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A REVIEW OF PRICES FOR PHOTOVOLTAIC SYSTEMS

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Abstract- Solar energy is the most abundant, useful, efficient and environmental friendly source among the renewable energy sources. Also, in recent years, the capacity of photovoltaic electricity generation systems has increased exponentially in the world due to increase in economic viability and reliability of photovoltaic systems. Anyway, many studies state that photovoltaic power systems will play a key role for electricity of the future. When first produced, photovoltaic systems had short lifetimes. Nowadays, with the development of technology life cycles of photovoltaic systems has been increased up to 20-25 years. Researches show that photovoltaic systems will be broadly used in the future. These analyses are achieved by considering fast decreasing cost of photovoltaic systems. As the price analysis is very important for energy marketing. In this study, a review of cost potential factors on photovoltaic panels is realized and the expected cost potential of the photovoltaic systems is examined considering lots of studies.

Keywords: Solar Energy, Renewable Energy, Efficiency, Solar Panel Cost, Solar Systems.

I. INTRODUCTION

Energy, like other essential needs such as food and shelter, is a basic need of people throughout the world. The increasing world's energy demand and environmental pollution are motivating related research and technological investments to improve energy efficiency and generation. The main objective to replace the large parts of fossil fuels, can be achieved by the help of renewable energy. This has made the investigators research on renewable energy resources and energy efficiency for present consumption of energy, because renewable energy technology turns the natural phenomenon into beneficial energy types. Among the renewable energy resources, solar power is the most beneficial, limitless, effective and dependable resource. Above all, solar power is ecology friendly.

For the socio-economic progress of developing and developed nations, energy is regarded as indispensable. Yet, maladministration of power generation has a detrimental effect on the ecosystem. Recently, environment-related concerns like global warming, have been rising all around the world. Consumption of world energy resources and excessive emission of dangerous greenhouse gas become a serious problem. This has substantial impact on climate change, an important subject which has been discussed all around the world. One of the main reasons of climate change is the extreme global greenhouse gas emission (ex. carbon dioxide and methane etc.) into the atmosphere in consequence of the activities carried out by humans.

Human activities mostly cause a huge CO_2 discharge. In 2002, universal CO_2 discharge regarding human activities, reached 2.6 billion, and in 2030, it is estimated that it would reach 4.2 billion tons annually; in addition, unless prevented, the surface temperature might reach 1.4-5.8 ◦C range in the future. Due to these developments, we will possibly face droughts, floods, rise in the sea level, glacial melting and critical spoilage concerning agriculture, therefore it is essential to reduce these emissions as soon as possible. It is possible to realize this by turning conventional energy applications into renewable energy technologies [1, 2].

Solar power is certainly favorable in terms of the environment. When compared to other energy types such as coal and oil, sun is considered as a fine energy resource as it is reliable and clean. Because the sunshine that can meet our energy requirement in the future, many scientists are pointing out the significance of solar power. Sunlight is considered as an alternative energy source as well as hydrogen and wind. Solar power has the capacity to transform ecology friendly energy into a more flexible, common and cheaper energy resource. Consequently, solar power is frequently used in many applications today such as water heating systems, satellite power systems, electrical power generation etc.

As is known, the best-known renewable energy technology is PV systems. In order to produce electrical energy, these photovoltaic (PV) systems use sunlight. Photovoltaic electricity generation systems appear quite attractive for electricity generation due to low carbon dioxide emission when operating, simple operation, noiseless, flexibility in scale and easy maintenance among the sustainable energy sources. In order to speed

up the extension of renewable energies and especially PV, environmental profits and the prevention of fossil fuel spoilage underlying the relevant price imbalance, are essential.

Hence, renewable energies significantly contribute to supply security. Also, photovoltaic system can be applied for small or large applications without any restriction. They are already installed on individual homes, housing developments, public and industrial buildings and generating energy around the world. Existing solar cell technologies are solidly installed, and these technologies provide safe products having the efficiency and energy that can last 25 years. The increasing power failure potential and the increase in electricity prices advertise photovoltaic systems [3].

Available solar irradiation that is required to meet the world's energy requirements, is more than adequate. Thanks to current technology, the sunlight irradiating on per square meter, has the capacity to produce 1.700 kWh of energy annually on the average. When overall energy consumption is taken into consideration, we can see that the overall solar power reaching the earth's surface, has the capacity to satisfy the current energy requirement for more than 10.000 times. If there is more sun, it means more energy can be produced. Solar energy is best produced in sub-tropical areas. While Europe produces 1.200 kWh/m^2 average energy annually, the Middle East produces 1.800 to 2.300 kWh/m^2 [4].

Depending on connection methods and working principles, the photovoltaic based electricity generation systems may be classified as stand-alone photovoltaic systems or grid-connected photovoltaic systems. Photovoltaic panels generates electricity in integrated with some equipment such as batteries, charge controllers and inverters. The majority of photovoltaic modules were used in independent applications in the areas where there was no network connection [5].

In 2014, over 100 nations enhanced their solar photovoltaic (PV) capacity, which also made PV the world's fastest power generation technology. In 2014, the enhanced capacity of PV was approximately 139 GW. Figure 1 shows solar PV, existing world PV capacity between 2004-2014 [6, 7].

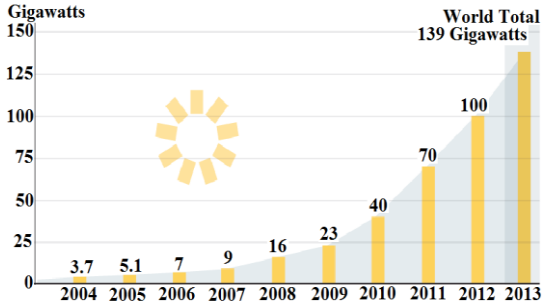


Figure 1. Solar PV, existing world PV capacity, 2004-2014 [7]

II. BASIC OF ELECTRICITY GENERATION PROCESS FOR PHOTOVOLTAIC SYSTEMS

PV systems have higher capital costs per unit and much lower operating costs when compared to traditional fossil-based electrical resources [8]. However, progress in the photovoltaic industry continues with reasonable scope for further improvements in cost-reduction in the near future. Also, economics of photovoltaic panels is closely related to the capacity of solar radiation and sunshine duration of the system. Photovoltaic systems are highly influenced by the local availability of solar radiation.

Photovoltaic panels generate electricity in integration with other system equipment. The other system equipment can be described as balance of system. These systems operate as on-grid or off-grid. There are lots of applications of photovoltaic systems in the world such as communications, remote monitoring, hotels, hospitals, houses, lighting, water pumping and rural areas. So, the photovoltaic systems can be used anywhere electricity is needed. When considered in general, the key parts of a photovoltaic energy generation system are [4];

• Photovoltaic panels to absorb sunlight,
• An inverter to turn direct current (DC) into alternative current (AC),
• A set of batteries for off-grid connected photovoltaic systems,
• A charge controller between the photovoltaic panel and batteries,
• Support structures to direct the photovoltaic modules toward the sun (to enhance efficiency of photovoltaic electricity production system).

Moreover, photovoltaic systems can be used on-grid or off-grid connected with electricity utility. There are lots of applications of photovoltaic systems in the world such as communications, remote monitoring, hotels, hospitals, houses, lighting, water pumping and rural areas. So, the photovoltaic systems can be used anywhere electricity is needed.

III. PAST AND PRESENT INCLUDING LEARNING CURVE APPROACH FOR PHOTOVOLTAIC SYSTEMS

Nowadays, main agenda of the world countries is energy. Price analysis factor is very important for electricity energy generation because of the increasing energy generation costs in the world. So, the cost of photovoltaic energy systems is crucial. In this section a technical analysis of cost reduction potential of photovoltaic systems is realized.

High cost and low efficiency, limits electricity production from solar energy. However, the developments taking place in PV sector, show that the costs will be reduced in the near future. Therefore, it is considered that low-cost and more efficient PV modules in PV sector, would be manufactured each passing day. Although the installation costs of photovoltaic system are fairly high, photovoltaic systems have many advantages. The major problem is that photovoltaic panels have low electricity generation conversion efficiency. The electricity generation system should be economical and feasible for widely usage. For the generation of electricity with the highest capacity, maximum sunlight is required by this system. Moreover, factors such as panel technology, environment and selection of material etc. influence the operation and efficiency of photovoltaic based electricity production systems.

50 years ago, in the beginning days of photovoltaic panels, the energy needed to produce a photovoltaic panel was more than that the panel could produce in its lifetime. In the last ten years, the payback times were reduced to 3-5 years because of improvements in the efficiency of the panels and production methods, basing upon the sunshine available at the installation area. Nowadays, photovoltaic panel systems cost is approximately €1.34 per watt peak.

In many countries, photovoltaic systems markets have not reached maturity yet. However, in Germany, today's system prices represent the lowest rational prices that can be reached in other parts of the world. Taking these prices into consideration, in 2010 it starts with €2.80/Wp on average for photovoltaic systems. Until the midst of 2010, there prices were minimum €2.20/Wp for large floor-mounted systems in some nations. Prices are to be reduced in accordance with the production volume [4]; however, when compared with fossil fuel generated electricity prices; photovoltaic panel systems are still regarded as expensive.

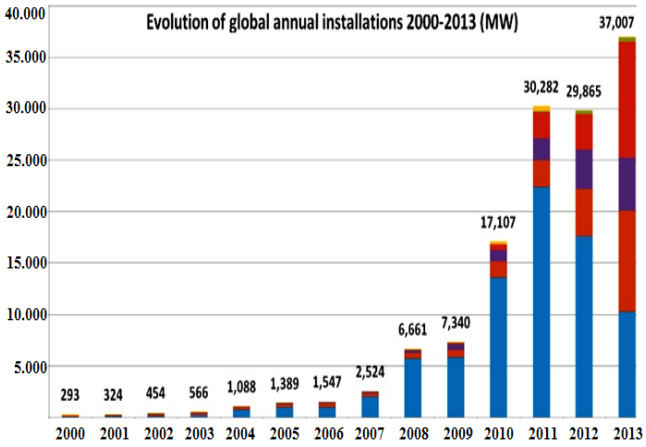
When the current situation is evaluated, turnkey photovoltaic systems installed in major markets have roughly the same production costs, but prices vary widely from country to country [8]. For instance, the researches show that Germany continue to set the standard for managing photovoltaic incentives, because the world's largest solar market also happens to be home to the cheapest photovoltaic systems. In markets with more generous funding, operators pay more for systems, essentially passing the grater incentives back up the value chain. Nowadays, in Germany, photovoltaic systems with a capacity of between 2 kW and 5 kW cost €2.772 ($3.930) per kW on average, including installation. Prices are as low as €2.300 ($3.620) per kW for some photovoltaic systems in this category because the some incentive policies are highly influenced the capacity of photovoltaic electricity generation.

Photovoltaic panel efficiency, selection of correct product, selection of balance of the system equipment's and accurate prediction of the electricity generation are essential for reliable knowledge on the photovoltaic systems. So, the feasible work is very important to install photovoltaic systems. Also, the location of installation for photovoltaic systems is an important parameter due to the solar irradiance that affects directly capacity of electricity generation from photovoltaic panel.

Ten years ago, in order to produce a few MW of energy annually, cell and module production facilities were able to survive thanks to their production of sufficient solar modules. Nowadays the market leaders own facilities that have the capacity above 1 GW, several hundred times than it was ten years ago. Along with technological changes and optimization of production, increases in the capacity have decreased the cost per unit. For each time the production output is doubled, the decrease is approximately 22% [4].

In the last ten years, there has been an unprecedented growth in PV market. When compared to 2009, the capacity was increased from 7.2 GW to 16.6 GW in 2010.

Despite the difficult financial conditions, EU enhanced its 1 GW capacity in 2003 to 13 GW level in 2010, and today, continues to increase its PV capacity rapidly. While Germany is the lead in PV sector, USA and China also continue their investments in this field in order to have a say in PV sector. In addition, in 2009, $ 38.5 billion was generated by the PV industry in global revenues, rising over $ 13.5 billion in terms of equity and debt, up 8% on the previous year; in Figure 2, shows that evolution of global cumulative installed capacity 2000-2010 [9].



	2000	2001	2002	2003	2004	2005	2006
ROW	88	56	80	77	29	10	105
MEA	-	-	-	-	1	0	0
CHINA	19	5	19	10	10	8	10
AMERICA	2	3	30	48	61	82	110
APAC	126	128	190	230	282	304	325
EUROPE	58	133	134	202	705	985	997
TOTAL	293	324	454	566	1.088	1.389	1.547
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
ROW	42	76	80	284	508	-	85
MEA	1	1	22	46	125	365	383
CHINA	20	40	160	500	2.500	3.500	11.300
AMERICA	166	306	500	1.082	2.181	3.774	5.153
APAC	271	530	745	1.578	2.562	4.646	9.833
EUROPE	2.023	5.708	5.833	13.616	22.407	17.580	10.253
TOTAL	2.524	6.661	7.340	17.107	30.282	29.865	37.007

Figure 2. Annual installed capacity of photovoltaic electricity generation in the world [10]

In the last 30 years, there has been significant price reductions made by the PV industry. The cost of PV modules has been reduced by 22% each time the cumulative installed capacity (in MW) has been two-fold. Reduction in PV modules and systems prices, has also decreased power generation costs. This has been caused by wide-scale innovation, research, development and continuing political support for the development of the PV market [4]. Especially, photovoltaic industry has developed for recent years. This developed is showed that PV industry will develop and grow quickly in the future. The most important factor of this situation is falling of photovoltaic industry equipment's cost. Most of the research studies are supported the notion in the world.

Yet costs - for panels, inverters, mounting systems and other components - are basically the same in each market [10]. However, system prices seem to depend largely on anticipated rates of return–thus, the greater the incentives, the higher the prices.

IV. TECHNICAL ANALYSIS OF COST REDUCTION POTENTIAL OF PHOTOVOLTAIC SYSTEM INTEGRATED EQUIPMENTS

In recent years, there has been a rapid development in the photovoltaic systems and the researchers centered upon reducing the cost of PV systems in order to enhance their efficiency.

Thanks to R&D studies that are carried out at the present time, there have been developments on production methods of PV module technologies. Therefore, PV panels can be manufactured with lower costs and these panels can generate energy with higher efficiency. Each passing day, production cost per watt, is reduced [11]. However, silicon technologies have higher cost according to the thin film technologies but conversion efficiency of these systems is high. So, these panels are used widely in the world. Also, developing technology and future perspectives of the photovoltaic panel show that thin film and other advanced technologies are dominant and will be preferred in the future. The crystalline PV production chain consists of four stages.

The (crystalline) PV production chain covers four production stages. Their respective cost shares (of total processing costs) are given in Table 1 [12].

Table 1. Production chain with cost shares and technology improvement opportunities units for magnetic properties [12]

Supply Chain	Cost Share	Factors
Ingot (silicon)	17%	Ingot Casting
Wafer	20%	Kerf Loss
		Wafer Thickness
		Wafer Size
		Yield
Cell	22%	Cell Efficiency
		Stability
		Lifetime
		Yield
Module	41%	Module

In twenty years period, many industries have proved that it is possible to make significant cost reductions thanks to increasing volumes [13]. Photovoltaic industry is among these. The capacity of photovoltaic systems established, has increased 40% over the last ten years, and this rate is growing fast. Many studies show that the electricity generation from photovoltaic systems will be energy of the future in the world because the systems have many advantages; however, photovoltaic panel prices is the most important factor to expect this developing. As the industry developed, photovoltaic module costs decreased along a well-established learning curve, in which 22% cost reduction for each cumulative capacity has been observed in the last few decades as it is shown in Figure 3 [14].

Material charges covered by photovoltaic systems, correspond to 50%-70% of the overall cost regarding the technology. In addition, cost reduction is greatly affected by the location, and the reduction in material consumption and the increase in conversion efficiency might affect the material prices per watt [16].

Today, PV technology meets any type of power demand from a few watts to MWs level. It is the superiority of PV-based production to be able to manufacture PV modules from various mines and thus, to maintain energy generation. Wafer-based crystalline silicon technology is used by approximately 80% of the existing production [17, 18].

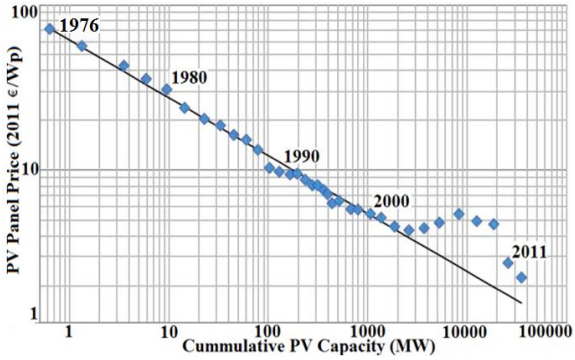


Figure 3. Learning curve on photovoltaic panel price development with 22% learning rate [15]

While photovoltaic installation capacity is increasing, costs of photovoltaic panels have decreased. PV installation capacity is associated also with cost reductions because when the installation capacity is increased, technological improvements and the economies of scale is increased for generation of photovoltaic panels. Also, photovoltaic panel manufacturing process is examined to determine cost reduction potential of photovoltaic panel [17, 18].

The c-Si photovoltaic module is obtained because of c-Si get to share of photovoltaic market is about 70% - 80% and the module have common usage area in the world. If the current cost analysis of photovoltaic systems is examined, cost of the photovoltaic module approximately is $1.75-$1.41. Also, developing technology and increased capacity of photovoltaic electricity generation show that photovoltaic systems prices will decrease until 2020. Expected cost of the photovoltaic module approximately is $0.85-$0.73. This target cost of the photovoltaic module is very important due to need electricity generation in the world and low cost of photovoltaic module will be used common area.

V. CONCLUSION

It is known that the energy generation cost is very important for all of the countries and the countries effort for low cost generation of energy. Solar energy is indispensable source for energy generation. However, the most important parameter is cost of the generated energy.

Solar energy is the most abundant, useful, efficient, environmental friendly, unlimited energy among the renewable energy sources. Also, in recent years, capacity of electricity generation systems from solar energy increases rapidly in the world due to increase in economic viability and reliability of the photovoltaic system.

In this study, cost of the photovoltaic systems is examined and investigated in detail. Firstly, the cost of photovoltaic systems is attained for today perspectives

and also, a discussion on advantages or disadvantages of the photovoltaic systems is included. Capacity of the photovoltaic electricity generation systems in the world is considered separately and the study is extended for expected developments in the future.

Enhanced efficiency of installation is accompanied by experience, scale and learning. There is a general opinion that the automatic tools and higher preassembly levels caused by economies of scale and standardization, will also reduce the costs of installation. Predictions point out that these strategies might save around 30% of work time and costs. 'Plug and play' installations, which reduce the needs of specialized labor, might become possible for the inverters.

Moreover, the paper presents some techniques that have crucial. These techniques contain the cost reduction potential of the photovoltaic systems. Firstly, the manufacturing cost of the photovoltaic module is examined for present-day in detail. Secondly, the cost of the photovoltaic module is predicted for the future times regarding the developed techniques and technology.

The C-Si photovoltaic module is obtained as c-Si and its get to share in photovoltaic market is about 70%- 80% with a wide area of application in the world. If the current cost analysis of photovoltaic systems is examined, cost of the photovoltaic module is approximately $1.75-$1.41. Also, developing technology and increasing capacity of photovoltaic electricity generation indicate that photovoltaic systems prices are going to decrease until 2020. Expected cost of the photovoltaic module is approximately $0.85-$0.73. This target cost of the photovoltaic module is very important due to need of electricity generation in the world and low cost of photovoltaic module be used in broad area.

Ultimately, it seems that the primary factor in determining system prices is the amount of profit available for photovoltaic system operators in each market. The greater the returns from feed-in tariffs and other incentives–such as tax breaks and subsidies - the higher the system prices.

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