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# Pattern of Patent-based Renewable Energy Technology Innovation in China

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**Abstract:** Renewable Energy sources could provide a solution to enhance energy efficiency and air pollution governance, and is one of the key strategies to address sustainable development. Renewable energy technology innovation is a fundamental determinant of energy-saving and pollution management performance. This paper profiles and classifies renewable energy patents and uses visual techniques to examine their innovation capabilities. A renewable energy patents dataset derived from China's State Intellectual Property Office (SIPO) containing 49,460 renewable energy invention patents granted between 1985 and 2014 was constructed. The temporal and spatial distribution of renewable energy patents shows that eastern provinces had the majority of renewable energy patents, which denote that renewable energy science is geographically concentrated. Drilling further, it is confirmed that a clear pattern of concentration of renewable energy knowledge generation in a small number of big cities. The pattern of renewable energy patents by features and ownership indicates that enterprise plays a very important role in renewable energy innovation and university also attributes a lot.

***Keywords:*** *Renewable Energy, Patents, Technology Innovation*

## 1. Introduction

China is the largest and fastest growing emerging economy in the world. During the period 1999–2013, China's gross domestic product (GDP) increased from US$ 4202.9 billion in PPP (purchasing power parity at 2005 price) to US$ 15,643.2 billion in PPP (World Bank, 2014) ;and its annual GDP growth rate was 19.44% during this period.

Owing to rapid economic development and rising level of industrialization and urbanization, China's consumption of energy is surging. Its energy consumption increased from 934.7 million tones oil equivalent (Mtoe) in 1999 to 2852.4 Mtoe in 2013 (BP, 2014). It is estimated that China's energy demand will reach 4671.6 Mtoe by 2035(BP, Energy outlook 2035). So China now is the second largest energy consumer, behind the United States.

However, because of the coal-dominated energy consumption structure and low energy efficiency, China has become the biggest $CO_2$ emitter in the world since 2007. According to a preliminary estimate, in 2013, China's $CO_2$ emissions are over 10 $GtCO_2$ and account for about 32% of the global gross emissions, and the level of emission is still increasing rapidly (Friedlingstein et al., 2014). Thus, China faces an increasing pressure to reduce $CO_2$ emissions. In a China–US joint statement on climate change on November 12, 2014, China first publicly pledged to reduce the $CO_2$ emission per unit of GDP by 60-65% in 2030 compared to the level of 2005.

On the other hand, a rising awareness of environmental issues, such as severe air pollution of fog and haze, which is directly related to massive use of fossil fuel (especially coal), has caused a strong public appeal to address environmental problems.

Renewable Energy(RE) sources could provide a solution to enhance energy efficiency and air pollution governance, as they are environment-friendly and capable of replacing conventional sources in a variety of applications at competitive prices (Aras et al. ; Haralambopoulos & Polatidis).Because the substitution of clean or carbon-free energy for coal requires technological advancement, renewable energy technology innovation is a fundamental determinant of energy-saving and pollution management performance.

Patent data has become important indicator to measure technological innovation performance because of its broad availability and information richness. They are the outputs of technology Research and Development (R&D) activities (Lee and Lee, 2013; Oltra et al., 2010; Wang et al., 2012), and offer great convenience to explore the process of knowledge innovation and diffusion. (Scherer, 1984; Griliches, 1990; Lamoreaux and Sokoloff, 1996; O'huallachain, 1999, 2010; Jaffe and Trajtenberg,

2002). Meanwhile, the statistical disadvantages of patent data as overall measures of economic and inventive activity are also obvious (Pavitt, 1985; Griliches, 1990; Furman et al, 2002). Not all inventions are patented. Companies can prefer secrecy, or rely on other mechanisms in order to gain market dominance. There is evidence of differing patenting behavior across industries and countries and over time. The value distribution of patents is known to be skewed, as a few have very high technical and economic value whereas many are ultimately never used. Simple counts, which give the same weight to all patents regardless of their value, can therefore be misleading, notably in the case of small samples. Different standards across patent offices and over time affect patent numbers although underlying inventive activities may remain unaffected (Griliches, 1990).

In conclusion, patent data's advantages outweigh its disadvantages. So patent is still a reliable index to evaluate innovation activities, because it has a solid theoretical foundation, a long history and uniquely detailed source of information on inventive activity (Griliches 1990, Acs et al. 2002).In this sense, renewable energy patents are suitable to measure the output of innovation performance and the latest advancement in energy technologies (Johnstone et al., 2010; OECD, 2008; Wang et al., 2012; WIPO, 2009). Most studies analyze the trend of renewable energy technological progress using energy patent counts (Albino et al., 2014; Wong et al., 2014). A few studies investigate renewable energy technology patents in China (Hu and Phillips, 2011; Lee and Sohn, 2014; Wang et al., 2012). Despite the increased use of patent counts to measure renewable energy technology innovation, very few studies analyze the development of China's renewable energy technology patents.

This paper investigates the spatiotemporal character of China's renewable energy technology innovation performance. Our discussion is structured as follows. In Section 2, the searching process, to identify renewable energy patents from all the patents, is introduced in detail, and the methods adopted in this article are also described. Section 3 analyses the temporal and spatial distribution of patent-based renewable energy innovation in China and discusses the outcome of data analysis. Section 4 rounds off with a discussion of the contributions and policy implications of our research.

## 2. Data and Method

### 2.1 Data

In China, patents are categorized into three different types: inventions, utility models, and designs. The invention patent is not only the primary kind of patent but also an important output indicator of innovative activity, which is the core and the most valuable part of the national scientific and technological resources to some extent. The development of the invention patent not only reflects the original innovation capability of a nation and region. Therefore, we use only invention patent information for construction of our analytical database.

In this paper, an individual patent database is developed by using internet data crawler technology under the condition of C# language. The time frame used was the period from September 10th, 1985 to December 31st, 2014, as we are interested in the long-term trajectory of renewable energy innovation. We extracted the granted invention patent data from the website of the State Intellectual Property Office of China (SIPO, http://www.sipo.gov.cn) year by year. After data collection, clean-up, pre-processing, we set up our original database, which is a text base file with bibliographic information of all invention patents granted from 1985 to 2014. We have extracted the following from this file, and compiled the patent database with 660,719 invention patents:

- Granted date.
- IPC code (primary one).
- Applicant's names and addresses.
- Inventor's names.
- Title of invention

Renewable energy usually refers to those energies that do not pollute environment and could be recycled in nature. The renewable energy mentioned in this article mainly refers to bio-fuels, solar energy, fuel cells, wind energy, geothermal energy and hydro energy. The International Patent Classification (IPC) system grew out of the Strasbourg Agreement of 1971 as an internationally acknowledged method of classifying patents for inventions, including published patent applications, utility models and utility certificates. Currently the IPC is used in more than 100 countries as the major or, in some instances, the only form of classifying these documents. The purpose of the IPC system is to group patent documents according to their technical field, whatever the language and terminology According to World Intellectual Property Organization's website, the IPC Committee of experts developed the "IPC Green Inventory" in order to facilitate searches for patent information relating to so-called Environmentally Sound Technologies(ESTs),as listed by the United Nations Framework Convention on Climate Change(UNFCCC). ESTs are currently scattered widely across the IPC in numerous technical fields. The Inventory attempts to collect ESTs in one place, although it should be noted that the Inventory does not purport to be fully exhaustive in its coverage. We use the "IPC Green Inventory" to extract renewable energy patents from the gross patent database (Table 1).

***Table 1**: Renewable Energy IPC Code*

| Renewable energy sub-sector | IPC |
|---|---|

| | |
|---|---|
| Bio-fuels | A01H;C02F 11/04;C02F 3/28; C07C 67/00;C07C 69/00;C10B 53/02;C10G;C10L 1/00;C10L 3/00;C10L 5/00 C10L 9/00;C11C 3/10;C12M 1/107; C12N 1/13,15,21;C12N 15/10; C12N 5/10;C12N 9/24;C12P 5/02; C12P 7/06,08,10,12,14,64;F02C 3/28 |
| Fuel cells | H01M 2/00;H01M 8;H01M 12; C10J H01M 4/86,88,90,92,94,96,98 C10B 53/00 |
| Hydro energy | B63H 19/02,04;E02B 9;F03B;F03C;F03G 7/05 |
| Wind energy | B60K 16/00;B60L 8/00;B63B 35/00; B63H 13/00;E04H 12/00;F03D;H02K 7/18 |
| Geothermal energy | F01K;F24F 5/00;F24J 3/08;H02N 10/00;F25B 30/06;F03G 4/00;F03G 4/02; F03G 4/04;F03G 4/06;F03G 7/04 |

*Sources http://www.wipo.int/classifications/ipc/en/est/*

The iterative search process identified 49,460 renewable energy invention patents. Based on the address of applicant, the codes for country and region (in case of Chinese applicant) are added to the database. In terms of inventors, however, only name information is available so that it is difficult to identify the location of each invention taking place. In terms of ownership, we divided the renewable energy patents into three types: owned by individuals, owned by enterprises, owned by universities and research institutes.

### 2.2. Method

Spatial analysis was conducted using ArcView, a GIS software package from ESRI.

The RTA index was used to analyze the discrepancy of renewable energy patents in different provinces in this article.

The identification of technology domains and industries in patent data makes it possible to analyze the relative technological position of a country relative to others or to the world average. More specifically, the sectorial structure of countries' patenting activity can be investigated using patent indicators of specialization (Soete and Wyatt, 1983). RTA index is also called "specialization index", and it is defined as the share of a country *i* in patents in a particular field of technology divided by the country's share in all patents.

The index is equal to zero when the country holds no patents in a given sector, is equal to 1 when the country's share in the sector is equal to its share in all fields (no specialization), and grows rapidly (the upper limit will depend on the world distribution used) when a positive specialization is found. Figures based on RTA indicators must be interpreted with caution, especially for international comparisons. A country with a very large total patent output will tend to have all its RTAs in the neighborhood of 1, whereas a country with a low output of patents will have a very high value for the fields in which its output is slightly higher than the average for the country.

$$\mathrm{RTA} = \frac{P_{d,i} / \sum_{d} P_{d,i}}{\sum_{di} P_{d,i} / \sum_{d,i} P_{d,i}}$$

## 3. Result

### 3.1 Distribution of Renewable Energy

In total, there were 49,460 invention patents granted in this period. Of which, 30,724 were granted to China's domestic inventors including Chinese residents and foreign invested enterprises in China, accounting for 62.12% of the total. While 18,736 were applied by foreign inventors making up 37.88% of the total. And among foreign inventors, Japanese rank the top (6411, 13.3%), followed by Americans (4202, 8.5%). In addition, Germans (1401, 3.03%), Koreans (1410, 2.85%), Taiwanese (898, 1.82%), Dutchmen (618, 1.25%) and Frenchmen (542, 1.1%) were also contributing foreign inventors, and their shares were all above 1 %.( Fig.1).

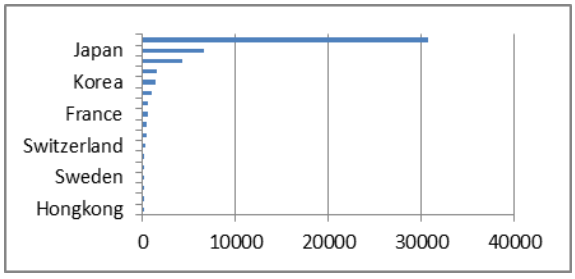



***Fig.1*** *The distribution of granted country of renewable energy invention patents (1985-2014)*

Fig. 2 provides a dynamic picture of the granted invention patents of renewable energy which carried out by China's resident throughout the observation period.

China's invention patent growth rate reached 900% in 1987, because there were few invention patents granted in 1986. According to the data in Fig. 2, the annual growth rates have exceeded 50% in 1988, 1989, 1992 1995, 2000, 2003 and 2012, it were above 150% in 2000 and 2003. Exclude the unusual year of 1987, the average growth rate of this specific period reached 34.8%. Despite the number of invention patents also had negative growth in some specific years; the overall development trend of invention patents was upward steadily. There was a little drop in the tail of the point range which represent the year 2014. The little drop may partially because that

China's economy has entered a period of new normal and shifted gear from the previous high speed to a medium-to-high speed growth.

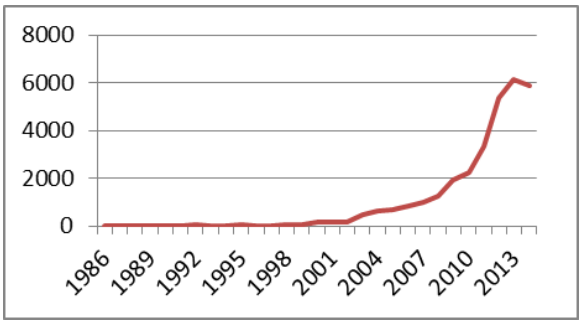



***Fig. 2*** *Number of renewable energy innovation patents granted to China's domestic inventors (1985-2014)*

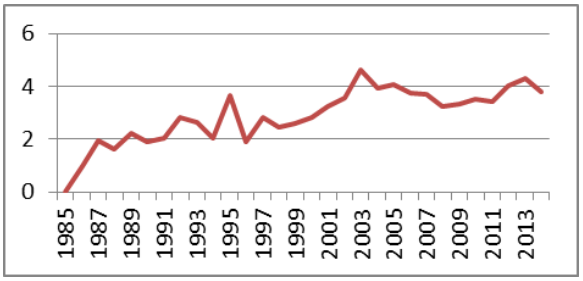



***Fig. 3*** *Percentage of renewable energy patents to all the patents from 1985-2014*

Though the total count of renewable energy patents increased year after year, renewable energy patents account for a small proportion of the total common patents. But the share of renewable energy patents was increasing gradually (Fig. 3). From 1985 to 1994, the average percentage of renewable energy patents to the total common patents was 1.82 percent, while the average percentage grew to 3.12 percent during the next decade (1995-2004), and the increasing trend continued with the average percentage of 3.71 percent from 2005 to 2014. The rate of renewable energy patents to common patents show an ascending trend in general and the average proportion was less than 4 percent, since renewable energy industry is still at initial stage and not as profitable as information and energy industries. There is a dilemma that on one hand the realization of public environmental objectives need more advanced technologies to provide systems solutions; on the other hand a few innovative renewable energy technologies are available. Therefore, more efforts and focus on renewable energy technology innovation are needed to maintain greater energy security in the face of uncertain markets for fossil fuels and to enable sustainable development.

### 3.2 Geographical Descriptive Analysis of Renewable Energy

The analysis in this section begins with an overview of the spatial distribution of renewable energy innovation patents in all prefectural-level and above cities during the period 1985 to 2014 (Table 2).

***Table 2****: Distribution of Renewable Energy Patent Granted to China's Prefectural-level and above Cities for Different Periods*

| Number of Prefectural-Level cities | Total RE Patent Count | Percentage of Total Patent Count | Mean | Median | Standard Deviation |
|---|---|---|---|---|---|
| **1986-2014** | | | | | |
| **310** | 30724 | 100 | 99.11 | 11 | 513.67 |
| **30** | 24582 | 80.01 | 819.4 | 365.5 | 1532.65 |
| **11** | 18451 | 60.05 | 1677.36 | 1049 | 2161.02 |
| **1986-1995** | | | | | |
| **310** | 282 | 100 | 0.91 | 0 | 5.18 |
| **30** | 232 | 82.27 | 7.73 | 4 | 14.98 |
| **11** | 168 | 59.57 | 15.27 | 7 | 22.82 |
| **1996-2005** | | | | | |
| **310** | 2472 | 100 | 7.97 | 1 | 62.18 |
| **30** | 2100 | 84.95 | 70 | 23.5 | 185.76 |
| **11** | 1738 | 70.31 | 158 | 61 | 291.47 |
| **2006-2014** | | | | | |
| **310** | 27970 | 100 | 90.23 | 9 | 448.61 |
| **30** | 22332 | 79.84 | 744.4 | 354 | 1264.05 |
| **11** | 16641 | 59.50 | 1512.82 | 889 | 1847.43 |

Similar to most inventive and innovative activity, renewable energy science is geographically concentrated. Of 337 prefectural-level and above cities, 310 have a share in the 30,724 renewable energy patents granted between 1985 and 2014. 24,582 patents were granted to the top 30 cities, which accounting for 80.01 percent of the total. During the same period, 60.05 percent of total renewable energy patent were granted to 3.3 percent, or 11, of the 337 prefectural-level and above cities. And these 11 cities are all sub-provincial cities.

These numbers confirmed a clear pattern of concentration of renewable energy knowledge generation in a small number of big cities, which indicates that big cities were endowed with strong innovative abilities because they have not only solid science & technological bases but also excellent development abilities. Furthermore big cities are the gathering places for high-level enterprises and high-quality human resources.

However, development during this period reveals an early increasing late diminishing spatial concentration. The share of renewable energy patent granted to the 11 most active patenting cities increased from 59.57 percent in the first period (1986-1995) to 70.31 percent in the second period (1996-2005), showing increasing concentration. But in the third period (2006-2014), the share decreased to 59.50 percent, which indicated that spatial concentration diminished. The reason behind this phenomenon needs further research and investigation.

Fig.4 illustrates the geographic spread of renewable energy patenting activity across China. The map shows a clear concentration of nearly half of the 11 cities in eastern China (Beijing, Shanghai, Nanjing, Hangzhou and Tianjin), in addition to Shenzhen, Guangzhou in southern China. Three other regions have cities that are among the most renewable energy knowledge-producing in China. These regions include Wuhan in Middle China, Dalian and Harbin in northern China, and Chengdu in western China. The reason why eastern and southern regions have strong motivation to develop renewable energy lies in that they are relatively lacking of traditional energy. Meanwhile, these areas have outstanding innovation competences because they have plenty of colleges and institutes with strong R&D abilities and high level of R&D inputs.

Although the total amount of innovation activity matters, another criterion for identifying the hubs of innovation is revealed technological advantage (RTA) index, which was used to analyze the sectoral structure of China' renewable energy patenting activity. Considering the top 20 most productive cities in renewable energy inventions distinguishes eight cities whose RTA is greater than 1. The eight cities are as follows: Beijing, Nanjing, Guangzhou, Wuhan, Dalian, Harbin, Jinan and Kunming. The RTA indicates that positive specialization in renewable energy could be found in these cities.

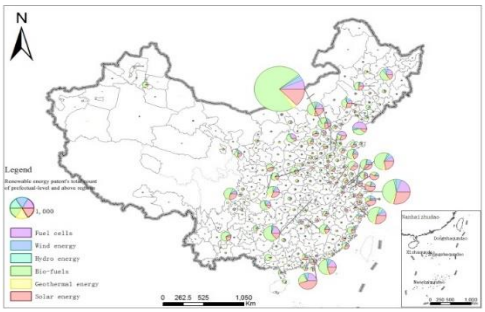



***Fig.4*** *Geographical distribution of China's RE's patents (1985-2014)*

### 3.3 Distribution of Renewable Energy's Sub-sector

Table 3 shows the total number of patents granted to six renewable energy sub-sectors (bio-fuels, solar, fuel cells, wind, geothermal and hydro). Note that the total of the renewable energy intention patents is slightly less than the sum of the invention patents of six subsectors, because one patent document can contain one or several IPC codes, so may be classified into more than one sub-sector simultaneously, as we mentioned in ?

The distribution of renewable energy's sub-sector was also shown by Table 2. Bio-fuels energy is the largest sub-sector, making up 51.15 percent. Followed by solar and Fuel cells, which comprising 23.36 percent and 12.07 percent of the total. While the share of wind, geothermal and hydro energy is all below 10 percent, which only accounted for 6.18, 4.15 and 3.08 percent respectively.

***Table 3****: Distribution of Renewable Energy's Sub-sector*

| RE's sub-sector | Number (1985-2014) | Percentage |
|---|---|---|
| Bio-fuels | 16487 | 51.15 |
| Solar energy | 7529 | 23.36 |
| Fuel cells | 3890 | 12.07 |
| Wind energy | 1993 | 6.18 |
| Geothermal energy | 1337 | 4.15 |
| Hydro energy | 994 | 3.08 |
| Renewable Energy | 30724 | |

The development trends of six sub-sectors of renewable energy have been showed by Fig. 5.

It obviously that bio-fuels energy is a sub-sector with the highest growth rate in the number of intention patent. Before 1999, bio-fuels had undergone a very slow development period. Specifically speaking, the number of invention patent granted to bio-fuels energy was 1 in the year of 1986 while this figure accrued to 48 in 1999. During the following decade (2000-2009) the number of bio-fuels patents granted has grown more quickly, from 115 to 865, with the increase of 7.5 times. Both its number and growth rate has increased sharply between 2010 and 2014.

The other five sub-sectors developed later than bio-fuels. Solar energy's development accelerated until 2005, and peaked in 2012 with an annual growth rate up to 355.58%. And then lightly slows down. The development of fuel cells become rapidly from 2002, the number of patents granted soared from 8 in 2002 to 742 in 2014.There is some similarity in the development of wind, geothermal and hydro energy. The patents number of these three sub-sectors increased moderately and then accelerated, but their growth rates were lower than the former three sub-sectors. It can be seen that, more and more research and development organizations pay attention to renewable energy industry, and the renewable energy technology is playing an important role in China's economic development.

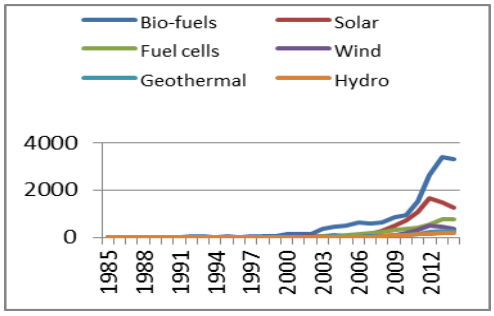
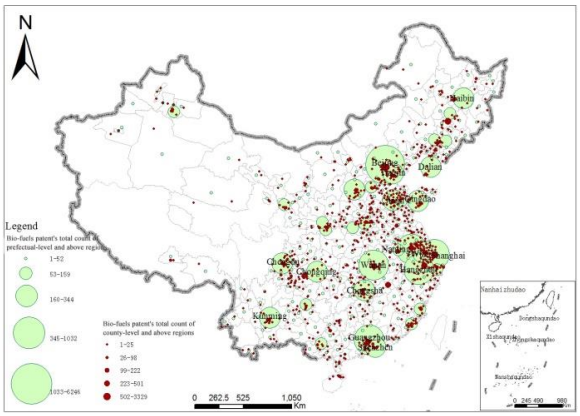
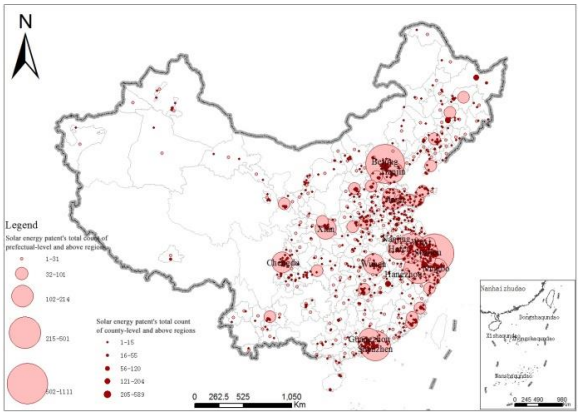



***Fig. 5*** *Patents Granted to RE's Sub-sectors (1985-2014)*

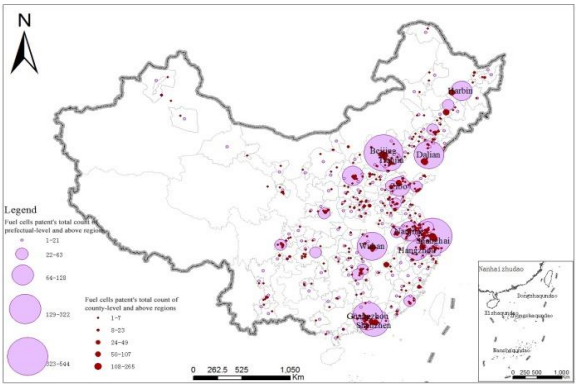
Fig.6 illustrates the geographical distribution of renewable energy sub-sectors patenting activities. More than 70 percent of the 337 China prefectural-level and above cities had some inventive activity in bio-fuels (280 cities) and solar energy (242 cities) between 1985 and 2014, which means there are broad innovation foundations in these two sub-sectors. But in other four sub-sectors, less than 70 percent of the 337 China prefectural-level and above cities had a share in the inventive activity, eg. fuel cells(177 cities), wind energy(176 cities), geothermal energy(145 cities) and hydro energy(145 cities). These four sub-sectors developed behind bio-fuels and solar energy. Therefore, more efforts and focuses are needed to enable the sustainable development.



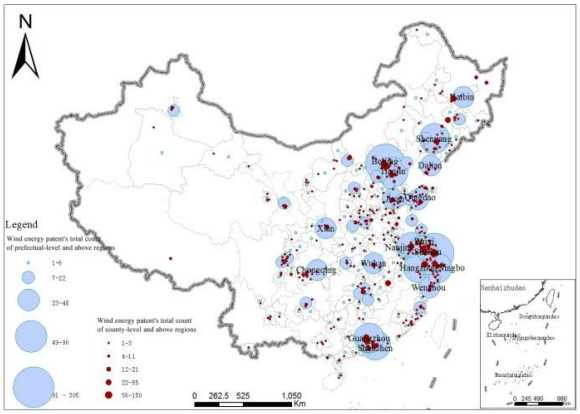
*Bio-fuels paten(1985-2014)*



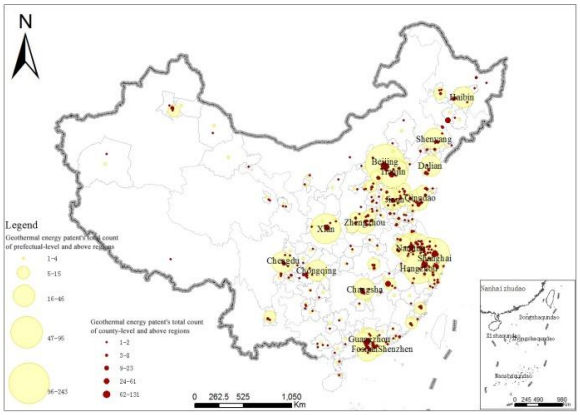
*Solar energy patent(1985-2014)*



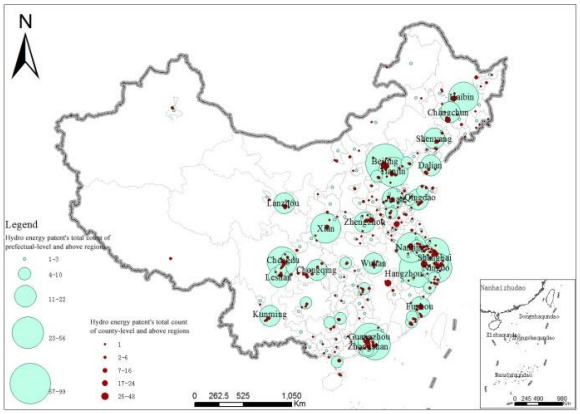
*Fuel cells patent(1985-2014)*



*Wind energy patent(1985-2014)*



*Geothermal energy patent(1985-2014)*



*Hydro energy patent(1985-2014)*

***Fig.6** Geographical distribution of renewable energy sub-sector patent (1985-2014)*

Fig.6 is that all the renewable energy sub-sectors concentrate geographically, especially in eastern and southern regions. Drilling down further, inventions in all the sub-sector occur predominantly in metropolises: in bio-fuels sub-sector, nearly 60 percent of the patents are attributable to inventors who lived in 7 sub-provincial cities, including Beijing, Shanghai, Nanjing, Hangzhou, Wuhan, Guangzhou and Tianjin; in solar energy sub-sector, 14 cities produced more than 60 percent of all solar energy patents granted; in fuel cell sub-sector, 9 cities dominated the count of fuel cell innovation, making

up nearly 60 percent of the total; as for wind, geothermal and hydro energy sub-sector, 60 percent of the patents attributed to 14,13 and 16 cities separately.

### 3.5 Pattern of renewable energy patents by ownership

To analyze the pattern of renewable energy patents by ownership, we divided the patents into three types: enterprise owned patents, individual owned patents and university and research institute owned patents. The sum of the invention patents of three kinds of ownership is 31,649; note that the sum is slightly more than the total of the renewable energy intention patents (30,724). Because the co-authorship patents contain more than one inventor, so may be classified into more than one kind of ownership simultaneously.

Among the total number of 31,649 renewable energy patents granted to domestic inventors from 1985 to 2014, university and research institute owned patents rank first, which accounted for 45.78 percent (14,064); and enterprise owned patents took up 40.84 percent (12,547); with individual owned patents the least percentage, only made up 16.40 percent of the total (5038).

The percentage of every kind of renewable energy patents per five years (enterprise owned patents, individual owned patents and university and research institute owned patents) to all the renewable energy patents was calculated respectively, as shown in Fig. 7.

The percentage of university and research institute owned patents underwent a first decrease later increase trajectory; it decreased from 1985 to 2004 and then increased from 2005 to 2014. Enterprise owned patents' share nearly doubled during the period from 1985 to 2004, then decreased during the next five years (2005-2009), but finally picked up again between 2010 and 2014. The percentage of individual owned patents showed the ascending trend and peaked at the end of 20th century (1995-1999), then dropped significantly and hit the bottom during 2010 to 2014. It indicated that university and research institute played an important role in renewable energy technology development, and more attention has been paid by enterprises to realize public environmental objectives, and the linkage between university and research institutes and enterprises has been strengthened for technology innovation.

Fig.8 showed that the patterns of domestic application of renewable energy six sub-sectors patents by ownership varied notably. The share of enterprise owned patents was 36.44 percent in geothermal, 40.60 percent in wind energy and 41.96 percent in solar energy. These three sub-sectors' share of enterprise owned patents is the highest in three types of ownership. It indicates that enterprises innovative activity is the most importance driving force in geothermal, wind energy and solar energy. It is worth noting that in the sub-sectors of fuel cell and bio-fuel, the share of university and research institute owned patents surpass the share of the other two kinds of ownership, accounting for 47.65 and 51.28 percent respectively. This phenomenon demonstrated that university and research institute played a very important role in fuel cell and bio-fuel patenting. Furthermore, 39.61 percent of hydro energy patents are attributable to individual inventors, accounting for the largest share in the three types of ownership. So we can draw a conclusion that individual inventive activity is the most dynamic strength to propel hydro energy patenting. Table 4 displays top 20 productive REs' Patents Prefectural-level and above Cities, the share of university and research institute patents and the share of enterprises patents over a 30-year period. According to the type of inventors, some regions are dominated by universities and research institutes, whereas others are dominated by enterprises.

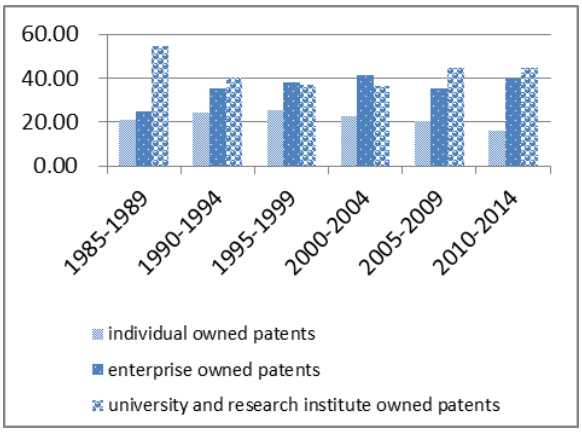



***Fig.7*** *Pattern of domestic application of RE's patents by ownership*

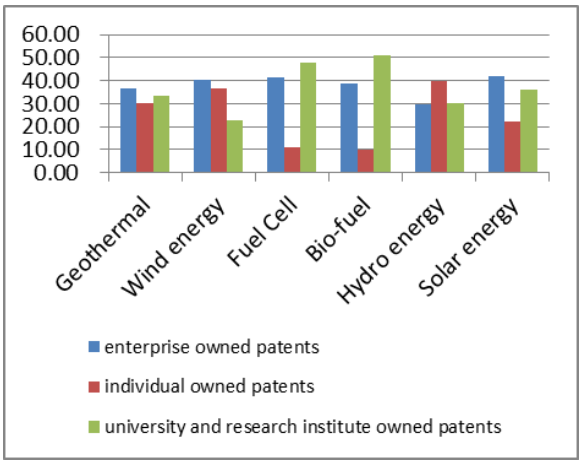



***Fig.8*** *Distribution of RE's Sub-sectors patents by ownership*

The percentage of university and research institute owned patents varies significantly among the largest renewable energy patenting cities, ranging from 4.91 percent to 76.54 percent. It is evident that some cities' renewable energy activities are primarily driven by

the research of universities and research institutes. The importance of universities and research institutes research can be observed in Nanjing (76.54 percent), Harbin (76.33 percent), Wuhan (72.65 percent), Guangzhou (69.25 percent), and Hangzhou (66.70 percent). It indicates that the agglomeration of universities and research institutes appears to create necessary prerequisites in renewable energy patents production in these cities.

***Table 4:*** *Top 20 productive REs' Patents Prefectural-level and above Cities, University and research institute Share and Enterprises Share*

| Prefectural-level and above Cities | Rank of REs' Patents | Rank of University and research institute patents | Rank of enterprises patents |
|---|---|---|---|
| Beijing | 1 | 15 | 5 |
| Shanghai | 2 | 10 | 7 |
| Nanjing | 3 | 1 | 18 |
| Hangzhou | 4 | 5 | 16 |
| Shenzhen | 5 | 20 | 1 |
| Guangzhou | 6 | 4 | 17 |
| Wuhan | 7 | 3 | 15 |
| Tianjin | 8 | 9 | 8 |
| Dalian | 9 | 8 | 10 |
| Chengdu | 10 | 12 | 9 |
| Harbin | 11 | 2 | 20 |
| Jinan | 12 | 14 | 13 |
| Xi'an | 13 | 6 | 11 |
| Wuxi | 14 | 16 | 4 |
| Kunming | 15 | 7 | 19 |
| Qingdao | 16 | 13 | 12 |
| Zibo | 17 | 19 | 3 |
| Suzhou | 18 | 17 | 2 |
| Chongqing | 19 | 11 | 14 |
| Ningbo | 20 | 18 | 6 |

## 4. Conclusions and Discussions

Patent data represent an important source of structured and accurate information about technology, innovative activity and performance. Analysis of patent data relative to a specific technology can reveal important information about the origins of a technology, how a technology space is developing and the process of knowledge innovation and diffusion, which can provide reliable information to support decision-making in both the public and private sectors

A patent landscape analysis was made over renewable energy technology to provide an overview of China's renewable energy patent activity from a historical, organizational, geographical and technological point of view. The objective of this study was building up a detailed picture of patterns of innovative activity and innovation dynamics in renewable energy technology through an analysis based on patent data.

Though the total count of renewable energy patents increased year after year, renewable energy patents account for a small proportion of the total common patents. But the share of renewable energy patents was increasing gradually, which denotes that innovation of renewable energy technologies has received heightened attention with the rise of concerns on environmental problems such as climate change and global warming.

The temporal and spatial distribution of renewable energy patents shows that eastern provinces had the majority of renewable energy patents, which denote that renewable energy science is geographically concentrated. Drilling further, it is confirmed that a clear pattern of concentration of renewable energy knowledge generation in a small number of big cities, and the degree of spatial concentration underwent a process of increasing first then diminishing later. The reason behind this phenomenon needs further research and investigation. Subsector of renewable energy also developed quickly and bio-fuels energy is a sub-sector with the highest growth rate in the number of intention patent. All the renewable energy subsectors showed geographical concentration. The pattern of renewable energy patents by features and ownership indicates that enterprise plays a very important role in renewable energy innovation and university also attributes a lot.

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