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A Comparative Study on Solar Photovoltaic Industrial Development In Germany, China and USA

Wei Long Oji-Okoro Izuchukwu*
School of Economics, Wuhan University of Technology Wuhan, P.R. China 430070.
*E-mail of corresponding author: izulenny@yahoo.com

Abstract
The world demand for energy has increased greatly that the conventional sources of electricity is unable to meet up this demand. In recent years this situation has made the solar power grow remarkably, while costs are decreasing dramatically as technology and rapid market growth enable economies of scale. This paper presents a comparative study on solar PV industrial development in Germany, China and USA by analyzing the PV industrial development, market positions and trend with a focus on their competitive policies. The analysis shows that German PV market is growing tremendously and had been the global leader in the PV market place but with the up spring of China and USA in the market there might be a global shift in developing a balanced market that will promote the PV industry globally. The paper also explores options for possible collaboration among the three countries in the field of PV industry.
Keywords: Photovoltaic (PV) Industry, Germany, China, USA, Market, Solar System, Balanced Development, Policies, Market Potentials.

1 Introduction

The Photovoltaic (PV) generation has long been acknowledged as a clean and secure energy technology, which draws the direct conversion of sunlight into energy by the means of solar cells without any moving parts or environmental emission during operation. In the world today, one of the major global energy challenges is ensuring access to clean and sustainable energy but with the world economic development and growing demand for energy, the conventional energy sources have become increasingly incapable to meet the world demand for energy. However, it has been estimated by IEA (2009) that about 1.3 billion people in the world lack electricity supply in the rural areas of which 585 million are in sub-Saharan Africa, thus the shortage in electricity supply has prevented most developing countries to attain the Millennium Development Goal (MDG) target,

The paper tends to focus on Germany, China and USA due to the rapid development of the PV sector in these countries, where constant improvement in production chain and the demand for PV panels is driven by deployment support schemes. More significantly, despite the economic crisis, the PV market of these countries has doubled in 2010 compared to previous years making the total power installed in the world increased by 65% to around 38GW.

This study, by using a comparative approach, tends to examine the solar PV industrial development in the above three countries, aiming at reviewing regional PV system development, the PV market distribution, national policies and the future market forecast of the PV industry.

2 Literature Review on Photovoltaic System

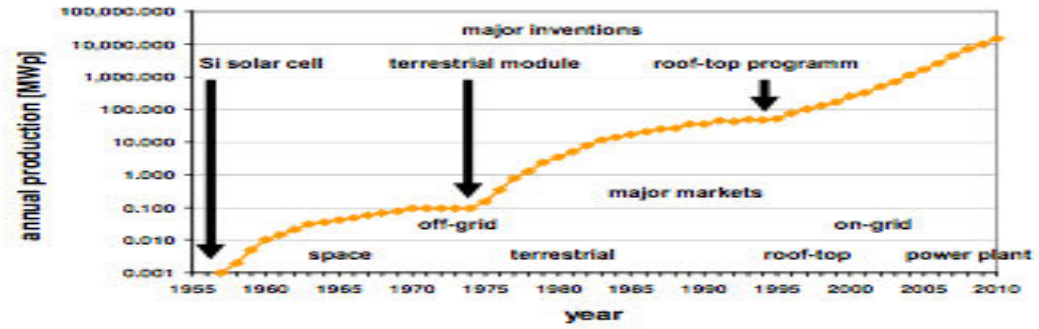
Many studies have been conducted on economic consideration of renewable energy system. However, they have been a critical restriction of the PV system integration on supply-demand balance of power system by various scholars (Charmers *et al* 1985; Bouzguenda and Rahman, 1993: Assno *et al*, 1996) they stipulated that the economic value of a PV system has reduced significantly which has an increase level penetration due to high variability. (Piwko *et al*., 2007; 2010; Ogimoto *et al*., 2010) stated that the critical impact on supply-demand balance of power comes from the total generation of the PV system within a power system, due to the fact that the total electricity generation of many PV system in broad areas should have less random and fast variation because the generation output variation of many PV system have low correlation and can rule each other in the smoothing effect. Therefore, in order to ascertain the financing options, viability, feasibility, risk and governance structure associated in implementing off-grid electrification, Bhattacharyya (2012) discussed the business dimensions covering the participatory business models, funding challenges and issues involving the regulations and governance in the off-grid electrification system. Maycock and Bradford (2007) Suggested that if these technologies do not become economically competitive, the public support would be unable to maintain their momentum as the cost of subsidies increases with the scale of the deployments. Thus, the future growth of the PV industries depends on finding a large market in which they are economically competitive without government intervention through subsidies.

3 Photovoltaic Market Diffusion Stages: A Historical Review

Historically, the PV system technology has begun over a hundred years ago. PV system does not pose threat of environmental hazard caused by fuel sources, such as global warming, water pollution, acid rain, destruction of natural resources caused by fuel spillage and smog-formation. Due to these advantages, the PV diffusion into the market has experienced different stages of development.

The diffusion of PV technology into the market started with the invention of silicon (Si) solar cell in 1954 by Darryl Chapin, Calvin Fuller and Gerald Pearson, associates of Bell Labs. Initially, the PV technology was developed to power satellites as less cost option for space applications and induced the first growth stage for early PV industry. Elliot Berman started the second growth stage of PV for terrestrial off-grid solutions, which as shown strong efficiency for decentralized energy supply in developing countries for rural population Ch. Breyer *et al* (2009). Roof -top programs and FiT laws in countries like Japan and Germany started the third high growth period for PV applications in on-grid markets, which is characterized in its economy by grid-parity concept Perlin (1999). Thereafter, it was the introduction of the PV power plant, which started in late 2000's and early 2010 and was fast gaining ground due to their positive economic impact and best described by the fuel-parity concept.

Fig 1. Historic PV diffusion stages and market segments.

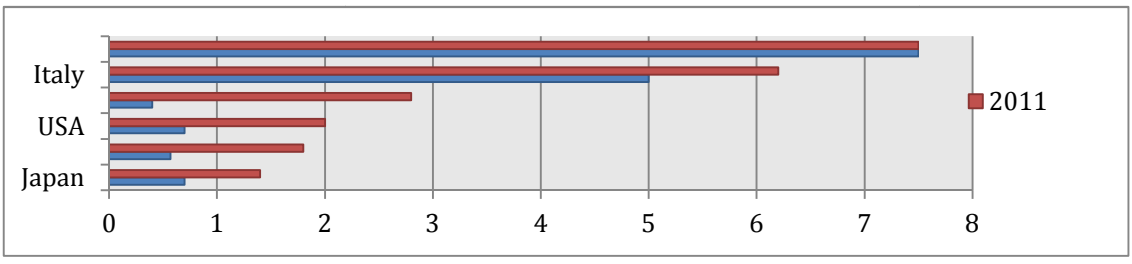


Sources: EUPVSEC 2010 trend in Photovoltaic application

The diagram above shows that the three diffusion stages are marked by three major inventions, Si solar cell, terrestrial PV module and Roof -top programs. From 1957- 1973, the off-grid space application dominated the first diffusion stage and showed an average annual growth rate of about 33%. 1975-1995 projected the terrestrial off-grid application dominating the second diffusion stage, generating an average of annual growth rate of about 33%. The roof top grid system dominated the third diffusion stage with an average annual growth rate as high as 45%, where as the first utility-scale start the next diffusion stage. The off-grid PV markets have been growing at a constant high rate of about 15-20% in the mid 1990s, but due to higher growth rates of on-grid markets, the relative proportion of global off-grid installation declined to 5% of total installed PV capacity.

The PV market in the past decade has grown faster than expectation around the world. However, the solar PV industry in 2011 has showed a remarkable growth trend even in the midst of the world financial crisis and the period of the PV industry consolidation. In 2011, the top five PV market globally were: Germany, Italy, China, USA and France. These countries together accounted for 74% of the global demand and China emerged as the fastest growing market, which had installation growth of 470% with 2.2GW. The European countries accounted for 18.7GW or 68% of the world demand in 2011, down from 82% in 2010. Another great achievement recorded in 2011 also witnessed the expansion of new markets in the Americas, Africa and Middle East. In these places, the pace of investment in solar is up to three times ahead the average in other parts of the world, particularly in countries like UAE, Jordan and Qatar.

Fig 2. Global Solar Photovoltaic Production Capacity 2010 - 2011.



Sources: NPD Solarbuzz 2012 Marketbuzz

Table1 Global Market and Cumulative Installed PV Capacity 2012

	Country	Cumulative 2011	Market 2012	Cumulative 2012
EU 27	Germany	24678	7600	32278
	Italy	12913	3337	16250
	France	3000	1200	4200
	UK	875	1100	1975
	Greece	624	912	1536
	Bulgaria	145	670	815
	Belgium	2018	655	2672
	Austria	190	230	420
	Denmark	16	200	216
	Spain	4900	200	5100
	Netherlands	145	125	270
	Czech Republic	1969	116	2085
	Slovenia	81	114	195
	Portugal	183	30	213
	Slovakia	468	10	478
Europe	Switzerland	230	170	400
	Ukraine	190	131	321
Non-Europe	China	3500	3500	7000
	US	4382.5	3200	7583
	Japan	4914.43	2000	6914
	India	460.91	1000	1461
	Australia	1400	800	2200
	Canada	563	200	763
	Thailand	150	210	360
	Korea	754	209	963
	Israel	189.7	60	250

Source: EPIA (2012)

The result from the table above shows that there is a strong global market for PV technology, despite tough economic crises and regulatory uncertainty.
According to the EPIA (2012), the rapid growth rate recorded by the PV industry cannot be expected to last forever, stating that the industry is now in a weathering period of uncertainty in the short term, but over the medium and long terms the prospect for continued robust growth are good.

4 Photovoltaic Market Positions in the Three Countries

Germany is the world's leading PV market with a total accumulation of PV capacity of 24.8GW and 7.5GW newly installed, converting more solar energy into electricity than any other countries with an equivalent of 35.6% shares. In 2011 Germany achieved grid parity with levelized cost of energy of newly installed system equivalent to retail electricity price for household.
The German government is committed to PV growth and pledge to support the installation of 52GW to the FiT. As a result, the volume is expected to reflect in the next 3 years with a 10% estimated PV share of total electricity consumption. However, the integrated market structure of the PV industry in Germany is been flooded with highly experienced research and developers, system integrators and system installers that provides the necessary support for sales which has led to rapid market growth. The PV industry in Germany is the largest producer worldwide that has 35% share of the market and also a leading PV manufacturer in Europe of high-tech PV technologies of wafer-based, thin-film and organic PV, employed over 110,000 people. In other market segments, such as inverter production where these high-tech PV technologies are developed, produced and made commercially available in Germany with 75% of European cell production capacity and more than 80% of European module production capacity in 2011, thus, making the industry a leading global player of renowned research institutes, innovation, small and medium–sized enterprises.
China, however is the world's largest PV cell manufacturer, it accounts for 40% of global output out of which 95% of the production is been exported with the remaining 5% installed domestically for off-grid rural electrification. China PV market in 2011 grew to a total of 2.75GW as a result of the national demand making it the third largest PV market. Therefore its domestic demand for PV power is expected to reach 5GW by the end of 2012 (China daily 2013). PV industry in China is a strategic emerging sector and measures are put in place to expand the domestic market as well encourage the use of electricity generation through PV cell. Moreover, China's PV industry gradually entered a golden period of development with strong support from government stimulating market demand as cumulative installed capacity of PV system in China was about 140MW at the end of 2008 and nearly 400 companies engaged in the production of PV modules and cells. China's PV supply chain includes ingots and wafers, solar cells and modules, solar grade silicon, installation and on/off grid system. They are mostly in the midstream and downstream of the industry chain in which the low cost of labor and the achievement of economies of scale are being controlled by per unit cost, however, the industry chain is faced with serious problems of technology progress and the homogenization of component. Production is heavily

dependent on imports and the level of technology is still at the infant stage, which has made China's PV industry to lag behind other developed countries.

Table 2 below illustrated Chinese PV production position as one of the top level in the world, but the market highly rely on foreign countries. Since 2006, the exported PV module shares were more than 95% and the domestic PV installation shares were only less than 5%.

Table 2: Share of Export and Domestic Installation of PV Modules for China (2006-2010)

Year	**2006**	**2007**	**2008**	**2009**	**2010**
PV Production (MW)	4000.0	1088.0	2600.0	4011.0	8000.0
Export (MW)	390.0	1068.0	2560.0	3581.0	7500.0
Installation (MW)	10.0	20.0	40.0	160.0	500.0
Share of Export (%)	97.5	98.2	98.5	96.0	93.8

Sources: *Photovoltaic Power Systems (PVPS) annual report* 2010

PV industry in the USA is booming due to strong consumer demand and financial incentives from the government, states and utilities. The capacity of PV installation doubled compared to 2010. More than 64,000 grid-connected PV installations were completed in 2011, which shows a 30% increase over the number of installations in 2010.

The market developed evenly in the residential, commercial and utility scale. The residential system accounted for 88% of these installations and is driven by third-party ownership instead of customer-owned system, which has made the USA rapidly emerging as one of the world leading markets for PV solar power. While the commercial segment of the market grew rapidly in 2011 with 45% share of the market representing close to 40% of the new added capacity, the manufacturing sector comprises about 100 production facilities making primary PV components such as (Polysilicon, wafers, cell modules and inverters) and produced PV modules with a capacity of 1.1 peak giga-watts in 2010, with the total shipment of the PV cell and modules at about $6.4billion. The US market development was connected in seven states namely California, New Jersey, Arizona, New Mexico, Colorado, Pennsylvania and New York.

In summary to the comparison of photovoltaic market structure in these three countries, the Germany PV market is flooded with highly experienced R&D compared to other countries which provides them the necessary support for the matured sales that has led to rapid market growth. While the Chinese PV Market structure is mostly the midstream and downstream in the industry chain, where as per unit cost are controlled through low labor cost and achieving economies of scale. Comparatively, the USA PV market remain huge and stimulated by the subsidies for residential solar system that has caused the PV price to decline by 18% with doubling of installation volume that has led to the growth of the market.

4.1 Competitive Policies in Photovoltaic Industry

The investigation found that the main mechanism for PV growth in Germany was the combinations of low interest financing, long contract length and multi-year FiT pricing. Policy initiated by the government has been successful and has led to numerous projects being developed and financed.

Whereas in China, a combination of large-scale demonstration projects, feed-in tariffs has been applied and the scale of support has also increased which has resulted in a strong increase of annual installation in 2009. The Chinese government is aware of the strategic emerging PV industry and has put up measures to expand the domestic market and as well encourage the use of electricity generation through PV cells in balancing demand and supply. On the demand side, China targeted the residential sector and provided incentives such as subsidies to purchase and install solar PV system while on the supply side, the government supported the PV industry to reduce cost and develop an exportation strategy to export solar PV system globally which is in contrast with Germany and USA.

However in United State each state has drafted policies and programs that seek best advantage of a particular market and social assets of their jurisdiction which differ from China and Germany in order to stimulate rapid growth in the utilization of PV system. Unlike the other countries the US has a patchwork of highly complex intermittently funded incentive schemes, which varies widely from one state to another. The following table gives an overview of current PV policy instrument in Germany, China and USA.

Table 3. Current PV Policy of Germany, China and USA

	Germany	China	USA
Deployment Program	*Erneuerbare-Energien Gesetz (EEG) in 2000. *100 Roofs program in 2003. *Corridor Revision Proposal 2011.	* Gold Sun Initiative in 2009. *FiT by Jiangsu Province in 2009. * Loan Guarantee for Utilities by Government.	*Renewable Portfolio Standard (RPS) in 2009. *Net metering in 2009. *Rebate Programs in 2009.
Investment support	* Grants/ Cash incentives (Joint Task program and investment Allows Program). *Reduced interest loan in the National and state level. *Public guarantees at state and combined state and federal level.	*Small technology based firm innovation fund. *Loan guarantee by government. *Credits and Loans facilities provided by government or state banks. *Tax by local government and Refund of Land fee.	*Investment Tax Credit (ITC) *Modified Accelerated Cost Recovery System (MACRS) aim at reducing initial PV projects development cost by more than 50% *American Recovery & Reinvestment Act (ARRA) Allow manufacturers to benefit 30% Federal Tax Credit.
R&D Support	*Germany Government Federal Ministry of Environment, Natural conservation and Nuclear Safety Pv R&D support of $52.4 M. *Germany Federal Ministry of Education and Research PV R&D support of $24.9M.	*Refund of Import and Value Added Tax for R&D equipment. *National Development and Reform Commission (NDRC) Invested $ 6.5M for High Tech Industry Development.	Department of Energy (DOE) funding of $112.5M to drive down cost of PV through R&D. * R&D tax credit. *San Francisco based global research organization invested $8.99B

Sources: Authors

4.2 The Possible Collaboration Among the Big Three

The PV system will undoubtedly keep on playing strategic role in the world. With vast PV resources existing in many countries where deployment has not yet begun to approach its potential, many emerging economies like China are becoming important global player in PV both in terms of installed capacity and in manufacturing. Therefore, to strengthen the position of the PV industry in this segment of the global market, possible cross border collaboration is essential in technology, industrial division and policy adaption with Germany, China and USA. However, collaboration with this big three will ensure that important issues are addressed according to areas of national expertise, which will expand their R&D collaboration and make best use of the countries national competencies to address the fundamental challenge of the PV industry. This will further reduce the cost of energy, provide strategic and technological knowledge and enhance policy support to increase the industry capacity to deploy safe and reliable PV system within the countries. This is critical to fulfill each government's responsibilities in achieving part of its energy sustainability through renewable energy resource and addressing clean energy priorities. Furthermore, a leveraged effort by these three countries through collaboration will mobilize significant efforts in adopting the most efficient of PV technologies, meet cost-reduction targets and make a significant contribution to the electricity supply in the long run.

5 Market Expectation of Photovoltaic Industry

European market has dominated the global PV market in the past, but yet, there is still big potentials for PV market growth in the rest of the world with steady stream of policy incentives put into action by policy markers such as FiT, renewable portfolio standard, community solar financing and sustainable energy utilities which will demonstrate a capacity of change globally, more significantly driven by local and global energy demand.

China is expected to be one of the fastest growing PV market following it achievements in coming years when it was clearly and officially known to the world as a multi-gigawatt market, which was driven by various national and provincial programs. It has set 5GW as an official minimum PV target by 2015 with a long-term target of 20 to 30GW by 2020. This build on the 2,200MW installed in 2011 (1.8GW) for large scale ground mounted installations and 400MW for the rooftop project which gave cumulative capacity of 3,093MW thus, making China one of the global top three markets with extraordinary potential and a bright development for years to come. However, it is estimated that a total of installed capacity in 2016 could reach more than 35GW with an

annual market that could reach 10GW. Other fast growing markets include USA, Asia particularly India, Latin America, the Middle East and North African Countries. Furthermore the US market is also expected to reach more than 10GW in 2016 due to the fact that the US PV market is one of the developed economies able to absorb PV projects in significant quantities that have resulted in potential rapid growth with the utility-scale project driving the market outside of any support-scheme framework.

The future PV market growth highly depends on public support to develop markets and collaboration among the Big Three, which can drive down cost. According to EPIA report (2012) which stated that the "PV potential of the sunbelt countries where PV can readily compete with diesel generators for peak power generation without financial support could range from 60 to 250GW by 2020 and 260 to 1,100GW in 2030 and with the faster than expected price decrease that the industry experienced in 2011." The number of established markets with growth potential is limited and the lowering cost is becoming less of an option. But with the problem of climate change and pressure on government to explore alternative sources of energy, many markets are emerging along with competition lending to price decline. This could lead to production plant closures around the world, as a result of non-profitability which on the other hand is happening. PV manufacturers are grappling with falling module prices.

This has adversely affected the operations of many solar companies. Some of the companies are forced to reassess their business models and others to close factories or declare bankruptcy, like the case of one of the world largest makers of solar panels Suntech Power Holdings, declared bankrupt by the Chinese government on 18th March 2013. This was due to trade disputes the Chinese solar industry had with the United States and Europe over alleged Chinese dumping and subsidies. However, lower prices may be good for PV consumer, but they are squeezing manufacturers. As a result, there is need for policy makers and market strategies to rescue the industry, which will depend largely on the market evolution in European countries and the ability of the policy makers to maintain a favorable consumer-manufacturer market condition. Through these strategies, the market could be expected to increase more than 75GW in 2016 with two-third coming from the new markets outside Europe that will help ensure a major growth and market development in the coming years. Therefore, in achieving this goal of public investment in PV, R&D is required to sustain progress in the technology, performance and economic value while incentives are utilized to organize higher scale investment in solar energy.

6 Conclusions

It is imperative to note that PV energy generation system could be seen as one of the significant sources of alternative energy and a unique prospective solution to energy crises in the future. The study identified that the rapid rate at which German market is growing globally and had become a leader in PV market, other countries like China and US are showing signs that there may soon be a slight shift of this balance to their favor especially China is now seen as a production giant and a source of increase in supply followed by US which is also gaining momentum. The future PV market growth highly depends on public support to develop the market and collaboration among the Big Three. More significantly, if the PV market is expected to grow continually and it is seen as a strategic emerging sector with significant importance, there is a need for shift in balance development to focus on new markets both outside and inside Europe and also a progressive adjustment in energy structure that will promote reforms in energy production and consumption with proper policy support, balance market development and continued industrial innovation which will lead to continuous and remarkable growth rate of PV market in the short and long period.

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