

## A Research on Solar Based Renewable Energy Production

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### ABSTRACT

Increasing consumption of fossil energy resources, which has become a general problem of our world, has led to researches on renewable energy sources as an alternative in developed and developing countries. In this article, the integration problems of population, economy, state politics and solar-based renewable energy production that affect the energy production and consumption of developed and developing countries have been addressed. In this study, the total electricity consumption and production in China, India, USA, Germany and Turkey along with the renewable energy and the value of solar energy in electricity production are considered. Among the countries discussed in the study, the share of electricity production of renewable energy can be seen in light of these data that Turkey has the highest values with 32%. Turkey is followed by Germany with 30%, China with 24%, India with 15% and US with 13%.

**Keywords:** Electricity, Solar energy, China, India, United State, Germany, Turkey

### INTRODUCTION

In the physical sense, energy is an abstract concept expressed as the ability to do work. The energy that exists in the structure of the material; is one of the most critical factors that provide economic and social progression. The fact that rapidly consumed fossil energy resources will be exhausted within a century has led the developed and developing countries in the world to seek new methods. Excessive consumption of fossil energy fuels also cause global warming, acid rain and air pollution (Dinçer 2011). Many international studies, such as the "Kyoto Protocol", have been carried out in order to keep the CO<sub>2</sub> emissions generated by human activities below certain levels. In an article published by the International Energy Agency (IEA) in March 2017, the CO<sub>2</sub> level during the three years of 2014, 2015 and 2016 has remained stable at 32 Gt (Anonymous 2017a, b). In China and the US, one of the world's largest economies, carbon emissions have declined and have been on a steady course in Europe. In order to minimize climate and fossil based problems, developed and developing countries have guaranteed increasing the efficiency of renewable energy resources (Hua *et al.* 2016). For this reason, there are different levels of policies for promoting the development of renewable energy in developed and developing countries. While there are at least 144 countries (Hua 2016) that have implemented different renewable energy targets and policies to support renewable energy development in 2013, this number has increased even more today. Renewable energy applications in existing electricity Networks are natural stepson protecting the environment and meeting the energy need for the future (Tran and Smith 2017). 'Solar Energy' (Figure 1) and 'Electricity generation with PV (photovoltaic)' (Figure 2), which are in renewable energy sources, constitute one of the important agenda items of developed and developing countries. Almost all of the primary energy sources used today are solar origin, which is the main energy source of Earth. The sun brightens our world, creates the winds, and forms the climatic conditions suitable for people's life.

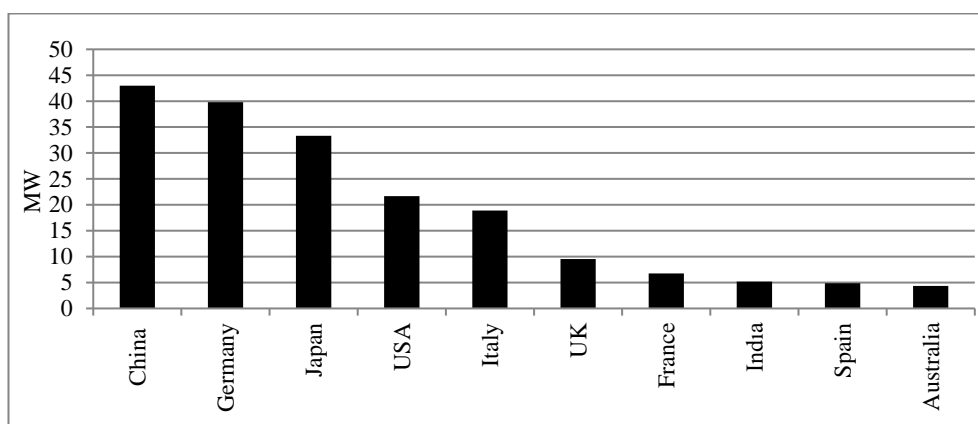
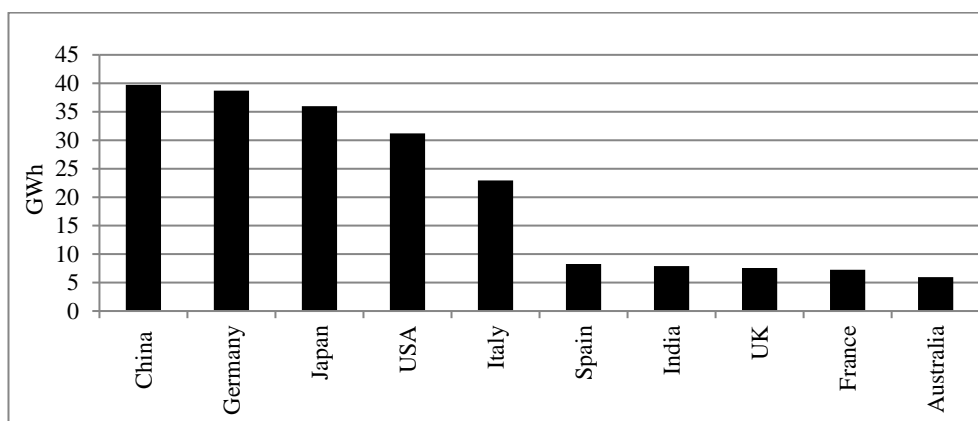


Figure 1. Solar PV Installed Capacity (MW) 2015 - Top 10 Countries (IRENA 2018).

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**Figure 2.** Solar Electricity Generation (GWh) 2015 - Top 10 Countries (IRENA 2018).

Different forms of solar energy can be grouped under three headings. These are;

- Heat from the sun's rays (for various methods of heating the water),
- Solar power (except night and cloudy weather) and
- The power provided by air and water movement caused by the effect of the sun (Bedeloğlu *et al.* 2010). Solar energy, which is an almost infinite energy source that does not have a negative effect on the environment, is utilized in two ways as "Thermal Systems" and "Electrical Systems". In thermal systems, heat is first obtained and then converted to other types of energy. In electrical systems, heat can be converted to electricity or electricity can be generated directly. The electricity in the world, is the fastest growing energy resource that has definite user. It is expected that the share of final energy consumption of electricity will increase from 18,2% in 2012 to 19,9% in 2020 and to 23,8% in 2040 (Anonymous 2015). In 2017, solar energy dominates global investment in new energy production. Since 2016, the renewable energy sector has employed 9,8 million people and the solar energy sector has become the renewable energy sector with the highest employment with 3,1 million people (Anonymous 2017c).

## MATERIALS AND METHODS

In this study, China, India, USA, Germany and Turkey's population distribution, electricity generation, electricity consumption per capacity, the share of renewable energy in electricity generation and PV capacity is used as a material. In terms of the related datas, International Energy Agency (IEA 2018), the National Bureau of Statistics of China (NBScan 2018), Worldometers website (Worldometers 2018), International Renewable Energy Agency (IRENA 2018), Turkey Electricity Transmission Company (TEIAS 2018), Republic of Turkey Ministry of Energy (TEB 2018) and Turkey Statistical Institute (TUIK 2018) were utilized. The results were given under the title of Research Results, comparatively on the basis of countries.

## RESULTS AND DISCUSSION

### China

China is the country of production and development with a population of 1,41 billion (Worldometers 2018), as well as the country with the highest energy consumption and CO<sub>2</sub> emissions (Wang *et al.* 2011). China has enacted national legislation and regulations by creating renewable energy targets at national level (Hua *et al.* 2016). The Chinese government has reported that by 2020, CO<sub>2</sub> emissions will be reduced by 40-45% and emissions have been reduced by about 40% (Anonymous 2013). China is also rich in renewable resources, integrating these resources into the Chinese energy mix, and has recently reduced its CO<sub>2</sub> emissions by 1% (Hua *et al.* 2016; Anonymous 2017a). Thus, it has also been observed that growing economically will not negatively affect CO<sub>2</sub> reduction. China consumes the most electricity in the world (Figure 3). As can be seen from Figure 4, according to 2015 data, 5.840.000 GWh of electricity is consumed in China (IEA 2018). Just as in all the countries of the world, China is expanding its electricity production capacity by investing in solar energy (Figure 5). The Chinese PV industry has grown rapidly since 2004 and has seen an average increase of more than 100% per year. China has been in the first place in the world since 2007 for the production of PV cells. With the direct supports for PV systems incentive and FIT (Feed-in Tariffs) program are also implemented by the government

(Zhang and He 2013). During this period, China's domestic PV market has grown steadily, raising the cumulative board capacity to 43.180 MW by the end of 2015 (Zhang *et al.* 2017). The newly established solar energy capacity reached 15,13 GW in 2015, which is more than a quarter of the world's solar energy capacity (Zhang *et al.* 2017).

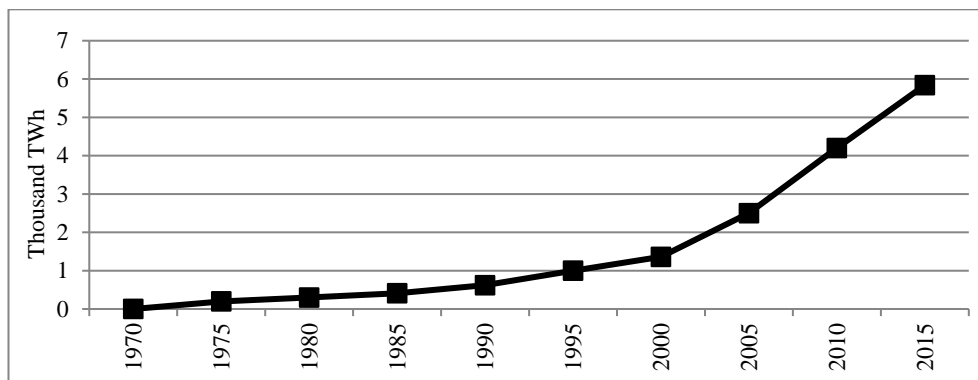


Figure 3. Electricity Generation in China.

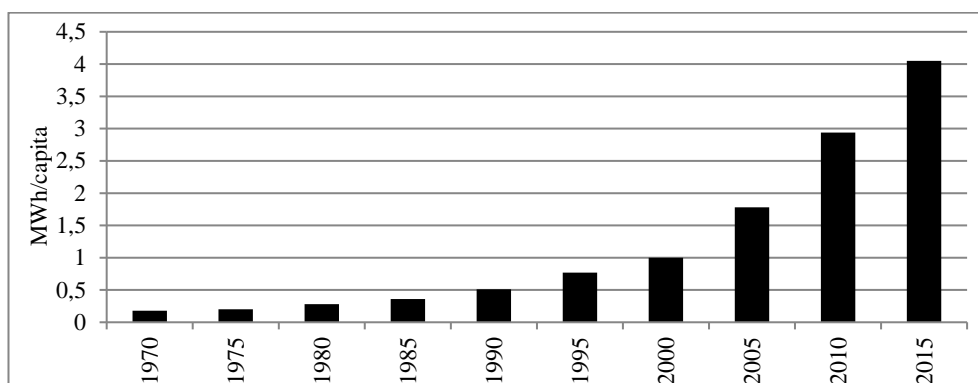


Figure 4. Electricity Consumption per Capita in China.

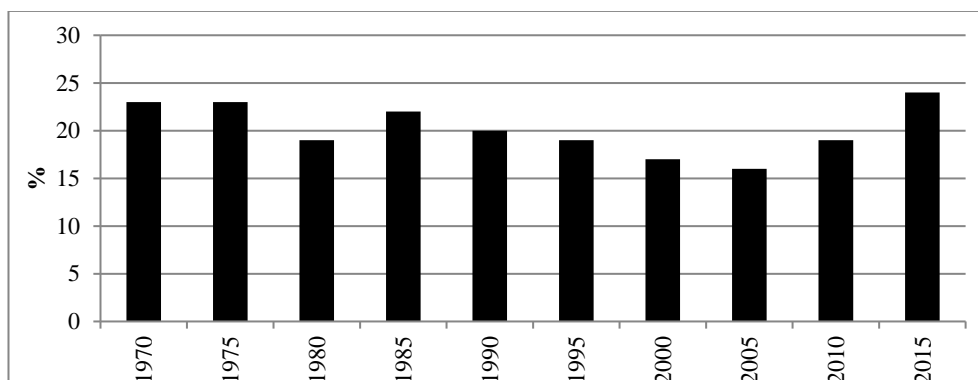
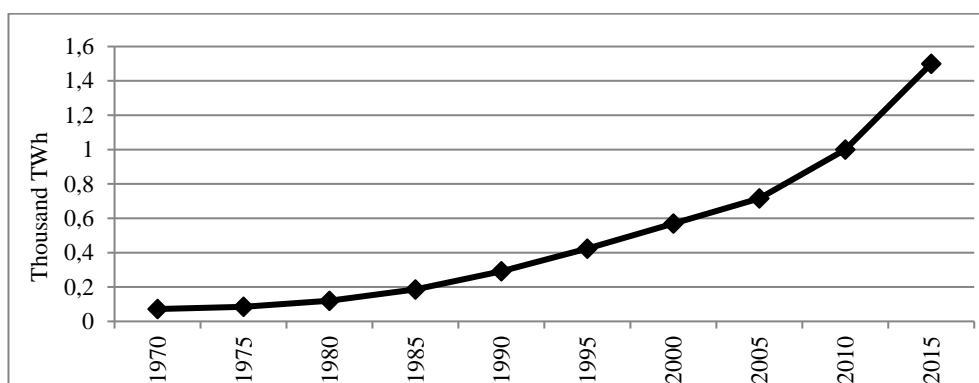


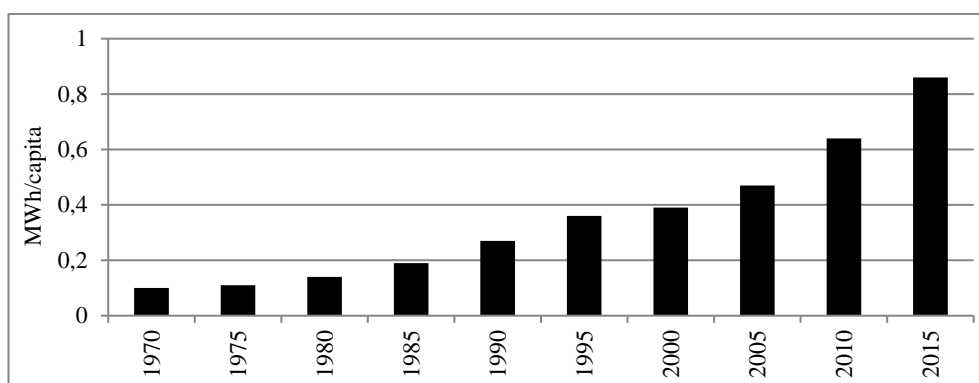
Figure 5. Share of Renewable Energy in China.

## India

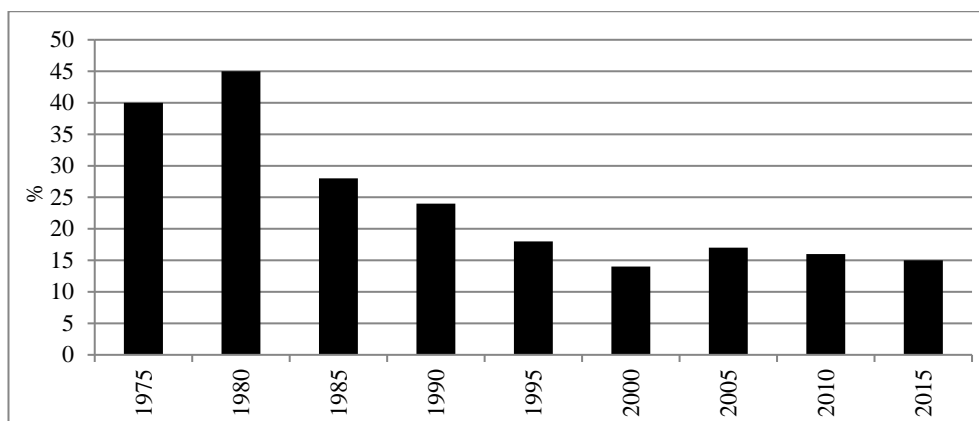
India, like other countries, is seeking solutions to energy problems and is using renewable energy sources and technologies. 79% of the primary energy consumed in the world is fossil fuels and fossil fuel consumption in India accounts for 4% of that amount (Anonymous 2017d). The population of India is about 1,35 billion (Worldometers 2018) and continues to increase rapidly. Increased consumption of fossil fuels in the growing population is causing India to face major energy problems and increase environmental problems (Kumar *et al.* 2010). India ranks 6th among the world's largest economies with its fastest growing economy (Anonymous 2017d). This means that India must pass renewable energy for the energy future (Kumar *et al.* 2010). This can be clearly seen when Figure 6, Figure 7 and Figure 8 are examined.



**Figure 6.** Electricity Generation in India.



**Figure 7.** Electricity Consumption per Capita in India.



**Figure 8.** Share of Renewables in Electricity Production in India.

India is among the countries that receive more solar radiation. The average of 300 days of the year is 4-7 kWh/m<sup>2</sup> solar radiation. The third largest market in Asia is the seventh in total capacity (9.1 GW) (Anonymous 2017e). India's west Rajasthan region receives the highest radiation while the North-East region receives the lowest radiation (Kumar *et al.*2010). In the case of cumulative capacity, Tamil Nadu (about 1,6 GW), Gujarat (1,1 GW), Andhra Pradesh (1 GW) followed the Rajasthan region (1,3 GW) (Anonymous 2017e). Although policy support and falling prices have recently led to an increase in the PV market, there has been only an increase of 16% in 2016 (Anonymous 2017e). The share of renewable energy in the national electricity system is expected to be 5% by 2032 (Pillai and Banerjee 2009). Due to financial and logistical problems; India is building a 'green energy corridor' as a solution (Anonymous 2017e).

### United States of America

Solar energy is becoming increasingly important in the United States, where today's population is 327 million (Worldometers 2018). The fastest developing energy sources in the United States are solar and wind energy. Renewable portfolio standards (RPS) constitute the largest portion of developing projects in the United States (Anonymous 2017e). Among renewable energies, biomass energy, hydroelectric energy, wind energy, solar energy and geothermal energy are primary contributors (Tran and Smith 2017). The primary energy output of solar energy increased from 17,6 million MWh in 1990 to 176 million MWh in 2016 (Anonymous 2017e). In Figure 9, Figure 10 and Figure 11, the total electricity generation of the United States, per capita electricity consumption, and the share of renewable energies in electricity generation are given.

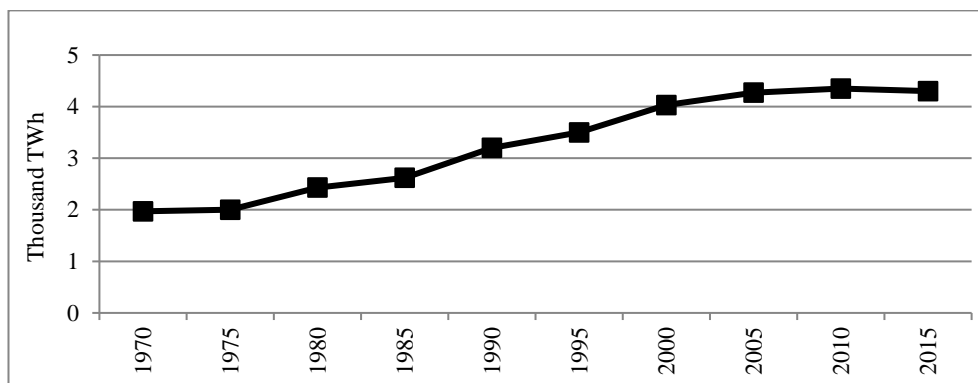


Figure 9. Electricity Generation in United States.

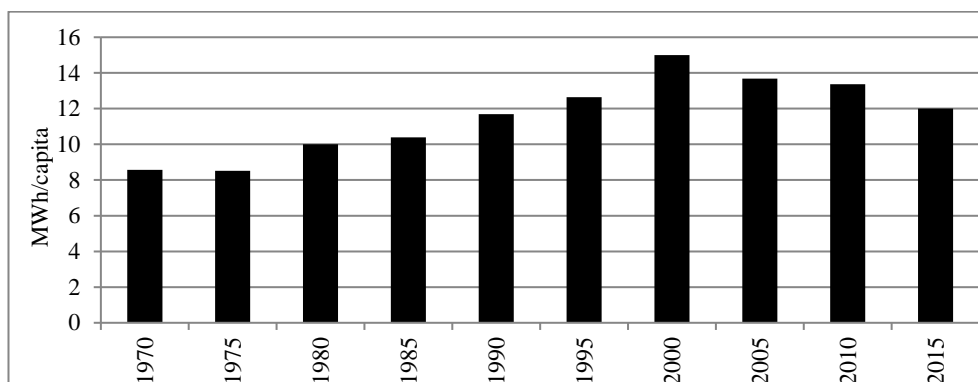


Figure 10. Electricity Consumption per Capita in United States.

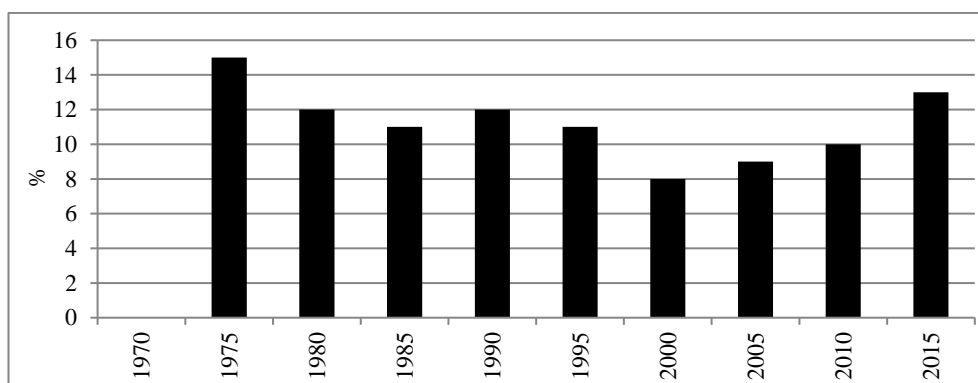


Figure 11. Share of Renewables in Electricity Production in United States.

Just as in the whole world, there are also ways to increase solar cell efficiency in the United States. For example, organic solar cell research is being conducted as an alternative to silicon-based solar cells (Agrawal *et al.*, 2016; Chong *et al.* 2016). There are also many problems in the transition to renewable energy. These

problems can be exemplified as integrating renewable energy sources into the existing system, cost and lifetime of the system.

### Germany

The most important building block of climate and energy strategies in the EU is renewable energy policies. As a result of many studies, the support policies of all EU states have been influential. In the EU, the share of RES (renewable energy sources) in electricity consumption increased from 14,3% in 2004 to 25,4% in 2013 and from 9,3% to 25,4% at the same period in Germany. (Strunz *et al.* 2016). The target of Germany's annual market provides 2,56 GW increase. This number stays at 1,56 GW per year. In 2015, Germany increased its solar energy share by 41% by adding storage areas to new residential systems. Figures 12, 13 and 14 show Germany's total electricity generation, per capita electricity consumption and the share of renewable energy in electricity generation.

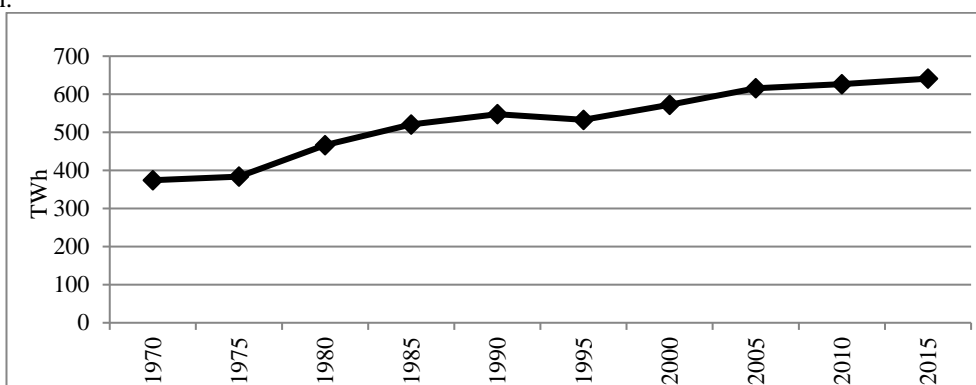


Figure 12. Electricity Generation in Germany

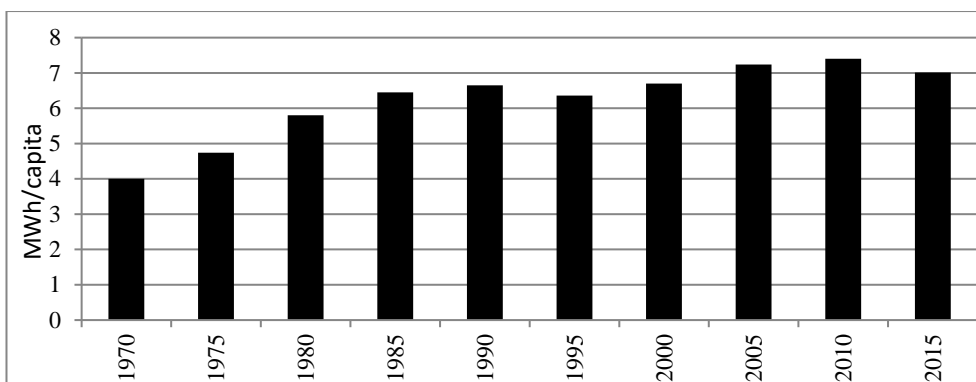


Figure 13. Electricity Consumption Per Capita in Germany.

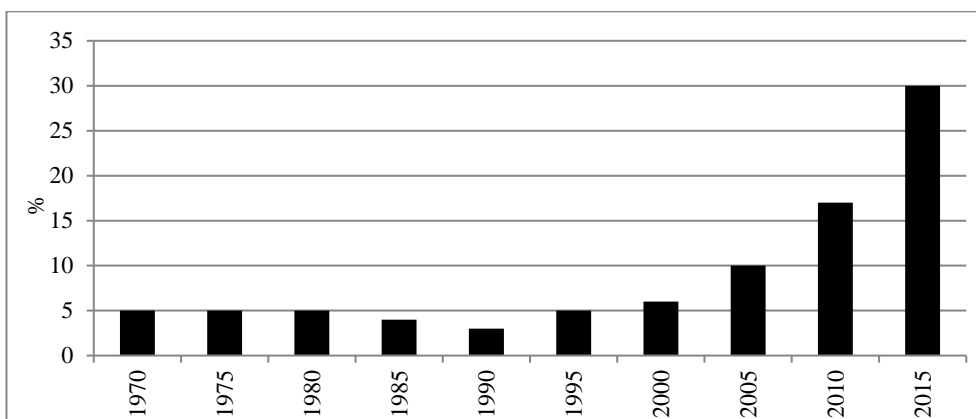


Figure 14. Share of Renewables in Electricity Production in Germany.

Germany accounts for 80% of its market share in Europe in terms of home energy storage system. However, the RES is exposed to criticism and leads to political problems among the States (Strunz *et al.* 2016). In the EU and Germany there are econometric models. In Germany there are studies based on the econometric model (Sectoral Energy-Economic Econometric Model) (Blazejczak *et al.* 2011). This study reveals the economic and employment effects of the expansion of the RES in Germany (Lehr *et al.* 2012). Such negative factors are also taken into consideration. Long-term efforts by the Organization for Economic Development (OECD) to accelerate economic recovery have become an additional reason for climate change strategies such as the 2009 Green Growth Strategy (Anonymous 2009). When compared to other energy production technologies, more pre-investment is made for renewable energy. Economic benefit and cost balance, ie the net impact of the renewable energy allocation is still controversial. (Blazejczaka *et al.* 2011). From a public point of view, the term of "Energiewende" reflects a mix of ideology (Strunz *et al.* 2016). In addition, renewable energy transfer is supported in the EU. Farmers (except Germany) want to be beneficial to the environment, not to be exposed to future rising energy prices, and to have long-term stable income sources (Anonymous 2011). Especially in rural areas, heat and electricity from solar energy can reduce the costs of farm work and provide development (Anonymous 2011).

## Turkey

According to TEİAŞ datas, Turkey has a total of 73.427 MW installed electric power and the share of solar energy (unlicensed) is 288,99 MW. The installed power in 2017 is 78.529 MW and the share of solar power (unlicensed) is 847,73MW. Approximately 190% increase in electricity production per year was observed. In Figure 15 are given change in Turkey's total electricity production.

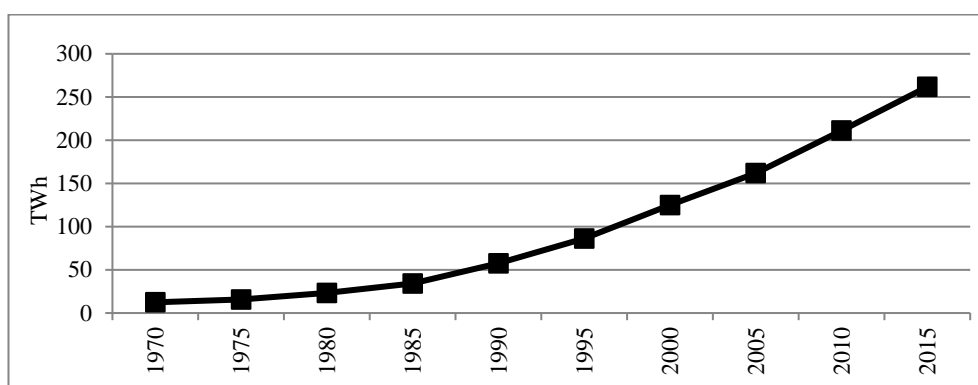


Figure 15. Electricity Generation in Turkey.

Turkey is a country rich in renewable energy resources but poor in terms of fossil energy sources. Especially hydroelectric, wind and geothermal energy are in the first place. With the increase in the share of total electricity consumption (Figure 16), the importance of solar energy has also accelerated.

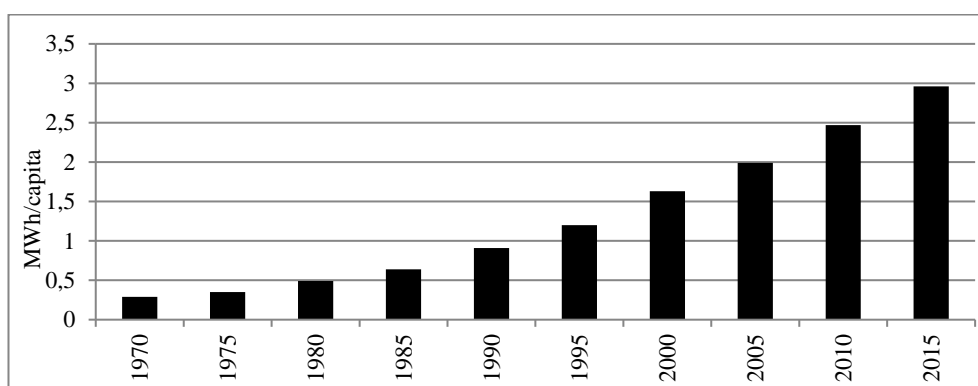


Figure 16. Electricity Consumption per Capita in Turkey.

The main objective of energy policies is to meet the energy needs of the population and the economy, which are increasing at a minimum cost (Çapıka *et al.* 2012). Turkey is continuing its dependence on energy

imports. Recently, it aims to improve the existing sources of renewable energy, to prevent import dependency and to support investment of private or public institutions. Turkey has a strategic importance due to its geographic location. Turkey is located where Asian, European and African continents are closing to each other. It has territories both in Asia and Europe. That is why the passage of energy transmission lines is the issue. Turkey would be an energy corridor can be expressed in the course of 2023. On the one hand, 'Trans-Adriatic Natural Gas Pipeline Project (TAP)' and on the other side 'Trans Anatolian Natural Gas Pipeline Project (TANAP)' continues their existence (Anonymous 2017c). The first filling stations of LNG were produced in Turkey within the scope of Blue Corridor, which is the clean fuel project of Europe. (Anonymous 2017c). Due to geographical location, Turkey is rich in solar energy GEPA (Solar Energy Potential Atlas), according to the annual sunshine time of 2.737 hours, annual total incoming solar energy is 1.527 kWh/m<sup>2</sup>.year that have been identified. In Figure 17 the share of renewable energy on electricity generation in Turkey is given.

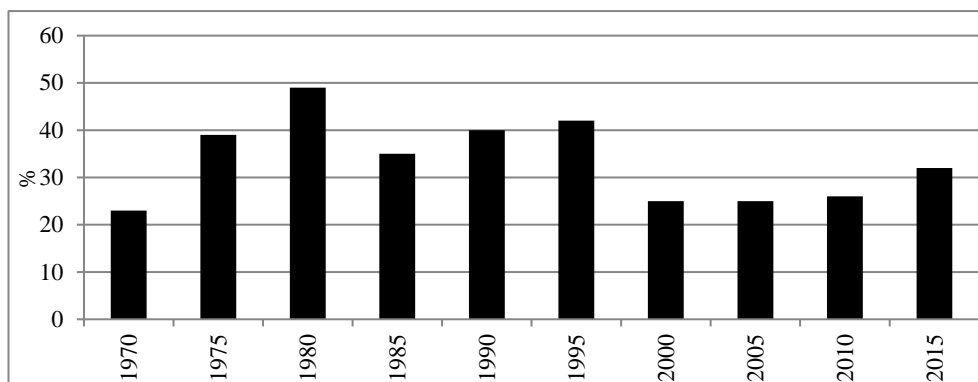


Figure 17. Share of Renewables in Electricity Production in Turkey.

Turkey's population is 82 million as of the end of 2017 (Worldometers 2018) and the total amount of electricity produced in 2016 was 274.408 GWh. The electricity consumed in the same year is 231.204 GWh. The Turkish government aims to increase the share of renewable resources in electricity generation by at least 30% by 2023. In addition, technically and economically the entire hydroelectric potential of the country will be used with until 2023 (Tükenmez and Demireli 2012). In Figure 18, the share of renewable energy on electricity generation are given in comparisons for USA, India, Germany, China and Turkey. As can be understood from the picture, the country that has the highest share of renewable energy on electricity consumption is Turkey with 32%. Turkey is followed by Germany with 30%, China with 24%, India with 15% and US with 13%. In 1980, Turkey has reached a considerably high as 49%. On the basis of these high rates, Turkey's extreme hydroelectric potential is located.

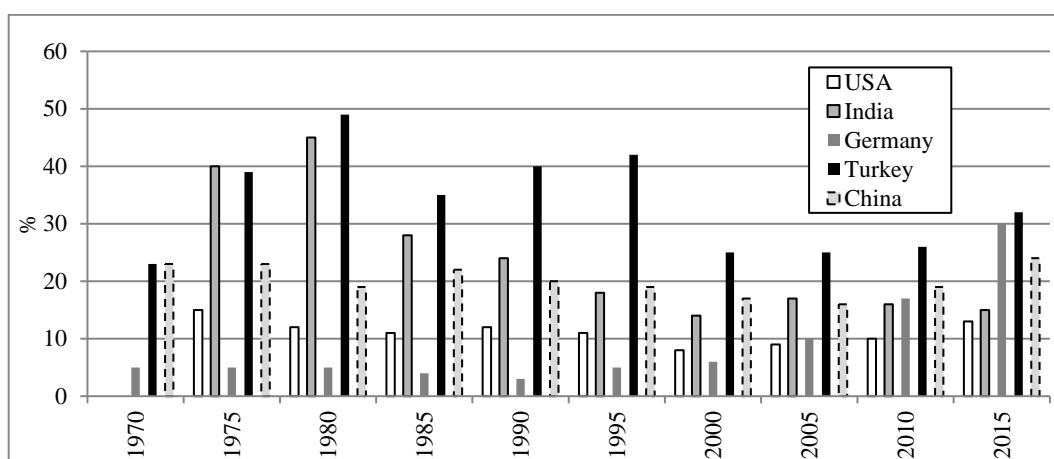


Figure 18. Share of Renewable in Electricity Production.

## CONCLUSIONS

The main agenda of developed and developing countries is how to use alternative energy sources and integrate the fossil energy resources into existing systems to reduce CO<sub>2</sub> emissions, to prevent environmental and air



pollution, to solve the larger problems of global warming. The increasing population is the basis of these problems. The growing economy of the countries seems to ease the transition to renewable energy. Common problems of states are how to integrate new systems, the need of awareness regarding to the problem for the public, correct policies to follow, high product costs, lack of coordination between states and insufficient market. Suggested solutions are to replicate solutions such as monitoring correct policies in interstate agreements, making and supporting research that will reduce costs on renewable energy products, increasing market share, providing appropriate funds for private sector investors and making necessary regulations, and increasing R&D work. In the long run, solar energy will show rapid growth with national policy supports, technological breakthroughs and lower costs. Positive employment effects strongly depended on the growth of global markets and exports. The Chinese government needs to solve the problem of R&D and innovation. The Indian government should give importance to the production and development of renewable energy products in the national electricity system. When we examine the relevance of these five countries to renewable energy sources, we can easily see the importance of renewable energy sources. The ratio of renewable energy to total energy has increased considerably thanks to the incentives given by governments. As can be seen from the statistical data, the share of renewable energy is steadily increasing and seems to continue to increase.

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