

**Research Article****Two countries at same parallel in solar energy productions: USA and Turkey****Gülcan İner <sup>a,\*</sup> and Evren Çağlarer <sup>b</sup>**<sup>a</sup>Kirklareli University, Vocational School of Technical Sciences, Kirklareli, 39100, Turkey<sup>b</sup>Kirklareli University, Faculty of Technology, Kirklareli, Turkey

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## ABSTRACT

Energy is a basic necessity after the industrial revolution in our lives. Energy demand is increasing with the development of technology from day by day. Humanity has head towards to the alternative energy sources. Therefore, alternative energy must have renewable sources. This situation can be supply a significant benefit for future energy demand. These resources play an important role in meeting the demand and provide significant benefits in terms of economic and environmental protection. Among the renewable energy sources have taken an important place like hydroelectric power plants, wind turbines, geothermal energy, wave energy, biomass energy, rock gas, etc. However, solar energy is the biggest renewable energy potential most countries in the world. Various countries around the world use renewable energies solar energy and photovoltaic panel technology to choose energy production and increasing the production potentials day by day. In this study, samples will be compared to the United States and Turkey in energy production from solar energy.

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**1. Introduction**

Developing technologies, rapid increase in population, need for more comfortable life increase energy need each day. Studies conducted for resource supply of the energy that may fulfil such needs and use of fossil resources in production may cause global warming, increase of environmental pollution, limitation of agricultural production and the risk of extinction of animal and plant variety. According to OECD 2016 data, 6 to 9 million people in the world will encounter early death risk each year due to air pollution until 2060. Today, global warming and increase in sea levels, floods, air pollution, stress, heat stroke, diseases, agricultural losses, severe storms and drought, loss of corals and fish in oceans cost annually 2,6 billion USD globally and this amount increases day by day [1].

Lack of resources for energy production is also a significant problem for countries. Non-renewable and mostly used energy resources used today are coal, oil and natural gas. Import of such resources causes economically significant costs and foreign borrowing for countries which have insufficient own reserves such as Turkey.

There is a need for renewable, economical and sustainable resources which are not harmful to the environment and ecosystem for producing the energy required. It is possible to obtain this energy from wind, rain, sun and geothermal resources which can renew itself in the nature. There is no doubt that the most important resource in terms of reserve amongst these alternatives is the sun.

The temperature of the sun measured using various methods is 5800 °C. The power of such a hot object, in other words the radiant energy it radiates per second is measured approximately as  $4 \times 10^{23}$  kW. The power falling on each square meter of the earth after this energy is absorbed in the atmosphere is approximately 1.000 watt/m<sup>2</sup> [2] (317 BTU-h/ft<sup>2</sup> in USA). Since solar energy is an environmentally clean resource, it is a strong alternative for fossil fuel. Solar radiant energy falling on earth each year is almost 160 times of the fossil fuel reservoirs on Earth determined until today, and is approximately 15.000 times more than the energy that all fossil, nuclear and hydroelectricity plants may generate in one year.

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Therefore, it is very significant that solar energy is transformed into an energy type that can be used accordingly in human activities [1].

## 2. Electricity Energy Consumption and Generation Potentials

While China, United States of America, India, Russia, Japan and Germany are respectively ranked as the countries which consume and generate energy most in the world according to 2015 data, Turkey ranks as the 19<sup>th</sup> in consumption and 17<sup>th</sup> in generation (Table 1 and 2).

Most commonly used energy resources used for energy generation are coal, oil and natural gas. These reserves are rapidly decreasing in proportion with the increasing energy need. Consumption time projected for 892 billion tons of coal reserve is 114 years, 186,9 trillion m<sup>3</sup> natural gas is 53 years, 250 billion tons of oil is only 51 years.

Majority of the energy is generated by nuclear plants after fossil originated resources globally. According to January 2017 data of International Atom Energy Agency (IAEA), there are 449 nuclear plants active in 31 countries in total. While Germany and many European countries chose to shut down the present nuclear plants and obtain energy from renewable resources, construction of 60 nuclear plants are in progress in 16 countries which wish to increase their energy generation capacities and do not have any nuclear plants including United Arab Emirates which has a sunshine duration more than European countries [3].

Annual electricity energy consumption of Turkey increased 3.3% in 2016 and reached to 278.3 billion kWh. Annual electricity generation increased 4.9% in 2016 and reached to 274,7 billion kWh [4]. 32,1% of electricity generation was obtained from natural gas; 33,9% thereof was obtained from coal, 24,7% thereof was obtained from hydroelectricity, 5,7% thereof was obtained from wind, 1,8% thereof was obtained from geothermal and 1,8% thereof was obtained from other resources [4].

22,3% of the electricity energy presented for consumption was used in dwellings, 1,9% thereof was used in illumination, 1,8% thereof was used in agricultural irrigation, 47,2% thereof was used in industry, 26,2% thereof was used in business organizations and public buildings.

Energy consumption in USA in 2016 is 4,303.0 TWh. 37% of this energy was obtained from oil; 29% of this energy was obtained from natural gas; 15% of this energy was obtained from coal; 9% of this energy was obtained from nuclear plants; 10% of this energy was obtained from renewable energy resources. 6% of renewable energy resources generate electricity from sun [5]. USA uses 39% of the energy it generates to generate electricity energy. 29% of the remaining energy is used in transportation; 22%

thereof is used industry; 6% thereof is used in settlements; and 4% thereof is used in commercial activities.

Energy is one of the basic inputs needed by any sector. Therefore, the most important reason of the increase in energy demand in every field is the effort to maintain or improve the present structure. The efforts to achieve better, more comfortable, more practical and more economical also support this need.

Table 1. Global Primary Energy Consumption

COUNTRY	2014 (TWh)	2015	Share (%)	Line
China	2.970,3	3.014,0	22,9	1
USA	2.300,5	2.280,6	17,3	2
India	666,2	700,5	5,3	3
Russia	689,8	666,8	5,1	4
Japan	453,9	448,5	3,4	5
Canada	335,5	329,9	2,5	6
Germany	311,9	320,6	2,4	7
Brazil	297,6	292,8	2,2	8
S. Korean	273,1	276,9	2,1	9
Iranian	260,8	267,2	2,0	10
S. Arabian	252,4	264,0	2,0	11
France	237,5	239,0	1,8	12
Indonesia	188,3	195,6	1,5	13
U.K.	188,9	191,2	1,5	14
Mexica	190,0	185,0	1,4	15
Italy	146,8	151,7	1,2	16
Spain	132,1	134,4	1,0	17
Australia	129,9	131,4	1,0	18
<b>Turkey</b>	<b>123,9</b>	<b>126,9</b>	<b>1,0</b>	<b>19</b>
Thailand	123,4	124,9	0,9	20
S. Africa	128,0	124,2	0,9	21
Taiwan	111,4	110,7	0,8	22
UAE	99,0	103,9	0,8	23
Poland	92,4	95,0	0,7	24
Ukraine	101,0	85,1	0,6	25
<b>TOTAL</b>	<b>13.020,6</b>	<b>13.147,3</b>	<b>100,0</b>	

## 3. Electricity Generation from Solar Energy

The sun is the resource with the highest potential amongst the renewable energy resources. USA ranks on the 4<sup>th</sup> place in electricity generation from solar energy with 36.75 TWh [7].

Turkey's annual average sunshine duration of has been determined as 2640 hours and daily total sunshine duration as 7.2 hours; average total radiant intensity has been determined as 1.311 kWh/m<sup>2</sup>-year and daily total radiant intensity as 3,6 kWh/m<sup>2</sup>. Photovoltaic panels were started to be used in 2008 to generate electricity from solar energy [4]. Directorate General of Renewable Energy was established in 2011 and research & development activities were accelerated.

Table 2. Global Primary Energy Generation

COUNTRY	Generate (TWh)	Share (%)	Line
China	5.810,6	24,1	1
USA	4.303,0	17,9	2
India	1.304,8	5,4	3
Russia	1.063,4	4,4	4
Japan	1.035,5	4,3	5
Germany	647,1	2,7	6
Canada	633,3	2,6	7
Brazil	579,8	2,4	8
France	568,8	2,4	9
S. Korean	522,3	2,2	10
U.K.	337,7	1,4	11
S. Arabian	328,1	1,4	12
Mexica	306,7	1,3	13
Iranian	281,8	1,2	14
Italy	281,8	1,2	15
Spain	278,8	1,2	16
<b>Turkey</b>	<b>261,8</b>	<b>1,1</b>	<b>17</b>
Taiwan	258,0	1,1	18
Australia	253,6	1,1	19
S. Africa	249,7	1,0	20
Indonesia	234,7	1,0	21
Egypt	180,6	0,7	22
<b>TOTAL</b>	<b>24.097,7</b>	<b>100,0</b>	

While energy from solar energy is generated using photovoltaic panels in Turkey, solar and thermal (solar thermal) systems with greater capacity were developed in USA after use of photovoltaic panels for energy generation. Concentrated solar panels (CSP) or single focal solar panel systems, parabolic systems, energy tower systems are used in large scale entities for electricity generation.

Annual sunshine duration varies according to states in USA. California, Arizona, Nevada and Texas located geographically on the south of USA have large scaled generation plants in electricity generation from solar energy. USA Ministry of Energy established Solar Energy Research Institute in 1977. In 1980, studies directed towards electricity generation using photovoltaic panels started. In 1982, large scale electricity generation plants were started to be established with solar towers, and photovoltaic panel technology, thermal solar and concentrated solar technology (CSP) were started to be used [8].

Today, one million dwellings benefit from energy generated by solar panels in USA; and it is aimed to increase this number to 2 million at the end of 2018 [9].

Turkey is a country located between 36° - 42° northern latitudes and has an area of 783.562 km<sup>2</sup>; and USA is continental country which has 50 states, located between 25° - 48° northern latitudes and has an area of 9.629.091 km<sup>2</sup>. The energy generated from solar energy plants as of the end of 2016 was 832,5 MWh and this amount covers 1.1% of the energy generation on resource basis. 12.700 persons work in this field [6].

Comparative chart of USA states based upon the data obtained from SEIA is presented in Table 3.

Table 3. Turkey-USA Comparative Chart for Renewable Energy

	Turkey	California	Arizona	Nevada	Texas
<b>Area (km<sup>2</sup>-sq mi)</b>	783.56 302.534	423.970 163,696	295.2541 13,990	286.3821 10,577	696.24 1268,5 81
<b>Latitude (N)</b>	36-42	32-42	36-37	35-42	25-36
<b>Generate (MWh)</b>	832,5	19.664,7	3.254,23	2.349,9	1.620,1 9
<b>Gen. Per. (%)</b>	1,1	14,2	5,43	9,06	0,39
<b>Num. of Gener.</b>	520	2639	428	130	565
<b>Num. of Emp.</b>	12.700	100.050	7310	8371	9396

California State, which has an area of 423.970 km<sup>2</sup> (163,696 sq mi.) and is located between 32°-42° northern latitudes, has the greatest plants which generate electricity from solar energy in USA. There are 2.639 individual and corporate electricity generators in total and 14,2% of annual electricity energy need is provided from the sun. The generation capacity for 2016 was 19.664,7 MWh and it is aimed to increase this capacity 14.272 MWh more within the following 5 years. 100.500 persons are employed in this sector in total.

Arizona State, which has an area of 295.254 km<sup>2</sup> (113,990 sq mi) and is located between 36°-37° northern latitudes, is ranked in the second place with an electricity generation of 3,254.23 MW. 5,43% of electricity generation is provided from the sun. There are 428 individual and corporate electricity generators. It is aimed to increase this current capacity 3.240 MWh more within the following 5 years. 7.310 persons are employed in this sector in total.

Nevada State, which has an area of 286.382 km<sup>2</sup> (110,577 sq mi) and is located between 35°-42° northern latitudes, is ranked in the third place with an electricity generation of 2.349,9 MW. 9,06% of electricity generation is provided from the sun. There are 130 individual and corporate electricity generators. It is aimed to increase this current capacity 2.632 MW more within the following 5 years. 8.371 persons are employed in this sector in total.

Texas State has an area of 696.241 km<sup>2</sup> (268,581 sq mi) and is located between 25°-36° northern latitudes. 0,39% of electricity fourth place with an electricity generation of

1.620,19 MW and 565 electricity generators. It is aimed to increase this current capacity 4.673 MW more within the following 5 years. 9.396 persons are employed in this sector in total [9].

Current solar energy plant quantity in Turkey is 1644. 520 of these plants are active. Total installed power there is of 1.362,60 MWh. In 2016, totally 1.020.000 MWh electricity was generated through solar energy plants. 0,46% of the total consumption was obtained from solar energy [4].

Turkey aims to increase photovoltaic solar panel capacity to 5 GWh and wind energy capacity to 20 GWh until 2023 with regards to increase of renewable energy capacity [7].

### 3. Conclusions

Electricity generation from solar energy using planar photovoltaic panels was initiated in USA in 1980 and in 2008 in Turkey. In Table 3, data relating to four states ranking in the first places in USA which generate electricity from solar energy are compared to Turkey.

Electricity generation from solar energy in these states, which is smaller than Turkey in terms of area, is much more than the current generation in Turkey. When plant quantities are taken into consideration, electricity generation in Nevada State which has the least plants with 130 plants in total is three times of the plant quantity in Turkey. The electricity generation in Arizona State, which has 428 plants, is almost four times, in Texas State, which has 565 plants, it is twice and in California State, which has 2639 plants, it is twenty-three times of the electricity generation of Turkey.

When the ratios of contribution in generation Texas State has the least contribution ratio with 0,39%. This ratio is 5,43% for Arizona State, 9,06% for Nevada State, and 14,2% for California State. This significant difference in ratios of contribution in generation arises from network connected or not network connected generation styles of states. The facts that Texas State is an important centre in oil production and that it covers the energy need from this source also affect its ratio of contribution in generation.

The reason why Nevada State has a 9,06% contribution in generation despite of 130 generation plants is the large scaled plants and parabolic solar collectors & heliostats and solar tower technologies used in energy generation.

The greatest solar energy generation plant in USA is 'Ivanpah Solar Electric Generating System' is located on the border of California and Nevada States. The size of California in terms of area, redundancy of plant quantity and high capacities increase the contribution in electricity generation.

Energy generation from renewable resources provides a significant employment opportunity. More than 260.000 persons were employed in solar energy industry in 43 states of USA in 2016. The number of persons employed in this industry in Turkey is 12.700 despite of low generation capacity. This employment number is 9.396 in Texas State, 8.371 in Nevada State, 7.310 in Arizona State and 100.050 in California State. The fact that this number is high in

Turkey shows the numerical existence of small scaled generation plants and that they use a generation system requiring workforce.

When the quantity of generation plants and the workforce employed by such plants in Turkey are taken into consideration, the generation capacities of plants in our country is quite low. Individual generators can only generate energy with limited amounts, and they have to consume the energy they generate. Therefore, the plant quantity which seems to be high in number cannot provide conditions appropriate for storage and distribution.

Turkey should start to utilize developed new technologies in solar energy generation in order to reduce foreign dependency for energy resources and to ensure resource continuity and increase the quantity of generation sites. Continuity of energy can only be achieved thus.

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### Nomenclature

OECD	:	Organisation for Economic Cooperation and Development
kW	:	Kilo Watt
MW	:	Mega Watt
TWh	:	Tera Watt Hour
IRENA	:	International Renewable Energy Agency
SEIA	:	Solar Energy Industries Association
REN	:	Renewable Energy Policies Network
IAEA	:	International Atom Energy Agency

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