

EXPERIENCES AND RESULTS OF THE WORLD COUNTRIES IN USING SOLAR ENERGY

*Aim:* To investigate the experiences and results of the world countries in using solar energy and to make a comparative analysis

*Results:* The demand for energy in the world is increasing day by day. Between 1990 and 2012, world primary energy demand increased by approximately 53 percent and reached 13,361 million tons of oil equivalent (MTEP). In 2012, approximately 82 percent of primary energy demand was met by fossil fuels. In this article, the history and methodology of utilizing solar energy has been researched. The increasing need for energy in the world day by day causes the gradual depletion of fossil fuel resource reserves, which are limited in the world. In addition, with the increase in the use of fossil fuels after the industrial revolution, the concentration of greenhouse gases (greenhouse gases), especially carbon dioxide (CO<sub>2</sub>), in the atmosphere increased significantly and a global warming began to be experienced. The recent energy crises and the reality of global warming have led countries to seek constantly renewed and environmentally friendly energy sources instead of fossil fuels, which are traditional energy sources, which have a common use, risk of depletion, share in greenhouse gas emissions. These resources, which are called as renewable energy resources, attract great attention today. Among the renewable energy sources, solar energy is both environmentally friendly as it does not emit CO<sub>2</sub>, and is a large enough energy source to potentially meet the energy demand of the whole world.

Solar energy reaches the earth in a sufficient amount to meet all the electrical energy needs of the world. However, considering a fixed location on the earth, the amount of solar and wind energy at that location is variable due to the nature of these energy sources or due to atmospheric events.

*Scientific novelty:* In this work compares the history, methods and innovations of the use of solar energy in Azerbaijan and other countries of the world.

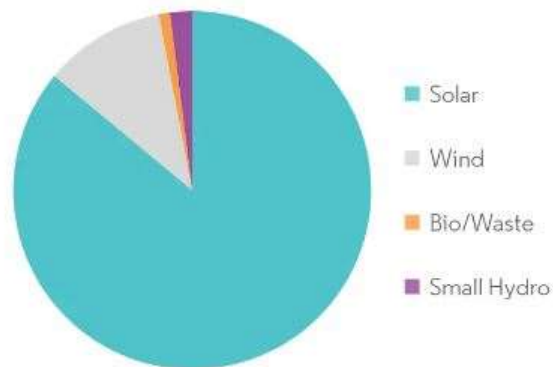
*Keywords:* PV system, photovoltaic, climate change, global warming, energy, CO<sub>2</sub>

*Problem formulation:* Increasing energy demand and depleting fossil fuels have increased the interest in renewable energy systems. Photovoltaic (PV) and wind systems are at the forefront of these systems. Although solar energy was used to heat up or meet the need for hot water at first, it is also used to generate electricity today with the developing technology and decreasing unit costs. Electricity generation is possible with both concentrated solar energy (CSP) and photovoltaic (PV) based technology [11].

In parallel with the economic growth, increasing population, industrialization and improvement of living conditions of Azerbaijan, the need for energy is increasing rapidly. The Azerbaijani government plans to decrease the heavy reliance of oil in power generation and increase the share of the nation's electricity from solar. This is expected to drive the demand for solar energy, and in turn, for renewable in the country [13].

According to the IRENA, Azerbaijan has an estimated solar energy potential of 23,040 MW, which is expected to be the highest in comparison to other renewable power segments [5]. As of 2019, the country had 36.30 MW of solar PV installed capacity, with a total target of 50 MW by the end of 2020 [9].

Azerbaijan Renewable Energy Potential Share (%), by Source, 2019



The search for alternative sources to fossil fuels, which meet a large part of the world's energy demand, advanced in terms of production technologies, high efficiency and low cost, emerged for the first time after the Oil Crisis in 1973. The unexpected increase in oil prices has brought the issue of security of

supply in energy to the agenda [8]. In addition, greenhouse gas emissions caused by fossil fuels during energy production have led countries to turn to environmentally compatible renewable energy sources. Solar energy, which has a potential above the world's energy needs, has an important place among renewable energy sources.

The advantages it has when compared to traditional energy sources have led countries to develop and expand the use of solar energy in electricity generation. The most important reason behind the widespread use of solar energy for electricity generation is that countries support PV and CSP system technologies with their legal regulations and policy tools [7]. Many countries have set themselves the goal of generating electricity from solar energy and have put in place support tools to achieve these goals.

Depending on the incentive mechanisms applied, SPPs have become widespread in many countries, especially in Germany, China, Italy, Spain, Japan and the USA.

Since 1992, the PV system installed power has grown at an annual average rate of 62 percent, reaching 177 GW at the end of 2014, and solar energy has a capacity to meet almost 1 percent of the world's electricity. In the said period, a few countries that discovered that PV is a promising renewable energy technology started to support investments by implementing various financial support policies such as feed-in tariff (FIT).

The growth in world PV capacity was mainly in Japan until 2004, and some European countries (such as Spain, Italy) have started to have a say in the PV market, especially Germany, since that year.

With the support given to PV technologies, PV technology has developed at the global level and economies of scale have emerged. In addition to these developments, PV system costs have been greatly reduced as China has greatly increased the production of cells and modules.

Between 2008 and 2010, approximately 80 percent of the total PV installed power was located in the European region [12]. However, as a result of the reduction in the support for solar energy investments in Europe and the policy changes made by some countries, a slowdown was observed in the annual PV installed power increases. Thus, the share of the said region in the total installed power decreased to approximately 59 percent at the end of 2013.

Analyzes and discussions. In some countries in the Asia-Pacific region and North America with high solar radiation value, PV system production costs have decreased to a level that can compete with conventional power plants. In addition to decreasing costs, the continuation of incentives enabled the share of countries in the Asia-Pacific region in total PV installed power to increase to 30 percent in 2013.

The PV system industry has been developing simultaneously with the rapidly increasing demand, especially since the mid-2000s. While module production was mostly carried out in the USA ten years ago, in the following years, most of the production shifted to Japan, Europe and less developed Asian countries.

At the end of 2014, 87 percent of global module production was carried out in Asia, 8 percent in Europe and 2 percent in the USA. In the same year, among Asian countries, China supplied 67 percent of the total modules produced in the world, and Japan 5%. Due to the low capital, land and labor costs in the country and the incentive system implemented, China has become the leader in PV module and cell production. Although solar energy meets a very small share of the global electricity demand, it is estimated that the role of solar energy in the carbon-free energy system will increase in the coming years with technological developments and cost reductions.

PV technology is dominant among solar power generation systems due to its rapid growth and decreasing costs. Although CSP technology has shown less development to date, its share in electricity generation is expected to increase in the future.

*Table.*

*2020 report World Photovoltaic Installed Power Country Ranking*

<i>N</i>	<i>Countries</i>	<i>Installed Power (MW)</i>
1	China	254.355
2	USA	75.572
3	Japan	67.000
4	Germany	53.783
5	India	39.211
6	Italy	21.600
7	Australia	17.627
8	Vietnam	16.504
9	South Korea	14.575
10	Spain	14.089
11	UK	13.563
12	France	11.733

13	Netherland	10.213
14	Brazil	7.881

In the evaluation made for the electricity generation market from solar energy, Germany, Italy, China, Japan and the USA in electricity generation from PV systems; it is understood that the USA and Spain are the leading countries in electricity generation from CSP systems. The policies and supports implemented in these countries are discussed below.

#### Germany

With the excessively rising energy prices, the idea of not being dependent only on classical energy sources led Germany to encourage electricity production from renewable energy sources in the 1980s. As a result of its support policies, Germany has been in the first place in the global PV market in terms of cumulative installed capacity since 2009. The PV installed power, which was 89.4 MW in 2000, reached 38.2 GW in 2014 and met 6 percent of the total electricity consumption [10]. It is thought that the efforts to achieve the medium and long-term production targets set for renewable energy sources with the successful FIT policy initiated in 2000 also play an important role in this development .

Germany started the solar roofs program in the late 1980s to create a market for renewable energy technologies. Within the scope of the program, 70 percent of the investment cost of PV systems was covered by the government. Within the scope of the said program, until 1993, 2,250 roofs were covered with solar panels with a total installed power of 5.3 MW [4].

Looking at the policy documents regarding renewable energy resources and the historical development of practices, the Law on Feeding Electricity into the Grid, enacted in 1990, stands out as a milestone. With the said Law, electricity produced from renewable energy sources was tariffed at a rate of 90 percent of the retail price. The law promoted wind and other renewable energy installations. Due to the determination of a single tariff for all renewable energy technologies in the Law and the high cost of PV system production, the Law in question could not provide sufficient incentives for solar energy systems. Despite this, Germany ranked second after Japan in the global market with a cumulative PV installed capacity of 89 MW at the end of 2000.

The FIT system is the most preferred incentive policy that enables the increase in electricity production from renewable energy sources in Germany. The tariff rate determined in the applied FIT policy; Although it varies depending on the type of PV facility (mounting the system on the ground or on the roof), its installed power, and the date of commissioning, the purchase guarantee determined for all applications is valid for the 20-year operating period after the power plant is commissioned.

In Germany, apart from FIT, a double-sided metering system policy is implemented in order to ensure that citizens meet their consumption with the electricity they produce. All of the electricity produced from PV systems before 2012 and supplied to the grid was evaluated within the scope of FIT. However, in the amendment made in the Law in 2012, in order to reduce the amount of electricity supplied by the system operators to the grid, it was regulated that up to 90 percent of the electricity produced in systems with an installed power of up to 1 MW could be purchased within the scope of FIT, and the remaining part could be sold from the spot market or the wholesale market.

#### China

China, which turns to renewable energy sources to ensure energy supply security, is one of the countries that supports electricity production from solar energy the most. Thanks to its policies and support mechanism, China has become the world's largest producer of solar cells and modules, and also ranked first in the global market with its 28.1 GW of PV installed power capacity in 2014. It is predicted that China's role in the development of the global PV market will increase in the coming years.

The continuous increase in energy demand in China between 1980 and 1995 caused the government to give more importance to renewable energy sources. Thus, the Outline for New Energy and Renewable Energy Development was announced and the focus was on energy efficient buildings, PV power generation facilities and solar heating systems [10]. On the demand side, the government sought a solution to the need in regions without electricity and as a result decided to put PV systems into operation.

In the late 1990s and early 2000s, the growth of the Chinese PV market started with the implementation of the Brightness Electrification Program and the Township Electrification Program, which the government implemented to provide access to electricity for citizens living in remote areas.

Firstly, PV systems with an average capacity of 100 W were installed in each household in order to meet the electricity demand of 23 million people, and then large-scale (20 MW) PV systems were installed in distant cities without electricity. Thus, the electricity needs of millions of citizens living in rural

areas were met. The development of the PV industry has been encouraged by evaluating the experience gained in pilot-scale PV system applications in large-scale off-grid PV system installations.

In 2009 and 2010, the government initiated a two-stage public bidding process for solar projects. As a result of the tenders, PV system electricity prices were determined at lower levels than expected by the PV industry in the country, which adversely affected the investment decisions of PV equipment suppliers and energy companies. Afterwards, PV manufacturers pressured the government to provide higher levels of incentives, so in 2011 the national FIT policy was announced for the first time by the National Development and Reform Commission. In the first application, a single FIT ratio was determined for all solar energy systems. In the FIT policy, which was renewed in 2013, the states are divided into three groups and the tariff changes according to the average annual radiation value of the region and the cost of installation.

China is one of the most important countries contributing to the development of the PV market in the world, with the programs it prepared in 2000 to meet the electricity needs of its citizens living in rural areas, and then with subsidies and FIT incentives for SPPs in line with the targets set in its national programs.

#### USA

As a result of the energy crisis that emerged in 1973, the significant increase in the prices of fossil fuels caused the USA, like other countries in the world, to develop policies to increase the use of domestic and renewable energy resources. In 1978, the National Energy Services Regulatory Policies Act (PURPA), the first legal regulation to promote renewable energy sources, was approved. With the said Law, the FIT policy began to be implemented for the first time in the country.

71 percent of the additional large-scale PV system installed capacity in the USA in 2013 is located in California. The policy of double-sided metering systems was first implemented in Massachusetts in 1982 [10].

As a result of the policy, distributed PV system installations have increased by more than 50 percent annually on average. In 2013, 95 percent of the distributed PV system installations in the USA were evaluated within the scope of the double-sided meter policy, and the rest are installations that are realized only to meet their own consumption.

#### Japan

The oil crisis of 1974 affected the oil-exporting countries in a big way, and the burden of rising energy prices on the budget increased. This has led to the inclusion of renewable energy sources in Japan's energy production policy, which has very little oil and natural gas reserves.

In the same year, with the Sun Shine Program launched by the International Ministry of Commerce and Industry, the government for the first time switched to an alternative source of petroleum. In this context, Ar-Ge activities in the field of renewable energy have been supported through public, industrial and academic cooperation, and implementation projects have also been implemented [3]. The program has made a significant contribution to the development of the PV industry in the country. As a result of the program, electricity was first generated from PV systems in 1992.

The renewable energy quota application was included in the government's renewable energy policies in 2003 and it was aimed to meet 1.35 percent of electricity production from renewable energy sources until 2010 with this policy [10]. However, the incentive policies implemented afterwards were not enough to increase solar energy investments.

After the Fukushima disaster in 2011, energy policies in Japan were restructured and in order to reduce the dependence on nuclear energy in electricity supply, policies for other energy sources began to be emphasized, so the PV market in the country started to rise again. It is predicted that the Japanese PV market will continue to grow rapidly in the coming years.

In this direction, according to the PV road map study conducted by the Japan Photovoltaic Energy Association, it is predicted that the installed PV power in the country will increase to 49 GW by 2020 and to 102 GW by 2030.

Conclusion: The sudden increase in energy prices after the oil crisis in the world in the 1970s caused countries to turn to renewable energy sources. Thus, many support policies have started to be implemented in the world to increase the use of renewable energy sources.

Among the incentive mechanisms that enable the development of renewable energy sources, the most effective one to date (providing 66 percent of the increase in renewable energy installations in the world) is the FIT policy [1]. In the implementation of the FIT policy, countries generally differentiated the tariff rate according to the PV system capacity. After the FIT policy, the policy instruments that contribute the most to the development of the renewable energy market are capital subsidies and tax incentives. In the

mid-1980s, Ar-Ge studies on solar energy technologies were initiated, pilot-scale applications were carried out at the same time, and grid-connected SPPs were built [6]. In the following years, roof-type PV system installations were encouraged by the states, and in this way, the PV manufacturing industry began to mature. From the beginning of the 1990s until 2004, Japan ranked first in the size of PV installed power, while after 2004 Germany started to rise rapidly [4]. Apart from Germany and Japan, China, USA, Italy and Spain are other leading countries in the global PV market. After 2012, the incentives given to PV systems in Europe were greatly reduced and retrospective policy changes were made due to the financial crises in some countries (such as Italy and Spain), which created an environment of uncertainty in the European PV market, and as a result, the rate of PV system capacity increase slowed down. These developments have heralded that Asian countries will become leaders in the market in the coming years [2]. The rapid decrease in solar energy technology costs in recent years has affected public authorities both positively and negatively. On the one hand, electricity production from solar energy has increased in line with the targets set by the countries. On the other hand, it has been difficult for public institutions to determine the appropriate and sufficient amount of support that will prevent investors from making undesirable profits while continuing to encourage solar energy investments.

In recent years, energy supply security has become the first priority issue in developed and developing countries such as Azerbaijan, which are net importers in the supply of total energy resources. One of the most important reasons for this is that the fluctuations in energy prices negatively affect the national economies of the countries. Energy prices in the global market are determined under conditions of imperfect competition.

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