Analysis on Patent Intelligence of Solar Energy Technology in China in the Aspect of Global Competition

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Abstract
Faced with the increasingly fierce international competition, climate change and other global challenges, it is more important for national governments to take the analysis on patent intelligence of solar energy technology one step further. Based on Innography patent information retrieval platform, this paper analyzed the competition pattern and development trend in patents for global solar energy technology from the aspect of patent country, application country, IPC distribution and patent rights. A comparative study was conducted on the technology layout in Chinese market between local technology developers and global technology developers. It is of great interest to discover the competition trends in patents for global solar energy and hot technology layout, on which this paper evaluated from the competitive environment, competitors, competitive technology and international strategy.

Keywords: solar energy technology; patent intelligence; Innography; patent intelligence; core patent; technology layout.

1. Introduction

Nowadays, whether a country is at the forefront of energy technology will influence national economy development, which is associated with the potentiality of economic growth, long-term energy security, economic development and technological innovation(Hoppmann, Peters, Schneider, & Hoffmann, 2013). However, carbon-dioxide emission which is related to energy consumption counts the majority of greenhouse-gas emission of human activity and causes a serious impact on climate warming. Fortunately, the development of renewable energy sources has had a crucial influence on the reduction of carbon-dioxide emission and geopolitics problem(Fan, Liu, & Zhu, 2017). The Asian markets headed by Japan, China, and South Korea have also experienced significant growth in recent years because of technological advances and government support(Timilsina, Kurdgelashvili, & Narbel, 2012). "Renewable Energy Directive" published by European commission has greatly promoted the rapid development of renewable energy generation in Europe, especially solar power(Frietsch & Schmoch, 2010). Three technologies among seventeen renewable energy technologies that most potential for carbon dioxide emission reduction announced by the International Energy Agency (IEA) are correlating with solar energy, including solar photovoltaic systems, solar thermal power plants, and solar heating and hot water supply [6]. Solar energy technology is one of the core technologies in the field of renewable energy. In order to gain leading advantages in the future energy market, lots of enterprises have participated in solar patents fierce competition under the support of national policies(Zhao, Zhao, Deng, & Zheng, 2015).

In recent years, statistical and comparative methods are used in patent and literature information inspection of solar energy field. Johnstone, Haščič, and Popp (2010) analyzed the patent data from 1978-2003 in 25 countries and concluded that public policy plays an important role in the application of renewable energy patents. Pettersson, Nonumura, Kloo, and Hagfeldt (2012) analyzed the patent application trends of dye-sensitized solar cells and amorphous silicon thin-film solar cells, respectively. Frauke[11]study the development of global concentrated solar power technology based on patent data. Tour, Glachant, and Ménière (2011) analyze the superiorities and limitations of China's photovoltaic industry based on international patent data, and particular emphasis the positive influence of technological transformation and innovation. Luan, Liu and Wang (2013) study global solar energy patent measurement and reveal two evolutionary trends of divergence and convergence caused by the linkage changes of solar energy technology. Zhang and Chen (2013) took the length of patent duration as a measure of patent quality, study the quality of patents for R&D units from 1985 to 2009, they find that cooperative research across different units can significantly improve the patent quality of solar energy. In this background, it is of great significance to carry out competitive analysis in global deployment of solar energy technologies, track key technologies, and discovery prospective new technologies. In view of this, this research adopts patent intelligence analysis technology, and the key issues to be solved are: the answer to this key issue will serve as a reference for the development and breakthrough of China's solar patent technology. Hence, we studied global solar energy technology competition pattern and development trend and China's solar energy technology's global competitiveness by data mining technology. This research is critical for the development of solar energy R&D, especially in China.

2. Data Retrieval and Collection

Innography is a highly-respected patent retrieval and analysis tool in recent years (Zhang, 2014). It integrates database and information retrieval functions, and its underlying data includes more than 80 million patent data, US patent litigation data, U.S. trademark data, and organizational business data in 90 countries and regions around the world. The platform has its algorithm constructed by a unique scoring system to recognize core patents. For the integrity and independence of data, this study based on EST Concordance patent classification index and solar research features to formulate patent search strategy and the database is Innography platform. Patent search strategy is as follows: ((abstract, claims, title) ("solar energy") or ("solar power") ("suns energy") or ("sun power")) AND (IPC_F24J002 OR IPC_H01L031 OR IPC_F03G006 OR IPC_H01L031 OR IPC_F24J002 OR IPC_F24D017 OR IPC_F24D003 OR IPC_F24J002) (@* inno_utility_patent). What's more, retrieval time is from January 1,1910 to May 10, 2017. We retrieved 69,479 patents, including patents for inventions and patens for utility models. It should be noted that the Chinese region in this patent database only refers to mainland China and does not include Hong Kong, Macao, and Taiwan.

3. Patent Analysis

3.1 Patent application analysis

The current status and scale of global solar technology development can be reflected by the annul applications amount of priority patents and the amount of patent disclosures. Trends in the priority years and public years of 69,479 solar energy patents are shown in Figures 1 and 2[1].

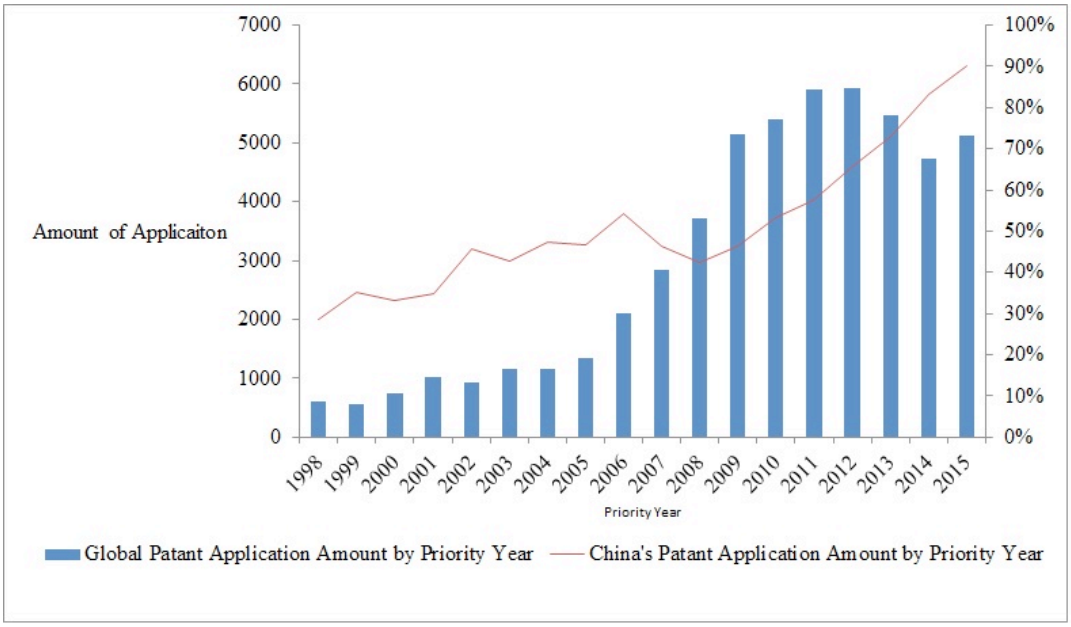

Figure 1. Solar energy patents application by priority year

[1] Before 1998, the number of patent applications in the global solar field was few, therefore, it was not shown in figure 1 and figure 2.

As we can know from figure 1, before 2000 the number of patent applications was few, and the average annual application number was less than 1,000. This period is the introduction period of solar energy technology. In 2001, the number of solar energy patent applications exceeded 1,000 for the first time, except for a slight drop of 918 applications in 2002. After five years of accumulation, the number of patent applications for solar energy exceeded 2,000 in 2006, and the number of patent applications for that year was 2,099, marking that the solar energy technology enters a slow growth period. Under the dual drive of global climate change and low-carbon energy technologies, solar energy technology entered a phase of rapid development in 2007, ushering in an upsurge of application and peaking in 2012. In total, 5,921 patents were filed in 2012. The surge in the number of applications for patents during this period was mainly due to the strong demand for low-carbon energy technologies represented by Europe and the United States under the pressure of global climate change, and countries have been advancing the development of low-carbon energy technologies. In particular, with the pushing of Copenhagen Climate Conference held in 2009, China's solar patent applications have reached the highest historical rate of 39%. However, as countries failed to achieve the global cooperative emission reduction plan for climate change, the growth rate of patent applications for solar energy has slowed down significantly since 2009, and the number of applications has decreased for two consecutive years since 2012. The number of patent applications in 2015 has increased slightly when compared with 2014 but was still lower than 2009. Analysis above shows that the development of global solar energy technology is mainly influenced by the factor of international political environment.

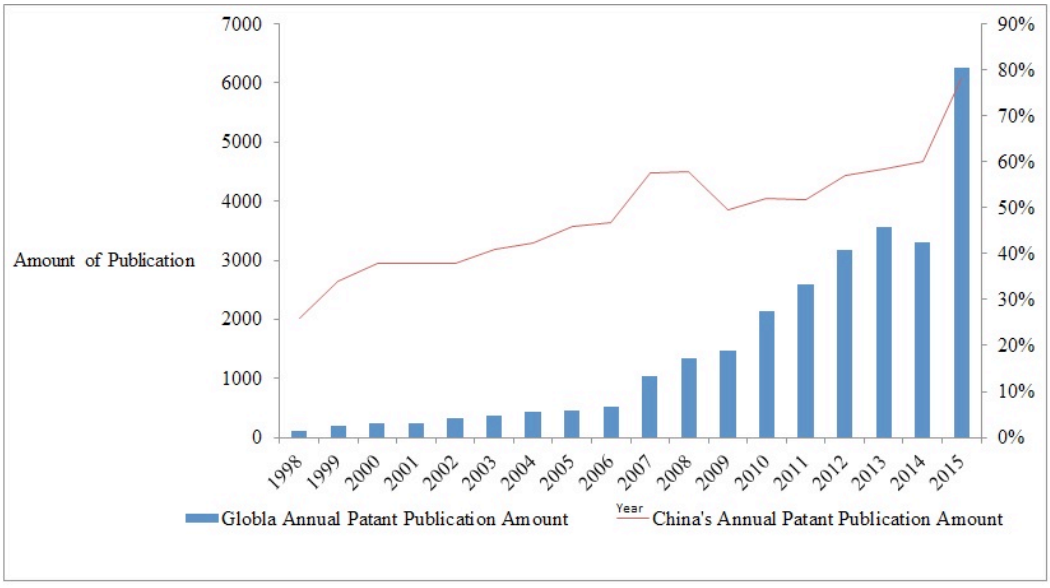

Figure 2. Solar energy patents application by publication year

Figure 2 shows the global solar patent disclosure volume. It can be seen that its overall trend is similar with the trend of priority patent application number. Statistics show that period of 2001-2006 and period of 2007-2015 respectively correspond to the slow growth and rapid development of solar energy technology in the world. For the two phases, there are 2328 and 24,895 solar energy patent disclosures respectively.

Under the driving of global climate change and low-carbon energy demand , Countries are striving to develop solar energy technology and continuously achieve technological

breakthroughs. The Copenhagen Climate Conference effect appeared in 2010, with the number of global solar patents speeding up at a rate of 45%, and the absolute number peaked at 6256 in 2015. It can be predicted that this trend will last for some time and the solar energy industry will boom in the near future.

Whether the number of patent applications for priority applications or the number of annual patent disclosures, the number of Chinese patents has been in a rapid growth, and its proportion of the world has increased year by year. Since the global solar energy technology entered a period of rapid development from 2007, China has accounted for more than 50% of the global solar patent disclosure volume, and the number of applications from 2010 accounted for more than 50%. In 2015, China's patented solar energy technology applications accounted for nearly 90% of the global patents applications. The greatly change due to China's promotion of solar energy industry development policy. Before 2009, the Chinese government mainly adopted financial subsidies to encourage the use of renewable energy such as solar energy to solve the problem of electricity consumption in remote and uncharged areas and promote energy conservation in construction. From 2009 to 2012, the Chinese government promoted solar (photovoltaic) power technology by means of leading projects that combined construction with solar energy. The photovoltaic industry has also been established as a strategic potential industry, which has been included in the key support of national industrial policies. After 2012, the Chinese government strengthened the elimination of photovoltaic power and the development of industrial standards, encouraged the development of distributed power stations and large-scale ground power stations, and increased the proportion of renewable energy such as solar power.

3.2 Patent application country analysis

The patent application country analysis can reveal the regional distribution of patent layout. Usually, patent applicants will pay attention to areas that are gathering high input in research and development or potential in commercial application. The statistical results of the solar technology applicant country are shown in Figure 3:

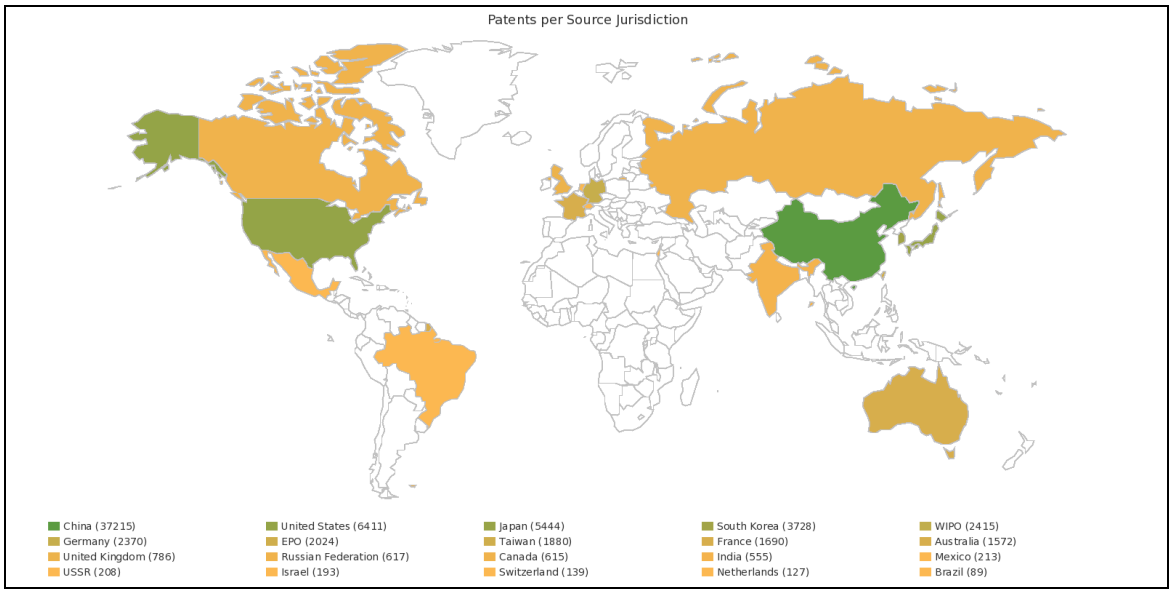

Figure 3. Solar energy patents application countries

Figure 3 shows that China, the United States, Japan, and South Korea are the main countries which have lots of patents. China has the largest number of open patents, a total of 37,215, accounting for 54% of the world's share; the United States followed, with 6411 open patents, accounting for 9%; followed by Japan and South Korea with 5,444 and 3,728 open patents respectively, both accounting over 5%. The above four countries open patent count 52,798 patents, accounting for 76% of global solar energy patents. Therefore, China, the United States, Japan, and South Korea are the main forces in global solar energy technology innovation. In addition, the number of applications from the World Intellectual Property Organization (WIPO), Germany, and the European Patent Office (EPO) is more than 2,000, which indicates that the patent holders are generally optimistic about the prospects of solar energy technology development and are actively conducting global patent distribution to enter the international market.

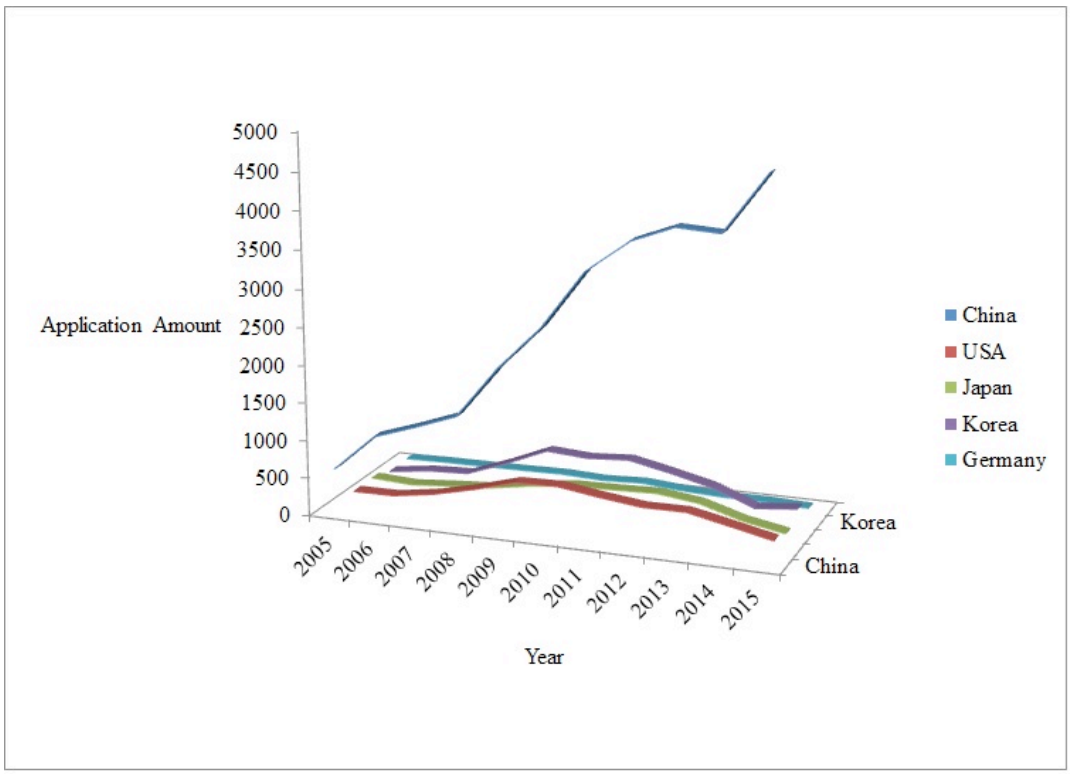

Figure 4. Solar energy patents application number in main application countries during 2005-2015

Figure 4 shows the status of solar patent applications in main countries from 2005 to 2015. Since 2005, the number of patent applications has shown a certain growth trend. However, there are certain differences in the growth rate of solar energy technology during its rapid development. The application in Germany is relatively stable. The number of patent applications in Germany is less than 100 each year. South Korea had 354 patent applications in 2005 and reached the highest level of 589 in 2011. In the US, there were 351 patent applications in 2005, and 521 in 2010. The number of Japanese patent applications has increased from 192 in 2005 to 379 in 2012. The change in the number of patent applications indicates that South Korea, the United States, and Japan used to be prospective market in the solar energy field, but then it has a clear downward trend. For example, South Korea had only 128 patents in 2014, and the number of US patent applications in 2015 decreased to 143, Japan 2015 There are

already less than 100 items in the year. The overall decline in solar patent applications affected 4 major countries other than China. China's patent applications for solar energy have maintained a steady and rapid development trend. In 2005, there were 607 patent applications, which soared to 4116 in 2013. In 2015, it was as high as 4843, indicating that China, as an emerging market in the global solar energy market, is the most critical market now and attractive for applicators from all over the world.

3.3 Solar Energy Technology Global Competitors Analysis

This research got 69,479 patents in the field of solar energy technology and there are 70 technology application countries and 96 technology source countries. We found that top 4 patent application countries are China, the United States, Japan, and South Korea. These four countries are also four of the most important markets in the world. In consideration of France's competitive advantage in the field of solar energy technology, we choose the four major solar energy application countries mentioned above and France as the main competitors in the global market. As table 1 showed the global solar technology layout based on the distribution of their patent families.

Table 1. Local solar energy technology distribution of main patens application countries

Main patent application country	Local assignees' global patents application number	Number of patents distribution countries	Partition of local patents in all patent application (%)	Number of patents in areas	
China	33925	19	98.62	Aisia-pacific	33551
				Europe	56
				North America	109
				Else	209
America	9291	37	48.49	Aisia-pacific	1952
				Europe	1060
				North America	4837
				Else	1442
Japan	6181	24	70.64	Aisia-pacific	5459
				Europe	222
				North America	213
				Else	287
Korea	4053	14	82.78	Aisia-pacific	3825
				Europe	36
				North America	84
				Else	108
France	1066	16	85.18	Aisia-pacific	56
				Europe	968
				North America	26
				Else	16

3.4 Global core patents distribution

In order to identify the specific technology distribution of solar energy R&D and to further explore its development trend and concentration distribution more accurately, we count the number of these 670 patents by IPC class. We find 36 IPC class with more than 2 patents and table 5 shows 4 of them which has more than 10 patents for each class.

Table 2. Core solar patents technology distribution

IPC class	Tecnology	Patents number
F24J 2/00:	Solar thermal device	219
H01L 31/00:	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation	217
F03G 6/00:	Devices for producing mechanical power from solar energy	34
E04D 13/00:	Special arrangements or devices in connection with roof coverings	12

From Table 2, it can be seen that the global solar core technology are concentrated in the field of photothermic and photovoltaic, for 65% of the core patents are in class F24J 2/00 and H01L 31/00. And other class may be the future growth point of solar energy core technology.

We further analyzed these core patents application countries and found that the core patents gathered in 8 countries. They are the United States, China, Germany, Japan, the United Kingdom, WIPO and Canada. Table 6 shows countries with more than 10 core patented technologies:

Table 3. Core solar patents market distribution

Main application countries	Number of Core patents	Local core patents	Partition of local core patents in application patents
America	506	396	78.26%
China	126	29	23.02%
Germany	12	11	91.67%

According to Table 3, the United States is the most important solar energy core technology application country. The majority of core patents are deployed in the United States and these core technologies are nearly applied by local companies, which indicating that the United States is both an important market and a powerful competitor. China is the second largest solar energy core technology application country. Statistics show that China is an important technology market who gain the attention of global core competitors. However, the proportion of domestic patents application of China is only 23.02%, indicating that local competitors do not have

technology advantages. This also confirms that China is an important country in the field of solar energy technology, not a powerful technology innovation country.

3.5 Solar technology distribution in China market

Of all the patents applied in China, 33,458 are from China, 3,757 from other countries in the world. Figure 7 is a view of patents distribution by IPC class in China:

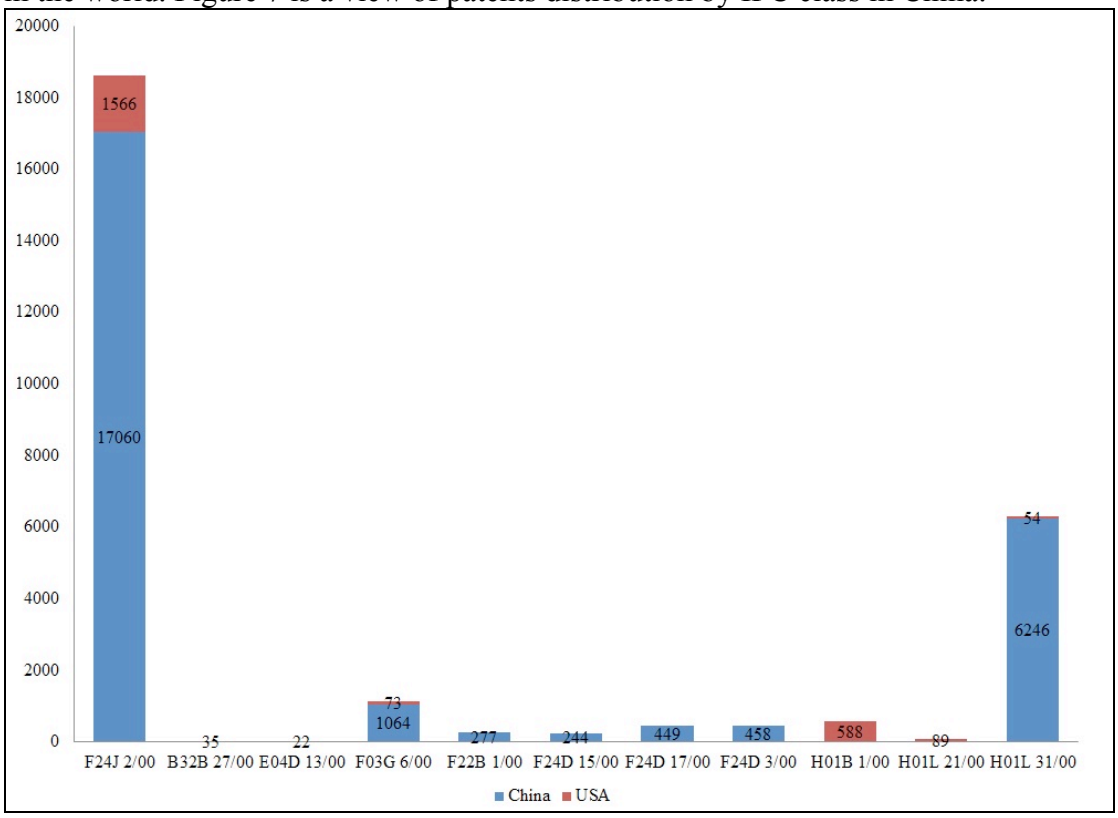

Figure 5. Solar energy technology distribution in China market

According to Figure 5, we found that applicants applied in China mainly focus on technologies belonged to F24J 2/00, H01L 31/00, and F03G 6/00 class, and the domestic applicants China also focus on these three technologies. The number of patent Chinese applications is large , even more than the total of other countries. Other countries also applied B32B 27/00, E04D 13/00, H01B 1/00, and H01L 21/00 patents in the China; in which H01L 21/00 and H01B 1/00 have relatively large volumes and are both related to semiconductor material technology. Semiconductor material technology is a technical shortcoming of Chinese local companies, and foreign companies have made up for the technical defects in Chinese market. Chinese local applicants have some patents distributed in F24D 3/00, F24D 17/00, F22B 1/00, F24D 15/00, which are related to residential hot water technology while others have no patents in this area.

4. Conclusion

This study analyzed the global solar technology competition situation and development trend, and the following is what we found:
From the perspective of patent application trends, global solar energy technology development state can be describe as three-phase before 2000 is introduction period,

from 2001 to 2006 is slow growth period and 2007 up till now is rapid development period. It can be predicted that in the next few years, solar energy is still in the rapid growth of technological life, and its development space and potential are huge.

From the perspective of patent application country, China, the United States, Japan, and South Korea are the main countries that apply for solar energy technology patents. The World Intellectual Property Organization, Germany, and the European Patent Office are also important applicants for solar energy technology. This is related to the global distribution of solar energy resources. Global climate change and renewable energy demand have a significant impact on the application of solar energy technology. The number of Chinese patent applications has been growing at a high rate and its global share has been rising. On the one hand, the solar energy industry has been supported by the national strategic emerging industries policy; on the other hand, China as a important market it has a strong attraction for applicants.

The patent text clustering results show that the global solar core patents are mainly concentrated in solar cells, solar energy, solar energy receivers, solar panels, and solar radiation fields. From the perspective of the IPC distribution of patent applications, we know that 65% of the core patents focus on F24J 2/00 and H01L 31/00 technology, and F03G 6/00 is also of great importance. In that case, it is obvious that technology about conversion of thermal energy and light radiation energy is critical in competition. global technology distribution in the China market also includes B32B 27/00, E04D 13/00, H01B 1/00, and H01L 21/00; among them H01L 21/00 and H01B 1/00 are relatively rich in patents and they are both related to semiconductor material technology. Some patents are distributed on F24D 3/00, F24D 17/00, F22B 1/00, F24D 15/00, which shows that China has obvious advantages in using solar energy for residential hot water technology. However, foreign companies have made up the technical deficiencies in Chinese market of semiconductor technology and materials in the process of solar energy utilization. For Chinese enterprises, it is conducive to evaluate the commercial potentiality of solar energy for residential hot water technology and invest semiconductor technology and materials in the process of solar energy utilization field. Furthermore, Chinese local applicants should continuously strengthen technological innovation, break through technical barriers, and grasp the right to speak in their own markets.

From the perspective of patent technology distribution, the Asia-Pacific region is the main battlefield for global solar technology deployment and the United States, Japan, South Korea, and France all have applied the largest number of patents in China except their domestic market. America and Japan have an obvious international patent layout with a partition of 50% and 30% patents in domestic market respectively, and both of them have mastered most of the core patents in the Chinese market. Although China is a major market, China’s global patent distribution is weak comparing with other major solar energy application countries. China need an internationalization strategy urgently. Especially, China has fewer basic, original, high-value and core patents when compared with America and Japan. Faced with increasingly fierce global challenges and lack of international competitiveness, Chinese local R&D need to improve patents competitive advantage, grand core technological high ground, and expand international market.

References

Fan, X., Liu, W., & Zhu, G. (2017). Scientific linkage and technological innovation capabilities: international comparisons of patenting in the solar energy industry. *Scientometrics, 111*(1), 117-138.

Frietsch, R., & Schmoch, U. (2010). Transnational patents and international markets. *Scientometrics, 82*(1), 185-200.

Hoppmann, J., Peters, M., Schneider, M., & Hoffmann, V. H. (2013). The two faces of market support—How deployment policies affect technological exploration and exploitation in the solar photovoltaic industry. *Research Policy, 42*(4), 989-1003.

Johnstone, N., Haščič, I., & Popp, D. (2010). Renewable Energy Policies and Technological Innovation: Evidence Based on Patent Counts. *Environmental & Resource Economics, 45*(1), 133-155.

Pettersson, H., Nonumura, N., Kloo, L., & Hagfeldt, A. (2012). Trends in patent applications for dye-sensitized solar cells. *Energy & Environmental Science, 5*(6), 7376-7380.

Timilsina, G. R., Kurdgelashvili, L., & Narbel, P. A. (2012). Solar energy: Markets, economics and policies. *Renewable & Sustainable Energy Reviews, 16*(1), 449-465.

Tour, A. D. L., Glachant, M., & Ménière, Y. (2011). Innovation and international technology transfer: The case of the Chinese photovoltaic industry. *Energy Policy, 39*(2), 761-770.

Zhang, X. (2014). Interactive patent classification based on multi-classifier fusion and active learning. *Neurocomputing, 127*(3), 200-205.

Zhao, R., Zhao, L., Deng, S., & Zheng, N. (2015). Trends in patents for solar thermal utilization in China. *Renewable & Sustainable Energy Reviews, 52*, 852-862.

Luan, C. J., Liu Z. Y., & Wang, X., W. (2013). Divergence and Convergence: analysis on evolving trend of technology relatness – case sutdy on patentometrics of worldwild solar energy technology. *Research and Management Development, 25*(4), 87-95.

ZHANG, G. P., & Chen, X. D. (2013). Analysis on patant qulity in new energy techonology field: a case study on wind energy and solar energytechnologies. *Research and Management Development, 25*(1), 73-81.

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