Fostering the Use of Photovoltaic Systems in China

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Abstract

This paper provides information on photovoltaic (PV) systems, the challenges and possibilities for their use and discusses some policy and planning implications that can be derived from the use of such systems. It presents the main issues concerned and the current status of the market, a discussion of the disadvantages and advantages and risks and opportunities related to the use of solar energy. Off-grid PV systems can represent a cheaper and more feasible option than connection to the remote grids and can secure energy for a larger portion of the population. Grid-connected PV systems also support energy security since they attenuate the risks related to peak demand and guarantee a more diversified energy portfolio. The authors conclude that the government of the People's Republic of China should implement a subsidy scheme based on a well-designed fed-in tariff in order to develop its PV program throughout the country.
Keywords: China, photovoltaic systems, solar energy, energy security.
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1. Introduction

The present work aims to provide information on photovoltaic (PV) systems, the challenges and possibilities related to this topic and discuss some policy and planning implications that can be derived from the use of this energy source. It will present the main issues concerned and the current status of the market.

This work was prepared based on literature review, experts' opinions and critical analyses. It is structured in the following way. Firstly, the disadvantages and advantages of the use of solar energy are discussed. This is followed by a discussion of some of the risks and opportunities related to this energy source. The final section presents some innovative tools, based on subsidies and other means, to foster the use of PV systems and provide policy recommendations to the government of the People's Republic of China.

China faces two issues today, which are intimately connected and of utmost urgency: one, the country needs to secure energy in order to attend to its growing internal demand, and two, it cannot depend solely on its non-renewable sources, such as coal and oil. Regarding the first issue, China is one of the largest and fastest growing economies in the world, which, adding to its huge population, makes the country one of the countries that will have the greatest energy needs. Energy security, then, is a top priority on the agenda to enable the country to continue to grow. Addressing the second issue, the country obtains most of the energy produced and consumed from non-renewable fossil sources, making use mainly of coal and oil. Coal is an abundant resource: the total theoretical amount is over 800 billion tons, which ranks China first in the world's largest reserves. However, the country cannot depend on these, since according to Liu et al. (2010), China's coal resources are expected to be depleted by the year 2050 and its abundant oil resources, within the next twenty years. This dirty and non-renewable source, added to the amount of energy used by the country, has pushed China to the top of the list of the largest CO_2 emitters in the world. The country can and should fulfil its energy needs with renewable and clean energy, as a way to build a sustainable, long-lasting and clean future.

Considering the willingness of the Chinese central government, through its recent statements and through the 12th Five Year Plan, and considering the pressure from the rest of the world for reducing emissions, the authors' recommendations address China's and the world's expectations for increasing the use of renewable energy and consequently tackling part of the problem posed by climate change. In this sense, the promotion and use of PV modules to produce electricity is one of the means to achieve a more sustainable future, by cleaning up the country's energy matrix and securing energy. Therefore, some steps towards a low-carbon economy for China are suggested here.

2. Literature Review

Several studies have been conducted on the potential of PV systems and the problems concerning such systems in China. This first section shall present some of the findings that these studies have already produced.

Liu et al. (2010) discussed the distribution zone and the current development situation of solar energy in China. The authors described solar energy greenhouses, solar energy heat, solar water heaters, solar lighting systems, solar water pumps, distributed generation, grid-connect photovoltaic generation and wind-solar hybrid systems. The policies and laws of China's central government and local governments are described and some prospects, development barriers and recommendations of PVfor China in the future were introduced.

Yuan et al. (2011) conducted a large-scale questionnaire survey that showed that there is a considerably high level of social acceptance and public awareness of solar water heating. However, PV has not gained a high level of social acceptance or public awareness in Shandong. The study provided useful references for policymakers to further promote the use of solar energy innovations.

Zhao et al. (2011) analysed the present status of the Chinese PV market, discussed the available opportunities and the potential challenges for the development process, including some engineering roadblocks encountered in PV systems, and outlined possible future scenarios in this field.

Li et al. (2007) analysed both global and domestic PV development, provided recommendations to policymakers and presented an industrial blueprint.

D'Agostino et al. (2011) presented the first independent review with the intent of determining if the anticipated project benefits have been sustained. The study adopted the format of a case study, supported by in-depth interviews with the project's relevant stakeholder groups and found that solar home systems (SHS) provide monetary and non-monetary benefits to users.

3. Photovoltaic Systems: Background and Overview

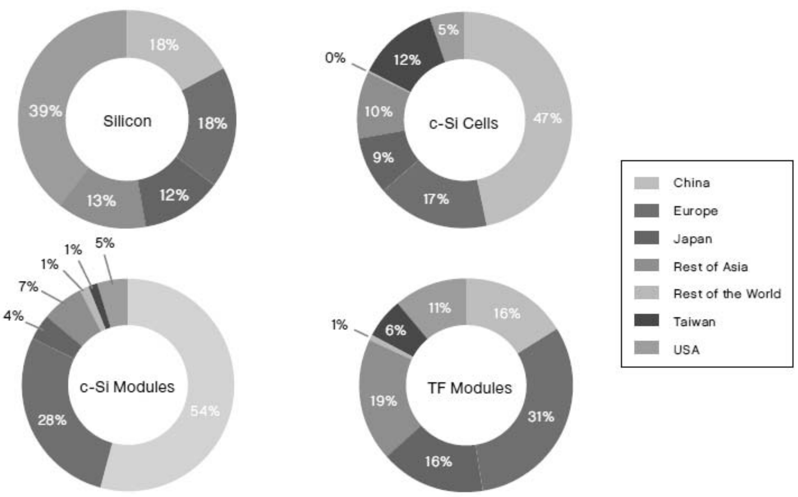
3.1. World Market

The total amount of PV power installed worldwide in 2009 was approximately 23 gigawatt (GW), according to EPIA (2010), with an additional 17 GW installed worldwide in 2010, resulting in a total of 40 GW installed capacity. Germany is by far the world's leader regarding newly installed and cumulative installed capacity. In 2010 alone, 7.2 GW were installed amounting to a cumulative installation of 17 GW (EPIA, 2011). Other prominent countries within Europe are Italy, Czech Republic, Spain, Belgium and France. Outside Europe, the leading countries are Japan with almost 1 GW capacity installed in 2010, amounting to 2.6 GW cumulative, followed by the United States and China (EPIA, 2011).

This development was strongly policy-driven rather than market-driven. Thus, the PV industry, and accordingly the PV market, is strongly dependent on policy support for this technology in the respective countries. After very high growth rates in the last few years, most of the leading countries started to review their support structures, which led to a significant lowering in the market from 2011 onwards, putting pressure on the industry worldwide. Nevertheless, further market development can be expected as PV is regarded as one of the most promising technologies for future energy production in many parts of the world.

The most recognized technologies in the market so far are crystalline solar cells. According to the European Photovoltaic Industry Association (EPIA), this technology accounts for 85% of all worldwide installations, followed by thin film technology, with around 15% (EPIA, 2011). In 2009, 18% of raw silicon production, 47% of solar cell production, 16% of thin film module and even 54% of crystalline module production took place in China, as seen in Figure 1.

Figure 1: Worldwide PV production distribution in 2009 (EPIA, 2010)



3.2. Market Development in China

China has built up an important PV manufacturing industry. However, this industry is almost entirely dependent on the export market and, therefore, completely reliant on external developments. The PV market inside China is still quite small, when considering the installed capacity per capita. However, when looking at the development of the Chinese PV market, one can observe substantial growth over the last few years. While in 2006, 12 MW (megawatt) of PV were installed, installations increased to 20 MW, 45 MW, 228 MW and 520 MW for 2007, 2008, 2009 and 2010 respectively (EPIA, 2011). Further growth is forecast if support is provided by the government in a sufficient amount and by the right means. As renewable energies are also emphasized in the 12^{th} Five Year Plan, further PV market development can be expected in the future. Nonetheless, PV technology is still regarded as expensive in China, more expensive when compared to Europe, where the conventional electricity prices are relatively low.

From 2002 to 2007, more than 400,000 PV solar home systems were sold in north-western China under the US$316 million World Bank/ Global Environment Facility-supported Renewable Energy Development Project (REDP) (D'Agostino et al., 2011). The development of the PV industry in China has occurred without any correlation to market development. However, as the markets in many European countries, Japan and the United States developed significantly in the last few years, in China too, industries started to produce in this field. A PV industry covering almost the entire PV value chain has emerged. This is due to comparative advantages in production costs, allowing Chinese companies to sell PV components more cheaply than their competitors. Therefore just 2% of the PV modules produced in China are actually installed within the country (D'Agostino et al., 2011).

4. Disadvantages and Advantages of Photovoltaic Systems

Solar power is a permanent source that is broadly available in many regions of the planet. It represents hope for the increasing energy needs of the world's population. Its use as an energy source is not recent, but it is far from being widespread or commonplace. Here, we will briefly present some of the disadvantages and advantages related to the use of PV systems.

Considering the novelty of the large-scale use of PV systems throughout the world, the initial costs are still high when compared to other sources of energy, mainly due to the size of the demand of this relatively new technology. Also increasing efficiency is leading to improved cost-effectiveness. Grid-connected small-scale PV systems are more expensive than large-scale applications. Moreover, solar farms ask for large spaces in order to produce a desirable amount of energy. Due to the volatility of solar energy, there are also risks related to the Internet. As for off-grid PV systems (mainly small-scale users), the barriers include disbelief, lack of information, and difficulties related to maintenance (especially for those systems installed in remote and rural areas).

There are also advantages from the technological perspective. Solar energy can help diminish pressure on the grid during peak hours. China offers available land space for the use of PV systems that are connected to the electricity network. Further, they can be easily adapted to the existing network. Problems related to inefficiency and high costs are being overcome with time, thanks to technological innovations and gains of scale.

Social benefits range from improvement in health conditions of the people, increase in income with extra hours for work at home and improved performance of school age children. D'Agostino et al. (2011) concluded that SHS use had a positive effect on household income for more than 53% of their survey's respondents regarding off-grid systems and issues of electrification. They also estimate improvements in family communication levels, increased workable hours, and improved access to information through radio and television (Finucane, 2008, pp. 26, *in* D'Agostino et al., 2011).

5. Risks and Opportunities of Photovoltaic Systems in China

In this section, the main risks and opportunities related to the use of PV systems will be discussed in general and, then, specifically for China.

5.1. Risks

The risks related to the use of solar energy itself are related to the fluctuation of the energy supply: production capacity decreases during cloudy or rainy days and in winter months. However, these fluctuations do not represent a great risk as conventional sources can provide the missing energy. This fluctuation could be more of a problem for off-grid applications. On the other hand, in any case they will rely to a certain extent on additional back-up devices, either a mix of PV and, for example, wind, or a battery system.

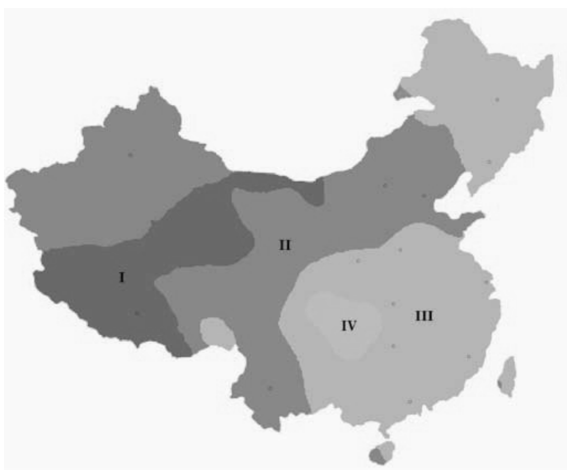
The risks related to the commercialization of PV systems are concentrated on market risks related to fluctuations in demand, competition, changes in public policies and changes in technologies. For a country that will invest in the production of PV panels and their peripherals, decreasing demand from overseas is due to many factors, such as the emergence of new technologies, new suppliers and competitors in the market, and can directly affect production and profit. Moreover, changes in public policies can have the same effect, especially in the case of leading markets.

5.2. Opportunities

PV systems represent the possibility to create electricity from sunlight using the photovoltaic effect. They provide access to energy in a sustainable way via the current electricity network (grid-connected) or off-grid. There are several opportunities offered by the implementation of solar power through PV systems. It is a clean source of energy. Moreover in the current period of environmental concern, a green source of energy will bring emissions reductions, as well as cleaning up the country's energy matrix and providing an opportunity to diversify the energy matrix, which is a good way to secure energy from the viewpoint of the supply side.

China has a large availability of solar energy throughout its enormous territory. The country is geographically well-located, receiving sunlight every day of the year, which makes it a suitable user of this source of energy. The irradiation level ranges from 1,050 to 2,450 kWh/m^2 (Li et al., 2007), a very high level compared to other countries. Especially in the northwest part of China the potential is very high, accompanied by the fact that these areas are very remote and not densely populated. For this reason, the region generally lacks electricity grids (Zhao et al., 2011). The irradiation potentials are displayed in Figure 2, grouped into different zones, with a further description of these zones in Table 1.

Figure 2: Irradiation potential in China (Li et al., 2007)



The potential in China is, therefore, sufficient for large and small-scale grids connected as well as off-grid use of PV systems. Considering the large population as well as the available area together with the geography of the country,

Table 1: Irradiation zones distribution in China (Li et al., 2007)

Zone	Classification	Annual radiation (kWh/m^2)	Share of land area (%)
I	Most abundant	>1750	17.4
II	Very abundant	1400–1750	42.7
III	Abundant	1050–1400	36.3
IV	Least abundant	<1050	3.6

China may have the leading potential for PV worldwide (Zhao et al., 2011)

There are many regions where PV can be potentially implemented with success. For example, Xinjiang, which has a maximum 3,500 hours of sunshine annually, and 6,342.31 MJ per square meter of radiation (Zhao et al., 2011). The desert zone of northwest China is over 1.3 million square km. The capacity of PV on average is 100 MW per square km. If 1% of this desert area is used, the shared capacity of PV can reach up to 1,300 GW (Liu et al., 2009).

The constructed area in China is over 40 billion square meters, with over 4 billion square meters of house top area, and over 5 billion square meters of walls facing south. The total area that can be utilized is over 49 billion square meters. If the fixed PV area of architecture accounts for 20%, then the total capacity is 100 GW (Liu et al., 2009)

Moreover, PV systems represent a relatively low cost option for remote and rural areas (Zhou and Byrne, 2002, in D'Agostino et al., 2011) with low population density and low energy demand. These places in China represent a population of 8 million people (IEA, 2009, in D'Agostino et al., 2011). The emergence of a strong PV market has also proven to create jobs, directly and indirectly.

In addition, the price of the main raw material for photovoltaic cells, poly-silicon, fell at the end of 2008. In the second quarter of 2009, this reduced the cost of solar cells by nearly 40% and, therefore, the cost of PV-generated electricity (Zhao et al., 2011). It is expected that the price for electricity generated by PV can be reduced to that of conventional electricity, and the PV market can become very competitive.

6. Innovative Tools to Foster the Use of Photovoltaic Systems

PVs are a feasible option to be incorporated into China's energy matrix, especially due to the fact that the technology is becoming more and more efficient, with panels that can absorb more sunlight, therefore working more effectively. Cell efficiency has been increasing at a rate of about 0.5% to 1% per year in recent years. Efficiencies are expected to continue to increase toward 45% to 50% (Kurtz, 2009, pp. 27). Recent prototype innovations have proven to be able to absorb up to 80% of the solar incidence. Moreover, with rapid economic development in China, purchasing power is increasing and incorporating policy with technological innovation in this field can promote use of PV in China. Currently, this is far from achieving realistic efficiency in the near future, but it indicates that there is still much potential for future development.

Therefore, the following promotional policies and initiatives for the implementation of a successful PV market in the country could be adopted.

6.1. Building awareness

Social acceptance of the photovoltaic technologies from the end user perspective is the first essential thing to focus on. There is often a lack of knowledge among end users of PV capabilities, especially in developing countries like China, and utilities remain conservative regarding small, decentralized technologies and departures from political interference in the operation of rural distribution companies. The lack of action by governments in developing countries to educate the masses on the benefits and advantages of PV energy adds to the problem (Murthy, 2001). In this way, it is necessary to convey to people the latest information and technology, as well as information on commercially-available PV for producing electricity. Government measures should include building awareness about the reality of solar power and its effectiveness, in order to address disbelief and lack of information among small-scale users. Also, credit for the purchase of PV systems and installation is needed both for small and large-scale uses.

6.2. Training

Measures should cover some training for users on proper use of the products in order to avoid damage, which can reduce the product lifespan, and good after-sales service, which will decrease risk aversion for new purchases. As stated by

D'Agostino et al. (2011), the dissatisfaction with SHS performance demonstrated fixed beliefs about equipment unreliability and risk aversion to new purchases. Proper training can enhance improvement of after sales. Good service at the community level is also mandatory for success.

6.3. Fostering Research and Development (R&D)

The development of technology related to PV is still not regarded by government experts and academia in China as being so important that it would be considered ideal (Liu et al., 2009). The interrelated technology of renewable energy should be offered in universities throughout the country. Abundant funding and resources (human, technological and others) should be devoted to interrelated research on PV. Universities and graduate schools should be encouraged to foster the development and promotion of research into solar energy. Cooperation between the private sector and academia is highly recommended. The successful promotion of PV use in China requires development and well coordinated work between different sectors.

6.4. Differentiated Strategies according to regions

China requires a region-specific emission reduction roadmap that is implemented by both the local and central government. There are more than 30 provinces in China, and different provinces have a different impetus when implementing renewable energy because of their different natural resources. At present, local governments can reject the policies and regulations of the central government (Liu et al., 2009). For example, as some western and northern provinces have enough fossil resources, there is little impetus for exploitation of renewable resources. On the other hand, the eastern and southern provinces lack fossil resources, and regard the development of renewable energy, such as wind, solar and tidal energy, as important, so the impetus is greater than those other provinces. It is not feasible that all provinces are assigned the same proportional reduction in emissions. This is also true for the utilization of solar energy.

6.5. Subsidies

The development of the PV industry requires large investment and the price of PV is costly, meaning that ordinary people cannot bear the cost of PV. For example, while the price of one kilowatt-hour electricity is 0.5 RMB at present, the price of PV-generated electricity is more than 5 RMB (Liu et al., 2009), although today it is already lower. So, financial aid from the government is still necessary to implement the sustainable development of the PV industry.

Out of the different possibilities for supporting renewables and, in this case specifically PV, the feed-in tariff (FIT) has proved to be a best practice. Many countries in Europe that have significant PV markets today owe this development the introduction of FIT systems. Germany was among the first countries to introduce a continuous FIT system and today has the largest market worldwide. In addition to German PV technology, the FIT scheme was also applied and became a top export. Due to the good experiences with this model, the authors consider this to be the right tool for the fostering of the PV market in China concerning grid-connected applications.

Just recently, the Chinese government announced that a FIT is planning to be introduced, however one has to be very cautious when setting the tariff, the timespan of the support and the digression rate. The level of support should, together with the timespan for which the guaranteed tariff is provided, be sufficient to compensate for the costs incurred by the PV system. Over time, the tariff has to be reduced in order to take into account the steady decrease of system prices.

The policy lessons from Europe, provided in the next part of this report, are in this sense indented as to show a best practice example in designing this subsidy tool, as well as an example where there was overly generous support, market overheating and, as a result, the collapse of the market.

Out of the different possibilities of supporting renewables and, in this case especially PV, as already stated, FIT has proved to be the best method. One of the most important goals is to maintain a sustainable growth rate that is feasible and should not exceed industrial and economical means. Therefore, when considering FIT, as China had also implemented such a tariff, policymakers must be cautious regarding the tariff level. If the tariff is too high, unintended overheating of the market may occur. Some examples of such a development can be found in Europe and should serve as an example. In Spain, for instance, the conditions for the installations of PV were so favourable that growth was too high and the costs for the government grew too fast. Installations increased five-fold between 2007 and 2008 (EPIA, 2011). In addition, as the return for investing in PV in Spain was very high, foreign companies started to invest and build large-scale PV farms, which led to capital outflow from the country. This, then, resulted in a cut in government support and a complete collapse of the market. In this respect it is very important that the FIT decreases steadily, which should reflect the learning curve of the technology as the system prices are decreasing as well. Therefore, the prices of PV should be analysed on a regular basis and the support lowered accordingly.

Figure 3: Different possible market developments (based on EPIA, 2011)

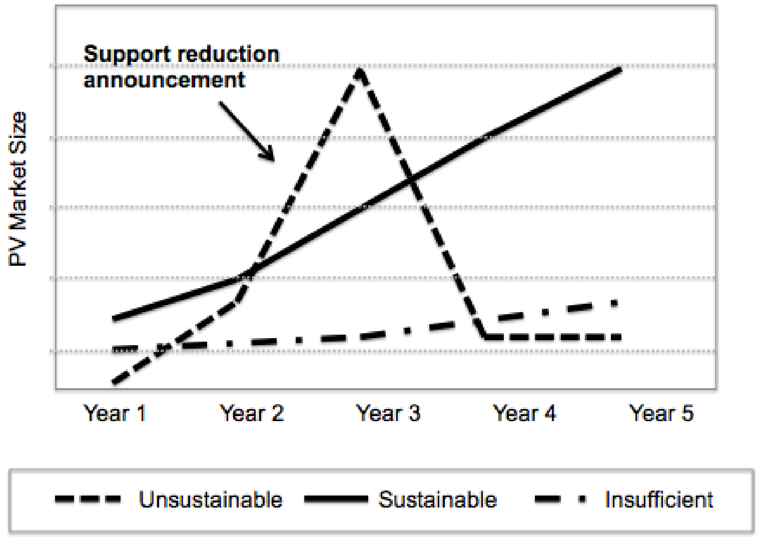


Figure 3 displays the above-mentioned statements. The line for sustainable growth therefore could represent market development in Germany, the line for unsustainable, Spain and, the line for insufficient, a regular case with insufficient support.

Generally, it can be said that it is not just the financial component of supporting PV that is important. For example, EPIA provides key recommendations for sustainable support of PV. Amongst the considerations already stated regarding support there is also a clear call for the establishment of a PV roadmap that leads the way to the achievement of grid parity and the point from which financial support is no longer required.

6.6. Eco Points System

Eco points are environmental attributes or benefits provided to the power generator (household or company) using PV systems. To encourage households and entrepreneurs to use PV systems, the government should provide eco points for every kilowatt-hour of electricity generated by the PV that they use or supply to the grid. These eco points can be tradable and can be used to obtain tax relief from the government, either general or in the purchase of specific green products, i.e. for extra PV panels and peripherals. Eco points have recently become popular among policymakers concerning the reduction of carbon dioxide emissions. A program to promote the spread of green home appliances by utilizing eco-points has been conducted in Japan since 2009. Those who purchased eco-friendly home appliances could apply for eco-points and the exchange of issued points for various goods (Yoshida et al., 2010).

7. Conclusions and Discussion

When implementing policies for the promotion of PV, several issues should be taken into account. Lessons should also be learned from the experience of other countries. Policy lessons from case studies were provided to help in achieving sustainable growth. Since the costs for the support will be quite high, a reasonable growth path should be found. However, as the analysis showed, this support is justified. Over time, as the system prices start to fall, support should decrease.

As the energy supply in China is heavily reliant on fossil, therefore non-renewable, sources, a diversification of the energy portfolio is needed. As a result of this fact the carbon emissions in total numbers as well as the carbon emission per unit of GDP are very high. As China has committed to reduce its carbon intensity and also emphasized the need for achieving a low carbon society in the future, action must be taken.

PV is one of the means to do so and a green technology with huge potential for the future. This is true for natural potential, concerning irradiation, but also regarding the usable area, which is very high in China. Yet, PV is not commonplace in the country.

In order to tackle the high initial costs, the implementation of subsidies is recommended. Subsidizing PV requires large amounts of capital and considering carbon emission savings alone, other means are thought to be able to achieve this in a cheaper way today. However, it was shown in this report that there are more issues that need to be considered and that increase the value of PV. First of all, the already significant PV industry needs a substantial home market in order to move away from total dependence on foreign markets, since policy changes or other reasons for a decreasing PV market in the leading countries in the world could cause severe troubles for China. In addition, with off-grid PV systems, rural electrification efforts can be supported. Installing a PV system is often cheaper and more feasible than a connection to remote grids. Moreover, it can secure energy for a larger section of the population. Finally, the nature of PV electricity generation supports energy security due to the fact that peak demand occurs during the time in which PV produces the most energy. A mix in the energy portfolio would be advantageous and highly recommended for China.

Taking all of these facts into account, a subsidy scheme based on a well-designed fed-in tariff would be most appropriate. This type of scheme is considered a best practice and it is used in most of the PV market's leading countries. In addition, a system of eco points similar to those already applied in other fields would be supportive.

References

D'Agostino, A. L., Sovacoll K. B. & Bambawale J. M. (2011). And then what happened? A retrospective appraisal of China's Renewable Energy Development Project (REDP). *Renewable Energy, 36*, 3154 - 3165.

EPIA (2010): Global Market Outlook for Photovoltaics until 2014. May 2010 update. Brussels: European Photovoltaic Industry Association.

EPIA (2011): *Global Market Outlook for Photovoltaics* until 2015. Brussels: European Photovoltaic Industry Association

Kurtz, S. (2009) *Opportunities and Challenges for Development of a Mature Concentrating Photovoltaic Power Industry*. Technical Report NREL/TP-520-43208 Revised November 2009 National Renewable Energy Laboratory.

Li, J., Wang S., Zhang M. & Ma L. (2007) China Solar PV Report 2007, *China Environmental Science Press*.

Liu, L., Wang Z., Zhang H. & Xue Y. (2010) Solar energy development in China - A review. *Renewable and Sustainable Energy Reviews* 14 (2010) 301-311.

Murthy, M.R.L.N. (2001) PV promotion in developing countries by World Bank and other international organizations, *Solar Energy Materials & Solar Cells*, Vol. 67, 629-637

Yoshida Y., Inahata Y., Enokibori. & Matsuhashi R. (2010) Estimating CO2 Emission Reduction in Eco-Point Program for Green Home Appliances in Japan, *International Society for Environmental Information Sciences* 2010 Annual Conference (ISEIS)

Yuan, X., Zuo J. & Ma C. (2011) Social acceptance of solar energy technologies in China - End users' perspective, *Energy Policy 39* (2011), 1031-1036.

Zhao, R., Shi G. Chen H., Ren A. & Finlow D. (2011) Present status and prospects of photovoltaic market in China *Energy Policy 39* (2011), 2204-2207.