting the energy needs of the country in the future, the necessary importance should be given to start the domestic production of photovoltaic systems and the spread of the installation of these systems. However, investments and production should be made in a way not to create a separate expenditure for photovoltaic systems by developing integrative building elements consisting of photovoltaic and other similar systems. Today, there are neighborhoods where the entire building roofs are covered with photovoltaic systems and which generate a lot more electric energy than is consumed. While some countries are still trying to spread solar panels, an ecocity in Germany can produce four times more electric energy than it consumes through photovoltaic panels [20]. The south facades of the buildings, parking lots, multipurpose roads, and roofs of bigger facilities cover places too wide to ignore, and these areas should definitely be used for energy production by installing photovoltaic systems besides their use for their main purposes.

Turkey is one of the countries in Europe with a great potential for solar energy [21]. In order to evaluate the situation of Turkey's electric energy production from solar energy, it should be compared with Germany, one of the countries that stand out on this issue. Figure 1 shows the solar energy potential map of Europe. When Figure 1 is considered, it can be seen that Turkey's solar energy potential is much higher than Germany's solar energy potential.

The data in 2018 indicate that Turkey's electric energy production and consumption were nearly equal to each other. Production being equal to consumption means that the need for electricity cannot be met if some of the plants are out of service due to the occurrence of events such as faults and disasters [23, 24]. In order to reduce the risks in electricity supply, it is necessary to diversify electric energy production sources and increase sources. When the plans for the electric energy sources for Turkey for the year 2013 are considered, it is understood that Turkey will provide 2% of its total electric production capacity for the year 2023 from solar energy [25]. In addition to this, in 2016, Turkey made changes to the plans for the total electricity production capacity for the year 2022 and planned to build 8.6% of the total electricity production capacity as solar energy systems for 2022 [26]. Besides this, Turkey also aims to provide 30% of its electric energy production for the year 2023 from renewable energy sources [27]. Realistic approaches to evaluate the available energy sources of the country enabled the updating of resource planning for electric energy in favour of renewable energy sources. Germany plans to build 62 GW of its total electricity production capacity, which corresponds to 29.31%, as solar PV for the year 2030 [28]. Moreover, Germany aims to provide 85% of its electric energy production from renewable energy sources [29]. In 2018, the share of electricity production from solar energy in electricity generation for several countries that prioritize solar energy is 7% for Spain, 9% for China, 17% for Italy, and 20% for Germany. The share of electricity production from solar energy of Turkey's electricity production in 2018 is 6%. This data show that Turkey is moving slowly compared to these other countries in the production of electricity from solar energy [28].

Although Turkey's solar energy potential is much higher than Germany's solar energy potential, Turkey falls behind Germany in the future planning of generating electric energy from renewable energy and solar energy. This shows that Turkey should revise the future planning of electric energy production by taking rational steps on the evaluation of its own resources. Today, countries make the necessary investments in renewable energy besides providing their energy needs from fossil fuels. In this context, when more investments in renewable energy are made in Turkey and the country is not foreign dependent anymore and starts to produce more electric energy than it needs today, it will be able to switch into the systems that use more electric energy by providing conversion in the systems using fossil fuels in energy consumption. As a result of this, the need for fossil resources in energy will be reduced and the dependence on foreign fossil fuels will be reduced. Clean, cheap, and abundant production of electric energy obtained from solar energy available on roofs within the scope of renewable energy will provide conversion of the systems that are used in dwellings such as heating and cooking into the systems using electric energy, and thus the cost spent on compulsory needs will be reduced, which will make living in the country easier [30]. Also, this cheap, clean, and abundant energy will enable dwellings to meet their energy needs, provide energy for industry, and provide energy for public transportation means such as electric automobiles, busses, trucks, tramways, and undergrounds. In this way, the employment rate will increase with the development and growth of related sectors.

The studies in the literature are summarized as follows. Çakmak and Altaş conducted a study to break down the prejudices about the solar energy potential of the Eastern

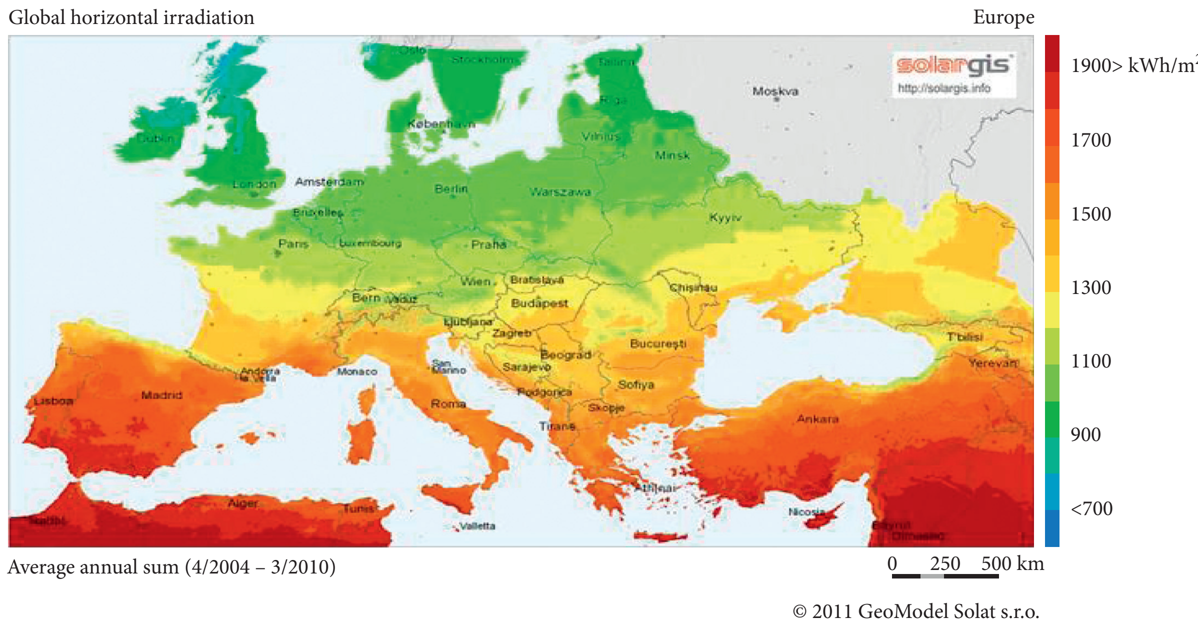

Figure 1: Solar energy potential map of Europe [22].

Black Sea region and raise awareness about the electric energy production from solar energy in Trabzon. In the study, it was stated that the installed photovoltaic power per person in Germany, which has a lower solar energy potential than Trabzon, took top place in the world. Then, by providing photovoltaic power plant examples from Germany, the calculation of electric amounts to be generated by photovoltaic systems in Trabzon and the electric energy amounts to be produced in the case that the same systems were installed in Trabzon was compared. As a result of the comparison, it was determined that solar energy potential in Trabzon and energy amounts to be produced by photovoltaic systems in Trabzon were higher than they were in Germany. Besides, the data showed that Trabzon and the Eastern Black Sea region in general was not a poor region in terms of solar energy potential. They suggested that Trabzon and the Eastern Black Sea region was a region that could be considered for electric energy production from solar energy potential, and with the installation of photovoltaic systems especially on the roofs of buildings, these available and idle areas could be turned into small energy power plants [31].

Alcan et al. examined the solar data of Sinop province by examining Turkey and Germany in general and carried out an evaluation according to the results. It was emphasized in the study that Turkey had a very suitable location in terms of renewable energy sources when compared with the entire European Union countries. However, it was also stated in the study that Turkey was far behind when compared to these countries in terms of electricity production and that Germany, one of the leading countries among these countries, had lower levels than Sinop province and Turkey in terms of both the number of insolation days and insolation rate. It was emphasized that Sinop province was found out to be in an area that could make use of solar energy, but there was not enough electricity production from solar energy except for hot water in Sinop province, which is located in the Western Black Sea region [4].

In his study, Türe examined hi-tech photovoltaic products used in building integrated roofing and facade lining and inspected sample buildings and their technical features in detail. Roof integrated photovoltaic panels can be placed onto the roof or can be used as a roof material in a way to protect the roof from weather conditions instead of the roof, and thus the roof becomes more economical in the long run because it will also function as a coating for the surface while producing electricity. The author specified the advantages of building integrated photovoltaic systems in his study as follows: they reduce the price of roofing and facing materials; they are architecturally clean and attractive; they require low maintenance and repair expenses (durability between 20 and 50 years); they reduce the amount of electricity bills; they are a stringent measure for constant voltage and device breakdowns and a solution to power cuts; and they reduce emissions in the context of social responsibility and provide environmental protection and contribute to thermal insulation [32].

In their research, Gümüş et al. made a calculation for the installation of the Ilısu hydroelectric power plant (HEPP), which caused many eyebrows to raise because of the danger that a twelve thousand-year-old historical and cultural heritage site would be submerged under water along with Hasankeyf district, the people to be forced to migrate, the ecological environment to be damaged, and the arable lands to be drowned under water, and for the installation of alternative solar energy power stations with a parabolic trough system and a power tower system that would provide the same amount of energy and made a theoretical comparison (Table 1). Considering Table 1, they state that solar energy power plants require smaller areas and create lower costs for the same energy production capacity and that solar energy

Table 1: Comparison of Ilısu HEPP and most suitable alternative solution.

	Ilısu hydro power system	Parabolic gutter system	Power tower system
Maximum annual power generation (GWh)	3833	3833	3833
Installed power (MW)	1200	1070	675.94
Covered area (km^2)	331 (Dam Lake)	36.82	56.58
Cost (Euro)	1.2 billion	306.2 million	610.14 million

power plants with a parabolic trough system are more advantageous from all aspects [33].

Of the historical artifacts removed from Ilısu Dam Lake, 37 million TL was spent just for the transportation of the Artuklu Bath. If alternative solar systems had been built instead of the Ilısu hydroelectric power plant, then there would have been no such extra expenditures and the historical artifacts would not have been relocated [34].

Sayın and Koç, in their study, researched the components, materials, structures, and types of photovoltaic systems and their use in buildings. They specified the advantages and disadvantages of photovoltaic systems in buildings and stated that these systems were required to be used in buildings. Today, it is not enough to design buildings considering energy conservation; although measures that have to be taken in the first place such as the use of insulation systems, energy saving, and use of recyclable materials help to use as little energy as possible, these measures are not sufficient. Therefore, they emphasized that it was necessary to design buildings which provide efficient energy use and could benefit from the Sun actively and passively. The additional systems done after the completion of buildings are not fully efficient. Therefore, buildings will be ones that do not consume but produce energy with the systems to be integrated by means of interdisciplinary collaboration beginning from the design of the building. By considering the future as well, within the context of sustainable architecture, benefiting from solar energy in buildings is now a must and it was emphasized that architects should not discard this reality [1].

1.1.2. Hot Water. The use of energy is fundamental for life on Earth to continue. In fact, almost all of the tools and devices we use to continue our daily lives in our era use up energy and such technological devices have become an indispensable part of our lives. Today, available energy sources are on the verge of depletion, but as dependence on technological devices that facilitate human beings' lives and improve their living standards increases, dependence on energy also increases. Two steps should be taken at this point. First, productivity should be increased by developing conventional energy conversion systems or deriving new systems and second, efforts should be made to consider alternative energy sources, increase productivity, and spread their utilization. The most commonly used alternative energy source is solar energy heating systems [35]. Solar energy heating systems are often used for the supply of hot water. Until recently, energy consumption level per capita was considered as a parameter in the comparison of the development levels of societies and states. However, this consideration has changed today. Instead, the term energy density that means being able to reach peak production or to reach the highest well-being with the unit energy consumption has become the criterion. Moreover, the areas in which energy consumption of countries becomes dense (domestic, industrial area, public services, and transportation) are taken as a criterion in the determination of their development levels [36].

For instance, a country that utilizes a significant portion of its energy consumption in the industrial field can be argued to be a country that has developed in the field of industry. In the most general way, the areas of energy utilization are gathered under four headings. These are residential and service sectors, fields of transportation, and industry. When world energy consumption is taken into consideration, the amount of energy used in households is seen to have the highest rate among these four sectors [37]. When dwellings are considered, it is concluded that the type of energy used can be divided into two as thermal and electric energy and that thermal energy is used for the purposes of heating, the production of domestic hot water, and cooking. In Turkey, which is among the developing countries in the world, nearly 31% of the total energy consumption is in the residential sector, 42% in the industrial sector, 19% in the field of transportation, 5% in the agricultural sector, and the remaining 3% in other sectors. 82% of the energy used in dwellings corresponds to the energy consumed for heating and hot water production [38]. In Turkey, nearly 25% of the total energy consumption is for heating [39]. The most preferred new and renewable energy source that can be used for domestic hot water production is solar energy systems [40]. Solar energy heating systems can be used in almost every region because they are simple, easy to install, and economic [41, 42]. Besides using solar energy for hot water supply in buildings, compact systems that use solar energy for supporting purposes in heating systems have also become mass produced today [43].

1.1.3. Daylight. Lighting has a profound effect on people's lives. Today, the need for the conscious consumption of energy sources is a fact that should be accepted by everyone. One of the most important energy saving areas is lighting. Lighting has a share of nearly 15–30% in electricity consumption in buildings [44, 45]. Therefore, providing solutions towards the efficient use of daylight and decreasing lighting energy consumption has become an important issue in today's world. The use of daylight in buildings increases visual comfort and decreases ultimate energy demand for artificial lighting [46]. With the energy saving methods that are applied to the lighting systems of buildings, energy consumption decreases considerably [47, 48]. In order to reach the desired lighting levels by transmitting daylight into the areas lacking daylight in buildings as much as possible and decrease electricity expenditures, not using lighting in the buildings in the day hours but using direct daylight through light tubes from the roofs is of great importance for sustainability (Figure 2) [49, 50].

1.2. Rainwater Harvesting. Improvements in life comfort over time have led to an increase in freshwater consumption per capita. Only 2.5% of the available water in the world is fresh water. 0.4% of fresh water is made up of easily accessible freshwater lakes, rivers, and wetlands [51, 52]. In the last century, industrialism led to rapid economic development and rapid urbanization in parallel to the increasing population. This situation led to global warming due to the pollution of nature and droughts due to climate change. Pollution of nature and global warming creates irregularities in the natural cycle of fresh water and causes freshwater resources to decrease and get polluted in most places in the world. Rapid urbanization led to the formation of heat islands that support the formation of windy rains causing floods in the cities with dense populations. Now, the effect of heat islands and global warming causes rain which was expected to fall in a long time in its natural cycle to fall in a very short time. On the other hand, along with dense structuring and concretion, big cities with large impermeable lands emerged instead of permeable natural ground cover. These effects led to surface flows in which more severe rain could not pass underground and water could not complete its natural cycle, which brought flooding in the cities, water scarcity due to a lack of feeding of freshwater resources, and pollution of fresh water. In the near future, lack of freshwater resources and unconscious consumption will leave cities in a difficult position regarding the supply of fresh water the increasing populations will need. This makes sufficient fresh water supply the most important issue. Research shows that in the future Turkey will be among the countries that will experience water stress [51, 53].

To avoid water shortage problems in the future, it is important to develop productive systems that use less fresh water, take steps to raise awareness in all parts of society about economical water consumption in agriculture, dwellings, and industry and develop systems to refine and reuse grey water and collect and use rainwater (Figure 3). Although very few sample projects are seen in Turkey on the harvesting and reuse of rainwater from the roofs [51, 54], rainwater harvesting is common in several parts of the world [55–59].

When a literature review is done, it can be seen that there is research which has been conducted with a method which offers finding the total roof areas of buildings in residential areas with absolute accuracy by measuring them one by one for the determination of solar energy and rainwater potential on roofs. For this reason, in order to draw attention to the evaluation of the existing solar energy and rainwater potential in the total roof area of buildings, this research approached the Izmit district example. Izmit is the central district of Kocaeli, Turkey's busiest industrial center. This research offers an evaluation of the existing solar energy and rainwater potential in the total roof area of buildings in the Izmit district.

2. Experimental Method

The main outline of the steps used to evaluate the existing solar energy and rainwater potential in the total roof area of the buildings in Izmit can be pointed out as follows. For electrical energy, the solar energy data of Kocaeli province are obtained from the General Directorate of Meteorology Affairs, and the number of existing buildings in Izmit district as of January 2018 and the total roof area of these buildings are obtained from Izmit Municipality. The solar energy that is provided from the total roof area of the buildings in Izmit and the electrical energy to be obtained from this energy have been calculated. This calculated electrical energy was proportioned with the electrical energy consumed by Izmit district in 2017, which was obtained from Sakarya Electricity Distribution Company. Thus, the values of production meeting consumption were calculated on a monthly and annual basis.

For hot water, the amount of hot water and temperature value needed by a family of 4 living in an apartment in Izmit district was determined from the literature, as an example. The heat to be provided from solar energy in Izmit district was calculated on a monthly and annual basis by using the solar energy data of Kocaeli province again. Production values meeting the consumption were calculated on a monthly and annual basis by proportioning the energy required for the amount of hot water that a family of four needs to the heat from solar energy. Finally, for the rainwater harvesting, monthly and annual calculations of the amount of rainwater to be provided from the total roof area of the buildings in Izmit were made by utilizing the rainwater data falling in Kocaeli province on a monthly and annual basis obtained from the General Directorate of Meteorology Affairs. Production values meeting the consumption were calculated on a monthly and annual basis by proportioning these values to the water used by Izmit district in 2017 provided by the Kocaeli Water and Sewerage Administration General Directorate. The detailing of the method used in the article is given below.

2.1. Total Number of Buildings Available in Izmit District. Buildings in a city are classified according to the purpose of construction as accommodation facilities, health facilities, religious buildings, commercial buildings, social facilities, sports facilities, educational buildings, dwellings, and industrial facilities [60]. As of January 2018, the total number of registered buildings in Izmit is 53,088 [61].

2.2. Electric Energy Consumed in Izmit District in 2017. Sakarya Electricity Distribution Inc. classified electricity consumption types as residential, industrial, commercial, lighting, and agricultural irrigation areas, and in this regard, it was found out from the data constantly recorded that the

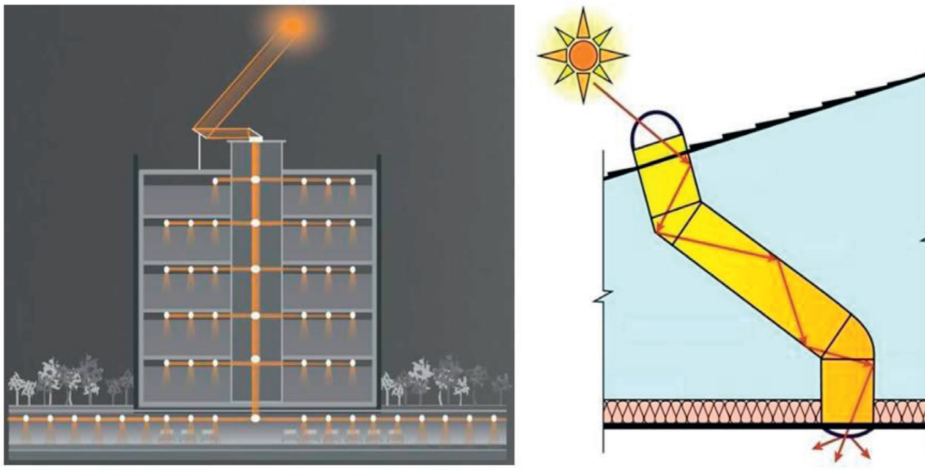

Figure 2: Utilization of daylight in buildings.

Figure 3: Rainwater harvesting.

district of Izmit consumed in total 751468230 kWh of electric energy in 2017 [62].

2.3. Calculation of Total Area. A similar study in the calculation of the total area for electricity generation with photovoltaic systems from the roofs was conducted for the city of Osaka in Japan. In that study, to estimate the available roof area in the city, pixel analysis technique of the C++ program using the aerial photo data of the city was utilized. The useful area for photovoltaic systems in the city was estimated as $42{,}000{,}000 \pm 9{,}000{,}000\,\mathrm{m}^2$ [63]. In another study titled "Determination of the solar energy potential on the total roof area of the buildings in the provincial center of Erzincan," a sample building was selected for the calculation of the roof area. By taking measurements on the south facade of the selected building, a drawing of the roof was made by using SolidWorks according to the measurement values and the area of the roof facing the south facade was found. In addition, measurements were made on the roof of the building whose real area value was calculated with Google Earth Pro and on the land registry cadastral map on which this sample building was located with the Netcad program used in land registry cadastral area measurements and compared with the actual measured value. For the sample building, the real area calculation and those calculated by means of Google Earth Pro and Netcad were 98.06, 92.61, and $91.50\,\mathrm{m}^2$, respectively. When the values were compared, it was seen that the measurements done by the programs were smaller than the real value. The real roof area being 5-6% bigger than the calculated values showed that working with the programs was safer and more applicable [64].

In a similar study conducted for Erzincan province, the use of the Netcad program to calculate the roof area was experimentally checked and the measurements and calculations carried out by using Netcad were found to give correct results. Therefore, the present study used the data obtained from the Netcad program. The area of each building was calculated by Izmit Municipality by using the Netcad program, the aerial photos taken in 2010 and current satellite imaging of the district of Izmit, and the total projection area of the buildings were computed (Figure 4). The total roof area that was calculated considering the number of the buildings in the district is regularly recorded by Izmit Municipality. The total area of the buildings in Izmit is determined by Izmit Municipality by working on each building individually without referring to any statistical methods. These data were directly used for the calculations in the present study. The margin of error for the determination of electric energy values to be generated from solar energy through the panels on the roofs of the available buildings in the district was eliminated with the method applied and exact data used [61, 64].

2.4. Calculation of the Amount of Electric Energy to Be Obtained. Data for the calculation of the electric energy value that can be produced from solar energy falling onto the buildings available in the district, and the determination of the ratio of how much of the energy that can be generated in the district meets the electric energy consumed and the transactions carried out in the light of the data are explained below. It was determined with the measurements by the General Directorate of Energy Works that the most efficient solar panel for Kocaeli district for electric energy to be

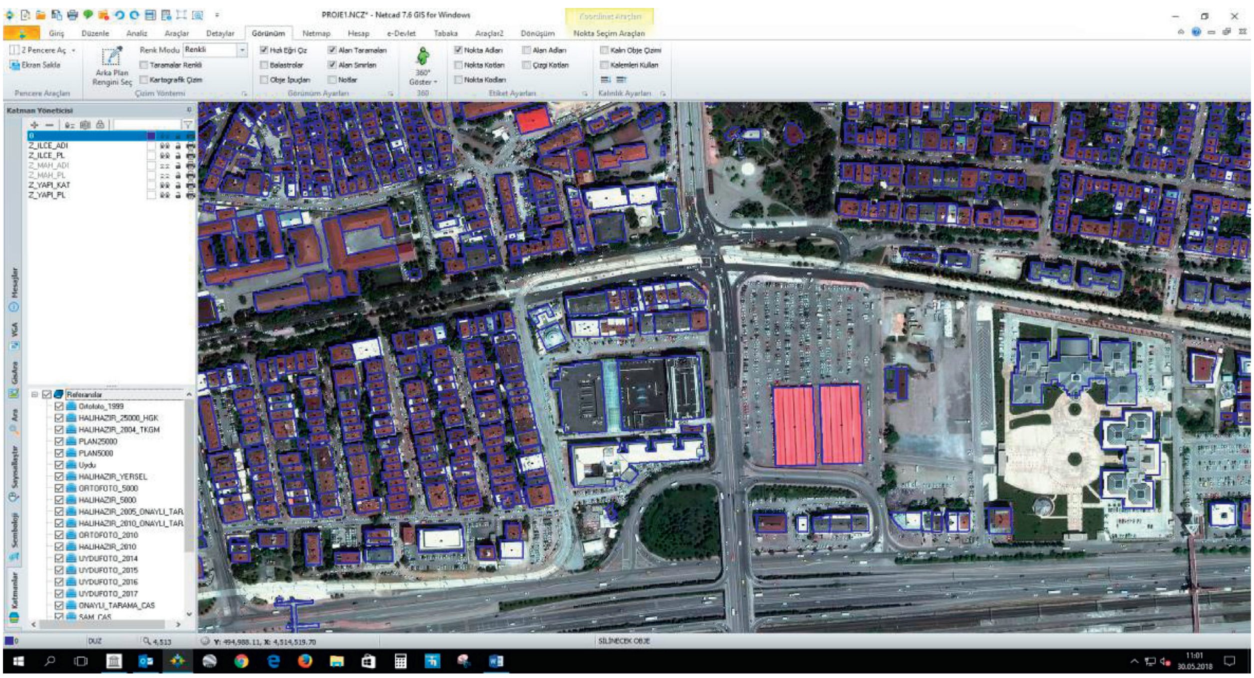

Figure 4: Calculation of total building projection areas of Izmit district with the Netcad program.

generated from the roofs by means of photovoltaic systems was monocrystal silicon panels [65]. In the calculations, year-long means of the radiation values measured by the General Directorate of Meteorology Works for Kocaeli province were used (Table 2).

In order to determine the monthly electric energy value to be provided from the roofs by means of photovoltaic systems, it is necessary to find the electric energy to be produced from the unit area [63, 67]. The amount of electrical energy to be generated from the unit area can be obtained using the following equation [68, 69]:

$$E_{\mathrm{PV}} = \eta A I_{\mathrm{et}} N_a, \quad (1)$$

where E_{PV} is the generated electrical energy (kWh), η is the panel efficiency, a is the total panel area (m^2), I_{et} is the monthly average solar radiation intensity on inclined surface (kWh/m^2), and N_a is the number of days in a month.

With equation (1), the real electrical energy values to be generated from the unit area for each month were calculated. Then, this calculated value was multiplied by the total roof area, and the total electric energy values that could be generated monthly were found. The monthly electricity consumption values in Izmit for the year 2017 were obtained from Izmit electricity distribution company [62]. Electric energy values that can be generated from the monthly solar energy from the total roof area of the existing buildings in Izmit, monthly electricity consumption values in Izmit, and the percentages of production covering consumption are indicated in Table 3 and Figure 5.

Table 2: Solar radiation values of Kocaeli province (1928–2017) [66].

Months	Monthly average solar radiation intensity on inclined surface (kWh/m^2)
January	1.2479
February	1.78637
March	2.66443
April	3.52738
May	4.50663
June	5.13232
July	5.05905
August	4.41707
September	3.63321
October	2.32135
November	1.48283
December	1.08275

2.5. Calculation of the Amount of Hot Water to Be Obtained

2.5.1. Solar Powered Water Heating System. When solar radiation passes through the atmosphere, it is swallowed or scattered by the particles in the atmosphere; thus, only radiation which amounts to 0.1–0.8 coming out of the atmosphere reaches the Earth. One of the main factors that stop radiation in the atmosphere is the humidity it has inside [70]. The projection of solar energy systems is carried out by considering the density of incoming solar radiation, sunshine duration, the Sun's angle of incidence, the most suitable productivity temperature, geographical location, seasonal climate conditions, and shade effect along with the abovementioned factors. A schematized solar powered water heating system can be seen in Figure 6. In the system, the temperature of hot water produced by using sun collectors in the winter period is measured in a three-way thermostatic valve. In the case that the water temperature level is at the desired level, it is directly sent to the users. However, in the case that the water temperature is not at the desired level, water coming from the collectors is sent to a combi boiler or

Table 3: Izmit district's monthly electricity consumption in 2017 and consumption coverage percentage of electricity energy that can be produced from the total roof area.

Months	Electrical energy that can be produced from the total roof area (MWh)	Electrical energy consumed in 2017 (MWh)	Consumption coverage percentage of production (%)
January	52673.44	70330.01	74.89468362
February	68105.08	60867.45	111.8908037
March	112464.9	65959.19	170.5068076
April	144086.7	58044.17	248.2363138
May	190223.3	56439.43	337.0396814
June	209645.4	53189.47	394.1484048
July	213541	63497.75	336.2969031
August	186443.4	62325.78	299.1432349
September	148409.8	59951.73	247.5487935
October	97983.4	59802.7	163.844434
November	60570.57	67237.08	90.08507593
December	45702.68	73823.47	61.908057
Annual total	**1529849.609**	**751468.23**	**203.5814087**

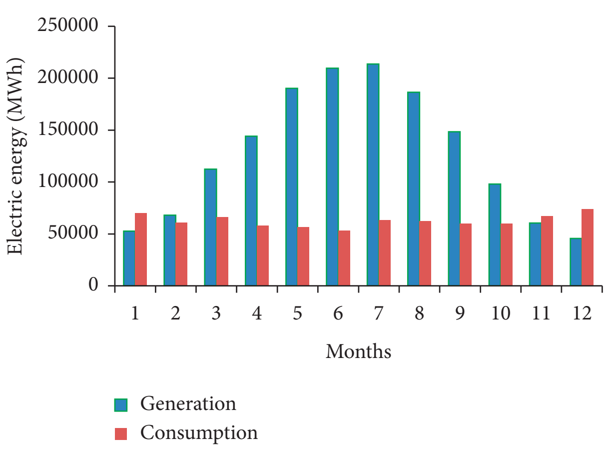

Figure 5: Izmit district's monthly electricity consumption in 2017 and the electricity that can be produced from the total roof area.

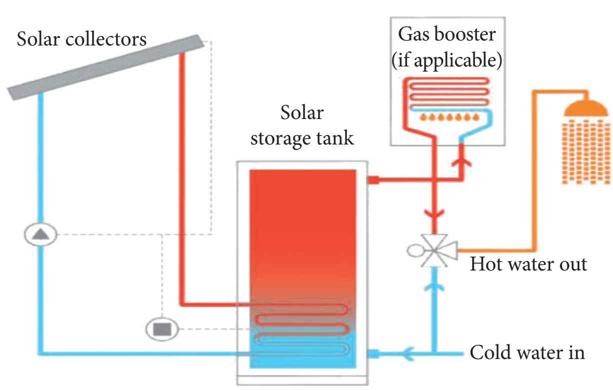

Figure 6: Schematic representation of the solar powered water heating system.

a water heater in which fossil fuels are used for a second heating process to reach the desired level. When there is no Sun or it is not enough, the solar energy system has been designed in a way to be used with fossil fuels so as not to interrupt the operation of the system.

2.5.2. Economic Analysis. Solar powered hot water production systems are very economical systems regarding both their installation and operational costs when compared with similar applications. The cost of hot water obtained using these systems is only made up of the initial investment cost of the facility, and maintenance and repair costs are very little if any. One of the primary reasons for preferring solar powered water heating systems is their economy. Because these systems are usually used in domestic applications, they are supposed to be economical. However, there is not or cannot be a design to meet the needs for the whole year with solar powered water heating systems [71]. Even if the needs are met in the summer months, they must be supported with auxiliary energy sources for the winter months or times when there is no Sun. Therefore, solar powered heating systems can be projected in a way to provide fuel saving and decrease the cost of hot water [70, 72].

In this study, the economic condition and efficiency of a solar energy-aided water heating system were investigated for a family of four in Izmit district as an example [73].

2.5.3. Monthly Thermal Needs and Solar Energy Utilization. Considering the standards in the literature, 60 L of domestic water at 60°C was accepted per capita for an individual flat where a family of four lives [73], and in order to heat the domestic water up to the desired temperature, 3 different collector areas were selected as 4, 6, and 8 m^2. In order to heat the 240-liter domestic water to a temperature of 60°C, thermal loads (Q_m) were calculated for each month of the year using equation (2), and thermal load values for each month are shown in Table 4 [41, 74].

$$Q_m = n m_y C_{P,w}\left(T_y - T_{\text{tap}}\right), \quad (2)$$

where T_y is the domestic water temperature (°C), n is the number of days in a month, m_y is the amount of hot water needed (L), T_{tap} is the tap water temperature (°C), and $C_{p,w}$ is the specific heat value (4.18 kJ/kg · K) [75, 76].

Table 4: Calculation chart for solar energy utilization rate.

Months	n	T_{tap} (°C)	T_a (°C)	Q_e (MJ/m^2-day)	Q_m (MJ/m^2-month)	X	Y	f_i
January	31	11	6.2	4.49244	1523.8608	3.8282	0.3711	0.12
February	28	10	6.9	6.43093	1404.4800	3.7236	0.5206	0.25
March	31	10	8.8	9.59194	1554.9600	3.6476	0.7765	0.44
April	30	12.3	13.2	12.6985	1435.5792	3.6390	1.0776	0.63
May	31	15.7	17.7	16.2238	1377.6945	3.7152	1.4824	0.84
June	30	19.5	21.9	18.4763	1218.8880	3.8564	1.8466	0.97
July	31	22.7	23.9	18.2125	1160.0001	4.0800	1.9764	1.00
August	31	24.1	23.8	15.9014	1116.4612	4.2447	1.7929	0.93
September	30	23.3	20.4	13.0795	1104.5232	4.3374	1.4426	0.79
October	31	20.1	16.1	8.35686	1240.8580	4.2051	0.8478	0.46
November	30	16.5	12	5.33818	1309.1760	4.0455	0.4967	0.21
December	31	12.6	8.3	3.8979	1474.1020	3.8688	0.3328	0.09
Annually	—	—	—	132.70064	15920.5833	—	—	—

2.5.4. Calculation of Monthly Utilization Rate. The term that shows the part of thermal energy needed for the required hot water production that is met by the Sun is called the utilization rate. In the projections, the ratio of meeting the need from the Sun will not be 100% for the entire year and it should not be below 10%. In practical applications, it is useful to design the project thinking that 70% of the need will be met in May [70]. In the study, in the determination of the monthly utilization rate from solar energy, the f-chart method, which includes equations (3)–(5), was used, and the results are provided in Table 4 [2, 76, 77].

$$X = F_R U_L \frac{F_R'}{F_R} (T_{\text{ref}} - T_a) \Delta t \frac{A_C}{Q_m}, \tag{3}$$

$$Y = F_R (\tau\alpha)_n \frac{F_R'}{F_R} \frac{(\tau'\alpha)}{(\tau\alpha)_n} Q_e n \frac{A_C}{Q_m}, \tag{4}$$

$$f_i = 1.029Y - 0.065X - 0.245Y^2 + 0.0018X^2 + 0.0215Y^3. \tag{5}$$

In equations (3)–(5) and Table 4, the explanations of the symbols used are as follows: X: equation parameter, F_R: collector gain factor, F_R'/F_R: the effect of the heat changer on the collector heat gain factor, U_L: collector heat loss coefficient (W/m^2·°C), T_{ref}: reference temperature (100°C) [73], T_a: monthly average ambient temperature (°C), Δt: total number of seconds for the concerned month, Q_m: thermal load for monthly hot water need (J), A_C: total collector area (m^2), Y: equation parameter, Q_e: monthly average daily total solar radiation coming onto the collector having s inclination (local latitude angle for the fixed panel) [78, 79] (J/m^2), $(\tau\alpha)_n$: collector absorption transmittance for the solar radiation coming in the normal direction, $((\tau\alpha)/(\tau\alpha)_n)$: monthly average absorption transmittance, f_i: utilization rate, and n: number of days in the month concerned [75–77].

In the study, it is planned to place the flat collectors exactly facing the south in the inclination calculated for each month. The values of the variables used in the calculation of the utilization rate are provided in Table 5 [74, 77].

Of the results obtained in the calculations, the utilization rate of solar energy by month for a 6 m^2 collector area in Izmit district is presented in Figure 7; the utilization rate of solar energy by different collector areas in Izmit district is provided in Figure 8; and the annual utilization rate of solar energy by variable collector areas is provided in Figure 9 [74].

Table 5: Utilization rate calculation variables [75, 77].

$F_R\ U_L$	F_R'/F_R	T_{ref}	$F_R\ (\tau\alpha)_n$	$((\tau\alpha)/(\tau\alpha)_n)$
4.3	0.9	100°C	0.8	0.94

2.6. Rainwater Harvesting. In the projects designed to collect and use rainwater, firstly, the rainwater and water consumption of the area where rainwater will be used should be compared. If the rainwater to be collected meets the consumption or it meets an acceptable part of it, it will be suitable to carry out such a study. The amount of rainwater to be harvested according to the meteorological information is calculated by using the following equation [52, 80]:

$$V_R = \frac{A_C Y \Phi}{1000}, \tag{6}$$

where V_R denotes the total amount of rainwater (m^3), A_C is the rainwater collection area (total roof area of the district) (m^2), Y is the amount of rainfall (mm; rainfall per unit area (m^2) forming unit height (mm)), and Φ is the loss coefficient according to the rainwater collection area (0.95 was used for tile, metal, and concrete roofs) [81]. Individual rainwater project planning calculations were not added to this manuscript because this research's aim is to make a general evaluation for the total rainwater harvest from the roof area of the buildings in the district.

Monthly and annual amounts of rainfall to be provided from the total roof area of Izmit district were determined by using the values showing the total roof area of Izmit district, the monthly amount of rainfall in the district, and the loss coefficient in equation (6). The rainwater values obtained from the calculations were proportioned to domestic water consumed in Izmit district in 2017 (V_T) [82], and the rates of utilizing rainwater in the district were determined (Figure 10 and Table 6) [80, 83].

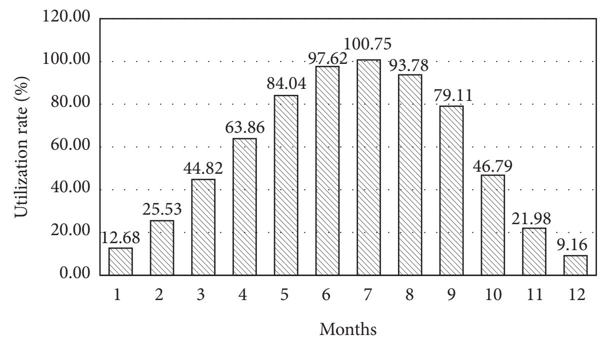

Figure 7: Utilization of solar energy by month for a 6 m^2 collector area in Izmit district.

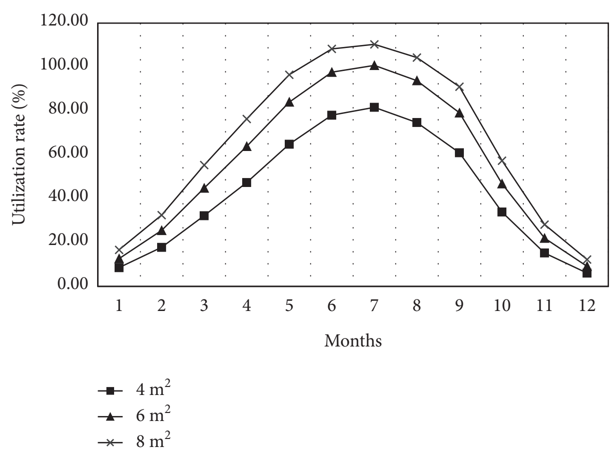

Figure 8: Utilization rate of solar energy by different collector areas for Izmit district.

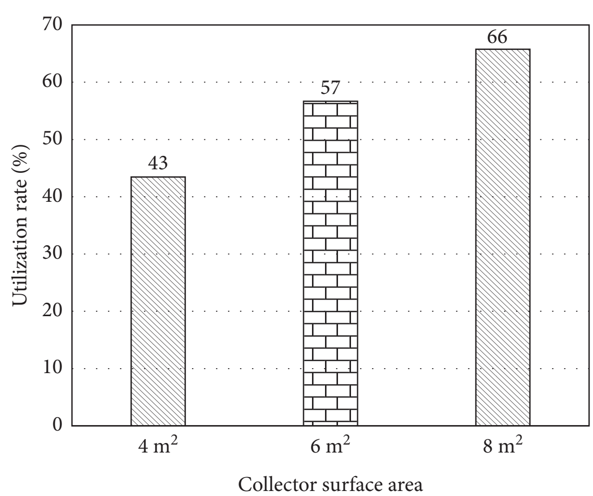

Figure 9: Annual utilization rate of solar energy by variable collector areas for Izmit district.

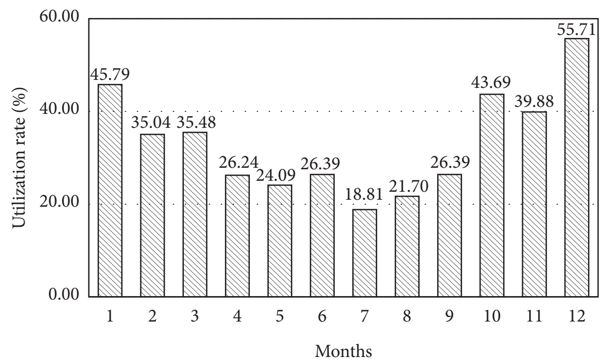

Figure 10: Utilization rate of rainwater of Izmit district by months.

Table 6: Calculation chart for rainwater utilization rate.

Months	A_C (m^2)	Y (mm)	Φ	V_R (m^3)	V_T (m^3)	f_i (%)
January	9077354.16	93.7	0.95	808020.6806	1764652.417	45.79
February	9077354.16	71.7	0.95	618303.9786	1764652.417	35.04
March	9077354.16	72.6	0.95	626065.1164	1764652.417	35.48
April	9077354.16	53.7	0.95	463081.2225	1764652.417	26.24
May	9077354.16	49.3	0.95	425137.8821	1764652.417	24.09
June	9077354.16	54	0.95	465668.2684	1764652.417	26.39
July	9077354.16	38.5	0.95	332004.2284	1764652.417	18.81
August	9077354.16	44.4	0.95	382882.7985	1764652.417	21.70
September	9077354.16	54	0.95	465668.2684	1764652.417	26.39
October	9077354.16	89.4	0.95	770939.6888	1764652.417	43.69
November	9077354.16	81.6	0.95	703676.4945	1764652.417	39.88
December	9077354.16	114	0.95	983077.4555	1764652.417	55.71
Annually	9077354.16	816.9	0.95	7044526.083	21175829	**33.27**

3. Conclusions

3.1. Electric Energy. The research was carried out to determine the electric energy that can be provided from the solar energy potential of all of the roof area of the existing buildings in Izmit the central district of Kocaeli province, by photovoltaic systems, and the ratio of how much of this energy meets the electrical energy consumed by the district. Technology is developing day by day, and these developments can be seen in solar energy systems as well. Today, more efficient photovoltaic panels are produced. In addition to this, record values have been reached such as 44% in panel efficiency [84] and 41.1% in module efficiency [85]. In order to carry out a reliable calculation for the electrical energy to be provided by means of photovoltaic systems, panel efficiency in this study was chosen as 15%, which is a low value. With the selection of 15% of efficiency, the calculations were made with the lowest values promised by the producer companies for the total efficiency of the module and the system [86]. Increases seen in the efficiency of photovoltaic systems over time will make photovoltaic systems become a profitable sector increasing the interest and reliability in electric energy. As of January 2018, there are totally 53,088 buildings in Izmit, and the total roof area of these buildings was determined as 9077354.16 m^2 as a result of the measurements and calculations. The amount of electrical energy that could be annually produced by solar energy from the total roof area was calculated as 1529849609 kWh [87, 88]. The electrical energy consumed on a yearly basis in Izmit in 2017 was determined to be 751468230 kWh. The ratio of how much of the electric energy that could be annually produced by means of photovoltaic systems from the total roof area in Izmit met the electric energy that the district consumed annually was determined to be 203.581%. This situation is valid in the design of all roofs suitable for electrical energy production with photovoltaic systems because this detected value shows the maximum values that can be achieved. This value will decrease considering the random situation of existing roofs. Data obtained from the study show that importance should be given to the electric energy production by means of photovoltaic systems from the available solar energy potential on the roofs, and serious steps should be taken on the issue. Determination of the fact that twice as much energy can be produced with the installation of photovoltaic cells onto the roofs of existing buildings in the district of Izmit, Kocaeli province, and the solar radiation values of Turkey are well above those of Kocaeli province as seen in Figure 11. This study shows that electric energy production through photovoltaic systems from the existing solar energy potential on the roofs across Turkey should be initiated without losing time and in an effective way [65].

If buildings are designed and built in a way to allow for maximum solar energy, then it will be possible to reach the potential values of the calculated solar energy, and producing electric energy from available solar energy potential by means of photovoltaic systems will become an attractive

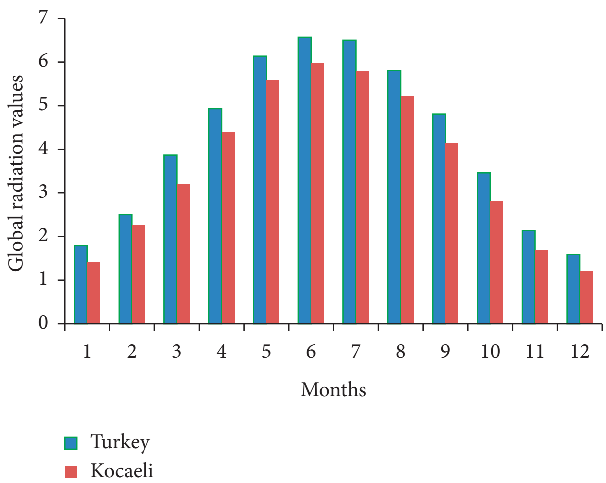

FIGURE 11: Monthly value of the global solar radiation in Kocaeli Province and in Turkey (kWh/m^2-day).

and profitable investment. The roofs that do not have problems regarding license, agricultural soil, and a separate land allocation can only have static problems. This problem can be eliminated with the production of lighter solar panels and the calculation of panel load as well. The production and consumption of electric energy should be considered holistically, and in this context, necessary reinforcements and strengthening should be carried out on the electricity distribution network. Regulations should be updated in a way to facilitate the production of electric energy from solar energy potential available on the roofs by means of photovoltaic systems and any kind of evaluation. The government should facilitate and promote the production of electric energy from solar energy potential by means of photovoltaic systems and enable all kinds of new buildings to be equipped with solar panels by means of model implementations in institutions like TOKİ. TÜBİTAK Marmara Research Centre (MRC) Materials Institute developed a photovoltaic solar panel that obtained an efficiency of 16.8%. Their prospective aim is to promote and guide the sector by producing 100% native panels that have an efficiency of 20% and that last more than 25 years [89]. The biggest photovoltaic panel production factory in Turkey was established by Bereket Energy in Denizli and commenced production. The factory continues the production of photovoltaic-based solar power plant equipment and native solar cells of Turkey within the scope of the R&D works with a project supported by Tubitak [90]. Similar investments should be promoted in order to reduce external dependence on photovoltaic based solar power plant equipment and solar cells.

3.2. Hot Water. A study was carried out in Izmit district to determine the percentage of thermal energy required for providing hot water by means of a combi boiler/water heater-aided solar powered water heating system for a family of four. 60 L of domestic water at a temperature of 60°C was accepted per capita for an individual flat where a family of four lives, and in order to heat the domestic water up to the desired temperature, 3 different collector areas were selected as 4, 6, and 8 m^2. Monthly and annual thermal loads were calculated by using equation (2) in order to heat the 240-liter domestic water to a temperature of 60°C, and thermal load values were obtained (Table 4). Although thermal loads differed according to the months, the amount of annual thermal load (Q_m) to meet the required hot water was calculated as 15920.5833 MJ. The *f*-chart method was used in order to determine how much of the thermal load needed to heat the 240 liter daily domestic water up to 60°C would be covered by solar energy, and the results are provided in Table 4. Annual solar energy utilization rates that were obtained from the calculations in the 3 different collector areas as 4, 6, and 8 m^2 were found to be 43%, 57%, and 66%, respectively (Figure 9). The results showed that solar energy alone would not be sufficient for the supply of the required hot water and that the use of the combi boiler/water heater-aided solar powered water heating system was of great importance.

3.3. Rainwater Harvesting. A study was conducted to determine the amount of rainwater that can be harvested from the total roof area of existing buildings in Izmit and what percentage of this rainwater would meet the water consumed by the district. In order to minimize the utilization of water, rainwater utilization provides a good alternative for water saving. On average, 26% of the water used in dwellings is used in toilets, 22% in washing machines, 17% in the shower, 16% in the bathroom and kitchen armatures, 2% in the bathroom, and 3% in other areas. 14% is lost due to leaks in the fittings in the dwelling. Depending on its quality, water is divided into two as drinking and domestic water. Domestic water is used to clean homes, to extinguish fires, to do the laundry, in the toilet tanks, to wash vehicles, to water gardens, and to fill swimming pools. Drinking water is used when having a shower, cooking, and washing the dishes. The water harvested from the roof of the houses is usually used as domestic water because it is not drinkable. However, when it is treated, it can be used as drinking water as well. Rainwater harvested from roofs can be used in toilet tanks and washing machines without being subjected to chemical treatment [51, 91]. Barrels, rain gardens, and wet and dry ponds that are used to store rainwater can be shown as an example for them. Monthly and annual amounts of rainfall (V_R) to be provided from the total roof area of Izmit district were determined by using the values showing the total roof area of Izmit district, monthly amount of rainfall in the district, and loss coefficient in equation (6) (Table 6). Although the amount of rainwater to be harvested varied by months, the amount of rainwater was calculated as 7044526.083 m^3. The rainwater values obtained from the calculations were proportioned to domestic water consumed in Izmit district in 2017 (V_T), and the rates of utilizing rainwater in the district were determined (Figure 10 and Table 6). The rainwater utilization rate of Izmit district in 2017 was found to be (f_i) 33.27%. This situation is valid in the design of all roofs and other equipment to benefit from rainwater because this detected value shows the maximum values that can be achieved. This value will decrease considering the random situation of existing roofs and other equipment. In conclusion, harvesting and storing rainwater on the roofs of large facilities and using it as domestic water for ice rinks, industry, toilet tanks, and garden irrigation are possible [91]. The use of rainwater in the kitchen is not considered appropriate. However, there are countries that allow rainwater to be used in the shower and laundry after a simple filtration. In addition, storing rainwater when rainfall is high will help decrease the amount of water leaking into the network and reduce the risk of floods [52, 80]. The data obtained from the research showed that the available solar energy and rainwater potential on the roof areas of the buildings in Izmit district was considerably high.

Data Availability

The data used to support the findings of the study are available from the corresponding author upon request.

Additional Points

Highlights. (i) Evaluation of the available potential on the roofs of buildings such as solar power and rainwater. (ii) The ratio of the water from solar-supported water heating systems to meet the hot water demand for Izmit district. (iii) The ratio of rainwater that can be collected from roofs in Izmit district to meet the demand of water consumed by the district. (iv) The ratio of electric energy that can be produced from solar energy in Izmit district to meet the district's electricity consumption.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] S. Sayın and İ. Koç, "Photovoltaic (PV) panels which are used to utilize solar energy actively and their usage forms on building," *Selçuk University Journal of Faculty of Engineering and Architecture*, vol. 26, no. 3, pp. 89–106, 2011.

[2] M. A. M. Rosli, D. S. M. Zaki, F. A. Rahman, S. Sepeai, N. A. Hamid, and M. Z. Nawam, "F-chart method for design domestic hot water heating system in Ayer Keroh Melaka," *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, vol. 56, no. 1, pp. 59–67, 2019.

[3] Chamber of Mechanical Engineers, *As of January 2015, Turkey's Energy Outlook Report*, Chamber of Mechanical Engineers, Ankara, Turkey, 2015, https://www.mmo.org.tr/kitaplar/turkiyenin-enerji-gorunumu-raporu.

[4] Y. Alcan, M. Demir, and S. Duman, "Sinop province's solar power generation potential in comparison with our country and Germany," *El-Cezeri Fen ve Mühendislik Dergisi*, vol. 5, no. 1, pp. 35–44, 2018.

[5] International Energy Agency, "Total primary energy supply (TPES) by source, Turkey 1990–2018," 2019, https://www.iea.org/countries/turkey.

[6] Solar Systems, "Turkey's solar energy potential," 2019, https://www.gunessistemleri.com/potansiyel.php.

[7] E. Toklu, "Overview of potential and utilization of renewable energy sources in Turkey," *Renewable Energy*, vol. 50, pp. 456–463, 2013.

[8] K.-C. Chang, W.-M. Lin, and K.-M. Chung, "A lesson learned from the long-term subsidy program for solar water heaters in Taiwan," *Sustainable Cities and Society*, vol. 41, pp. 810–815, 2018.

[9] Bilgikesesi, "General information," 2016, http://www.bilgikesesi.com/genel-bilgiler-enerji-turleri-nelerdir-enerj-12023.html.

[10] A. Rumeli, "Electric energy and Turkey," 2010, https://www.rekabet.gov.tr/File/.

[11] Chamber of Mechanical Engineers, "Renewable energy sources," 2016, https://www.mmo.org.tr/resimler/dosya_ekler/9514e888b8f2aca_ek.pdf.

[12] Ministry of Education, *Renewable Energy Sources and Their Importance*, Ministry of Education, Ankara, Turkey, 2012, http://tarim.kalkinma.gov.tr/wp-content/uploads/2014/12/Tarim_Arazilerinin_Surdurulebilir_Kullanimi_Calisma_Grubu_Raporu.pdf.

[13] G. Kum, M. E. Sönmez, and M. Karabaş, "Determination of solar energy potential in Gazi Antep province by analytical hierarchy process method (AHP)," *Journal of Geography*, vol. 39, pp. 61–72, 2019.

[14] J. R. S. Doorga, S. D. D. V. Rughooputh, and R. Boojhawon, "Multi-criteria GIS-based modelling technique for identifying potential solar farm sites: a case study in Mauritius," *Renewable Energy*, vol. 133, pp. 1201–1219, 2019.

[15] A. Korfiati, C. Gkonos, F. Veronesi et al., "Estimation of the global solar energy potential and photovoltaic cost with the use of open data," *International Journal of Sustainable Energy Planning and Management*, vol. 9, pp. 17–30, 2016.

[16] S. Cebeci, "Utilization of solar electricity generation potential in Turkey," Planning expertise thesis, General Directorate for Economic Sectors and Coordination, Ministry of Development, Ankara, Turkey, 2017.

[17] Chamber of Mechanical Engineers, *Turkey's Energy Situation 2018, Chamber Report*, Chamber of Mechanical Engineers, Ankara, Turkey, 2018.

[18] Ministry of Development, *Sustainable Use of Agricultural Land Working Group Report, Tenth Development Plan (2014–2018). Special Commission of Agriculture*, Ministry of Development, Ankara, Turkey, 2014, https://www.tarim.kalkinma.gov.tr/.

[19] P. Topçu, "Policies for the protection and effective use of agricultural land," Planning expertise thesis, Ministry of Development, Ankara, Turkey, 2012.

[20] gaiaDERGİ, "The Eco city that produces 4 times the energy it consumes: solar ship," 2015, https://www.gaiadergi.com/tukettiginin-4-kati-enerji-ureten-ekokent-gunes-gemisi/.

[21] H. Benli, "Potential application of solar water heaters for hot water production in Turkey," *Renewable and Sustainable Energy Reviews*, vol. 54, pp. 99–109, 2016.

[22] Wikimedia Commons, "Solar radiation map of Europe," 2011, https://commons.wikimedia.org/wiki/File:SolarGIS-Solar-map-Europe-en.png.

[23] Chamber of Electrical Engineers, "Turkey electricity energy statistics," 2019, https://www.emo.org.tr/genel/bizden_detay.php?kod=88369.

[24] "TEİAŞ," 2019, https://www.teias.gov.tr/.

[25] M. Melikoglu, "Vision 2023: feasibility analysis of Turkey's renewable energy projection," *Renewable Energy*, vol. 50, pp. 570–575, 2013.

[26] Turkish Electricity Transmission Corporation, *Turkey's 5 Year Electricity Generation Capacity Projection (2018–2022)*,

Turkish Electricity Transmission Corporation, Ankara, Turkey, 2018.

[27] İ. V. Öner, M. K. Yeşilyurt, G. Ömeroğlu, and E. Ç. Yılmaz, "Wind energy: potential, policies and status in Turkey," *International Journal of Engineering Research & Science (IJOER)*, vol. 2, no. 12, pp. 114–120, 2016.

[28] IRENA, "Renewable energy prospects: Germany," 2015, http://www.irena.org/.

[29] Nature, "Renewable power: Germany's energy gamble," 2013, https://www.nature.com/news/renewable-power-germany-s-energy-gamble-1.12755.

[30] K. Çomaklı, U. Çakır, M. Kaya, and B. Şahin, "Energetic and exergetic analysis of a water heating system using solar energy," in *Proceedings of the 5th International Ege Energy Symposium and Exhibition (IEESE-5)*, Pamukkale University, Denizli, Turkey, June 2010.

[31] R. Çakmak and İ. H. Altaş, "Solar energy potential of eastern Black sea region of Turkey: a case study for Trabzon province," in *Proceedings of the 2016 National Conference on Electrical, Electronics and Biomedical Engineering (ELECO)*, pp. 86–90, Bursa, Turkey, 2016.

[32] E. Türe, "Solar energy systems as roofing materials," in *Proceedings of the 4th Symposium on Contemporary Materials for Materials & Technologies for Roof & Facade Cladding*, pp. 13-14, Istanbul, Turkey, October 2008.

[33] B. Gümüş, B. E. Serhat, C. Kutlu et al., "As an alternative to Ilısu HEPP and its applicability to the southeast Anatolia region," in *Proceedings of the Renewable Energy Resources Symposium*, pp. 19–21, Diyarbakır, Turkey, 2009.

[34] MilliGazete, "Art and culture," 2018, https://www.milligazete.com.tr/foto/1666933/tarihi-artuklu-hamami-37-milyon-lira-maliyetle-tasinmaya-baslandi.

[35] S. A. Kalogirou, "Solar thermal collectors and applications," *Progress in Energy and Combustion Science*, vol. 30, no. 3, pp. 231–295, 2004.

[36] M. Narin and S. Akdemir, "Energy efficiency and Turkey," in *Proceedings of the International Conference on Economics, Economic Council of Turkey*, Ankara, Turkey, September 2006.

[37] Ş. Efe, "Economic analysis of heating systems used in Erzurum," Master thesis, Institute of Science, Atatürk University, Erzurum, Turkey, 2007.

[38] T. Urmee, E. Walker, P. A. Bahri, G. Baverstock, S. Rezvani, and W. Saman, "Solar water heaters uptake in Australia—issues and barriers," *Sustainable Energy Technologies and Assessments*, vol. 30, pp. 11–23, 2018.

[39] Electrical Works Survey Administration, *Energy Efficiency Bulletin in Buildings*, Electrical Works Survey Administration, Ankara, Turkey, 2004.

[40] G. Sadeghi, H. Safarzadeh, M. Bahiraei, M. Ameri, and M. Raziani, "Comparative study of air and argon gases between cover and absorber coil in a cylindrical solar water heater: an experimental study," *Renewable Energy*, vol. 135, pp. 426–436, 2019.

[41] H. N. S. Al-Joboory, "Comparative experimental investigation of two evacuated tube solar water heaters of different configurations for domestic application of Baghdad- Iraq," *Energy and Buildings*, vol. 203, Article ID 109437, 2019.

[42] T. A. Yassen, N. D. Mokhlif, and M. A. Eleiwi, "Performance investigation of an integrated solar water heater with corrugated absorber surface for domestic use," *Renewable Energy*, vol. 138, pp. 852–860, 2019.

[43] Wiessman, *Solar Powered Gas Condensed Compact Condensing Boiler (VITODENS 242-F Type FB2A)*, Wiessman, Dülmen, Germany, 2009.

[44] I. Acosta, M. Á. Campano, S. Domínguez, and J. Fernández-Agüera, "Minimum daylight autonomy: a new concept to link daylight dynamic metrics with daylight factors," *Leukos*, vol. 15, no. 4, pp. 251–269, 2019.

[45] A. Chel, G. N. Tiwari, and A. Chandra, "A model for estimation of daylight factor for skylight: an experimental validation using pyramid shape skylight over vault roof mudhouse in New Delhi (India)," *Applied Energy*, vol. 86, no. 11, pp. 2507–2519, 2009.

[46] D. Gürlich, A. Reber, A. Biesinger, and U. Eicker, "Daylight performance of a translucent textile membrane roof with thermal insulation," *Buildings*, vol. 8, no. 118, pp. 1–19, 2018.

[47] C. H. Kim and K. S. Kim, "Development of sky luminance and daylight illuminance prediction methods for lighting energy saving in office buildings," *Energies*, vol. 12, no. 592, pp. 1–37, 2019.

[48] M. Sudan, G. N. Tiwari, and I. M. Al-Helal, "Dynamic analysis of daylight metrics and energy saving for rooftop window integrated flat roof structure of building," *Solar Energy*, vol. 122, pp. 834–846, 2015.

[49] A. E. Asker, "Design of lighting systems based on efficiency and occupational health," Expertise thesis, ILBANK, Ankara, Turkey, 2007.

[50] A. K. Yener, "Daylight saving methods in buildings: contemporary techniques," in *Proceedings of the 8th National Installation Engineering Congress*, Ankara, Turkey, October 2007.

[51] N. İ. Şahin and G. Manioğlu, "Using rainwater in buildings," *Installation Engineering*, vol. 125, pp. 21–32, 2011.

[52] M. Y. Kılıç and M. N. Abuş, "Rainwater harvesting in a garden house sample," *International Journal of Agriculture and Wildlife Science (IJAWS)*, vol. 4, no. 2, pp. 209–215, 2018.

[53] T. T. Marangoni, J. N. Oliveira, and M. Marcelo Libânio, "Avaliação quantitativa equalitativa do emprego de paredes como nova perspectiva para captação de água de chuva," *Artigo Técnico*, vol. 24, no. 31, pp. 575–584, 2019.

[54] H. Silkin, "Evaluation of the application in Turkey of some special adaptation to climate change," Forestry and Water Affairs Specialist Thesis, General Directorate of Water Management, Republic of Turkey Ministry of Agriculture and Forestry, Ankara, Turkey, 2014.

[55] R. Hofman-Caris, C. Bertelkamp, L. de Waal et al., "Rainwater harvesting for drinking water production: a sustainable and cost-effective solution in the Netherlands?" *Water*, vol. 11, no. 3, p. 511, 2019.

[56] F. Abdulla, "Rainwater harvesting in Jordan: potential water saving, optimal tank sizing and economic analysis," *Urban Water Journal*, vol. 17, no. 5, pp. 446–456, 2019.

[57] S. Bae, J. P. Maestre, K. A. Kinney, and M. J. Kirisits, "An examination of the microbial community and occurrence of potential human pathogens in rainwater harvested from different roofing materials," *Water Research*, vol. 159, pp. 406–413, 2019.

[58] H. Yin, F. Kong, and I. Dronova, "Hydrological performance of extensive green roofs in response to different rain events in a subtropical monsoon climate," *Landscape and Ecological Engineering*, vol. 15, no. 3, pp. 297–313, 2019.

[59] J. R. Argue, "Towards a universal stormwater management practice for arid zone residential developments," *Water Science and Technology*, vol. 31, no. 1, pp. 15–24, 1995.

[60] "GN construction," 2018, https://www.gninsaat.com.tr/yapi-nedir-siniflari-nelerdir.

[61] Kocaeli University, *Geographical Information Systems*, Kocaeli University, Izmit, Turkey, 2018.

[62] Sakarya Electricity Distribution Inc, *Electric Energy Consumption in Izmit in 2017*, Sakarya Electricity Distribution Inc., Adapazarı, Turkey, 2018.

[63] J. Yuan, C. Farnham, K. Emura, and S. Lu, "A method to estimate the potential of rooftop photovoltaic power generation for a region," *Urban Climate*, vol. 17, pp. 1–19, 2016.

[64] M. Kaya, M. Akboğa, E. Mert, K. K. Yakak, and O. K. Surmali, "Determination of the existing solar energy potential of total roof area for the buildings in Erzincan province," in *Proceedings of the 2016 International Erzincan Symposium*, Erzincan, Turkey, September 2016.

[65] "General directorate of energy affairs," 2019, http://www.yegm.gov.tr/MyCalculator/pages/41.aspx.

[66] Ministry of Energy and Natural Resources, *General Directorate of Meteorology Affairs*, Ministry of Energy and Natural Resources, Ankara, Turkey, 2018.

[67] M. A. Khan, B. Ko, E. A. Nyari, S. E. Park, and H. J. Kim, "Performance evaluation of photovoltaic solar system with different cooling methods and a bi-reflector PV system (BRPVS): an experimental study and comparative analysis," *Energies*, vol. 10, no. 826, pp. 1–23, 2017.

[68] F. Dinçer and M. E. Meral, "Critical factors that affecting efficiency of solar cells," *Smart Grid and Renewable Energy*, vol. 1, no. 1, pp. 47–50, 2010.

[69] E. Kıyançiçek, "Pvs^2 software package implementation for sizing photovoltaic systems," MS thesis, Electrical-Electronics Engineering, Institute of Science and Technology, Selçuk University, Konya, Turkey, 2013.

[70] U. Çakır and K. Çomaklı, "Energy and economical analysis of solar hot water systems," in *Proceedings of the 2010 International Sustainable Buildings Symposium (ISBS)*, Ankara, Turkey, May 2010.

[71] H. Bulut, H. Şahin, and R. Karadağ, "Techno-economic analysis of solar water heating systems. Chamber of mechanical engineers," *Journal of Installation Engineering*, vol. 101, pp. 23–33, 2007.

[72] S. Sami, D. Semmar, A. Hamid, R. Mecheri, and M. Yaiche, "Viability of integrating solar water heating systems into high energy performance housing in Algeria," *Energy*, vol. 149, pp. 354–363, 2018.

[73] Turkish Standards Institution, "Solar heating residential water heating systems part 3," *Performance Tests of Solar and Additional Heating Systems (TS ISO 9459-3)*, Turkish Standards Institution, Ankara, Turkey, 1999.

[74] K. Çomaklı, U. Çakır, M. Kaya, and K. Bakirci, "The relation of collector and storage tank size in solar heating systems," *Energy Conversion and Management*, vol. 63, pp. 112–117, 2012.

[75] M. Kaya, U. Çakır, K. Çomaklı, and K. Bakırcı, "Energy and economic analysis of a combined fossil/solar water heating system in Erzincan (AES-013)," in *Proceedings of the 2011 Anadolu Energy Symposium*, Elazığ, Turkey, June 2011.

[76] G. G. Günerhan, "Use of solar energy for heating with active systems," 2019, https://www1.mmo.org.tr/resimler/dosya_ekler/5cc2c8205a05d73_ek.pdf?dergi=160.

[77] E. F. Kent and İ. N. ve Kaptan, "Solar assisted absorption applications for heating and cooling," in *Proceedings of the 5th International Advanced Technologies Symposium (IATS'09)*, Karabuk, Turkey, May 2009.

[78] General Directorate of Meteorological Affairs, *Statistical Data for Provinces and Districts*, General Directorate of Meteorological Affairs, Ankara, Turkey, 2010.

[79] K. Bakırcı and B. Yüksel, "Experimental investigation of solar water heating system," *Journal of Installation Engineering*, vol. 110, pp. 26–30, 2009.

[80] A. Can and Ü. Yılmaz, "Rainwater potential and using as usage water," in *Proceedings of the 14th National Installation Engineering Congress*, İzmir, Turkey, April 2019.

[81] M. Ekşi, M. Yılmaz, and Ö. Özden, "Quantitative assessment of rain gardens: a case study in Istanbul University faculty of forestry," *Journal of the Faculty of Engineering and Architecture of Gazi University*, vol. 31, no. 4, pp. 1113–1123, 2016.

[82] General Directorate of Kocaeli Water and Sewerage Administration, *Annual Report*, General Directorate of Kocaeli Water and Sewerage Administration, Istanbul, Turkey, 2017.

[83] A. C. González, "Study to analyze the viability of rainwater catchment from roofs for its reuse in Tegucigalpa, Honduras," Master thesis, Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, CO, USA, 2012.

[84] Energy Five, "Clean energy portal," 2016, https://www.enerjibes.com/gunes-paneli-verimi-artabilir-mi/.

[85] "PV education," 2019, https://www.pveducation.org/pvcdrom/appendices/solar-cell-efficiency-results2.

[86] SolarReviews, "Solar panel efficiency rankings: the 15 most efficient solar panels for home in 2019," 2019, https://www.solarreviews.com/blog/what-are-the-most-efficient-solar-panels-for-2019.

[87] A. Özgöçmen, "Electricity generation using solar cells," MS thesis, Electrical Engineering, Institute of Science and Technology, Gazi University, Ankara, Turkey, 2007.

[88] İ. Arslan, "Monocyrstal and polycrystal solar panels under Tekirdag conditions investigation of efficiency," MS thesis, Department of Biosystem Engineering, Institute of Science and Technology, Namik Kemal University, Tekirdağ, Turkey, 2018.

[89] "Tübitak," 2016, http://mam.tubitak.gov.tr/tr/node/1209/backlinks.

[90] Bereket Energy, "Research and development," 2019, https://www.parlasolar.com/arge.

[91] K. A. Akaydın Sel, "Investigation of rainwater over residential building scope in the context of sustainable design," Master thesis, Haliç University Institute of Science and Architecture Department of Architecture Program, İstanbul, Turkey, 2017.