Impact of Political Economy on Photovoltaic (PV) Solar Power in Germany

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Abstract

Solar power can help the fight against climate change. This paper analyzes the political economy of the photovoltaic (PV) solar power industry in Germany. The many aspects of the analyses are vital to the understanding. Germany became one of the largest producers of PV solar power in the world over the past few decades, with significant growth in installations and capacity from 2005 to 2015. By examining the role of government policy, public opinion, and technology in Germany's PV solar power growth and development, we can consider lessons that other nations can learn from the German experience in developing their PV solar industries. The results of this study contribute knowledge to the subject by showing how a combination of social, political, economic, and technological factors facilitated the growth of PV solar power in Germany. As technological innovation advances and cost barriers to photovoltaic (PV) power steadily decrease, photovoltaic power is becoming an affordable and irreplaceable renewable and sustainable energy source. Facing the challenges of replacing "dirty energy" with PV solar power, Germany has driven itself to become a "solar super power".

Keywords: political economy, photovoltaic power, PV solar industry, technological innovation, solar super power

Introduction

The rapid development of photovoltaic (PV) solar power in Germany has made Germany a "solar super power". This paper will examine how Germany has developed PV power and managed the significant challenges of capturing the sun's energy and turning it into electricity.

The fears of global warming caused by the increase of greenhouse gases into the atmosphere are growing. Climate change is the most pressing issue facing mankind today according to many scientists. The Earth has set a temperature record for the third straight year in 2016 (Gillis, 2017). As a result, renewable and sustainable energy development is increasing around the world today. One of these renewable and sustainable resources is PV solar power. (Crook J., Crook, R., Foster, P., & Peirs, M., 2011). As a solar super power, Germany has been vigorously designing and implementing a comprehensive solar photovoltaic (PV) infrastructure to make the gradual transition from burning fossil fuels and the reliance on atomic power toward renewable and sustainable energy sources. The growth of PV solar power production and installation over the past several decades in Germany are impressive (Kunzig, 2015). It has had to overcome numerous barriers along the way to attain its position as the second the leading generator of solar PV power in the world. This paper will not only introduce the basics of PV solar power, for the layman, but also examine the geographic, social, economic, political and technological support and challenges that Germany has faced and how it is overcoming these obstacles. Finally, this paper will explore what lessons other countries might discover from Germany's experience in developing its PV solar power industry and where the solar PV industry in Germany is heading.

The rationale for choosing Germany in this study is because it has been a world leader in PV solar power generation for decades. It has approached its PV solar energy strategies and policies in a coordinated, strategic and integrated framework (Wirth, 2017).

PV solar power

PV solar power uses semiconductor technology to directly convert sunlight into electricity. PV solar power is produced from the sun by a concept called "solar irradiance". Solar irradiance is the power per unit of area received from the sun in the form of electromagnetic radiation (Knier, 2008). The sun hits every square meter of Earth with more than 1360 watts of power. In fourteen and one-half seconds, the sun provides as much energy to Earth as humanity uses in one day (Naam, 2011). The sun's power is endless.

Measurement of PV solar power

Solar power generation is measured in kilowatts (kW): a kilowatt is a unit of electrical power equal to 1,000 watts, a megawatt (MW) is equal to1 million watts, and a gigawatt is equal to 1 billion watts of power.

Types of PV solar systems

There are several types of PV solar systems: roof top, building integrated systems and "farm" PV solar systems. The later has the most scale. The end users of solar power operators may be residential, commercial or utility owned and operated solar power generation units. While PV solar power can be generated for just individual residential needs, disconnected to the electricity grid, this paper will examine the PV solar power connected to the electricity grid. For residential and commercial units, the PV panels are usually placed on the roofs of residential and commercial buildings, while for scaled solar projects, the panels are set on large areas of land (solar farms). When sunlight hits the panels, electric fields are created due to the semi-conductive nature of the cells. (Solar Power Authority, 2016). Metrics of PV solar power production in the world. The world leaders in PV solar power capacity and installation at the end of 2015 are found in Figure 1 below:

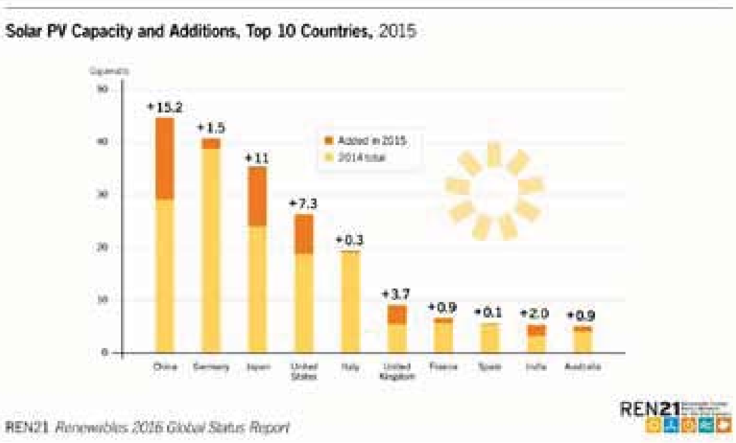

Figure 1: Solar PV Capacity and Additions, Top 10 Countries, 2015
Source: REN 21 Renewable 2016 Global Status Report

Germany was second in the world in PV solar capacity with 39,787 MWh in 2015; however, it only installed 1.5 GW of new PV power in 2015. As recently as 2014, Germany was the top producer of PV solar power, but China surpassed Germany's PV solar production by the end of 2015 (Rose, 2016). By the end of 2016, PV solar energy had nearly tripled in Germany over the past ten years (Thompson, 2015). PV solar power provided approximately 7.4% of Germany's net electricity consumption or approximately 38.3 Terawatts of power in 2016 (Wirth, 2017).

Table 1

Statistics of PV capacity and installation in Germany from 2005 to 2015

Year	PV Capacity (MW)	% change	PV Installations	% change
2005	2,056	-	1,000	-
2006	2,899	41.0	900	-10.0
2007	4,170	43.8	1,200	33.3
2008	6,120	46.8	1,900	58.3
2009	10,566	72.6	4,300	126.3
2010	17,944	69.8	7,200	67.4
2011	25,429	41.7	7,300	1.4
2012	33,033	29.9	7,400	1.4
2013	36,337	10.0	3,200	-56.8
2014	38,343	5.5	2,000	-37.5
2015	39,787	3.8	1,200	-40.0

Source: Federal Ministry for Economic Affairs and Energy, Germany

Analysis: The growth of solar energy capacity has increased greatly in the past ten years from 2,056 MW in 2005 to 39,787 MW in 2015. More than 7000 MW of PV solar capacity had been installed annually during the record years of 2010 through 2012. From 2008 to 2009, PV solar installations grew by over one hundred and twenty percent, while total PV solar capacity increased by over seventy percent. From 2009 to 2010, installations grew by over sixty percent and total capacity increased by over sixty nine percent. PV solar installations and capacity grew so fast during this time because the German public were "true believers" in the benefits of solar power and the government subsidies created monetary incentives. These incentives became more attractive as the installations costs declined.

PV capacity was 2,056 MW in 2005, comprising only .21 per-cent of gross electricity consumption. However, in 2015, PV capacity was 39,787 MW which comprised approximately 6.5 per-cent of gross electricity consumption. (Federal Ministry for Economic Affairs and Energy, 2016). From 2012 till 2015, new installations decreased significantly as total PV capacity increased by approximately 20 percent. In 2015, Germany added only 1200 MW of new PV installations. The main reasons for this downward trend were due to the decrease in the feed-in-tariffs (FIT) subsidies. Also, "too much" solar power was being produced, at times, which was causing instability to the electric power grid.

Geographic setting

Germany imports most of its oil. It relies on Russia for its natural gas supply. Germany has a lot of coal reserves but it is mostly lignite coal, one of the dirtiest of coal types. Germany does not have an abundance of solar irradiation, like Thailand or the Western parts of the United States. Even though Germany combines a high northern latitude and high cloud cover, it is a world leader in PV solar capacity (Curry, 2013). Its solar potential averages only about 3.08 sun hours per day. This solar irradiance is equivalent to that of Alaska in the United States (Wilson, 2015). Therefore, it is remarkable that Germany has become a PV solar power leader in the world. Furthermore, Germany does not have a large land mass. It covers 348,672 square kilometers, making it the 62nd largest country in the world by size, slightly ahead of Congo (Republic), 63rd, Finland, 64th, and Malaysia, number 65th, but just behind Japan, ranked as the 61st largest country in the world. However, Germany's economy is huge. Its GDP is the 4th largest in the world: $3.468 trillion dollars. (International Monetary Fund, 2016). There are several reasons how Germany could become a "solar super power" - the strength of its economy is one of them.

Social support

Systematic "energy change" and the transformation of the national electricity infrastructure are difficult. The costs of PV solar power generation are higher than conventional power generation. In Germany's case, it required that the population accept higher utility bills to pay for subsidies that incentivized PV solar production. In many countries, this would have been politically and economically impossible. Moreover, because the fossil fuel power industries and utilities have vested economic and politcal interests in maintaining the status quo, strong public support was essential for PV solar power generation to gain traction. The Green Party movement in the 1970s held demonstrations for sustainable and renewable energy. The Chernobyl disaster reinforced these convictions (Gebauer, 2006). Most Germans understand that there would have to be "a price" to pay for "green power" and for PV solar development. At the beginning of 2000, 92% of the German people's support was rooted in "an eco-friendly culture", a collective desire to abandon nuclear energy and embrace policies that allowed citizens to profit from selling their electricity to the grid (Kunzig, 2015). Despite the cost to the consumers and the utility companies, there is wide spread public support for renewable energies in Germany. In a poll conducted in October 2016 by Universities of Stuttgart and Münster in cooperation with the Fraunhofer Institute for Systems and Innovation Research and published in "Clean Energy Wire" in 2016, when a sample of the German public was asked to give their opinion on the statement, "We need a resolute switch to renewable energies.", 33% of the respondents answered, "fully agree" while 27% answered "agree somewhat". On the other hand, only 13% answered "disagree somewhat" and 5% answered "fully disagree". (Amelang & Wettengel, 2017)

Political support

Established, influential, and economically powerful energy and utility corporations and their lobbyists do not favor giving away energy market share and incurring deep expenses due to government mandates relating to PV solar power. The word "government mandate" is an obscenity to the Republican Party in the United States, for example. But the German political system successfully passed legislation which spurred the growth of solar PV power, action that is changing the energy mix in Germany dramatically. In 2000, the German Parliament passed the Erneuerbare Energien Gesetz, the EEG, or renewable energy law. This legislation guaranteed a market for solar power by requiring utilities (a mandate) to buy renewable energy from producers and put this PV solar energy onto the grid (Thompson, 2015). The goals of Energiewende (EEG) were to "combat climate change, avoid nuclear risks, improve energy security, and guaranteeing competition and growth." German policy makers intended to establish an energy policy that would be able to produce "clean energy that is cheap and endless". Energiewende is a long-term energy and climate strategy which aims to build a low carbon energy system based on renewable energy and improving energy efficiencies. EEG is an integrated and comprehensive legislative policy, covering all sectors of the economy (Pesica & Raichen, 2015).

In 2000, when Parliament Law passed the EEG. it was very important because it guaranteed a market for electricity generated by PV solar power (Curry, 2013). The Feed-In-Tariff, FIT, system, launched in 2000, was a key component of the EEG legislation. FIT is a subsidy which pays PV producers when selling their power to the grid. This law required utility companies to plug PV solar power into the electrical grid and paid PV producers a fixed rate. (Deutsche Welle, 2016). The FIT incentivized the production of PV solar power greatly from 2000 onward. As we can see by looking at Table 1, PV solar capacity increased from 2,056 MWh in 2005 to 39,787 MWh in 2015. This met about 7.4 % of Germany's total electricity needs by December of 2016 (Wirth, 2017). During this time, the share of nuclear power generation declined from 29.5% of its energy needs in 2000 to 17% of its energy needs in 2015.

Renewable energy, including PV solar, provided one-third of all electricity consumed in Germany in 2015(Martin, 2016). In 2014, the carbon level was 27% lower than in 1990. To measure the success of government policies, in 2016, PV solar generated power amounted to 38.3 TW and covered 7.4% of Germany's net electrical consumption (Wirth, 2017). Germany's goal is to increase PV solar power percentage of total electricity production to 35% by 2020 (Morris, 2016).

Economic support

The economics of PV solar power and the economics of electricity can get very complicated. PV solar power has been more expensive than power generated from fossil fuels. Until very recently, PV solar power could not compete on costs alone with electricity generated from fossil fuel and nuclear powered plants. As a result, there was a need for investment incentives and other subsidies to promote PV solar power. (International Energy Agency, 2013). When looking at the economics of energy production, there are "externalities" of burning fossil fuels and generating atomic power which often go unreported and uncalculated. Externalities occur when producing or consuming something causes an impact on third parties not directly related to the transaction. Critics of traditional energy, coal, and gas, point out that there are hidden costs of burning carbon fuels, such as pollution and the emission of "greenhouse gases", and, there are hidden costs of nuclear energy, including the storage of waste water and problems with accidents. These hidden costs are not fully calculated in the price of power generated by burning fossil fuels or nuclear energy. (National Academy of Sciences, 2009). Who pays the price when carbon dioxide is released into the air? Who pays the price when the coal mine or coal plant pollutes the streams, the oceans, and the air? These hidden costs are not borne by the fossil fuel energy producers themselves. They are borne by society and its citizens, even transnationally, across borders. If these costs were borne by coal utilities, for example, it would triple the price of electricity produced by coal fired plants. According to one estimate, the hidden cost of burning coal for electrical power generation has a hidden cost of as much as $345 billion in the United States alone (Malone, 2016). Additionally, it is estimated that it will cost more than $80 billion USD, over a ten-year period, to clean up the atomic power reactors that "melted down" in Fukushima, Japan in 2011. (BBC News, 2016).

Germany used the feed-in tariff (FIT) system to incentivize production of PV solar power. FIT is a government subsidy paid to producers of PV power. Starting in 2000, the FIT, feed in tariff, paid approximately $.43 cents per kWh of solar energy produced. These FIT subsidies, however, caused the average German's utility bill to increase. Eventually, government subsidies for PV solar power increased the average German household's energy bill by an average of EURO 18 per month. PV solar producers, including homeowners, received $11.3 billion USD in subsidies in 2012 but contributed only 4% to the power supply (Neubacher, 2012). While the public accepted higher utility bills at first, it was a burden for many urban residence and renters who could not take advantage of the FIT scheme. As installation costs declined, this economic model was not sustainable (Curry, 2013). The FIT scheme was effective in promoting the growth of solar PV at first, but it was too costly and inefficient in the long run.

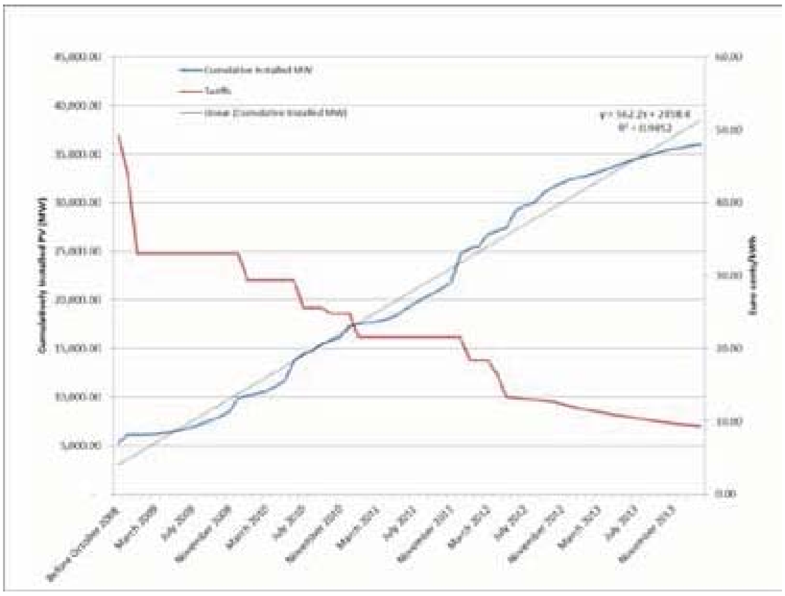

Figure 2: Relationship between cumulative installed MW and Tariffs

Source: Bundesnetzagentur, The Brattle Group analysis

Figure 2 demonstrates the correlation between FIT and cumulative installed MW. Cumulative installed MW of PV power is the line going up, from the lower left to the upper right, while the FIT rates are represented by the line going down, from the upper left to lower right. We can see as cumulative installed PV power increased from 5000 MW in 2008 to 35,000 MW in 2013, FIT subsidy decreased on average from EURO forty-three cents per kW to EURO thirteen cents per kW. Due to the success in the EEG subsidies, cumulative PV solar installations increased to such an extent that policy makers decreased FIT subsidies; however, overall FIT subsidy payments increased from EURO 2 billion in 2007 to EURO 10 billion in 2013. (European Commission, 2014). Clearly, the FIT had to be adjusted so electricity rates for retail customers wouldn't increase even more. Under the new subsidy rules, utilities will continue to pay residential solar electricity producers at the initial rate of as much as EURO 43 cents per kW but the new residential producers will only receive approximately EURO 13 cents per kW due to the decrease in FIT subsidies (Gahran, 2016). In summary, Figure 2 demonstrates that FIT subsidies for solar PV did not adjust quickly enough to the speed of installation of solar PV. Solar PV power production exceeded expectations which caused unforeseen problems. (SEIA: Solar Energy Association, 2014)

Germany has also benefited from its aggressive solar PV policies as a "first mover". Germany was one of the first countries to dedicate its political and economic capital to develop its PV solar industry on an integrated and large scale. As a result, Germany has gained many advantages. Germany exports PV solar technology worldwide. German firms have many solar technology patents and is developing solar technologies that can be marketed to the world. For example, German engineers have designed devices that can transmit power from rooftop panels and back in the grid. Employment is another area of the benefits of the PV solar industry The PV solar power industry has created tens of thousands of jobs. In 2013, the PV solar industry employed 68,000 people in the manufacture of materials, final products, construction, and installation (Hockenos, 2015).

By 2016, solar projects were outcompeting fossil fuel projects according to an executive of RWE Technology International Company, a large German utility company. This executive stated that solar projects are now cheaper to build than coal plants and much cheaper than nuclear power plants (Ball, 2017).

Technological support

The costs of PV solar modules and the total system prices have been a barrier for large scale PV solar production in the past. PV solar power used to be too expensive. Now, the costs of PV solar power have decreased significantly due to technological progress, decreasing material costs, savings accrued by economies of scale and because benefits of the "learning curve." (See Figure 3) The cost of solar panels has decreased more than 80% since 2008 (Miroff, 2017).

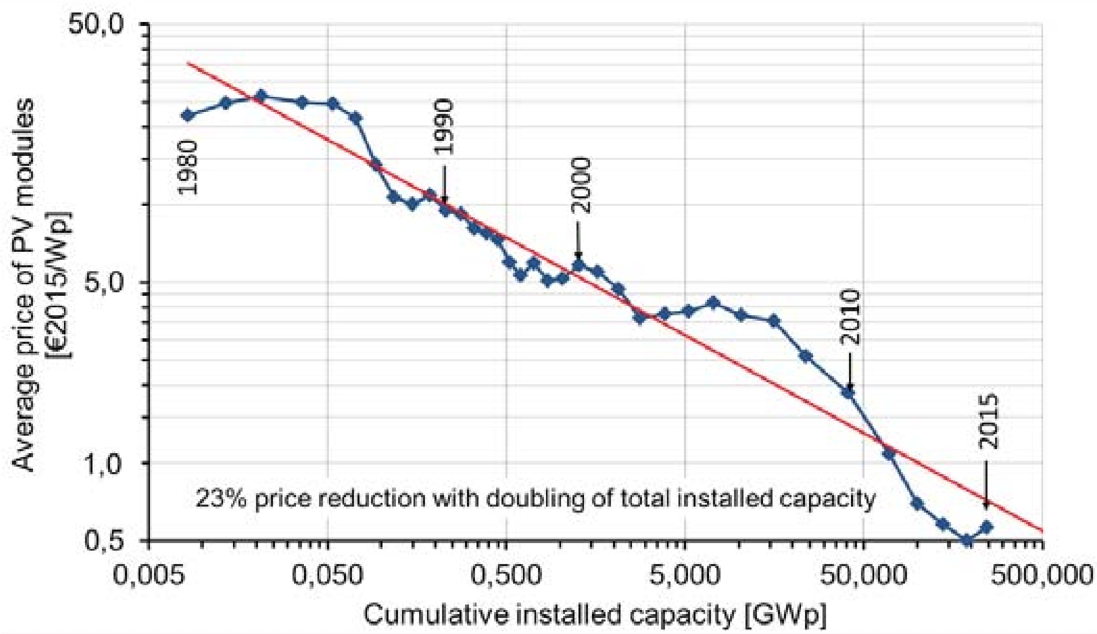

Figure 3: Average price of PV modules and total installed capacity

SOURCE: Recent Facts about Photovoltaic in Germany, Fraunhofer ISI, April 10, 2015

Analysis: There has been a 23% reduction of the price of solar modules with the doubling of installed capacity as we can see in Figure 3 (Wirth, 2017). The systems price of PV solar installation has declined rapidly due to technological improvement and the declining price of a PV solar panels. By 2016 over 1.4 million PV solar systems have been installed in Germany. It has been almost a "solar panel rush" in Southern Germany where there are three solar panels per capita (Curry, 2013). Since 2006, PV solar costs have fallen 75% (Wirth, 2017). Not only did the cost of solar panels drop greatly, but also installation costs declined making it cheaper to produce solar power. In many countries, the price of solar energy has fallen so much that it is increasingly beating out conventional sources of power. Industry experts and government regulators see this as a turning point in the history of human electricity making (Miroff, 2017).

PV solar technological innovations are advancing at a rapid pace. Solar power will soon be built into every part of our daily lives. There is a revolution underway to transform windows, skylights, and roads to generate electricity. The Tesla Company, in California, will soon begin selling solar shingles that can generate power for the home, but still look like everyday roofing tiles. Soon, PV cells will be installed on windows that let the light in but can still capture the ultraviolet and infrared light. Roadways will be generating solar power through PV solar power. PV solar technology and innovation is advancing: the sky is the limit for PV technological advances. (Baggaley, 2017).

Challenges

PV solar power development in Germany has had many challenges: The sun is not reliable when it is cloudy. And Germany has a lot of cloudy days when PV solar power cannot produce power. This creates instability in the power grid.

Another problem with the PV solar capacity in Germany is how to manage oversupply. PV solar power can produce too much power at unpredictable times, which is hard on the power grid and can cause black outs. When there is more electricity from PV power than the grid can manage, it reduces efficiency. The grid oftentimes cannot handle this oversupply due to the grid structure in Europe; and, it is very expensive to upgrade the grid structure in Europe (Follet, 2017).

In 2016, due to its high cost and the strain it put on the electricity grid and in response to other challenges, the German voters decided to abolish the energy subsidies under the former regulations for new PV solar producers. They decided to replace the FIT subsidies with a system of competitive auctions where the "cheapest electricity wins". This auction system is designed to reduce the rate of new renewable energy additions and keep Germany from producing too much PV solar power (Martin, 2016).

In Germany, the utilities are required to use renewable energy first, and then export excess electricity, which comes from coal, to other European countries. Although late in the game, German utility companies are adding "utility scale" solar projects nationwide. Beginning in January 2017, all German renewable projects larger than 750 kilowatts are funded through auctions. Two major German utilities companies are adjusting by expanding their solar and storage capacity by investing in energy storage companies in Germany and abroad (Gahran, 2016).

Since the launch of EEG (Erneuerbare Energien Gesetz) policy, German utility companies have spent over USD 210.5 billion on FIT subsidies. Despite PV solar success in Germany, there were questions about the efficiency of FIT subsidy system. For example, over half of Germany's renewable energy subsidies were used by PV solar generation but PV solar power only produced 20% of all renewable energy that was produced (Deutsche Welle, 2016).

Critics of Germany's policies, which subsidizes renewable energy. point to the fact that one of Germany's largest utility companies, RWE Technology International Company, has debts totaling 43 billion British pounds in 2016 because of subsidies. Green power has shrunk the utilities' profits in Germany while at the same time increased the price of electricity to the German consumer

(Booker, 2016). Total renewable energy surcharges cost EURO 20.4 billion in 2013 alone (Boisvert, 2013). By contrast, energy costs in the United States are much less expensive than in Germany. In the US, electricity costs on the average of USD 10.4 cents per kW but it costs USD 39 cents per kW in Germany (Follet, 2017).

Those who study this problem believe new technologies, better grid infrastructure and better PV solar power storage systems will help ameliorate these problems. (Shankleman, & Marti, 2017). In the short run, the main obstacles for PV solar power development worldwide are problems with the economics of PV solar energy as coal and atomic power are cheaper in the short run. The other main challenges include electricity storage, grid infrastructure development, and government strategies and support to meet PV solar energy goals (Mathieson, 2016). During the recent summit on climate change in Rome, summer 2016, one of the arguments for shifting toward clean energy and PV solar power was that clean energy technologies are predicted to become a USD three trillion-dollar industry within twenty years. (European network of transmission system operators for electricity, 2017). In conclusion, the EEG (Erneuerbare Energien Gesetz) policy was successful in producing PV solar power but created other problems such as oversupply of power, increase of consumers' electric bills, added strains on the grid system, and unprofitable utility companies.

Germany's Lessons for Other Countries

Germany has demonstrated the sense of urgency and commitment to battle global warming by replacing fossil fuels with PV solar power. But, recently China has declared renewable energy development as a strategic industry and has surged to the number one PV solar producer in the world. (Filka, 2016).

There are several lessons that the German PV solar experience can teach other countries that are keen to develop their PV solar power industries:

• With the European Union's largest economy, Germany is also a leader in PV solar technological innovation. Germany's experiences in developing its PV solar industry, and all renewable energy sources, sets an example and a road map for all other EU member states to follow.

• The German model demonstrates that public opinion and public support are important. If there is public support, government leaders can develop and implement PV solar policies and legislation successfully.

• The FIT, feed in tariff, scheme is expensive. The FIT system is not sustainable. A market based or "auction based" system is more efficient and effective. Additionally, government policies can incentivize PV solar production through the use national, state and local tax credits.

• The Germany model suggests that nations need to take the long view of PV solar development. Even when the costs of oil and natural gas on world markets are low and the urgency for PV solar power wanes, the fast-breaking technological changes in PV solar technology will soon see PV solar power costs reaching parity with fossil fuel energy costs and without the negative externalities, like environmental damage and global warming (Coren, 2016).

• Initial investments in PV solar installations are expensive. Countries should encourage PV solar production through public-private partnership model, PPP, to share the risks and rewards of PV solar development. PPP is the blueprint when two interlocking engines are brought together – the public sector and the private sector – to drive progress and innovation (Lander & Schmidt, 2017). With public-private partnerships, there must be transparency over the structure of such public-private partnerships.

• Countries will need systematic political and economic strategies, coordinated among the stakeholders to develop PV solar power. In some countries, PV solar power development is held back due to "muddled policies" and special interests. This is a big hurdle to overcome. (Modern Energy Management, 2016).

In summary, nation states will need to establish comprehensive and cohesive PV solar development strategies. These include inducing strong public support, creating vibrant public-private partnerships, taking advantage of the latest technological innovations, and finding the political will to motivate the construction of a vital PV solar power industry.

Oxford University researchers found that solar electricity power generation, worldwide, will rise from 1.5% of total electricity production today to more than 20% by 2020. (Oxford University, 2017). Today, solar power is already cheaper than coal fired power in some parts of the world. And in the decades ahead, solar power is likely to be the lowest cost option for energy (Mathieson, 2016). Not only are PV solar technologies advancing rapidly, but the costs are declining significantly. The revolution of PV solar power is here to stay. This emerging PV solar industry of the future has great potential for jobs, economic growth, energy security, and clean and sustainable energy. (European network of transmission system operators for electricity, 2017). The PV solar power industry is an industry of the future!

Conclusion

Germany, as a PV solar super power, has been facing the challenges of its PV solar power growth and development with resolve and flexibility. The three main factors contributing to the success of PV solar growth and development in Germany are as follows: (1) Strong public support: PV solar power continues to hold wide public support in Germany. Public opinion is firmly behind government and private sector polices which incentivize the production of PV solar power (2) Legislative bills: Bold legislation that was passed contributed to "growing PV solar power". These laws, which defined the role of the government, citizens, and the private sector, have been coordinated in a systematic and integrated manner, and (3) Technological advances: Rapid technological innovation has rapidly brought down the costs of PV solar power. Better technology at lower costs is an important factor in the growth of PV solar power today. Furthermore, Germany is updating its grid structure for transmission lines and distribution grids to meet the new challenges. It is continuously adapting and inventing innovative new PV solar technologies; it is adjusting FIT subsidies to more reflect market forces (Gahran, 2016). Due these considerations, Germany will continue to be a world leader in PV solar power, using technological innovation and adjusting to market conditions. With typical German organization skill and a commitment, Germany will overcome the current problems related to oversupply, grid infrastructure, and technological challenges and will continue to lead the world in PV solar capacity and PV solar technology! The future is bright for PV solar power in Germany and the world.

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