PREDGOVOR

Intenzivan tehnološki razvoj, rast životnog standarda i porast broja ljudi na Zemlji, zahtevaju sve veću potrošnju svih vidova energije, dok se na drugoj strani kao posledica, javljaju negativni efekti po životnu sredinu. Imajući ovo u vidu, UN su definisale održiv ekonomski razvoj u Milenijumskim ciljevima a predsednici sedam najrazvijenih država, takozvane Grupe G7, potpisali su deklaraciju u Briselu u kojoj su, između ostalih, istakli i sledeće ciljeve:

- *smanjenje emisije gasova staklene bašte,*
- *unapređenje energetske efikasnosti, i*
- *promovisanje primene čistih i održivih energetskih tehnologija i nastavak ulaganja u istraživanja i inovacije.*

Posebno negativan uticaj na životnu sredinu imaju postrojenja za proizvodnju električne energije imajući u vidu da kao pogonsko gorivo uglavnom koriste fosilna goriva.

Zbog toga se u svetu, kao i kod nas, u narednom periodu očekuje povećanje primene obnovljivih izvora električne energije.

Osnovni cilj 6. Međunarodne konferencije o obnovljivim izvorima električne energije jeste da se analiziraju uporedne prednosti i nedostaci savremenih rešenja u oblasti obnovljivih izvora električne energije koja se primenjuju u svetu i kod nas, i da se obezbedi plodotvorna razmena kompetentnih mišljenja i ideja vezanih za razvoj i primenu ovih izvora.

Zavod za unapređenje obrazovanja Republike Srbije akreditovao je šestu Konferenciju.

Ovaj međunarodni skup po šesti put organizuje Društvo za obnovljive izvore električne energije koje u okviru Saveza mašinskih i elektrotehničkih inženjera i tehničara Srbije (SMEITS) postoji od 2010. godine.

U Beogradu,
oktobra 2018.

PREGLED PRIMENE FOTONAPONSKE TEHNOLOGIJE U SAVREMENOM SVETU

AN OVERVIEW OF THE PHOTOVOLTAIC TECHNOLOGY APPLICATION IN THE MODERN WORLD

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Pitanje energetske stabilnosti postalo je poslednjih godina krucijalno pitanje svetskog ekonomskog, privrednog i društvenog sistema. EU se pored svoje visoke razvijenosti i evolucije svog odnosa prema pitanju energetske sigurnosti, suočava sa problemom zagadjenja životne sredine, globalnim zagrevanjem i klimatskim promenama. Jos pre nekoliko decenija je prepoznato da obnovljivi izvori energije predstavljaju glavni oslonac energetske samostalnosti sveta u budućnosti.

Poznato je da među obnovljivim izvorima energije, solarna energija predstavlja najperspektivniji i najpouzdaniji energetski izvor, jer je Sunce neiscrpan, jeftin i izuzetno čist izvor enerije. Glavni razlozi za efikasnije korišćenje solarne energije u zemljama koje imaju potencijal za generisanje termalne i električne energije su smanjenje emisije "gasova staklene bašte", smanjenje uvoza i korišćenja fosilnih goriva, razvoj lokalne industrije i ovaranje novih radnih mesta.

Fotonaponska tehnologija je jedan od vodećih lanaca "održivog razvoja", pa zato vlade brojnih država pružaju podsticaje za izgradnju solarnih elektrana. Ova tehnologija direktne konverzije solarne u elektricnu energiju je zadnjih nekoliko godina u velikom usponu. U radu je dat pregled postojećeg stanja sa najnovijim podacima o razvoju, primeni i instaliranim kapacitetima fotonaponske tehnologije poslednjih godina u svetu.

Ključne reči: *fotonaponska tehnologija, primena, instalirani kapaciteti*

The query of energy stability has become the key query of the world economic and social system in the last few years. In addition to its high development and evolution of its relationship to energy security, the EU also faces with the problem of environmental pollution, global warming and climate changes. For several decades, it has been recognized that renewable energy sources are the main support of the energy independence of the world in the future.

It is well known that among renewable energy sources, solar energy represents the most promising and reliable energy source, because the Sun is a inexhaustible, cheap and extremely clean energy source. The main reasons for more efficient use of solar energy in countries that have the potential for generating thermal energy and electricity are the reduction of greenhouse gases emission, the reduction in imports and use of fossil fuels, the development of local industry and the promotion of new jobs.

Photovoltaic technology is one of the leading chains of "sustainable development", and therefore governments provide incentives for the construction of solar power plants. This technology of direct conversion of solar energy into electricity has been in a big increase in the last few years. This paper presents an overview of the current situation with the latest data on the development, application and installed capacities of photovoltaic technology in the last few years in the world.

Key words: *Photovoltaic technology, application, installed capacity*

1 Introduction

The development of the world economy leads to greater environmental pollution, ozone depletion and climate change on Earth. On the other hand, reserves of fossil fuels are diminishing. One way to mitigate these negative consequences is to use renewable energy sources instead of traditional fossil fuels. As of 2015, renewable energy provided an estimated 19.3% of global final energy consumption, and growth in capacity and production continued in 2016. For the third consecutive year, global ener-

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gy-related carbon dioxide emissions from fossil fuels and industry were nearly flat in 2016, due largely to declining coal use worldwide but also due to improvements in energy efficiency and to increasing use of renewable energy. Most new renewable energy capacity is installed in developing countries, and largely in China. In 2016, renewable energy spread to a growing number of developing and emerging economies, some of which have become important markets [1].

The most abundant source of renewable energy is solar energy - daily supply of solar energy is theoretically sufficient to meet all the needs for human energy during the year. The only disadvantage is that solar energy and other renewable energy sources are limited in the sense that their availability varies in space and time. Solar energy technologies can be divided into two categories: solar thermal systems and solar electric or photovoltaic (PV) technology.

Photovoltaic technology (PV) is one of the most prominent renewable energy technologies, which represents the direct conversion of solar radiation into electricity. Photovoltaic (PV) cells employ semiconductor material to generate a flow of electricity when struck by sunlight. Though the technology is now well developed and reliable, it is also expensive compared to current energy sources, perhaps three times as expensive as fossil-fuel generated electricity, depending on the specific circumstances being compared. Costs of solar PV have fallen considerably, and are projected to fall further; an important issue, discussed further below, is whether and when solar costs will reach a fully competitive range. In contrast to other renewable energy sources, solar PV is sustainably available in almost infinite quantities, and in almost any location.

PV effect was discovered in 1839 by Becquerel while studying the effect of light on electrolytic cells. Solar cells developed rapidly in the 1950s owing to space programs and used on satellites. Research on semi-conductors based solar cells were studied since1960 and new technology for polycrystalline Si and thin-film solar cell have been establish. Also, the energy crisis of the 1970s greatly stimulated research and development for PV technologies [2].

Current PV installations are still small and provide very small part of world total electricity generation, but through some report indicated that PV installations are growing 40 % annually [3, 4]. PV technology has reduced its unit costs with continuous technical advance and research for efficiency increase. PV will certainly become an important energy supplier in the world. It is predicted on the solar photovoltaic electricity empowering the world that PV will deliver about 1081 GW by 2030 [5].

Solar PV was the world's leading source of additional power generation capacity in 2016. The annual the market has increased nearly 50% to at least 75 GW, which is equivalent to more than 31,000 solar panels installed every hour. The top five countries, led by China accounted for 85% of additions. Yet emerging markets on all continents are contributing significantly to global growth, and many see solar PV as a cost-competitive source for increasing electricity production and providing energy access [1].

This paper represents a brief overview of all currently available PV technologies and current status of the world solar PV market today.

2 Solar PV Technologies

Silicon technology is the dominant one for the supply of power modules into photovoltaic applications. Silicon supply can be easily available since it is the second easiest raw material that can be found on the Earth [6]. It can be applied for use in either crystalline (wafer) form or in a non-crystalline (amorphous) form. From all other solar cell materials, crystalline silicon based solar cell has the highest efficiency compared to others. There are two types of crystalline silicon (c-Si): monocrystalline and polycrystalline. Monocrystalline silicon is expensive to manufacture, because it requires cutting slices from cylindrical ingots of silicon crystals that are grown with the Czochralski (CZ) process. Polycrystalline silicon is easier to manufacture and can be cut into a square shaped slices, but has slighter lower efficiency (approximately – 5%). It is comprised of small crystals or crystallites [7]. Amorphous silicon is a non-crystalline form of silicon in disordered structure and has 40 times higher rate of light absorptivity compared to monocrystalline silicon. Amorphous (uncrystallized) silicon is the most popular thin film technology with cell efficiencies of 5–7% [8]. Hybrid solar cells are combining crystalline silicon with non-crystalline silicon. Higher ratio of performance to cost has been evaluated by the adopting amorphous silicon with crystalline silicon [9].

Most researchers are trying to find new technology to reduce the material cost to produce solar cell and to till date, thin film technology can be seen as a suitable substitute. As an alternative to sili-

con, other semiconductor materials can be used for thin film solar cells. They have been proven to have greater efficiency than thin film amorphous silicon. Copper-indium gallium selenide (CIGS) has conversion efficiency of 20 %. It can be manufactured to be very thin due to its high absorption coefficient. Cadmium telluride (CdTe) has conversion efficiency of about 16 % and potentially offers cost advantages over CIGS [7].

Nanotechnology has brought new opportunities for the development of nanoelectronic devices for solar cell applications. Nanotubes (CNT), quantum dots (QDs) and ''hot carrier'' (HC) solar cell are three devices used in nanotechnology for PV cell production. The advantages of using this technology are: enhance material mechanical characteristic, low cost, lightweight and good electrical performances. All these nanomaterials materials have received considerable attention over the last decade as very attractive materials in a number of applications [10].

3 Solar PV Market Today

During 2016, at least 75 GW of solar PV capacity was added worldwide, which is equivalent to the installation of more than 31 000 solar panels every hour. More solar PV capacity was installed in 2016 (up 48% over 2015) than the cumulative world capacity five years earlier. By year's end, global solar PV capacity totaled at least 303 GW [1] (Figure 1).

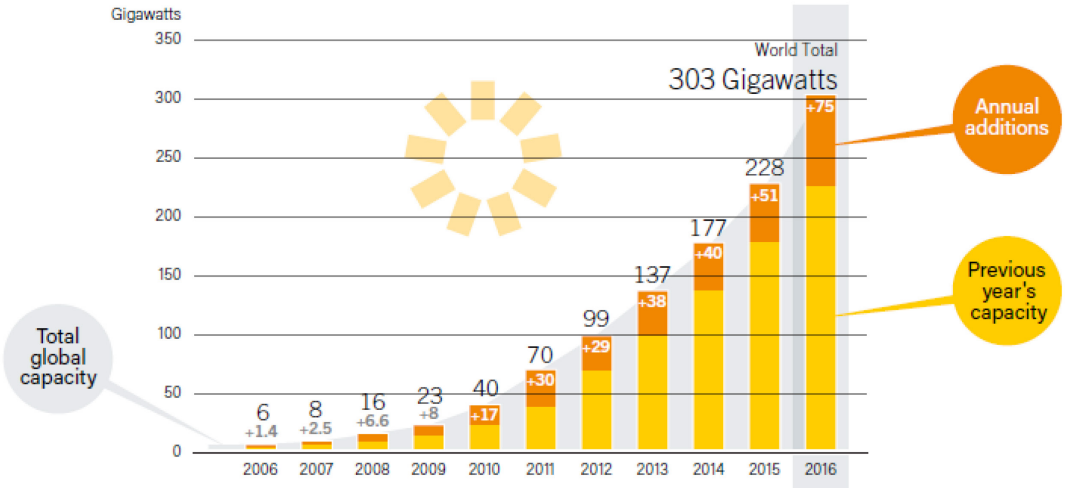

Figure 1 - Solar PV Global Capacity (annual) for period 2006-2016 [1]

For the fourth consecutive year, Asia eclipsed all other markets, accounting for about two-thirds of global additions. The top five markets – China, United States, Japan, India and the United Kingdom – accounted for about 85% of additions; others in the top 10 for additions were Germany, the Republic of Korea, Australia, the Philippines and Chile. For cumulative capacity, the top countries were China, Japan (which passed Germany) and the United States, with Italy a distant fifth (Figure 2). While China continued to dominate both the use and manufacturing of solar PV, emerging markets on all continents have begun to contribute significantly to global growth. By the end of 2016, every continent had installed at least 1 GW, at least 24 countries had 1 GW or more of capacity, and at least 114 countries had more than 10 MW. The leaders for solar PV capacity per inhabitant were Germany, Japan, Italy, Belgium and Australia.

Market expansion was due largely to the increasing competitiveness of solar PV, as well as to rising demand for electricity and improving awareness of solar PV's potential as countries seek to alleviate pollution and reduce CO_2 emissions. In many emerging markets PV now is considered a cost competitive source for increasing electricity production and for providing energy access. Nevertheless, markets in most locations continue to be driven largely by government incentives or regulations.

In 2016, China added 34.5 GW (up 126% over 2015), increasing its total solar PV capacity 45% to 77.4 GW, far more than that of any other country (Figure 3). The record increase came despite a downwards adjustment in China's target for 2020, made in response to a slowdown in the growth of electricity demand.

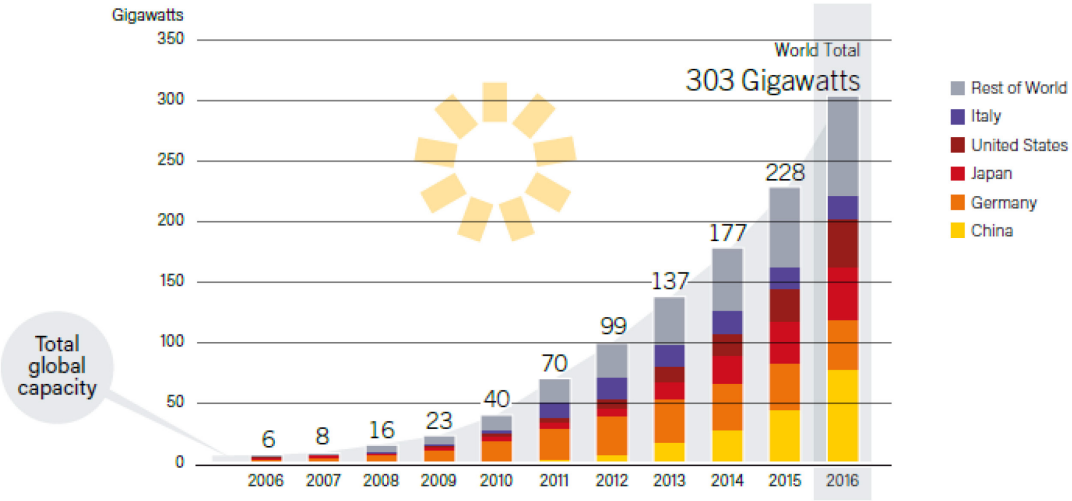

Figure 2 - Solar PV Global Capacity by country and by region, for period 2006-2016 [1]

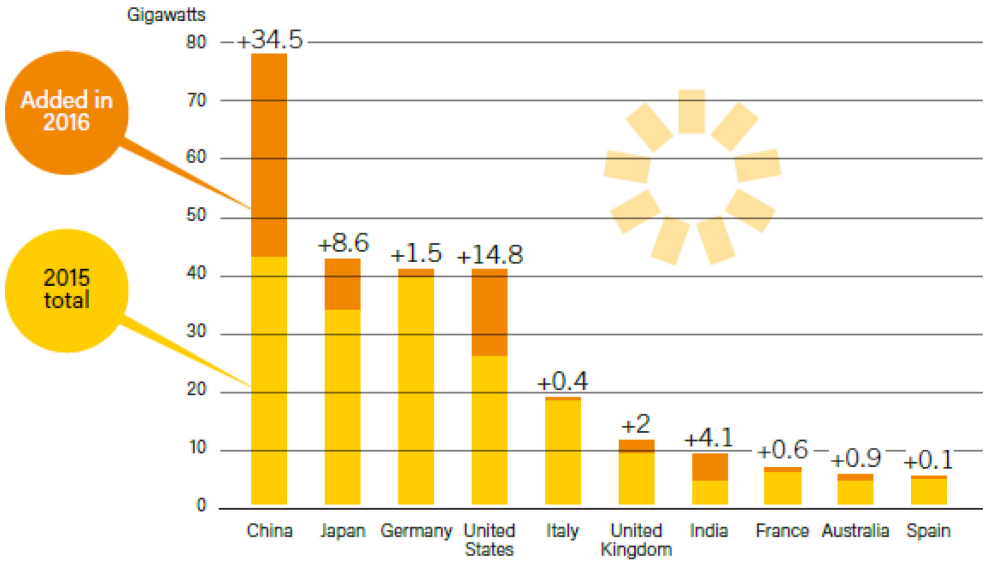

Figure 3 - Solar PV Capacity and Additions - top 10 Countries in 2016 [1]

Japan's market was the world's third largest in 2016 – despite contracting 20% after the 2015 boom – and was enough to propel the country past Germany to rank second for cumulative solar PV capacity. An estimated 8.6 GW was installed, bringing the country's total to 42.8 GW.

The United States was a distant second after China for new installations in 2016. For the first time, solar PV represented the country's leading source of new generating capacity. More than 14.8 GW of capacity – almost double the installations in 2015 – was brought online, for a total of 40.9 GW. The US non-residential (commercial and industrial) market increased 49%, to 1.6 GW, due primarily to looming regulatory deadlines in two key states and to an increase in community solar projects.

The EU became the first region to pass the 100 GW milestone in 2016 (quickly surpassed by Asia); the region ended the year with an estimated 106 GW, more than 32 times its 2006 capacity. Even so, as global additions increased 48% relative to 2015, EU demand fell by 24%. The United Kingdom accounted for most of the market decline, with several other EU countries seeing capacity increases relative to 2015. Approximately 5.7 GW was added in 2016, mostly in the United Kingdom, Germany and France – which together installed about 70% of the region's new grid-connected capacity. Others adding capacity included Belgium, Italy and the Netherlands.

Utilities in Australia also are facing major impacts from solar PV. The country added nearly 0.9 GW in 2016, for a total approaching 5.8 GW. Australia's market has been predominantly residential, although the commercial and large-scale sectors started to take hold in 2015 and 2016. By late 2016,

almost 1.6 million solar PV installations were operating in the country. About 30% of dwellings in both Queensland and South Australia had solar PV installations, with high shares also in several other states and territories. Australia's low wholesale electricity prices and high retail prices are encouraging consumers to shift to solar PV while providing them with little incentive to sell their generation into the grid.

Solar PV is playing an important role in providing energy access in Latin America and the Caribbean, although the vast majority of capacity installed to date has been in large-scale projects. Chile was the region's top installer and ranked tenth globally for newly added capacity, thanks to a booming mining industry that has pushed rapid development in the north. (Figure 4) The country added over 0.7 GW in 2016 for a year-end total of 1.6 GW. Mexico followed, adding about 150 MW for a total of 0.3 GW.

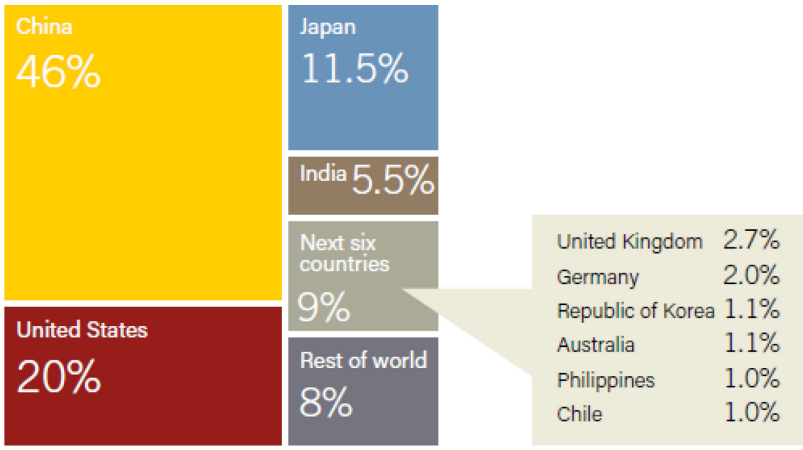

Figure 4 - Solar PV global capacity additions, shares of top 10 countries and rest of the world in 2016 [1]

Although relatively little capacity was operating in the Middle East by the end of 2016, interest in solar PV has started to pick up. Countries without domestic fossil fuels have begun investing in solar power to diversify energy sources and economies, and oil producers are taking advantage of good solar resources, low land and labor costs, and favorable loan rates to preservetheir fossil resources for export. Israel remained the region's leading market, adding 0.1 GW for a total over 0.9 GW. Jordan and Kuwait both brought large plants online during the year, and, in early 2017, Dubai inaugurated a 200 MW plant.

Across Africa, countries are turning to solar PV to diversify their energy mix, meet rising electricity demand and provide energy access. Rapidly falling costs, new business models and a global certification scheme have combined to enable the emergence of projects of all sizes. Leaders for new capacity in 2016 were South Africa (0.5 GW) and Algeria.

While demand is expanding rapidly for off-grid solar PV, the capacity of grid-connected systems is rising more quickly and continues to account for the vast majority of solar PV installations worldwide. Decentralised (residential, commercial and industrial rooftop systems) grid-connected applications have struggled to maintain a roughly stable global market (in terms of capacity added annually) since 2011, particularly with the transition from FITs and net metering to self-consumption. Centralised large-scale projects, by contrast, have comprised a rising share of annual installations – particularly in emerging markets – despite grid connection challenges, and now represent the majority of annual installations. (Figure 5) The drivers include increased use of tenders and availability of low-cost capital. By one estimate, the average solar (mostly PV) project size in early 2016 ranged from 3 MW in Europe and 11 MW in North America, to 45 MW in Africa and 64 MW in South America.

Around the world, the number and size of large-scale plants continued to grow in 2016. By year's end, at least 164 (up from 124 a year earlier) solar PV plants of 50 MW and larger Philippines and the United Kingdom joining the list during the year. The cumulative capacity of plants of 50 MW and larger that came online in 2016 was more than 5.9 GW. China's Yanchi project in Ningxia became the world's largest plant, with 1 GW generated electricity. Considering plants of 4 MW or larger, about 35 GW of projects was installed in 2016, bringing the world total to an estimated 96 GW.

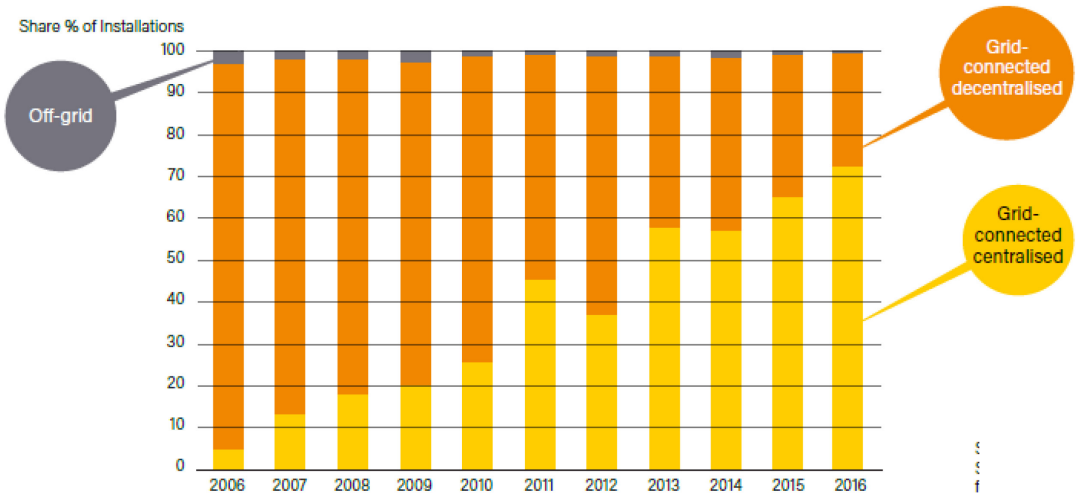

Figure 5 - Solar PV Global Additions, shares of grid-connected and off-grid installations for period 2006-2016 [1]

Several retailers and international corporations based in China, Europe, India, North America and elsewhere invested heavily in solar PV during the year. Solar PV plays a substantial role in electricity generation in several countries. In 2016, solar PV accounted for 9.8% of net generation in Honduras and met 7.3% of electricity demand in Italy, 7.2% in Greece and 6.4% in Germany. At least 17 countries (including Australia, Chile, Honduras, Israel, Japan and several in Europe) had enough solar PV capacity at the end of 2016 to meet 2% or more of their electricity demand.

At the end of 2016 there was enough world solar PV capacity in operation to produce close to 375 TWh of electricity per year.

4 Conclusion

In past a few decades the worldwide energy consumption is increasing every year and different technologies are using to produce electricity to compete the energy demand. The environmental pollution is also a serious problem nowadays. Solar PV technology is growing rapidly in past decades and can play an important role to achieve the high energy demand worldwide. Huge amount of PV systems installed yearly shows the seriousness and the responsibility of every country about the issue to save the earth by using renewable energy. This paper illustrated the worldwide status of solar PV cells and PV technology.

Today, mono and polycrystalline PV technology have more than 40 % market share with 15–17 % efficiency. However, thin film solar cells are also in development stage and extensive research work is going for efficiency improvement for commercial use. Non-silicon photovoltaic technology, based upon Cadmium telluride (CdTe) and Cadmium sulphide (CdS), Copper indium gallium selenide/copper indium selenide (CIGS/CIS), Dye-sensitized solar cell (DSSC) and ‘‘third- generation PV’’ solar cells are also in development stage and extensive research work is going for efficiency improvement for commercial use.

The solar cell production has some disadvantages on environment during manufacturing and process time but it gives much more advantages during use. The electricity production through PV system is clean and safe for environment with comparison to coal and fossil fuel. Electricity production through PV module reduces the carbon dioxide emission in environment and safe for global warming problem.

The efficiency of solar cell is one of the important parameter in order to establish this technology in the market.

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