Renewable and Sustainable Energy Reviews 15 (2011) 3768–3779

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Overview of the photovoltaic technology status and perspective in Turkey

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ARTICLE INFO

Article history:
Received 17 December 2010
Accepted 24 June 2011
Available online 6 August 2011

Keywords:
Solar energy
Photovoltaic systems
Turkey

ABSTRACT

The Republic of Turkey, located in Southeastern Europe and Southwestern Asia (that portion of Turkey west of the Bosporus is geographically part of Europe). Nowadays, Turkey with its young population and growing energy demand per person, its fast growing urbanization, and its economic development, has been one of the fast growing electrical energy markets of the world for the last two decades. Unfortunately, Turkey's energy is largely dependent on foreign countries and the country's energy is imported spending billions of dollars each year.

On the other hand, the effects on global and environmental air quality of pollutants released into the atmosphere from fossil fuels in electric power plants provide strong arguments for the development of renewable energy resources. Solar energy is one of the best available among renewable energy sources. There are possess many advantages of solar energy such as relativity, viability, silent, non-polluting, little maintenance, suitable for remote site application, not require any fuel and independent from electricity network.

Turkey has advanced a great deal in the generation of electricity from solar energy because of much higher solar energy potential than lots of developed countries on solar energy applications. This study is taken into account that overview of the photovoltaic technology status and perspective in Turkey and the contains of photovoltaic power systems utilization and potential status in the world, energy consumption and demand in Turkey, geographic description of the solar energy in Turkey, PV industry current and potential status in Turkey, solar energy legislation framework in Turkey, R&D status of photovoltaic industry in Turkey, future strategy of PV industry in Turkey, current and future status photovoltaic power systems economics in the world. Also, this paper on the basis of this subjects is analyzed the SWOT of Turkey's photovoltaic industry, its advantages, weaknesses, opportunities and threats.

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1364-0321/$ – see front matter
doi:10.1016/j.rser.2011.06.005

1. Introduction

Energy is a critical foundation for economic growth and social progress [1]. Desalination is an energy-intensive process, and the growing demand for desalination by the ever-increasing demographic and industrial growth requirements entails significant parallel needs for energy consumption [2]. Nowadays it is an indisputable fact that people are obliged to cover their continuously increasing energy needs with new, inexhaustible, and environmentally friendly electric power sources [3].

The World Energy Forum has predicted that fossil-based oil, coal and gas reserves will be exhausted in less than another 10 decades. Fossil fuels account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are diminishing rapidly. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternate sources. Renewable energy is energy derived from resources that are regenerative, and do not deplete over time [4]. Concern about the development of applications of, and the teaching about, renewable energies have increased markedly in recent years [5]. Increasing emphasis in modern-day society is placed on the use of renewable energy resources and improvements to the performance of the electricity generation system [6]. Renewable energy is a sustainable and clean source of energy derived from nature. The usage and development of renewable energy is flourishing because of shortages in fossil energy, impacts on the environment and energy sustainable usage [7].

Alternative energy plays an elementary function in resolving environmental pollution and warming problems [8]. The environmental issue has been rising in the worldwide scale such as global warming by exhausting carbon dioxide [9]. The production of dangerous greenhouse gas emissions and consumption of world energy resources become a serious problem [10]. The problems with energy supply and use are related not only to global warming but also to such environmental concerns as air pollution, acid precipitation, ozone depletion, forest destruction, and radioactive substance emissions [11]. Human activities are mainly blamed for the substantial discharge of CO_2. Global discharge of CO_2 related to human activities topped 2.6 billion tons in 2002 and is expected to reach 4.2 billion tons per year in 2030 [12]. To prevent these effects, some potential solutions have evolved including energy conservation through improved energy efficiency, a reduction in fossil fuel use and an increase in environmentally friendly energy supplies [11]. Also, this gives rise in renewed interest in renewable energy sources, alternative and abundant non conventional sources of energy such as photovoltaic, wind and fuel cells. These renewable energy sources particularly photovoltaic are proven to be both clean and economical due to new advanced technological and efficient cells [13].

Solar energy is obviously environmentally advantageous relative to any other energy source, and the linchpin of any serious sustainable development program. It does not deplete natural resources, does not cause CO_2 or other gaseous emission into air or generates liquid or solid waste products. Concerning sustainable development, the main direct or indirectly derived advantages of solar energy are the following; no emissions of greenhouse (mainly CO_2, NO_x) or toxic gases (SO_2, particulates), reclamation of degraded land, reduction of transmission lines from electricity grids, increase of regional/national energy independence, diversification and security of energy supply, acceleration of rural electrification in developing countries [14].

Today, we find ourselves in the midst of an energy debate centered around the international negotiations on emission targets and the price of crude oil. Global energy production is dominated by the use of fossil fuel such as coal, oil and natural gas [15]. Among them, the photovoltaic (PV) generation system has received great attention in research because it appears to be one of the possible solutions to the environmental problem [11]. The solar photovoltaic (PV) process uses cells to convert the sun's energy directly into electricity [16]. Solar radiation can be converted into useful energy directly, using various technologies. It can be absorbed in solar collectors to heat water and can also be converted directly into electrical energy using photovoltaic solar cells [17]. Unlike conventional generation systems, fuel of the solar photovoltaic energy is available at no cost and the interest in solar photovoltaic energy is growing worldwide [18].

In recent years, environmental problems have attracted worldwide attention and solar power generation system has been gaining unprecedented attention as a method to solve the energy problem [19]. Solar energy has been one of the dominant renewable energy resources. The rapid growth of the solar industry over the past several years has expanded the importance of PV system design and application for more reliable and efficient operation, especially with the utility power grid [20]. Solar energy not only can improve security of energy supply, but also can immediately relieve the peak load of electricity [21]. Conversion of solar energy into electricity is a key aspect for the sustainable development [22].

Moreover, solar energy is a vital that can make environment friendly energy more flexible, cost effective and commercially widespread. Photovoltaic source are widely used today in many applications such as battery charging, water heating system, satellite power system, and others [23]. Recently, researchers have strongly promoted the use of solar energy as a viable source of energy. Solar energy possesses characteristics that make it highly attractive as a primary energy source that can be integrated into local and regional power supplies since it represents a sustainable environmentally friendly source of energy that can reduce the occupants' energy bills [24].

2. Photovoltaic power systems utilization and potential status in the world

The amount of energy sources such as the gas, the water, the coal and the petrol are decreasing day by day since they are used in industry intensively. On the other hand, the need of electrical energy is increasing in parallel with developing technology [25]. The limited fossil energy resource is a critical issue worldwide [26]. The electrical energy production of the world in 2004 was 17,450 TWh and it is estimated that the world will consume 31,657 TWh in 2030. In order to supply the required electricity demand, thousands of new power plants had to be built [27].

Renewable energy can play an important role in meeting the ultimate goal of replacing large parts of fossil fuels. One of the promising applications of renewable energy technology is the installation of photovoltaic (PV) systems to generate power without emitting pollutants and requiring no fuel [28].

Alternative renewable energy sources such as sun energy can be substituted for exceeding human energy needs. Covering 0.16% of the land on earth with 10% efficient solar conversion systems would provide 20 TW of power, nearly twice the world's consumption rate of fossil energy [29]. The economic barriers that typically limit the use of PV systems have been in some cases reduced by significant regulatory or governmental incentives towards wider use of PV systems [30]. Solar radiation is available at any location on the surface of the Earth [31]. The energy intensity of the sun to the world, the atmosphere on the kW per square meter is about 1.35. The diameter of the footprint area of the world from the solar power density is 178×10^6 MW. The entire surface of the world's solar energy falling is 1.22×10^{14} TCE (tons coal equivalent) in one year, or as imposing size is 0.814×10^{14} TOE (tons of oil equiva-

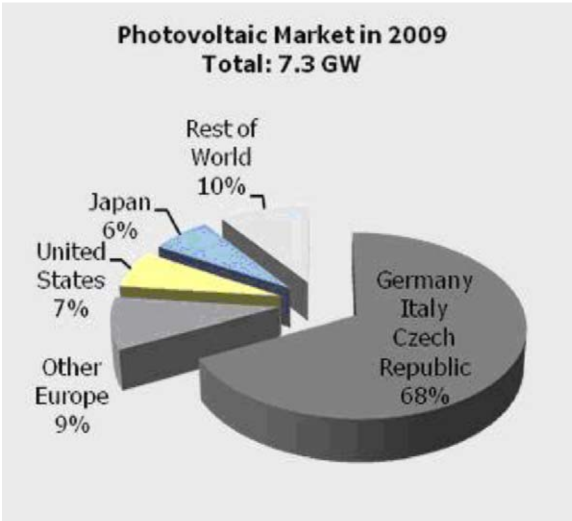

Fig. 1. PV market demand in 2009 [38].

lent). In other words, the amount of incoming solar energy in one year, fifty times the known reserves of coal, 800 times the known oil reserves [32].

The use of new efficient photovoltaic solar cells (PVSCs) has emerged as an important solution in energy conservation and demand-side management during the last decades [33]. In terms of cell production, production volume rose by 85% in 2008 (7.9 GW) compared to the volume of 4.3 GW in 2007 [34]. The International Energy Agency (IEA) estimates that solar power could provide as much as 11% of global electricity production in 2050. However, this is conditional on many countries putting in place incentive schemes to support solar energy in the next 5–10 years so that investment costs come down. The share would be roughly divided equally between photovoltaic and concentrating solar power [35].

As a solution for the depletion of conventional fossil fuel energy sources and serious environmental problems, focus on the photovoltaic (PV) system has been increasing around the world [36]. The photovoltaic (PV) field has given rise to a global industry capable of producing many gigawatts (GW) of additional installed capacity per year [37]. Fig. 1 shows that PV market demand in 2009. World solar photovoltaic (PV) market installations reached a record high of 7.3 gigawatt (GW) in 2009, representing growth of 20% over the previous year. The PV industry generated $38.5 billion in global revenues in 2009, while successfully rising over $13.5 billion in equity and debt, up 8% on the prior year [38]. Demand by European countries, Germany, Italy and Czech Republic being the main markets, accounted for 5.60 GW, constituting 77% of world demand [39].

The countries with most installed photovoltaic power currently are Germany, Japan, Italy and the USA, which are being the biggest photovoltaic module producing countries as well. The 90% of the whole photovoltaic modules produced in the world are produced in the USA, Japan and the European Union (EU) countries. The EU countries have set a target of 3000 MW of installed photovoltaic power by the year 2010. The increase in the production rate of photovoltaic modules has been 15% annually in the last decade. Most of these photovoltaic modules were used in stand-alone applications in places where the grid-connection was non-existent [40].

Some key actions for the development of PV industry; provide long-term targets and supporting policies to build confidence for investments in manufacturing capacity and deployment of PV systems. There is a need to expand international collaboration in PV research, development, capacity building and financing to accelerate learning and avoid duplicating efforts. Implement effective and cost-efficient PV incentive schemes that are transitional and decrease over time so as to foster innovation and technological improvement. Governments and industry must increase R&D efforts to reduce costs and ensure PV readiness for rapid deployment, while also supporting longer-term technology innovations. Increase R&D efforts to reduce costs and ensure PV readiness for rapid deployment, while also supporting longer-term innovations [41]. Having environmental damage of solar energy is much less being compared today's energy generation systems. However, having high solar energy potential many leading countries in the world is not enough encouragement and attention to electrical energy generation from solar energy. The status and future of photovoltaic industry depend on national policy of countries.

3. Current and future status photovoltaic power systems economics in the world

For the optimum design of PV systems for any application, it is important to determine their performance at the site of installation. The amount of power generated by a PV panel depends upon the amount of sunlight it is exposed to. More light means more power [42]. In order to increase the competitiveness of PV energy and to attain a wider market share, the increase of efficiency and reduction of cost are the main targets in PV system technology development. To reach these aims the following efficiency improvement strategies can be employed [43]:

1. Increase cell and module efficiency,
2. Use sun concentrating modules,
3. Use one or two axis tracking array,
4. Minimize losses such as module mismatching and cabling,
5. Reduce PV temperature by cooling.

One of the key benefits of residential solar power systems is a lower electric utility bill resulting from the energy that the solar system produces. The energy savings to a homeowner can be estimated by simply multiplying the annual energy in kWh that a PV system might produce times the utility electric energy rate. These rates vary by local utility, and are likely to increase from their current values. For instance, estimated energy savings from small and large PV systems in Southern California are presented below to illustrate the kinds of savings that can be achieves [44].

Manufacturer's data often provide relatively easy access to parameters such as open circuit voltage, short circuit current, and nominal efficiency under standard test conditions (1000 W/m^2, 25 °C, air mass 1.5) [45]. The power rating of photovoltaic (PV) modules at a 1000 W/m^2 irradiance level under spectral irradiance distribution defined by AM 1.5 and junction temperature of 25 °C is not representative of PV modules operating conditions. These conditions nevertheless are, according to IEC Standard 61215, the so-called standard test conditions (STC), and deliver a reference for PV module peak performance [46]. Table 1 shows that sample annual electric utility bill savings for the appropriate and accurate design of solar energy conversion and utilization devices, a proper knowledge of the long term behavior of measured global solar radiation is necessary [47]. These parameters is used for this illustrate.

In addition to the example, the most successful application of a feed-in-tariff (FIT) program to help accelerate the adoption of PV systems was seen in Germany, where the program helped the country become the world leader in installed PV capacity, despite its less than favorable solar resource. The first jurisdiction to offer a FIT program in North America was Ontario: it offered $0.42/kWh of electricity generated from solar energy for 20 years and had 240 contracts for systems under 10 kW at the beginning of 2009. Ontario recently revised its system after the passing of its Green Energy Act

Table 1
Sample annual electric utility bill savings [44].

Solar array (STC)	Estimated annual energy	Utility electric energy rate			
		$0.10/kWh	$0.15/kWh	$0.20/kWh	$0.25/kWh
1.2 kW	1687 kWh	$168.70	$224.93	$337.40	$421.75
4.0 kW	5624 kWh	$562.40	$843.60	$1,124.80	$1406.00

and has increased the rate it pays homeowners to $0.802/kWh for roof-mounted systems under 10 kW for at least 20 years. In 2009, this rate was higher than any other jurisdictions offering similar programs. The $0.802/kWh tariff was chosen by the Ontario government based on an analysis that found that proponents could generally be expected to recover project costs and earn a reasonable rate of return at that price [48].

In the early days of photovoltaic, some 50 years ago, the energy required to produce a PV panel was more than the energy the panel could produce during its lifetime. During the last decade, however, due to improvements in the efficiency of the panels and manufacturing methods, the payback times were reduced to 3–5 years, depending on the sunshine available at the installation site. Today the cost of photovoltaic is around $2.5 US/W_{peak}$ and the target is to reduce this to about $1 US/W_{peak}$ by 2020 [41].

The photovoltaic (PV) output in kW is all that is required for sizing and it is assumed that output is linearly proportional to incident radiation. Other relevant factors such as PV technology type or area size (m^2) are not required. A standard cost of $10,000/kW of PV power produced was used with an operational and maintenance cost of $10/year/kW [49].

There is a common consensus that PV installations will grow in the coming years. However, some argue that periodical economic crises might cause no rapid increase in fossil fuel prices and conventional electricity price, making PV systems not competitive in the coming decades. International Energy Agency (IEA) agrees a PR of 80% represents a best fit to the available information on the experience curve analysis of solar PV. Experience curves have been derived for different PRs (progress ratio) (i.e. 75%, 80%, 85%, and 90%) during the period of 2006–2060 and are plotted in Fig. 2 [50].

Photovoltaic (PV) systems are now used through the world. With the decrease in the price of PV modules and the increase in the price of traditional petrochemical fuels for generation energy, the employment of PV generator (PVG) becomes more practical, feasible and realizable [51]. PV arrays are still widely considered as an expensive choice compared with existing utility fossil fuel generated electricity [52]. In concert with the drop in PV prices, the PV market has grown rapidly in recent years [53]. In fact, growing of PV for electricity generation is one of the highest in the field of the renewable energies and this tendency is expected to continue in the next years [54].

Even though commercial PV modules are available and being widely deployed, it is essential that more research is carried out to improve their cost-effectiveness and performance and target well known issues to increase their competitiveness. The expected development of PV technology over the coming decades is shown in Table 2 [55].

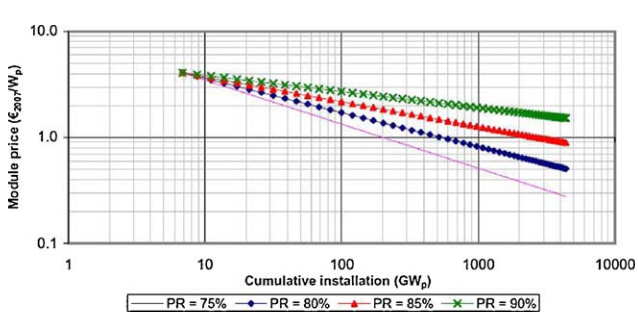

Fig. 2. PV experience curve based on world module price (2006–2060) [50].

Nevertheless, fossil fuel reserves are limited and they have severe environmental concerns. It is estimated that an average of 0.6 kg of CO_2 would be saved per kWh of PV electricity generation and external costs for fossil fuels are considered within a range of 4.3–160 US$ per tonne of CO_2 [50].

The present commercial solar cell converts solar into electricity with a relatively low efficiency, less than 20% [56]. Unfortunately, the widespread diffusion of PV systems is still limited by the large surface, which is needed for a significant energy generation, and by the high cost of the silicon raw material [57]. Solar Photovoltaic technology is considered to be ideally suited to illuminate and pump water at remote locations and dispersed settlements, where extension of the utility grid or making other alternatives available could be technically infeasible or economically unviable [58].

The energy payback time (EPBT) of a photovoltaic (PV) system lies between 10 and 15 years depending on insulation and the efficiency of the PV module. If the efficiency can be increased then the energy payback time can be reduced. In order to increase the efficiency of the PV module, the temperature of the PV module should be decreased [59]. The output power of PV arrays is always changing with weather conditions, i.e., solar irradiation and atmospheric temperature [60]. It is well-known that most of the solar radiation absorbed by a photovoltaic (PV) panel is not converted to electricity but contributes to increase the temperature of the module, thus reducing the electrical efficiency [61]. Different techniques have been used to improve the performance of photovoltaic (PV) modules and reduce the initial cost of the PV-driven systems. Some of these techniques are based on increasing the incoming radiation on the PV cells surface to reduce the PV panel area, which can be achieved by using solar concentrators, lenses, and/or using solar tracking. Using these techniques may reduce the PV system cost by 19% (for tracking technique) and 48% (for concentrating technique) [62].

4. Energy consumption and demand in Turkey

With a young and growing population, low per capita electricity consumption, rapid urbanization, and strong economic growth, Turkey is one of the fastest growing power markets in the world, for nearly two decades [63]. Electricity demand has shown a significant increase over the past decades and reached to 160 TWh in 2005, highlighting an almost three-fold increase over the past fifteen years. Total installed capacity reached to 39,000 MW by the end of 2005. Demand projections for the period until 2020 indicate that annual average increase in demand will be 7.7% and 6% in high and low demand scenarios respectively. According to the low scenario, 40,000 MW of new capacity will be required until 2020. The high scenario necessitates the addition of around 56,000 MW of new capacity over the same period. The investment requirement for the power sector is estimated at more than a hundred billion US dollars until 2020 [64].

Turkey uses mainly fossil fuels to produce electricity [65]. Turkey's primary energy resources, oil, lignite, coal, natural gas, geothermal and hydroelectric energy seems to be. Turkey's own

Table 2
Expected development of PV technology over the coming decades [55].

Description	2020	2030	Long term potential
Typical turn-key system price (s/W excl VAT)	2.5/2.0	1	0.5
Typical electricity generation costs southern Europe (s/kWh)	0.15/0.12	0.06	0.03
Typical commercial flat-plate module efficiencies	Up to 20%	Up to 25%	Up to 40%
Typical commercial concentrator module efficiencies	Up to 30%	Up to 40%	Up to 60%

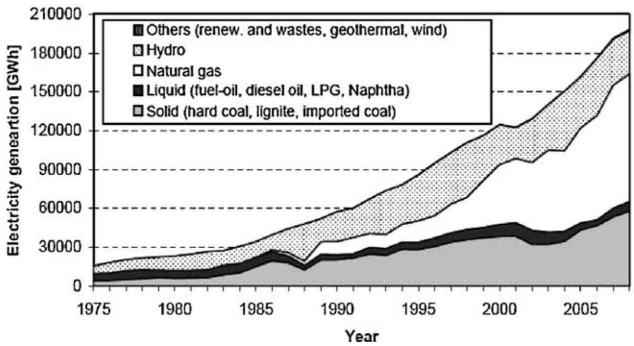

Fig. 3. Development of Turkey's electricity generation by the primary energy resources between 1975 and 2008 [67].

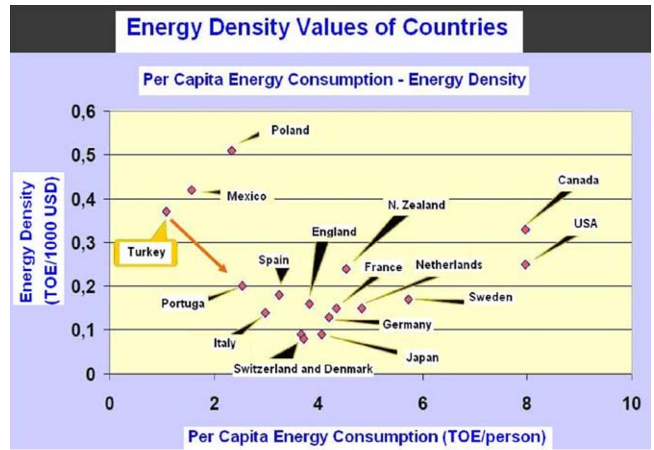

Fig. 5. Energy density values of countries [68].

energy generation can provide 48% of all the energy needs [32]. Long term planning studies indicate a heavy burden of investments between 1996 and 2010, amounting to some 68 billion US$. Turkey's funding needs for the energy sector is the highest of the southern and eastern Mediterranean countries [66]. Fig. 3 shows that the development of Turkey's electricity generation by the primary energy resources between 1975 and 2008. As seen from the Fig. 3 that the natural gas consumption became the fastest growing primary energy source in the country. In electricity generation, the share of the natural gas was 49.74% (98,685 GWh) in 2008. The solid-fired resources accounted for 29.09% (57,716 GWh), hydro for 16.77% (33,270 GWh), liquid for 3.79% (7519 GWh), and others such as Renewable energy and wastes sources for 0.62% (1229 GWh) [67].

As of 2008, total electricity installed capacity is 41,802.6 MW in Turkey. 33% of total installed capacity corresponds to hydroelectricity, 32% to natural gas, 24% to coal, and the remaining 11% to other resources. The installed capacities by resource type are presented Fig. 4 [39]:

Energy consumption rate is far below the world average and the rate of consumption of developed countries as seen Fig. 5, Turkey being a developing country cannot be explained simply this situation. This uncontrolled growth depends on many variables that are energy resources be used inefficiently, the false to select the emerging sectors, transport, such placement policies. Also energy density value is indicated that consuming energy is not efficiently. Lots of studies carried out for using more energy efficiently but this is not enough. If studies are provided to increase, it is aimed that Turkey will show development towards indicated direct.

The energy density of Turkey is over the average of OECD and shows an increasing trend in energy density up to day. At present, Consuming of energy Per Capita is approximately 1 percent 5 of the OECD average. One of the importance things of this case is although the high rates of new investments to technology choice is not struggled to search new technology for energy savings. The industries which were unproductive and caused the environmental problems left from developed countries such as cement industry, iron-steal industries, moved and assembled to Turkey. So the energy density has increased in Turkey. Energy should be transferred to European Markets to meet Turkey's energy density and necessity of geographical area. Energy transporting projects must be applied in Turkey because Turkey is an important crossing center. These projects bring some economical alternative costs to Turkish Economy [69]. Energy using is an important indicator of the value of energy density and Turkey's energy density value is 0.39 [68]. Fig. 6 shows that growth rate of energy consumption.

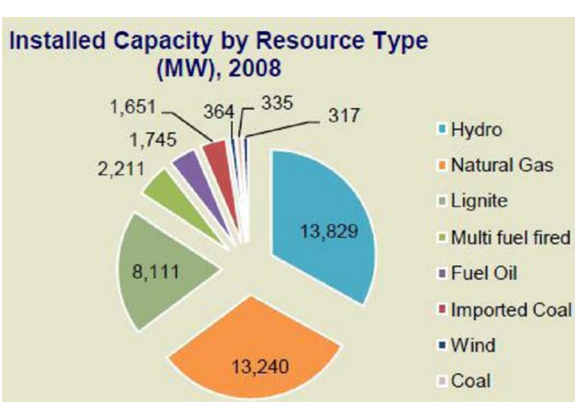

Fig. 4. Installed capacity by resource type (MW), 2008 in Turkey [39].

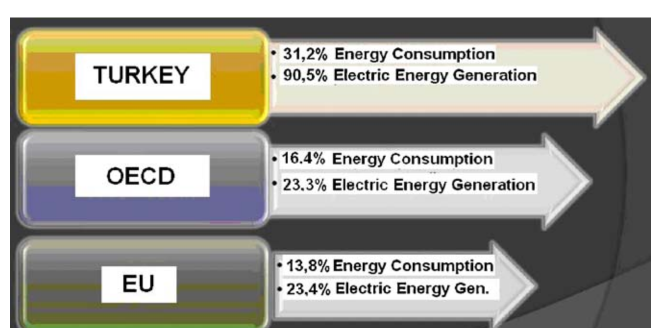

Fig. 6. Growth rate of energy consumption [68].

Long-term Electricity Capacity Forecast in Turkey

Plant Type	Installed Capacity (MW) 2010	2015	2020
Thermal	30,583	45,603	62,273
Renew able	18,234	25,670	34,076
Total capacity	**48,817**	**71,273**	**96,349**

Fig. 7. Long-term electricity forecast in Turkey [39].

2280 kWh of annual electricity consumption is per capita world average, while the OECD average is 7841 kWh; this value is 2511 kWh for Turkey [70]. Turkey of struggling to enter the EU has the chance to compete in all respects to be efficient and equipped with a solid distribution network and transmission of electricity and at the same time should requirement to need economic generating of electrical energy.

According to Electricity Transmission Company in Turkey (TEIAS) forecasts, Fig. 7 shows that total installed capacity is expected to grow from 48,817 MW to 71,273 MW between 2010 and 2015 with a Compound Annual Growth Rate (CAGR) of 6.5%. Renewable energy is expected to form 37% of the total installed capacity and to remain stable in future years whereas currently renewable energy corresponds to 34% of the total [39].

4.1. Geographic description of the solar energy in Turkey

The Republic of Turkey, located in Southeastern Europe and Southwestern Asia (that portion of Turkey west of the Bosporus is geographically part of Europe), has an area of about 780,580 km^2 and a population of over 70 million [71].

As it lies in a sunny belt between 36 °C and 42°N latitudes, Turkey has an abundant resource in solar energy [72]. An important part of Turkey is suitable for utilization of solar energy. The solar energy potential of Turkey is the equivalent of 1.3 billion tonne of oil [31]. Table gives the annual mean total solar radiation and annual sunshine hours over various regions. The yearly average total solar radiation varies from a low of 1.120 kWh/m^2 year in the Black Sea Region with 1971 h of sunshine a year to a high of 1.460 kWh/m^2 year in South East Anatolia with 2993 h of sunshine a year [72]. Table 3 shows that Southeastern Anatolia Region in Turkey can be carried out the solar energy applications are foreseen as the most suitable region. However it has been recognized that the existing meteorological data is lower than the actual solar energy data of Turkey. General Directorate of Electrical Power Resources Survey and Development Administration in Turkey (EIE) and General Directorate of State Meteorology Survey and Development in Turkey (DMI) have been taking new measurements since 1992 to determine the more accurate solar energy data. Although the measurements have not been completed yet, the collected data indicates that the actual solar energy radiation values are 20–25% higher than the existing data [73].

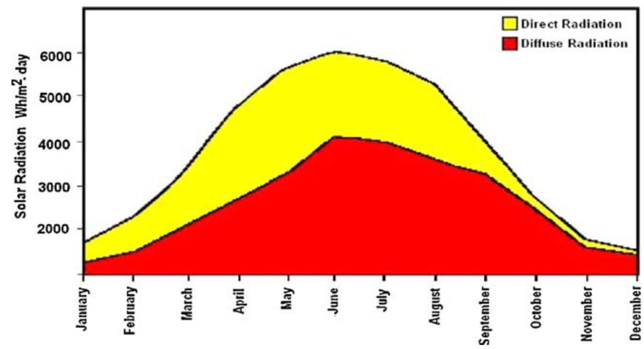

Fig. 8. Total radiation falling to the ground in Turkey [78].

The solar radiation reaching the surface of atmosphere of earth is known as extra terrestrial radiation. In which some part of radiation directly enters the earth atmosphere and some part enters the earth atmosphere by reflecting from clouds, gases, aerosols, etc. There are two types of radiation. These are direct radiation and diffused radiation. The radiation which directly enters the earth atmosphere is known as "Direct radiation" The radiation which enters the earth atmosphere by reflecting from clouds, gases, aerosols is known as diffused radiation. In meteorology the sum of both direct radiation and diffused radiation is called total radiation.

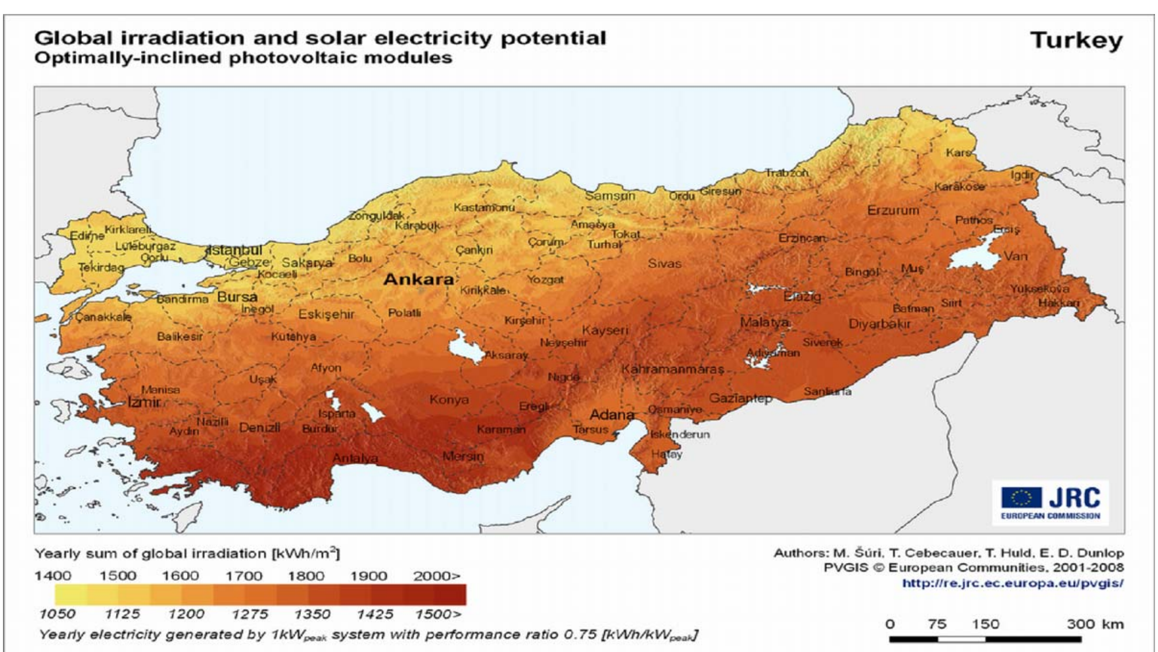

Fig. 9. Global irradiation and solar electricity potential for Turkey [79].

Table 3
Regional distribution sunshine duration and solar energy potential in Turkey [74].

Regions	Sun intensity			Sunshine duration		
	Annual Average (kWh/m^2-year)	Max. (kWh/m^2-year)	Min. (kWh/m^2-year)	Annual Average (h/year)	Max. (h/month)	Min. (h/month)
Southeast Anatolia	1491.2	188.1	49.6	3016	407	126
Mediterranean	1452.7	176.6	48.9	2923	360	101
Aegean	1432.6	176.6	42.2	2712	381	98
Central Anatolia	1406.6	168.7	40.9	2726	371	96
East Anatolia	1398.4	182.8	48.6	2693	373	165
Marmara	1144.2	166.9	33.4	2528	351	87
Black Sea	1086.3	141.7	34	1966	273	82

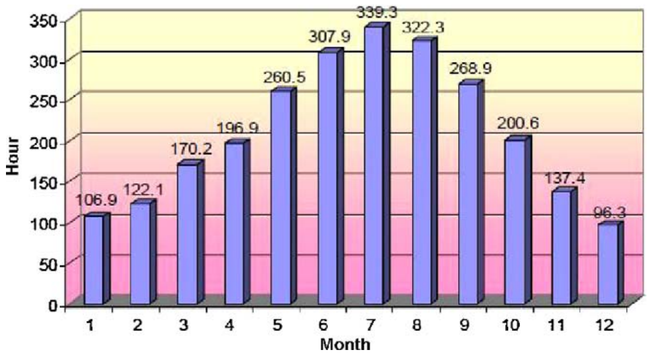

Fig. 10. Monthly sunshine hour in Turkey [81].

According to studies of the EIE in which Turkey's average annual total sunshine duration is 2640 h (a total of 7.2 h per day), the average total solar radiation as 1311 kWh/m^2-year (daily total of 3.6 kWh/m^2) was also found that [75]. This potential is composed of corresponding to around 30% of the year [76]. Solar energy potential is calculated as 380 billion kWh/year [77]. Turkey is taken as a whole in the time between April and September with both direct radiation, diffuse radiation and that the above average values in Fig. 8 is seen total radiation falling to the ground in Turkey [78].

The same colour legend represents also potential solar electricity (kWh/kWp) generated by a 1 kWp system per year with photovoltaic modules mounted at an optimum inclination and assuming system performance ratio 0.75 [79]. Fig. 9 shows that global irradiation and solar electricity potential for Turkey.

Turkey's monthly average sunshine duration and radiation values are higher than benefiting from solar energy many leading countries in the world. Turkey's sunshine duration is more than 3 times compared to European countries [80]. Figs. 10 and 11 respectively show that data of monthly sunshine hour and data of monthly radiation in Turkey.

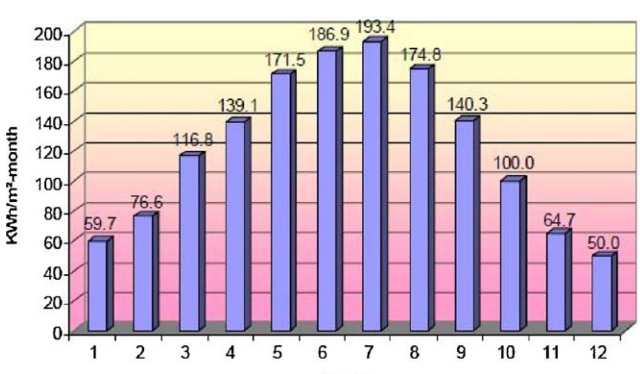

Fig. 11. Monthly radiation in Turkey [81].

4.2. PV industry current and potential status in Turkey

Solar energy could provide significant amount of power for Turkey, given the country's suitability in terms of solar radiation. Currently, solar power is used mainly for domestic hot water production. Turkey's gross solar potential is calculated as 88 MTOE (million tonne oil equivalent) per year, of which 40% can be used economically. Three-fourths of the economically usable potential is efficient for thermal use and the remainder for electricity production [82].

According to data from the Energy Ministry of Turkey; about 18% of electric energy needs of Turkey is met from renewable energy sources. The use of renewable energy sources, hydroelectric power generation plants have an important share of 95% with a rate. The remaining 5% of generation in the wind, geothermal, solar energy sources are used [83].

The potential of Turkey as a PV market is very large, since the country is very suitable in terms of insolation and large available land for solar farms. There are more than 30,000 small residential areas where solar powered electricity would likely be more economical than grid supply. Another potential for the PV market is holiday villages at the long coastal areas. These facilities are frequently far from the main grid nodes and require additional power when solar insolation is high. Unfortunately, Energy demand in Turkey is so large that utilities are concentrating on large conventional power plants and peak load facilities [84].

According to The World Solar Energy Potential Map, Turkey has fourth region in terms of solar energy potential in the sixth region. Turkey, Spain, Italy and Greece are with the same generation among the European countries. Germany has the fifth region. However, Germany and Spain all over the world performed more than half of investments in solar power generation technologies [83]. Despite an enormous potential for solar energy in Turkey, solar energy using in electricity generation is almost negligible. Unfortunately, solar panels only use a variety of experimental and basic applications. Solar energy can technically and economically be harnessed during 10 months over 63% of the land area, whereas 17% of the land area can be used during the entire year. In spite of this significant potential and the proper conditions for solar energy applications, the present contribution of solar energy to the total energy budged is at a negligible level. Photovoltaic (PV) power applications in Turkey are sorely limited with some state organizations use PV for meeting remote electricity demand. The main application areas include telecom stations, signaling purposes, the ministry of forest monitoring stations, fire observation stations, lighthouses and highway emergency systems [85].

About 1 MW of PV is estimated to have been installed in 2009, with the annual market increasingly slightly from the stable level of the previous four years. Off-grid applications account for around 90% of cumulative installed PV capacity of about 5 MW. In 2009, the grid electricity cost has continued to increase. The average electricity price per kWh has reached to 0.13 EUR/kWh for households and

0.08–0.12 EUR/kWh for industry at the beginning of. The grid parity for PV power systems in Turkey is expected to be carried in the next five years [86].

Turkey's geographic location has several advantages for extensive use of most of the renewable energy sources. It is on the humid and warm climatic belt which includes most of Europe, the near east and western Asia. A typical Mediterranean climate is predominant at most of its coastal areas, whereas the climate at the interior part between the mountains that are a part of the Alpine Himalayan mountain belt is dry with typical steppe vegetation [87].

The photovoltaic sector in Turkey is still fairly small, providing work for only a small number of employees. The main business types are importer, wholesale supplier, system integrator and retail sales. The companies serve in the installation, engineering and Project development parts. There are a few domestic battery manufacturers whose products can be used for off-grid PV applications. Currently there is no notable production of feedstocks, ingots and wafers in Turkey. There are three PV module manufacturers in Turkey: Aneles Co. (www.aneles.com.tr), DATATSP Co. (www.datatsp.com) and Terasolar Co. (www.tera-solar.com). The module prices in these local manufacturers were 2–2.5 EUR/Wp in 2009 [86].

At present, Turkey does not have an organized commercial and domestic photovoltaic (PV) programme because the government has no intention in PV technology. On the other hand, there is good potential for PV applications in the local market since the country is enormously suitable due to high rates of solar radiation and available land for PV applications. Installation costs of small PV systems (<5 kWh) in Turkey would be around 9€/Wh installed. Life cycle cost analysis, based on a 10% net discount factor and a 20 year lifetime, could be around €52 cents per kWh. Under these circumstances, small PV systems would have no payback period within this lifetime [76]. It has not widespread area of electricity generation from solar energy is one of the most important reasons that is insufficient amounts of incentive given to this area. According to the renewable energy legislation in Turkey, the amount of support given to all sources of renewable energy is respectively 5–5.5 Euro Cents/kWh. The rate support of investments in solar energy technologies for electricity generation is extremely insufficient [83].

Solar energy technologies are not extensively used, except for solar water heaters (SWH) in Turkey. The domestic or industrial SWH is a simple system that comprises a water tank and a solar flat-plate collector to heat the water [76]. Solar collector area installed is over 30 million m^2 of in the entire world. Most countries in the solar collector from the United States, Japan, Australia, Israel and Greece are located. Turkey, with 7.5 million square meters of collector area installed is one of the leading countries in the world [88]. With an installed solar thermal capacity of 7.1 GWt, Turkey is currently the third largest producer of solar thermal power worldwide, after China (84 GWt) and the EU (15.5 GWt) [89]. There is roof area of 394 km^2 in Turkey. If 189 km^2 of this area can be used as solar thermal and the other 205 km^2 can be used as photovoltaic panels of electricity generation, installed PV capacity will be reached power of 25,625 MW and annual energy generation for solar thermal power generation will be reached energy of 32,671 GWh. This situation also has an important place in Turkey [70].

Solar energy is used enough; it will be possible to develop appropriate technologies. However, hot water production systems are being used widely in many countries; even in Turkey is very little used. Solar power plants are considered a prerequisite for the sunny time of year at least 2000 h; Turkey at approximately 2600, especially only the Southeastern Anatolia region is provided by in the 3000-h period [90]. Photovoltaic now enjoy rapid growth in a subsidized market [91]. Today, solar cells applications were implemented with the support of the state in many countries, such applications should be implemented by Turkish government.

4.3. Solar energy legislation framework in Turkey

At the beginning of 2009, public interest in climate change and photovoltaic technology was quite high. The Turkish Parliamentary General Assembly approved a draft law foreseeing Turkey's adoption of a participation in the Kyoto Protocol on 5 February 2009. After the Republic of Turkey Ministry of Energy and Natural Resources announced the plans of the government for promoting PV power systems, a draft law which defines the feed-in-tariffs for the renewable energy sources by amending the Law on the Utilization of Renewable Energy Resources in the Generation of Electricity ("Renewable Energy Law") was accepted by the Industry, Commerce, Energy, Natural Resources, Information and Technology Commission of the Turkish Parliament on 5 June 2009 and submitted to the Turkish Parliamentary General Assembly [86].

The incentives provided by the Renewable Energy Law are that the price of the electricity to be purchased under the Renewable Energy Law should be the country average of the electricity wholesale price of the previous year to be determined by the Electricity Market Regulatory Authority (EMRA). In any case, the price to be determined cannot be less than the Turkish Lira equivalent of 5 Euro Cent/kWh and more than 5.5 Euro Cent/kWh. However a generator can sell the electrical energy generated for a higher price in the market if there is possibility. A draft Amending Law to the Renewable Energy Law has recently been prepared in order to provide further incentives to the renewable energy sector. According to the draft amending law, different minimum purchase prices varying between 5 Euro Cent/kWh to 18 Euro Cent/kWh are stipulated for electricity produced from different types of renewable energy resources. The purchase obligations are provided to be extended to facilities established prior to 1 January 2016 [92].

An announcement by Sharp Solar outlining the potential boom in the Turkish PV market has referred to the country's government's recent introduction of a €0.28 feed-in tariff for the first 10 years, with a rate of €0.22 thereafter for another 10-year period [93].

4.4. Future strategy of PV industry in Turkey

Turkey's geographical location makes it a natural bridge between the energy-rich Middle East and Central Asian regions. Energy is one of Turkey's most important development priorities. Rapid increase in domestic energy demand has forced Turkey to increase its dependence on foreign energy supplies [94].

The Ministry of Energy and Natural Resources of Turkey (MENR) has planned for a very large increase in electric generating capacity over the next 20 years. According to forecasts prepared by the MENR, the country will need about an electric power capacity of 65 GW by 2010, and about 105 GW by 2020. Electric energy generation capacity is expected to have to rise from about 117 TWh in 2001 to more than 347 and 624 TWh in 2010 and 2020, respectively. This implies power demand growth rates of at least 8% per annum for the coming decade and at least 6% per annum for the following decade. At present, not only the electricity sector, but also the whole energy sector in Turkey is in a dynamic change [95].

Covering the years 2006–2020 period, making 69 billion dollars will be needed investment in power plants. However, public investment and the investment costs are calculated on the basis of international documents, valuables and BOT (Build Operate Transfer) investment proposals were not taken into consideration. Fig. 12 shows that Turkey's estimated installed capacity in 2020 by type of fuel is prepared by State Planning Organization in Turkey (DPT) [70].

It is aimed that Turkey's solar energy power Generation will have 5000 MW electrical power board in 2023. The goals of this target with the current conditions on appear is unrealistic and for

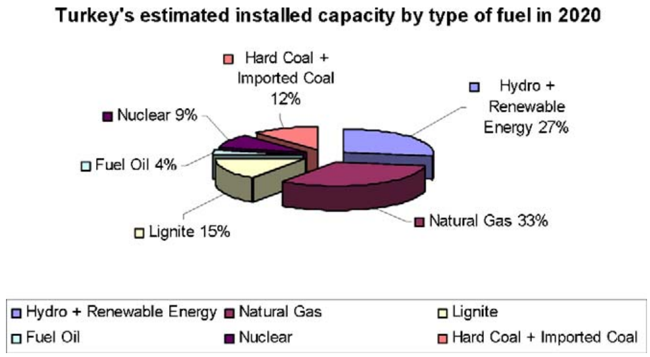

Fig. 12. Turkey's estimated installed capacity by type of fuel in 2020 [70].

the realization of this target should be stable policies are needed to carry out the important decisions [83].

Among renewable energy power sources of Turkey's firstly contain of solar, wind, geothermal energy and biogas. It is aimed that Turkey's Energy Ministry will be provided to 30% of electrical energy needs from renewable energy sources in 2023 [83]. Turkey's this potential of renewable energy sources is estimated about 482–569 billion kWh. However, there are not enough work indicated target to reach. So this target only is estimated for Turkey [68].

Turkey's energy policy objectives aim to reduce Turkey's dependence on fossil fuels by undertaking renewable options. Since the wind sector is quickly growing in Turkey, the learning curve of the Generation of electricity by renewable resources rises day by day. The target of 30% from renewable energy sources and 20 GW from wind power by 2023 is a good guideline for development and deployment of PV in Turkey. If the Turkish Grand National Assembly approves the amendments which enable the feed-in-tariffs for PV power systems on the draft law, a highly competitive market is expected to be emerged for the entire PVPS value chain in Turkey [86].

4.5. R&D status of PV industry in Turkey

The Turkish renewable energy sector has been one of the most attractive sectors in terms of M&A activity in the last couple of years. Many utility industry giants have entered Turkey and there are numerous local entrepreneurs who have obtained renewable licenses but are looking for international partnerships [39].

Photovoltaic research and development activities are still mainly undertaken across a range of universities, government and industry facilities and the projects are mainly financed by the research programme of State Planning Organization of Turkey (DPT) and The Scientific & Research Council of Turkey (TUBITAK) [86].

Turkey spent a total of $120 million (2005 prices and exchange rates) on government energy research and development (R&D) between 1980 and 2005. In this period 15.6% of its total energy R&D budget ($17.4 million) was allocated to renewable energy [97]. The photovoltaic sector in Turkey is still fairly small, providing work for only a small number of employees. The main actors consist of several companies and a number of research institutes. There are approximately 30 companies which are operating in Turkey's PV sector. The main business types are importer, wholesale supplier, system integrator and retail sales. The companies serve in the installation, engineering and project development sectors. PV modules, battery charge controllers and inverters are mainly imported. Batteries, solar lighting systems, etc., may be supplied by the domestic market. Some of the domestic products (batteries, tempered glass, etc.) are exported. There is not any cell production factory in Turkey [98]. Regarding the solar energy research, in addition to General Directorate of Electrical Power Resources Survey and Development Administration in Turkey (EIE), TUBITAK Marmara Research Center and some universities (Ege University Solar Energy Institute, Mugla University, Middle East Technical University, Kocaeli University, and Fırat University) carry on research projects [75].

The Technology Monitoring and Evaluation Board (TMEB) of TUBITAK has R&D assistance program for industrial companies. This includes a financial contribution by the Scientific and Technical Research Council of Turkey and by the Undersecretary of Foreign Trade for up to 60% of the total eligible cost incurred over the duration (up to 36 months) of an individual R&D Project [87].

Moreover, Turkey has joined European Community (EU) Sixth Frame project. There are many projects opportunities in this program about renewable energy. Turkey's universities and research institutes began to offer project proposal [87]. In addition, Turkey participates in international collaborative R&D in Photovoltaic Power Systems through the IEA Implementing Agreements [66] which is one of the most comprehensive programs on the grid-connected photovoltaic systems was undertaken by the Photovoltaic Power Systems Programme (PVPS), which is one of the collaborative research and development agreements established within the International Energy Agency (IEA). The PVPS has 20 countries as member including Turkey [40].

A legal foundation for the utilization of the solar power potential should be established, secondary legislation should put in to effect according to this law, determination of solar power production technology level, the scope of R&D activities, methods, pilot facilities, production facilities, manufacturing and assembly stages should be planned. Local production of Photovoltaic cells and condensing systems should be aimed [99]. Today, Turkey's domestic engineering technology and with making use of national power is realized possible an important solar energy applications because lots of international energy publications point that Turkey is one of the countries which the largest solar energy potential. Turkey has an important solar energy market for developed countries. However, research and development appropriations gross national income in Turkey (GDP) share of very low.

Government has no intention in PV production. PV cells are produced in various research establishments in order to study the feasibility of local manufacturing. So far none of these studies yielded a positive result in order to justify a mass production facility in Turkey [100].

4.6. SWOT analysis of Turkey's energy sector

SWOT analysis is a strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities, and Threats involved in a project or in a business venture. It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favorable and unfavorable to achieve that objective [101]. SWOT analysis of Turkey's energy sector [39];

Strengths:

- Suitable geography with various natural resources
- Turkey is among the first five countries in terms of geothermal resources
- The solar energy potential of Turkey is higher than the combined potential of several European countries
- According to the DSI Annual Report 2009, Turkey has 213 HEPPs with an installed capacity of 14.3 GW
- The Turkish electricity market represents one of the most promising markets in Europe with respect to growth potential in the coming years.

Weaknesses:

- Significant need for foreign environmental expertise in Turkey as most Turkish firms within the environmental technologies sector lack the capabilities to handle large environmental projects
- Lower efficiency in energy utilization compared to Europe
- Lack of financial resources of local entrepreneurs.

Opportunities:

- High potential of resources for the use of new renewable energy technologies (particularly boron an thorium resources)
- As a result of economic growth, industrialization and urbanization, the demand for EGS in Turkey is increasing, particularly in the waste management, water supply and management, and air pollution control sub-sectors
- Turkey has started to focus on renewable energy, in an effort to decrease energy imports
- Tremendous investment opportunities in renewables market.

Threats:

- Being import dependent on HEPP and WPP equipment
- Renewable energy resources are mainly state owned both in Turkey and globally
- Delay in the liberalization process and the private sector investments.

5. Conclusion

Solar energy and photovoltaic-panel applications, in the world and especially in Turkey, experienced a rapid process of production and investment. Improving projects is an important problem in terms of energy efficiency and investments as references energy planning maps. The project is basically to be done for starting values of solar radiation and sunshine duration is to measure at least one-year period. The feasibility study should be done according to data obtained.

In order to achieve environmentally benign sustainable energy programs, renewable energy sources should be promoted in every stage. This will create a strong basis for the short- and long-term policies [96]. The States should be promoted it, the individual participants should be encouraged and the generation of photovoltaic energy trade and photovoltaic cell production should be incentives. People who can be produced more facilitated their own electricity. Various activities should be organized to increase public awareness and applications. Public offices have an important role for this situation.

In the case of Turkey, due to some technological and economical consequences, renewable energy resources do not have wide applications, but renewable energy usage should be increased year by year by government and private companies because Turkey is an energy importing country and domestic fossil fuels are limited and the economical condition of the country is not good [84]. These potential paths to development are all representative of a new generation of solar cell technology in terms of breakthrough and markets, and besides the constant encouragement of Turkey's policies, the ability to create more technological advantage incentives and manufacturing advantageous conditions for learning cooperation internationally are areas in urgent need of attention [102].

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