International Journal of Applied Power Engineering (IJAPE)
Vol. 1, No. 3, December 2012, pp. 123~128
ISSN: 2252-8792

Photovoltaic Solar Energy Systems: Market Trends in the United States

Joshua Krautmann, Jinwen Zhu
Department of Engineering Technology, Missouri Western State University

Article Info

Article history:

Received Aug 2, 2012
Revised Oct 26, 2012
Accepted Nov 7, 2012

Keyword:

Photovoltaic Systems
Thin-Film Technology
Organic Solar Cells

ABSTRACT

The world today uses more energy than ever before. As a global society we must find more renewable and efficient sources to obtain our energy. One of these sources might come in the form of something that we interact with every day, the sun. Photovoltaic solar cells are a growing market in the renewable energy sector.Basic PV cell materials are discussed and the PV market in the United States is analyzed; arePV solar energysystems the answer to our current and future energy needs?

Corresponding Author:

Joshua Krautmann, Jinwen Zhu
Department of Engineering Technology, Missouri Western State University
e-mail: joshuakrautmann@hotmail.com, jzhu@missouriwestern.edu

1. INTRODUCTION

Energy is one of the most important resources in today's growing economy. Over the last forty years, energy consumption has increased 155% worldwide [1]. Today, the majority of the world's commercial energy supply, greater than 85%, is produced by fossil fuels [2].Moving forward, with the decrease in the production and use of fossil fuels, there will need to be new energy sources developed that can keep up with the global energy needed to run facilities and homes. A main challenge of many countries is finding a sufficient and reliable energy source to meet the needs of their growing economies. Several renewable energy sources are currently in use including wind power, thermal, and the use of photovoltaic solar cells.

The use of photovoltaic solar cells seems like a natural choice for renewable energy. After all, the sun puts out more energy everyday than we could ever think about using. This being said there are many barriers which must be overcome before solar energy can replace traditional sources of power. In an interview with the Bulletin of the Atomic Scientist, Standford Ovshinsky, atechnical pioneer in the field of photovoltaics, said, "The very biggest barrier in the United States is that there is no energy policy that allows for new approaches. Progress is blocked all the time by oil, automobile, coal, and utility industries. These are special interests that feel very challenged and seek to postpone change as long as possible" [3]. Another barrier is that generating electricity using photovoltaic's cost significantly more than from traditional power sources such as the burning of coal.

The purpose of this paper is to inform the reader of the market trends within the photovoltaic solar industry in the United States.

2. PHOTOVOLTAIC SOLAR CELL MATERIALS AND COSTS

A solar cell generates electricity through a difference in potential at the junction of the P and N layers. Several individual solar cells are connected in series on a solar panel and then several solar panels are connected in a solar array. The result is a circuit that can create enough electricity to power DC or AC electric loads. Materials for solar cells can be classified into two main categories, inorganic and organic.

Inorganic solar cell materials include both silicon and compound semiconductor materials. Silicon is still the most popular semiconductor material used to make photovoltaic solar cells, 80%-90%, due to its high efficiency and that the raw material is readily available [4]. Silicon photovoltaic cells are broken down into three categories, single-crystal silicon, polycrystalline silicon, and amorphous silicon. Both single-crystal silicon (sc-Si) and polycrystalline silicon (pc-Si) are used in large photovoltaic systems due to their efficiency and ability to stand up to the elements when installed in outdoor situations [5]. Crystalline silicon does have a major drawback, cost.

Thin film solar cells are an alternative to silicon. Thin film technologies include amorphous thin film silicon (a-Si), single-crystallinethin film, and polycrystalline thin film. Thin film silicon cells, while not being as efficient as single-crystal and multicrystalline silicon cells, are traditionally cheaper to produce. That being said silicon has recently had price reductions that have greatly reduced the thin film's cost advantage [4]. They can also be used in building-integrated photovoltaic products such as solar shingles and on the surface of glass windows. A major problem with amorphous silicon cells is that they don't hold up well when subjected to the elements in an outdoor application. Single-crystalline thin films, produced using gallium arsenide (GaAs), have an advantage due to their high efficiency and their ability to be insensitive to heat [6]. Polycrystalline thin films are made from copper indium diselenide (CIS) and Cadmium Telluride (CdTe). A major use of Cadmium Telluride is in utility-scale PV systems.

Organic solar cell materials include both carbon-based thin film and dye sensitized materials. Organic solar cells (OSC) use semiconducting conjugated polymers instead of silicon. An advantage of this technology is that it can be produced in ultra-thin semiconductor films [7]. These thin-films could be used, as with inorganic cells, in building-integrated PV products or, due to their flexibility and light weight, in an application such as the body of an automobile [8]. Polymers that are used to create OSC's include MDMO-PPV (poly[2-methoxy-5-(3,7-dimethyloctyloxy)] and F8TB (poly(9,9'-dioctylfluoreneco-benzothiadiazole) [9]. Even though OSC's are cheaper to produce than inorganic cells, there are three main problems that must be solved before organic solar cells can take over the market: 1) they are less efficient, 2) they don't offer the same stability as a silicon solar cell under regular operating conditions, and 3) mass production hasn't been developed up to this point[7].

Table 1 [10], shown below, lists the solar cell cost/watt by type of material, along with the maximum efficiency for a PV module using that material type. Notice that the cost and efficiency for the dye-sensitized and organic material types aren't listed. This is due to the fact that these two materials are still in the R&D phase and there isn't sufficient price and efficiency data about them at this time.

Table 1. Solar cell cost/watt and maximum efficiency

		Cell Material				
	units	sc-Si	pc-Si	a-Si	CIS	CdTe
Maximum PV Module Efficiency	%	23	16	7.1-10	12.1	11.2
PV Module Cost	USD/W	< 1.4	< 1.4	0.8	0.9	0.9

3. UNITED STATES SOLAR MARKET TRENDS

The use of photovoltaic (PV) solar systems has increased greatly in the United States over the past few years. This is largely due to three contributing factors:

1. The rising cost of electricity
2. The decrease in the price of photovoltaic solar systems
3. Federal and State incentives for installing PV systems

The United States is an attractive investment opportunity for many people involved in the PV industry because of our high electrical demand, available land for large PV systems, and our isolation from other countries.Even though the use of PV systems has increased in the United States, we still lag behind several countries including Japan, and Germany, which had an installed capacity of 7.4GW (see Figure 1) [11]. Freiburg, Germany is considered to be the solar capital of Europe and is the headquarters of the International Solar Energy Society. The Department of Energy analyzed three policy changes that would have the greatest impact on solar use in the United States in their 2007 Renewable Systems Interconnection reports [12]:

1. Doing away with net metering caps and starting net metering in areas that currently don't use the program
2. Extending the federal investment tax credit
3. Improving interconnection standards

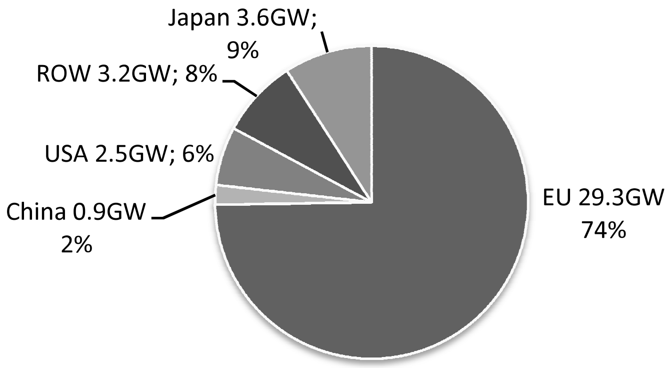

Figure 1. Global Cumulative Installed PV Capacity through 2010[11]

PV systems can be broken down into two main categories, grid-connected systems (tied to the electric grid) and off-grid systems. These categories can then each be broken down into sectors, residential, non-residential, and utility. Grid-connected systems have grown in popularity in all three sectors. In a grid-connected system the PV system is tied to the electrical grid. This allows the end user the ability to use the energy from the PV system during the day and use power from the utility at times when the PV system isn't producing enough power, such as nighttime or on overcast days. Figure 2 shows the rise in grid-connected systems over the past 10 years.As can be seen, in 2000 there were almost no grid-connected PV systems and only a little over 200MW of installed off-grid systems. By 2010 grid-connected systems made up approximately 2.1GW and off-grid systems made up 440MW of installed capacity[11].

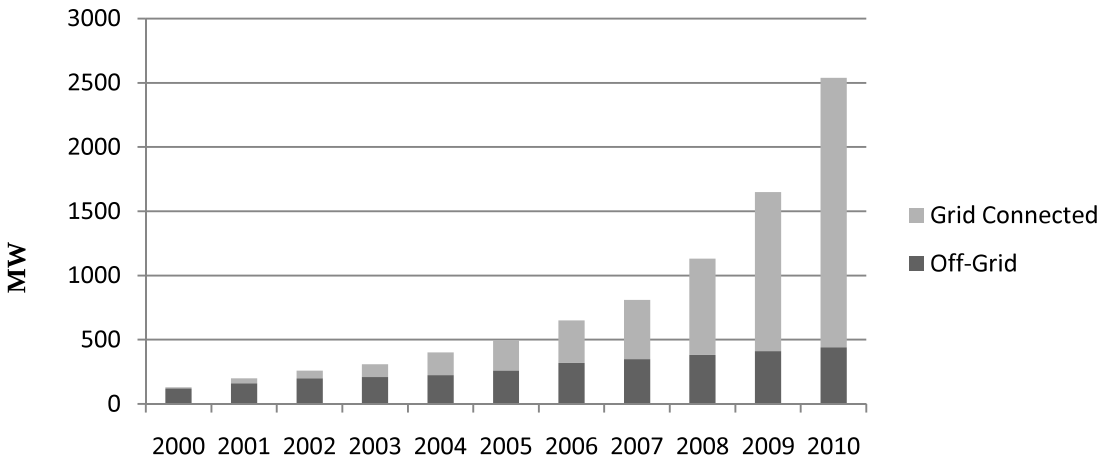

Figure 2. U.S. Cumulative Installed PV Capacity By Interconnection Status [11]

Figure 3 breaks down the annual installed grid-connected PV capacity by sector over the past 10 years. "In, 2010, annual distributed grid-connected PV installations in the United States grew by 62%, to $606MW_{DC}$" [13]. Also, notice that the sector that has grown the most over the last three years is the utility sector. Federal and State tax incentives along with renewable energy requirements in some states are the main reason for the growth in the utility sector.Between 2009 and 2011, utility-scale PV installations rose 630MW.The National Renewable Energy Laboratory states that there are around 16,043MW of solar projects currently in development in the United States [4]. Figure 4 shows a breakdown of the utility-scale solar systems under development in the United States by size and cell technology. Figure 5 shows the total utility-scale solar systems currently in operation.

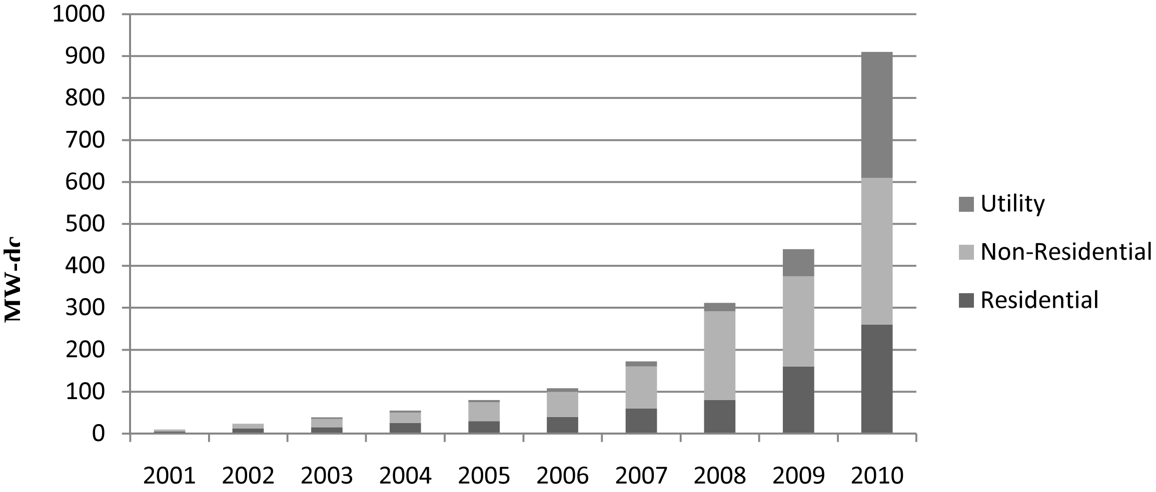

Figure 3. Annual Installed Grid-connected PV Capacity by Sector [13]

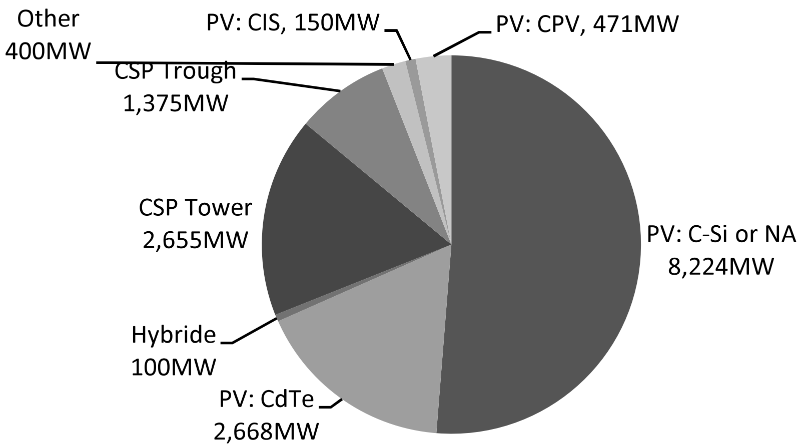

Figure 4.Total U.S. Utility-Scale Solar Capacity Under Development [4]

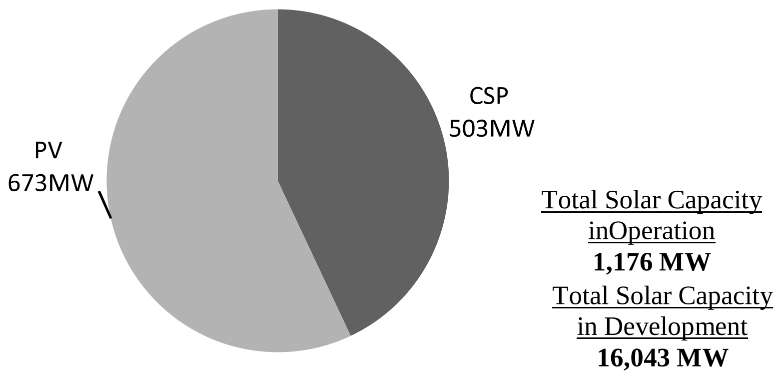

Figure 5. Total Utility-Scale Solar Capacity in Operation [4]

Incentives for installing non-residential photovoltaic systems occur on two different levels, federal and state. At the federal level, incentives are in three different forms, investment tax credit, accelerated tax depreciations, and tax credit bonds. Investment tax credits are tax incentives that permit companies or individuals to deduct a specified percentage of certain investment costs from their tax liability in addition to the normal allowances for depreciation. Prior to 2005, the IRS investment tax credit for solar energy equipment was 10%. In 2005, the Energy Policy Act was passed. The Energy Policy Act of 2005 provides tax breaks and loan guarantees for the development and use of innovative technologies. Included in this legislation was a 20% increase to the solar energy tax credit for projects that came online between 2006 and the beginning of 2008. The Energy Improvement and Extension Act of 2008 included tax credits and incentives for purchasing energy efficient devices along with extending the solar energy tax credit for non-residential installation to December 31, 2016. “This tax credit is realized in the year in which the PV project begins commercial operations, but vests linearly over a 5-year period (i.e., 20% of the 30% credit vests each year over a 5-year period)”[14]. Under provisions in the Internal Revenue Code, electricity producing solar energy equipment falls under an accelerated income tax deduction for depreciation. This allows for the purchaser of commercial solar equipment to obtain a tax benefit “equal to about 56% of the installed cost of a commercial PV system” [14]. Part of the Energy Policy Act of 2005 was the creation of Clean Renewable Energy Bonds. These bonds allow for the purchaser of solar equipment to receive a federal income tax bond instead of paying interest on their loan.

Incentives at the state level vary depending on the state, but generally include items such as net metering, cash incentives, state tax incentives, and multipliers within the state renewable energy portfolio (RPS) policies. Net metering is a policy that allows for utility customers to get reimbursed for electricity that they feed onto the electric grid when their solar energy system produces more power than they consume. The customer gets reimbursed at a rate which is comparable to the money that they would have paid per kilowatt/hour. Forty-four states and the District of Columbia participate is some level of net metering. State provided cash incentives for installing PV systems have been a major part of getting people interested in using solar energy for their facilities. The cash incentives help cover the cost of installing the systems. An example of these cash incentives is the California Solar Initiative. The program provides performance-based incentives to systems larger than 50kW [14]. Some states also provide tax incentives for installing PV systems. For example, a non-residential Grid-tied PV installation in Arizona that qualifies for the Utility Rebate Program can receive a rebate of $1.75/W for a PV system that produces up to 30kW of electricity [6]. A renewable energy portfolio is a regulation that some states have in place that requires the electrical providers to increase production of energy from renewable energy sources. In order to meet the RPS requirements, electricity providers have to prove they are using renewable energy sources. They do this by obtaining renewable energy credits (RECs) when they install items such a solar energy systems.

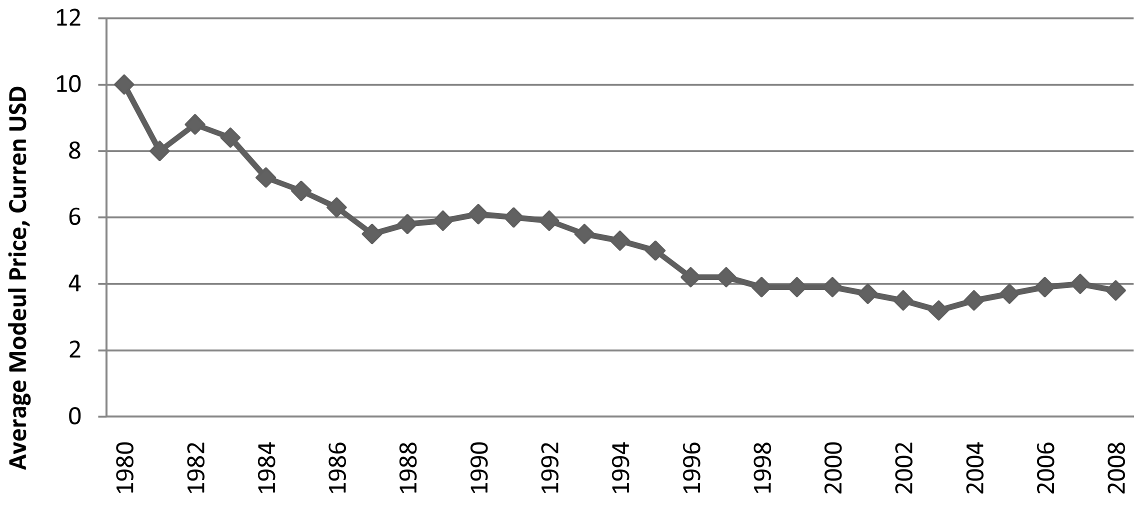

Figure 6. Average PV Module Prices, All Technologies, 1980-2008 [16]

The cost of PV Modules hasalways been a major factor in choosing to install a solar energy system at a facility. Research indicates the costs of purchasing and installing photovoltaic systems as varying greatly from country to country. Around 40 to 60 percent of the cost of a PV system is in production [15]. Initially, the high cost and low energy output were a big turnoff for many customers. The cost of PV modules has steadily decreased since the 1980's and today along with tax incentives and more strict energy regulations have finally reached a point where they are economical to install. Figure 6, below, shows the global average of PV modules across all PV technologies from 1980 through 2010 [16]. This graph indicates the average cost across all of the PV technologies. As discussed previously, some technologies are cheaper to produce than others. The cost increases between 1988 and 1990 due to a low supply and high demand for PV modules. The cost also increases from 2003 to mid 2008. This once again is due to strong demand for PV modules and a limited supply of materials such as polysilicon. The cost started to decrease again in 2008 due to the economic recession and a readily available supply of poly-silicon and modules [16].

4. CONCLUSION

Photovoltaic systems have started to gain ground in the United States, especially in the past couple of years. Federal and state incentives and tax breaks along with the rising cost of energy and lower PV cost have brought solar use to the forefront. Technological breakthroughs in photovoltaic efficiency and materials, such as thin-films and organic solar cells, have allowed solar technology to be lighter and more flexible than ever before, opening a whole new realm of possibilities. Increasing energy cost and environmental concerns demand that we find a solution to our energy needs. Photovoltaic systems and technology provide us with a possible solution to these issues and has a promising future.

REFERENCES

[1] Sinha, Bikramjit. "Trends in Global Solar Photovoltaic Research: Silicon Versus Non-Silicon Materials." *Current Science*; March 2011
[2] Abdullah, S.M., I.M. Muslih, and W. Abu Husain. "National Grid, Diesel, and PhotovoltaicPower Generation Systems in Jordan: An Engineering and Economical Evaluation." *Energy Sources, Part B*; 2010
[3] Bulletin of the Atomic Scientists. "Standford Ovshinsky: Pursuing Solar Electricity at a CostEqual to or Lower Than That of coal Electricity." 2011
[4] Mendelsohn, Michael, Travis Lowder, and Brendan Canavan. "Utility-Scale Concentrating SolarPower and Photovoltaics Projects: A Technology and Market Overview." NationalRenewable Energy Laboratory, Technical Report; April 2012
[5] Sinh, Dilawar, Philip Jennings. "The Outlook for Crystalline Solar Photovoltaic Technology overthe Next Decade." American Institute of Physics; 2007
[6] energy.gov, U.S. Department of Energy, 2012
[7] Liao, Kang-Shyang, Soniya D. Yambem, Amrita Haldar, Nigel J. Alley, Seamus A. Curran. "Designs and Architectures for the Next Generation of Organic Solar Cells." *Energies*; 2010
[8] Miyake, Kunihito, Yasunori Uetani, Takahiro Seike, Takehito Kato, Kenichiro Oya, KenYoshimura, and Toshihiro Ohnishi. "Development of Next Generation Organic Solar Cell." Sumitomo Chemical Co., Ltd; 2010
[9] Hoppe, Harald and Niyazi Serdar Sariciftci. "Organic Solar Cells: An Overview." Materials Research Society, 2004
[10] International Renewable Energy Agency. "Renewable Energy Technologies: CostAnalysis Series." June 2012
[11] United States Department of Energy. "2010 Solar Technology Market Report." 2010
[12] United States Department of Energy. "Solar Technology Program, Multi Year Program Plan 2008-2012." April 2008
[13] Sherwood, Larry. "U.S. Solar Market Trends 2010." June 2011
[14] Bolinger, Mark. "Financing Non-Residential Photovoltaic Projects: Options and Implications." *Lawrence Berkley National Laboratory*; January 2009
[15] www.solarserver.com, 2012
[16] United States Department of Energy. "2008 Solar Technology Market Report." 2008

BIOGRAPHIES OF AUTHORS

Joshua Krautmann holds a Bachelor of Science in Electronics Engineering Technology, May 2005, and a Masters of Applied Science in Engineering Technology Management, December 2012, both from Missouri Western State University. He has been employed as an Electrical Engineering Technician at Black and Veatch Corporation for seven and a half years completing electrical power and lighting designs for water and wastewater facilities.

Jinwen Zhu holds a Ph.D. in Electrical Engineering, August 2005, and a M.S. in Computer Science, December 2003, both from University of North Carolina at Charlotte. He is an associate professor at Missouri Western State University, USA. His research/teaching interests include renewable energy, nano-structured devices, power system automation, communications, and engineering education.