Technological change in the energy sector: The contribution of Chinese knowledge spillovers from renewable energy technologies

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List of Acronyms

CNIPA	Chinese National Intellectual Property Administration
EPO	European Patent Office
FF	Fossil Fuel
GPT	General Purpose Technology
IPC	International Patent Classification
ISS	Institute of Social Studies
PCT	Patent Cooperation Treaty
R&D	Research and Development
REN	Renewable Energy
SQL	Structured Query Language
WIPO	World Intellectual Property Organisation
WTO	World Trade Organisation

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Abstract

This research paper studies knowledge spillovers from Chinese-invented renewable energy technologies and which different technological fields benefit from the knowledge of solar, waste, wind, hydropower, marine, biomass and geothermal technologies. The dataset is based on patent citations of patents filed at the Chinese patent office in the period 2000-2017. The analysis differentiates between total knowledge flows, within the same technological field (intra-knowledge spillovers), to other technological fields within electricity production (inter-knowledge spillovers) and to external technological fields (external knowledge spillovers). Putting knowledge spillovers into the context of technological change and diffusion, suggests that Chinese-invented waste, solar and wind technologies contributed the most to technological change and diffused the most so far because they are the most frequently cited technologies. While wind technologies mainly profit from knowledge within their own technological field, solar and storage technologies are more likely applied in external technological fields. The latter suggests the promotion of more diversity and modularity within the economy which can increase technological opportunities to recombine knowledge. Marine and geothermal technologies should receive more policy support in China to accelerate their diffusion.

Relevance to Development Studies

The existent literature on knowledge spillovers in the energy sector focuses particularly on the context of OECD countries but is lacking the understanding of the Chinese context. Moreover, the analysis of patent citations of patent data filed at the Chinese patent office and additionally of such recent years has not been examined yet, to my knowledge.

Since China's increasingly more important role as a global economic player and the large-scale promotion of renewable energy technologies by its government, the Chinese contribution to the globalised process of technological change in the energy sector has become evident. To understand and characterise the Chinese contribution, knowledge spillovers between technologies reflected through patent citations are examined. The characterisation of knowledge spillovers explains how much the knowledge of technologies is diffused and what kind of knowledge is accumulated. Depending on what kind of knowledge is accumulated, an energy system which is based on diverse knowledge gives the opportunity to create more flexibility and modularity offering more ways to combine knowledge. This way, a technological lock-in can be avoided and general productivity gains across the whole economic system can be promoted.

Therefore, to understand one mechanism to direct technological change in the energy sector based on the Chinese context, can give insights on how to promote society's well-being not only through economic opportunities but also through paving the way for an energy structure based on renewable energy sources instead of fossil fuel sources.

Keywords

Technological change, knowledge spillovers, renewable energy, China

Chapter 1 Introduction

1.1 Context and relevance of the research work

One factor defining the direction of technological change in the energy sector towards REN technologies are knowledge spillovers. They are understood to be one driving force for the diffusion of technologies and occur when knowledge is transferred 'between different innovation actors and fields of technology application' (Wilson and Grübler 2014: 14). In other words, they drive technological change because they link technological fields and foster the accumulation of knowledge (Wilson and Grübler 2014: 13). However, if technological linkages become too close and localised, the scope of technological change becomes very narrow inducing a too high level of path dependency which can lead in the energy sector to a "carbon lock-in" (Unruh 2000: 81). Therefore, adequate policies need to be designed to direct knowledge spillovers in the energy sector.

Since technological change is a driver of economic growth, countries can harness environmentally-motivated technological change to spur economic development. Technological innovation has been concentrated in a few 'developed' countries since the Industrial Revolution (Tan 2010: 2916), reinforcing the inequality worldwide and contributing to the divergence of economically developed and developing countries. However, 'developing' countries have found ways to transfer technological knowledge through channels such as international collaborations in the private sector, transfer of skilled labour and reverse engineering (Gallagher 2014). Through the process of adaptation and absorption 'developing' countries accommodate knowledge spillovers for imitation while accumulating and developing knowledge for their own contribution to the globalised technological innovation process.

China is a successful example, as one of the fastest economically emerging countries, of making use of technology transfers from other countries. Initially technology transfers can lead to technological imitations to produce technologies at lower costs spurring economic growth. However, to create sustainable long-term economic growth, indigenous innovation (and not imitation) is the key reaping the full economic benefits of technological innovation (Tan 2010: 2921). Therefore, the Chinese government promotes science and technology along the lines of "coordinated, green, open, and shared development" (NDRC 2016: Part I). One of its focus areas is to "build a modern energy system that is clean, low-carbon, safe, and efficient, and will safeguard the country's energy security" (NDRC 2016: Chapter 30). While grasping the environmental benefits of REN technologies, China wants to profit from the economic opportunities they create through innovation and technological improvements which in turn drive economic growth.

China's commitment to innovation is reflected in innovation input indicators that have increased since the year 2000. The Chinese contribution to global growth in R&D expenditures from 2000-2015 was almost one third while the growth rates for the United states and the Europe Union declined by 11% and 5% respectively (National Science Board 2018: 13). Chinese gross domestic R&D expenditure rose from a worldwide share of 4.5% in 2000 to a share of 21% in 2015 (UNESCO 2018). Specifically, for the REN industry, investments in renewables power generation made up USD 90 billion out of USD 297 billion globally making China the worldwide leader in REN technologies investments (IEA 2017: 22). These input factors to innovation reflect the efforts of the Chinese government to promote innovation in its economy. However, more important is how these efforts translate into innovation output which in the end reflects the contribution to technological change and economic development.

A popular indicator for innovation output are patents which are 'exclusive rights granted for inventions' (WIPO n.d.a). With its *15-year science and technology plan*, implemented in 2006, the Chinese government officially set out to become 'one of the top five countries in the world in the number of invention patents granted to Chinese citizens' (Cao et al. 2006: 38). The number of granted patents was on the rise from 2000-2016, with 105,345 granted patents in 2000 (National Bureau of Statistics of China, 2005a) increasing to 1,753,763 patents granted in 2016 (National Bureau of Statistics of China, 2017a). Granted patents in the field of *generation, conversion and distribution of electric power* increased from 4,011 in 2003 (National Bureau of Statistics of China, 2005b) to 47,093 in 2016 (National Bureau of Statistics of China, 2017b).

However, the number of granted patents only grasps the quality of innovation to a very narrow extent and does not indicate in which way particular technologies contribute to technological change. A better indicator for this purpose is the counts of forward patent citations which indicate how many times one patent is cited by another (also called forward citations). They reflect knowledge flows from one technology to another, and through them it can be quantified how specific technologies contribute to technological change. Consequently, patent citations are an appropriate tool to analyse the effectiveness of China's promotion of innovation in cleaner electricity production and how China's dependence on coal can be reduced through the promotion of REN technologies.

China's increasingly more important role as an economic player in the field of cleaner electricity production becomes more evident. It was for example responsible for driving down global costs of solar panels through innovation and oversupply (Stacey 2018). Therefore, its relevance for the globalised technological innovation process cannot be neglected for directing technological change in the energy sector. Adequate policies are needed to pave the way for a REN-based energy structure through the promotion of more diverse technological opportunities (Azar and Sandén, 2011: 139). One aspect having an impact on technological diversity is how technologies relate to each other. Depending on what kind of knowledge is fostered through specific technologies the knowledge accumulation process is directed towards a certain technological path. Technologies informing only the generation *within* the same technological field (intra-knowledge spillovers) create a narrow range of technological opportunities. Technologies informing the generation of knowledge *within* and *between* other technological fields (external knowledge spillovers) create broader technological opportunities and increase the probability of combining knowledge from different technological field producing more generally applicable technologies. More generally applicable technologies help to avoid a technological lock-in. Through the characterisation of the generated knowledge spillovers, it can be described in what manner the Chinese contribution to technological change in the energy sector encourages since the beginning of the century an energy path based on REN sources. Moreover, having insights on the technological relatedness can give the opportunity to draw potential policy implications from the viewpoint of knowledge spillovers (which is only one factor influencing the direction of technological change). To improve our understanding this research paper makes use of Chinese patent citation data which, to my knowledge, has not been analysed yet in general and specifically has not been analysed yet to understand knowledge spillovers in the energy sector. Moreover, patent citations in the energy sector of such recent nature have not been examined yet.

The rest of the paper is structures as follows. Chapter 2 will explain the Chinese background on innovation and REN. The theoretical framework and the empirical literature will be discussed in Chapter 3. The methodology will be outlined in Chapter 4. The results and their analysis will be presented in Chapter 5. The last chapter will provide a conclusion and recommendations.

1.2 Research questions

The following research questions are guiding my analysis:

1. What are the knowledge spillover dynamics of Chinese-invented REN technologies and FF technologies? Do FF or REN technologies contribute more to technological change?
    a. Which of the two types of Chinese-invented technologies generates more knowledge spillovers in the period 2000-2017?
2. Which Chinese-invented REN technologies significantly contribute to the accumulation of knowledge?
    a. Which Chinese-invented REN technologies create the most technology spillovers in the period 2000-2017?
3. Which Chinese-invented REN technologies promote a diverse knowledge pool and contribute to the creation of general technologies?
    a. Which Chinese-invented REN technologies promote intra-, inter- or external knowledge spillovers in the period 2000-2017?

Chapter 2 China

China's political and economic system is characterised by five features, which encourage the development, innovation and diffusion of REN technologies. Firstly, China's large market attracts the localisation of cleaner technologies by domestic and foreign players. Secondly, the Chinese government is remarkably willing to finance cleaner energy technologies. Thirdly, the Chinese state emphasises long-term planning. Fourthly, the Chinese labour force is productive, relatively low-wage and big. Lastly, it has a good infrastructure to import and export technologies (Gallagher 2014: 154).

2.1 Innovation

The Chinese state plans its economy centrally with a strong focus on innovation in science and technology (S&T). Its five-year plans define guidelines, policies and targets to shape the future of the country along the lines of "innovative, coordinated, green, open, and shared development" (NDCR 2016: Part I). Various initiatives, such as laws and additional plans for key areas, support the realisation of China's economic development. The three key programs a*National Basic Research Program* (973 Program), *National High-tech R&D Program* (863 Program) and the *National Key Technology R&D Program* are pursued throughout the five-year plans. 60% of the governments' R&D funding were allocated to these three programs in 2000. From 1996-2008 it was more invested in the funds for the last two programs than for the first program indicating that the focus is not basic research but rather development and demonstration of key technologies (Huang et al. 2012: 123-4). One of the main plans to pursue S&T is the *Medium to Long-Term Plan for the Development of Science and Technology* implemented in 2006 to reach targets until 2020 with focus on indigenous innovation. China's gross expenditure on R&D are intended to rise to 2.5% of GDP (The State council and The People's Republic of China n.d.) reaching 2.1% in 2016 (OECD 2018) reflecting the input to spur innovation. Additionally, patents granted for inventions and international citations of scientific papers by Chinese nationals are aimed to rank among the five top countries recognising the importance of innovation output. To protect indigenous property rights (IPR), of which patents are a crucial part of, the plan defines the measure to improve China's IPR system and prevent the manipulation of the system guaranteeing fair market competition and the diffusion of innovations (The State council and The People's Republic of China n.d.). The Chinese state has not only recently recognised the importance of patents but established its current patenting system in the 1980s.

2.1.1 Patenting system

The first patent law was enacted in 1984 and implemented in 1985 (Cheung and Lin 2004). The country ratified the *Paris Convention for the Protection of Industrial Property* in the same year (WIPO 2018) to become part of the international patenting system. The Chinese National Intellectual Property Administration (CNIPA) started immediately its cooperation with the European Patent Office (EPO) (EPO 2014). China revised its patent law three times: in 1992, 2000 and 2009. The revision in 2000, was followed by China's accession to the World Trade Organisation (WTO) in 2001. The country had to adapt its intellectual property right to international standards. The third revision included the revision of the absolute novelty standard, which means that patents from now on had to be new to the world and not only China (Cass 2009). "Also, the requirement that inventions completed in China have to be filed in China first has been nullified. However, China now requires the patentee to apply for the confidentiality examination before filing abroad" (Devonshir-Ellis et al. 2011: 3). Not only has China adapted its national patenting system to international standards to facilitate domestic patent applications but it also became bound by the Patent Cooperation Treaty (PCT)[1] in 1994 (WIPO 2017a) to file international patent applications.

2.2.2 Patents

The number of filed patents in China has accelerated since the year 2000, while the number of granted patents did not increase with the same rate suggesting that the quality of the patents potentially decreased (Hu and Jefferson 2006: 9). There are many Chinese patents, which merely differentiate between "patents that protect real innovation and patents that merely pretend to protect real innovation" because the legal system has difficulties to do so (Lam et al. 2017: 597).

The Chinese patenting system differentiates three kinds of patents: invention, utility model and design. My dataset contains only the first two kinds of patents. The first one signals a more fundamental technological development whereas the second one signals an incremental technological development (Devonshir-Ellis et al. 2011: 7-8)[2].

For the invention and utility model patent a request, an abstract, a description and the claims have to be submitted when filing the application first (CNIPA 2014a).

The patentability for inventions and utility models are subject to the following three criteria: novelty, inventive step (or "creativity") as translated by the CNIPA) and practical/industrial application[3]. Through these criteria one can distinguish a patent from unprotected ideas and successful imitation or mere technical progress (Feng 1997: 180). These three criteria correspond with international standards (WIPO n.d.a).

In general, to identify a patent as novel and creative, the description of the invention and utility model patents includes a list of references to prior art relevant to the innovations. These citations help to identify what belongs to public knowledge and what can be regarded as a claim for this specific patent (Pillu 2009: 117). In other words, only knowledge what is not covered by already existing technologies and claimed knowledge can be patented (Feng 1997: 2009). Therefore, no royalties can be raised for the fact that an innovation uses existing knowledge to build upon. Royalties can be raised if a patent is licensed, which means that "the patent owner grants permission to another individual/organization to make, use, sell etc. his/her patented invention" (WIPO n.d.b).

2.2.3 Patent application process

After a patent application is filed at the Chinese patent office (CNIPA), the patent is published and hence made available to the public within 18 months. Within this period the filing is examined, it goes through a confidential examination and a preliminary examination & classification. Since the revision of the Chinese patent law in 2009, instead of obliging inventors to file the invention first in China which was developed within its territory, the confidential examination has to be taken if a patent for an invention or utility model developed in China is intended to be filed in a foreign country or an international application is intended

[1] "The PCT makes it possible to seek patent protection for an invention simultaneously in a large number of countries by filing a single 'international' patent application instead of filing several separate national or regional patent applications" (WIPO 2017b).

[2] For more details on the three patents see Table A.1 in Appendix A.

[3] For more details on the three criteria see Appendix A, Article 22.

to be filed. If a patent is regarded as too crucial for China's national security or state interests, the patent is not allowed to be filed outside the Chinese territory (CNIPA 2014a).

All three types of patents undergo the examination of the filing and the preliminary examination & classification. The invention and utility model can potentially undergo the confidentiality examination. However, only the invention type continues with a substantial examination of the patent application (CNIPA 2014b) for which the applicant has to submit a list of reference to prior existing art (but not necessary for the examination in the preliminary stage) (CNIPA 2013). The invention patent can be granted after successful examinations of both procedures. The utility model needs to fulfil in the preliminary stage the criteria of novelty, inventive step and industrial application because it is not further examined (CNIPA 2014b). The utility model and the design patent can be granted after successful examination in the preliminary stage.

2.2 Renewable energy

The Chinese state pursues to "build a modern energy system that is clean, low-carbon, safe, and efficient, and will safeguard the country's energy security" (NDRC 2016: Chapter 30). Innovation in the energy sector is encouraged through various initiatives by the Chinese government. Moreover, the development of REN technologies in China accelerated since the beginning of this century (Gallagher 2014: 159).

2.2.1 Measures and policies

Innovation in the Chinese REN sector has been subject to various Chinese five-year plans, the three key programs, the *Medium to Long-Term Plan for the Development of Science and Technology* (MLST) and the *REN law*.

The Chinese government announced to change its 'development mode' in its ninth five-year plan implemented from 1996-2000 (Gallagher 2014: 7) and started investing in REN technologies during the period of the tenth five-year plan (2001-2005) (Huang et al. 2012: 125). The tenth five-year plan set the target to commercialise solar, wind, geothermal and biomass technologies through increased installed capacity (IEA and IRENA 2017a). The eleventh five-year plan from 2006-2010 set targets for shares of REN sources of its energy portfolio through reaching certain thresholds of electricity production. The focus was especially solar, wind, biomass and waste technologies (Liu and Liang 2013: 495). The twelfth five-year plan from 2011-2015 aimed for a 9.5% of REN sources of total energy consumption by 2015 (IEA and IRENA 2016). A key priority is to make the transition from 'made in China' to 'designed in China' possible therefore the R&D expenditures were aimed to increase to 2.2% of GDP by 2015 (Liu and Liang 2013: 493) whereby 'new energy' (such as nuclear, solar and wind power) play a strategic role as one of the seven emerging key industries (Gang and Liping 2013: 6). The thirteenth five-year plan wants to increase the share in non-fossil energy consumption to 15% by 2020 and to 20% by 2030. Further targets are to become an innovation leader for REN technologies and become more independent from foreign companies in this field (IEA and IRENA 2018). The development and application of solar, wind, waste, biomass, geothermal and storage technologies are continued to be encouraged (NDRC 2016).

The *Medium and Long Term Development Plan for REN* was implemented in 2007 and allocated around 263 billion USD for the development of REN in China. Targets for wind, solar, biomass and hydropower were established. This plan was superseded by the twelfth year-plan for national strategic emerging industries (IEA and IRENA 2017b).

Two initiatives highlighting the importance of REN sources were implemented in 2006. First of all, the *REN law,* which created four key mechanisms to promote REN sources. The first mechanism is to set REN targets and plan REN development and utilisation. The second mechanism involves grid companies which have to connect and buy all electricity produced by renewable electricity generators in their jurisdiction. The third mechanism establishes a national feed-in tariff paying to renewable electricity generators a fixed, additional amount. The fourth mechanism covers the funding through a cost sharing mechanism and the *REN Development Special Fund*. The latter supports amongst other things science and technology research for renewable energies and the promotion of the manufacturing of REN technologies. The fund is financed by government budget allocations. R&D projects need to apply through the 863 or 973 programs (Schuman and Lin 2012: 98). Second of all, the *Medium to Long Term Plan for Science and Technology* which sets goals until 2020 with focus on indigenous innovation. One of the focus areas is the energy field where technological breakthroughs want to be achieved specifically also in clean energy. Wind, solar, biomass and geothermal energy technologies are specifically supported for the development of cleaner energy (The State council and The People's Republic of China n.d.).

One of the most recent initiative is the *China Energy Technology Innovation Action Plan 2016-2030* which wants to promote innovation in energy technologies and to reduce the country's dependence on suppliers from abroad. The main areas are wind, solar, biomass, geothermal and marine energy (IEA and IRENA 2017c).

2.2.2 Current status of REN sources in China

The dominating REN sources in China's power generation in 2016 were hydropower (the most), wind and solar PV (to a much lesser extent than hydropower). Although, coal still accounts for 60% (IEA 2017: 478). In the following I will depict the trends of the installed capacities of the individual REN sources in China to give an idea how far advanced they are in the diffusion process (Wilson 2014).

The share of hydropower electricity generation was about 17% in 1949 and about 19% in 2013. At the same time, installed capacity increased from a worldwide share of 8.8% in 1949 to 22.2% in 2014. Installed wind capacities in China accounted for a global share of 0.9% in 1995, while it rose to 34.9% in 2017 (GWEC n.d.). Today China is an important manufacturer of wind turbines, primarily producing for the domestic market. However, from 2007 until 2015 it exported its wind turbines to 28 destinations worldwide (IEA 2017: 490). The third dominant REN source in China is solar, with an increasing installed PV capacity (production) rising from a worldwide share of 2.3% (2.8%) in 2007 to 26.7% in 2016 (16.3% in 2015) (IRENA 2017: 56-7). China drives the global solar manufacturing industry through innovation and its massive expansion of manufacturing capacity decreasing costs in the solar industry. The output is mainly absorbed by the domestic market but at the same time China was the largest solar exporter in 2016. In 2015, Chinese companies held about 95% of patents in the main areas of solar water heating technologies (IEA 2017: 490). There is a big potential for China's biomass industry because of its abundant biomass resources as a large agricultural country accompanied by growing investments (Zhang et al. 2017: 868-9). Biomass capacity (production) increased from a global share of 6% (4.2%) in 2007 to 11.4% in 2016 (11% in 2015) (IRENA 2017: 64-5). Geothermal resources are also abundant with a theoretical potential of a worldwide share of 7.9% (Zhang et al. 2017: 868). Renewable energies like tidal energy, ocean thermal and marine current energy are being studied but due to "high cost, low efficiency, poor reliability, poor stability and small scale" (ibid) they are only in the very beginning of their diffusion process with of a share of 0.75% global installed capacity globally in 2016 (IRENA 2017: 34).

Chapter 3 Literature

3.1 Technologies and change

In this section the concepts of technology, technological change, knowledge and knowledge spillovers are introduced.

Technologies serve as ‘a means to fulfil human purpose’ (Arthur 2009: 28). To be produced, they require ‘hardware (such as machinery or manufacturing plant), factor inputs (labour, energy, raw material and capital) and software (know-how, human knowledge and skills)’ (Grübler 1998: 20). Not only is knowledge embodied in technologies, but without knowledge of how to use a technology, they cannot be applied. This means that hardware and software are interrelated, and the one cannot make its full contribution to technology without the other (Grübler 1998: 20).

Besides technologies increasing human comfort, their development is crucial to sustain the capitalist mode of production. Technological change is regarded as the driving force of capitalism (Schumpeter 2010; Solow 1956; Romer 1996) because it is expected to expand and discover resources, diversify production, increase output and enhance productivity. To sustain the unprecedented historical industrial production, already known natural resources had to be accessed and recovered. The exploitation of natural resources through technological improvements set the stage for a FF-based mode of production (Grübler 1998: 45-46).

Technologies are developed because of their economic and social context, while being responsible for shaping their context (Grübler 1998: 21). The three stages of the evolution of technological change are invention, innovation and diffusion. This process is not linear because feedback is exchanged between the different stages; it is therefore a dynamic process feeding itself (Grübler 1998: 23). If a set of new technologies are diffused by society and institutions to create a new “common sense” for best practices and shared beliefs (Perez 2016: 5), a new technological trajectory can be initiated. To support cleaner energy production, a paradigm promoting sustainable and “green” values needs to emerge. It ‘should be seen as a “mission-oriented” pathway to promote a major switch in production patterns and lifestyles, creating new sources of employment and well-being’ (Perez 2016: 12).

3.1.1 Invention and innovation: Knowledge and technology

To create technological change, knowledge production and accumulation serves as a basis thereof (Romer 1996: 96). Dedicating more resources to research, generates and accumulates more knowledge (Romer 1996: 96). After the conduct of research and development (R&D) and creation of technological inventions, the produced goods can be sold and turned into economic returns compensating the inventor for her R&D efforts. The commercial application of a technological invention makes the invention an innovation (Grübler 1998: 19) and “consists to a substantial extend of a recombination of conceptual and physical materials that were previously in existence” (Nelson and Winter 1982: 130).

To gain a better understanding of how the creation and commercialisation of knowledge is governed by market forces, Romer’s approach (1996) will be presented first in the following finalising this section with the contextualisation of the role of knowledge through the evolutionary approach.

In Romer's simplified model the only produced factor is knowledge (Romer 1996: 104) which is built on past knowledge. To understand how knowledge interacts with the market, a characterization of it needs to be provided first.

Knowledge is characterised by non-rivalry and various degrees of excludability. The first characteristic implies that any generated knowledge can be applied another time if not prevented which refers to the second characteristic. If the nature of knowledge is too simple and/or the sets of laws enforcing the property right (e.g. patents) are too weak, the knowledge is non-excludable and there is no incentive for the private sector allocating resources to develop this kind of knowledge. Therefore, the R&D has to be stimulated by another source (Romer 1996: 111-112).

The four main forces defining the optimal allocation of resources for the knowledge accumulation process are: 'support for scientific basic research, private incentives for R&D and innovation, alternative opportunities for talented individuals and learning-by-doing' (Romer 1996: 113). These forces inform the convergence towards an equilibrium determined by labour, capital and technology (Romer 1996: 96).

The first force does not inhibit private returns for the market and is made available freely. Therefore, it needs to be subsidised by governments and philanthropy (ibid).

The second force is entirely of private nature led by competitive market forces implying the necessity to exclude other to use the produced knowledge gaining a competitive advantage. One of the arising externalities is also called the 'knowledge externality' and is regarded as a positive externality. The innovator does not get compensated for the production of knowledge but 'only' for the production of goods. If the innovator applies for a patent, the knowledge is published so others engaged in R&D can benefit from it and the innovator cannot prevent them from doing so. If the competitive advantage does not compensate for this positive externality, there is not enough incentive given for the private actor to invest in R&D (Romer 1996: 113-14). Therefore, R&D needs to be subsidised.

The third force of talented individuals to produce knowledge which benefits society depends mainly on three main factors. The greater the market returns (the greater the market size), the greater are the incentives to pursue innovation in a certain activity. Another factor is that the smaller the degree of diminishing returns are, the greater the motivation of a talented individual to pursue innovation in a certain sector. The third factor is the enforcement of clear property rights which ensures that the returns are given to the inventor (Romer 1996: 115-16).

The last force is learning-by-doing which does not describe the innovation of a production process but rather the advancement of the production process, e.g. on how to make the production process faster. It is a by-product of typical economic activity (ibid).

These forces show that technological change is inherently endogenous to the system and cannot be regarded as a sudden external shock. The accumulation of knowledge, which is necessary for technological change, depends on created knowledge in the past and is pursued by profit-driven firms optimising their resource allocation.

This neoclassical approach neglects the social and institutional context in which technological change occurs describing the economic system as being directed towards one equilibrium. In contrast, the evolutionary approach not only recognises that the context is shaped by "cumulative expertise embodied…which is accumulated over time through equally specific learning processes" (Dosi and Orsenigo 1988: 16) but also that decision-making process of economic agents is of decentralised nature because their decisions are not based on rational agency. This leads to a sequence of evolutionary equilibria which is also described as a state of disequilibria (Dosi and Orsenigo 1988: 23). This depiction of the economic system gives justice to the dynamic nature of technological change.

3.1.2 Diffusion: Knowledge and spillovers

When enough resources are allocated to the creation of knowledge and technologies are accepted by their social and institutional contexts during the stage of innovation, diffusion is following (Grübler 1998: 19). 'Diffusion is the widespread replication of a technology and its assimilation in a socioeconomic setting' (Grübler 1998: 24). Technological diffusion is taking place if a technology creates a niche market or replaces existing technologies (ibid). This process generally follows the stylised S-shaped curve reflecting the diffusion rate: The initial slow take up of a technology, a subsequent period of growth and a late period of slower diffusion approaching saturation (Geroski 2000: 604). The first two stages are characterised by further technological improvements, the increasing application of technologies and the interaction with other existing technologies and infrastructures (Grübler 1998: 19). Towards increasing maturity and the last stage of the diffusion process, changes in the general technological system are of incremental nature (rather than radical nature). Additionally, the disbenefits of a technology, such as environmental impacts, become increasingly evident during the last stage (Grübler 1998: 55) like in the case of FF technologies.

The two macro factors defining the pace of the diffusion process are the size of the system and the kind of diffusion which is taking place. Firstly, the size of the technological system which wants to be diffused matters because the larger the system, the slower the pace. Secondly, the pace depends on the kind of diffusion; if it is a substitution of an existing system or if it is a pure diffusion of a new system. Replacing a new system takes longer than establishing an entirely new social, economic and spatial context (Grübler 1998: 68). Especially relevant are the needed capital stock and equipment since infrastructure has the longest lifetimes. For the energy sector, the replacement of a FF-based energy system through a system which is based on REN sources is a very slow process. For example, to replace power plants can take up to half a century (Grübler 1998: 354).

The process of diffusion is facilitated if technologies diffuse in groups and not as individuals (Grubler 2014: 42) highlighting the importance of combinations of interrelated individual technologies (clustering). The (inter)relatedness of technologies enforces the inertia of the diffusion or accelerates technological change depending on the characteristic of the technological linkages. Through the so-called 'knowledge spillovers' which are "knowledge transfers between different innovation actors and fields of technology application" (Wilson and Grubler 2014: 14) the technological linkages can be established. Once knowledge spillovers occur they can be fed into the feedback loop of technological change and contribute to the development and manifestation of a certain technological path (Wilson and Grubler 2014: 13). The literature differentiates between knowledge flows of formal and less formal nature, i.e. the initiating mechanisms are market or nonmarket based. Formal knowledge flows can be created through channels such as imitation, trade, foreign direct investment, licensing and movement of personnel. These kinds of knowledge flows are generally not referred to as 'spillovers', but rather knowledge or technological transfers. Knowledge spillovers are knowledge flows of less formal nature and can be unintended (Wilson and Grubler 2014: 16). Examples of mechanisms for knowledge spillovers are "formal and informal networks of scientists, engineers, and technicians; training and movement of personnel; universities, R&D labs, and international research collaborations; scientific publications and patents; and reverse engineering" (ibid). These mechanisms are possible channels to promote knowledge spillovers, but to make this possible, the absorptive capacity of an entity is decisive (Wilson and Grubler 2014: 17). Consequently, the question is what kind of knowledge encourages an entity to absorb knowledge spillovers. The more complex the combination of knowledge is, the slower is the diffusion process because "learning and knowledge requirements for producing and using new artifacts and techniques" (Grübler 1998: 68) need more time to be acquired. Therefore, some authors claim that close prior art (knowledge) is key to integrate knowledge spillovers benefitting from the incremental character of knowledge (Cohen and Levinthal, 1990: 128, 131). However, if too localised knowledge is used and generated, only incremental inventions are promoted. Therefore, a technological lock-in is more likely to occur and markets become saturated faster not allowing the system to grow at an earlier point in time than necessary (Grübler 1998: 55). The next section will discuss the drivers of the inherent path-dependent characteristic of technological change (based on the combinatorial nature of technological change) and how path dependency can be directed through the generation of certain knowledge.

3.1.3 Sources and direction of path dependency

Technologies follow a path dependent process which is driven by the "increasing returns" (Unruh 2000: 817) arising from the following main five sources: "learning by using, network externalities, scale economies in production, informational increasing returns and technological interrelatedness" (Arthur 1988: 591). The first source describes the dynamic of more usage and more learning with increasing adoption of a technology. Additionally, a network of users is created the more a technology is adopted implying that users benefit more the bigger the network is. The decisive economic source are economies of scale because with increasing production the marginal costs per product fall therefore prices fall, and broader range of adopters is reached. With increasing adoption, the technology is also better known and better understood expanding its adoption also to risk-averse users. The final source of increasing returns is the infrastructure accompanying the rising adoption of a technology. Technologies which are not as adopted face a disadvantage because the infrastructure orients itself towards the dominant technology making them not as compatible based on their technological characteristics (ibid). These five main sources (and others) can lead to a technological lock-in making knowledge become too specialised (David 1985: 336; Unruh 2000: 821-2).

Firms based in the FF industry benefit from these "increasing returns" (Arthur 1988: 591) even though this industry transitioned into a stage of saturated markets it dominates the energy market because of the earlier established advantages based on the right timing and the right historical conditions (Unruh 2000: 820). This means that firms follow the path which is given by the current high-carbon technologies making incremental efficiency improvements and not wanting to face the higher costs of fundamental changes. Firms based in the FF sector have vested interests in pursuing their business as usual because they already invested in capital needed for this sector and have their established market shares (Kemp 1994: 1038). Consequently, the incentive to overcome uncertainties and pursue a new technological path needs to be given by the government (Unruh 2000: 824). The public sector is the key in giving impulses for a new technological direction and to envision the society of the future (Mazzucato 2016: 107) discouraging technologies, which are regarded as harmful by society (Azar and Sandén 2011: 139). Whereas, the private sector is currently very much characterised by short-termism and invests very little in research but rather invests in developing existing technologies, i.e. areas with a narrower technological scope (Mazzucato 2016: 100). Therefore, the government needs to ensure the conduction of research with investments through public agencies or state development banks which have a long-term vision (Mazzucato 2016: 110). Nevertheless, as soon as the major risks of a new technology are overcome through incentives given by the government, private actors are needed to pursue and improve the new technology. Therefore, the markets are shaped by the choices of public and private actors (Mazzucato 2016: 113).

Governments can reduce uncertainties and design the right policies to avoid a "carbon lock-in" (Unruh 2000: 81). The generated knowledge for FF-technologies can serve as the foundation for REN technologies as every technological opportunity has occurred so far within the previous one. Examples are steam and electric power. The former was based on a well-established technology and the latter was developed over 50 years before it found a wide application (Kemp 1994: 1038). At the same time, they laid the ground for the FF-based energy system promoting generalised productivity gains (Bresnahan and Trajtenberg 1995: 84). These kinds of technologies finding wide general applications are called General Purpose Technologies (GPT's). "A GPT is a technology that initially has much scope for improvement and eventually comes to be widely used, to have many uses, and to have many Hicksian and technological complementaries" (Lipsey et al. 1998: 43). They don't offer a complete solution but rather encourage new technological opportunities because of their "innovational complementaries" (Bresnahan and Trajtenberg 1995: 84). Technological complementaries arise through knowledge relatedness which means that technological "fields share a common knowledge base and rely upon common heuristics and scientific principles" (Breschi et al. 2003: 69). There is no general measure of how general-purpose a technology is. However, the literature recognises to increase the technological opportunities diversity and technological distance are two enforcing characteristics of generality (Jaffe and Rassenfosse, 2017: 1363). Localised knowledge can lead to a too high degree of technological path-dependency (van den Bergh 2008: 567) leading faster to saturated markets and decreasing returns (Unruh 2000: 820). To avoid a technological lock-in, maintaining diversity in the technology pool increases the probability of "recombinant innovation" (van den Bergh, 2008: 566) and sustains the dynamic character of the innovation process. Optimal diversity can be determined through the assessment of the costs and benefits, i.e. to weigh the loss of increasing returns to scale against the opportunity for innovation and change (ibid). Keeping a system modular (i.e. the generalisation of the recombinant concept) increases the probability for radical innovations and spillovers and benefits a systems' flexibility and productivity (van den Bergh 2008: 567).

Based on the literature discussed above, promoting technologies which encourage a diverse and distant range of technological fields is beneficial for the whole economic system to avoid a technological lock-in. GPT's embody these characteristics and spread general productivity gains across the economy. At the same time, the development of technologies which are harmful for society's well-being (in this case FF technologies) should be discouraged. However, only technological development will not solve the environmental crisis and will not (fully) prevent human kind from the consequences of climate change because technology cannot prevent human kind to extract natural resources at a much faster rate than it regenerates (Dittrich et al. 2012; Schandl et al. 2016; IRP 2017).

3.2 Empirical literature

This part of the literature review provides an overview of how data has been used to analyse knowledge spillovers. The discussion is divided into OECD countries and China, because an analysis of knowledge spillovers has not been done, to my knowledge, for non-OECD countries such as China. Generally, for the analysis of "developing" countries, also China, the focus lies on the mechanisms of the technology transfer rather than on the technological interrelatedness of a set of technologies and how they interact with each other. Before looking into the existing research on knowledge spillovers, the indicator for knowledge spillovers to be used in this analysis is discussed.

3.2.1 Patent citations as an indicator for knowledge spillovers

Patent data can be a good measure of innovation and technological change because it documents the output of inventive activity (Hall et al. 2001: 4) and therefore the contribution to technological change. Patents describe an invention after the actual innovation process takes place and therefore describe the end product of the inventive activity. While being by definition an indicator for inventive output, patent data covers a broad range of years, countries and technologies (Pillu 2009: 116). Individual technologies can be analysed because patents identify them to the individual level. Another feature of patent documents is that they include precisely their linkages with knowledge from patents and non-patents. On the other hand, patent data also has some drawbacks. Firstly, not all patentable inventions are patented because patenting is a strategic decision. The regulatory framework can shape this decision, and/or the inventor prefers to protect the invention through secrecy. If secrecy is preferred, one reason could be the uncertainty if new inventions in emerging technological fields are patentable. Another reason can be the long and expensive process of patenting when expected profits are uncertain or lower than the costs (Basberg 1987: 133-34). Secondly, when using patent data purely scientific advances that are not industrially applicable are excluded from the analysis because inventions protected by patents have to be industrially applicable (Pillu 2009: 118).

The literature uses patent counts as an indicator for inventive activity. The followed logic is that the more patents an entity (country, firm, institution etc.) files, the more innovative it is. An improved version of filed patent counts is granted patent counts which means the patents were approved of the three criteria of novelty, inventive step and industrial application attributing a higher quality to a patent (Dechezleprêtre et al. 2014: 18). However, the quantity of (granted) patents does not necessarily reflect (sufficient) quality, the importance or social value of inventions (Basberg 1987: 132). Especially in the Chinese context, the number of filed patents in China has accelerated since the year 2000, while the number of granted patents did not increase with the same rate suggesting that the quality of the patents potentially decreased (Hu and Jefferson 2006: 9). Therefore, to assess the quality of a patent examining its impact on other inventions can account for this weakness. Patent documents include their connections to other knowledge through patent citations. They help to distinguish the area of a patents' property rights and can expose the lack of novelty of the citing invention (Pillu 2009: 119). At the same time, they reflect which (technological) existing knowledge is embodied in the new invention which is referred to as a backward citation, i.e. a patent cites another patent. On the other hand, when a patent is cited by another patent, it is referred to as a forward citation. To differentiate between the two, it is decisive weather the citing (backward citation) or the cited (forward citation) patent is identified. The forward citation signals the contribution to the knowledge stock (Hall et al., 2001: 14) and the technological importance of a patent (Trajtenberg 1990: 173-74; Hall et al. 2001: 4). The more a patent is cited the higher is the quality, the more valuable it is for society and technological change (Lanjouw and Schankerman 2004: 448-50). Consequently, it has more impact on the accumulation of knowledge and is more important for future technologies (Schoenmakers and Duysters 2010: 1057). Through the exact documentation of patents and their references to other patents, there is an existing paper trail document knowledge flows (Dechezleprêtre et al. 2015: 38), making patent citations widely available and the analysis of knowledge spillovers possible.

The logical grounding of forward citations to serve as an indicator for knowledge spillovers seems to be reasonable and has been widely accepted since the quantitative study of Jaffe et al. (2000) who sent questionnaires to inventors of the citing and cited patent to examine how relevant the referred patents are. They conclude that patent citations can be a good proxy for knowledge spillover intensity but that they are a noisy measurement of knowledge spillovers because citations can be added by the inventor after the invention process or it can be added by the examiner (Jaffe et al. 2000: 218). This means that citations added by inventors and examiners can potentially not reflect 'true' knowledge spillovers. The reason is the existence of self-citations, which means that the inventor cites a patent assigned to herself reflecting rather internalised knowledge spillovers instead of diffused ('pure') knowledge spillovers (Hall et al. 2001: 19; Noailly and Shestalova 2017: 5). Additionally, firms can cite patents filed by themselves for strategic reasons (Noailly and Shestalova 2017: 5) or they can avoid citations on purpose because they might reduce their chance of an approval due to the novelty criterion (Dechezleprêtre et al. 2014: 12). Another issue is that the inventor adds the citation after the invention stage during the conduction of a search by herself or hired lawyers and therefore not reflecting knowledge which was used for the building of the invention (Thompson 2006: 385; Jaffe et al. 2000: 216). Citations added by the patent examiner can mean that the inventor did not consider this knowledge during the invention process but is added by the examiner because of the scope of the property right (Jaffe et al. 2000: 216; Noailly and Shestalova 2017: 5). However, the inventor can forget to add patent citations even though a certain reference played a role in creating the new knowledge (Pillu 2009: 52).

A common assumption in the literature is that the knowledge references added by the inventor are more localised and that the ones added by the examiner are more comprehensive, meaning that examiners' citations refer more to external technological fields. However, Alcácer and Gittelman (2006) show that the bias introduced by examiners is not necessarily bad and that on average there is no significant difference between the distributions of examiner and inventor-added citations (p.778). Moreover, results by Criscuolo and Verspagen (2008) show that the statistical difference regarding inventor- and examiner-added citations is very small, indicating a small upward bias towards external citations when including examiners' citations (Criscuolo and Verspagen 2008: 1901). These findings suggest that patent citations by both actors track a similar distribution pattern and allows for the assumption that examiners' citations do not bias (much) the empirical analysis because they include more references to all technological fields and do not prefer one particular field.

3.2.1 OECD countries

The empirical literature has examined knowledge spillovers for OECD countries. For this set of countries it has been analysed if clean or dirty inventions are more valuable for society from the viewpoint of knowledge spillovers, what kind of knowledge spillovers are generated by clean and dirty technologies and if specialised or diversified knowledge matters for future technological advances.

Dechezleprêtre et al. (2014) compare clean and dirty technologies analysing a dataset with patents from patent offices all over the world for the period 1950 to 2005 provided by the PATSTAT database. Their results show that in the fields of energy production, automobiles, fuel and lighting, clean inventions create in general more knowledge spillovers than dirty inventions because of their radical novelty compared to the incremental inventions in dirty technologies. The clean technologies receive on average 43% more patent citations than their dirty counterparts. The authors claim that these results suggest that clean inventions are more valuable for society and should receive higher R&D support than dirty inventions. The study by Noailly and Shestalova (2017) not only compares clean and dirty technologies, but also makes the comparison of individual renewable energies technologies. They base their examination on a dataset of patent applications filed at the European Patent Office and 17 national European patent offices during the period of 1978 to 2006. They show that in particular the REN technologies in storage, wind and solar receive more citations than FF technologies. Comparing only REN technologies with each other they find that storage and wind receive more citations than solar technologies. This analysis suggests the importance of storage, wind and solar technologies for the European context. The authors of both beforementioned studies claim that these three technologies in particular should receive more support. However, the researchers disregard the diffusion stages of the technologies and make incorrect conclusions regarding policies. Increasing knowledge spillovers means that these technologies are in the growth phase of diffusion and therefore being characterised by higher likelihood of citation. Henceforth, REN technologies experience increasing diffusion. REN technologies which are just in the take off of the diffusion process should receive more support.

Not only is the overall likelihood of knowledge spillovers analysed but also the nature of knowledge spillovers which means to what kind of knowledge technologies contribute, i.e. are intra- (within the same kind of technology), inter- (between clean and dirty energy technologies) or external (outside the field of energy production) knowledge spillovers generated.

Using patent citations, Dechezleprêtre et al. (2014) find that clean inventions are characterised by intra- and inter-knowledge spillovers[4] indicating that clean inventions have a stronger relationship with intra than with inter-knowledge spillovers. Noailly and Shestalova (2017) find that storage and wind technologies are more likely to be cited within their own technological fields than solar technologies that wind technologies have the strongest relationship to intra-knowledge spillovers. The remainder of the REN technologies are not characterised by intra-technology spillovers. To identify different kinds of knowledge spillovers, the literature has also made use of the knowledge production function. Noailly and Smeets (2015) find knowledge spillovers in firms innovating in REN and FF technologies in the EU-15 countries, Switzerland and Norway over the period 1978 to 2006. They find spillovers within the REN sector, i.e. past knowledge stock of REN technologies encourages innovation in REN technologies. Additionally, past knowledge stock in FF technologies increases the likelihood of innovation in REN technologies. Looking at two specific REN technologies, Braun et al. (2010) examine knowledge spillovers in solar and wind technologies in 21 OECD countries over the period 1978 to 2004. They find that intra-sectoral spillovers created by existing knowledge stock have a significant impact on patent counts in both industries. Inter-sectoral knowledge spillovers play a more important role in the wind industry than in the solar industry. Johnstone and Haščič (2010) find inter-sectoral knowledge spillovers for a set of 28 OECD countries for the period 1974/8 to 2004. Accumulated knowledge stock from storage technologies have a positive impact on innovation in REN generation, especially intermittent (solar, wind, ocean) technologies. Noailly and Shestalova (2017) find that storage and solar technologies generate more knowledge spillovers than FF technologies to external technological fields outside the field of electricity production. When only comparing REN technologies to solar technologies, storage technologies receive more external citations.

Furthermore, the empirical literature examines if REN technologies are of general nature. Popp and Newell (2012) and Dechezleprêtre et al. (2014) use the Herfindahl index to do so. This index 'measures the extent to which the follow-up technical advances (i.e. the citations) are spread across different technological fields, rather than being concentrated in

[4] In their case inter-knowledge spillovers are citations received from a different technological field than clean inventions.

just a few of them' (Dechezleprêtre et al. 2014: 42). The logic of being "spread across different technological fields" (ibid) will also be used for my analysis in Chapter 5 to identify generality.

Popp and Newell (2012) use a dataset of patents granted from 1971-2002. They find that alternative energy patents (solar, wind, geothermal) are more general than chemistry, medical, electronics and mechanical patents. Additionally, they show that alternative energy patents are more general than refinery and coal-based fuel patents. Dechezleprêtre et al. (2014) find that overall more general technologies increase the counts of forward citations. Another regression shows that overall clean inventions are more general than dirty inventions. Although, when only looking at the electricity sector clean inventions are less general than dirty ones but clean transportation inventions are more general than dirty ones. These results show that it is important to differentiate individual technologies within the clean sector because their diffusion stages may differ and therefore their probabilities of being cited may differ.

The characteristic of generality defined by Dechezleprêtre et al. (2014: 42) (see above) implies that if a technology contributes to all four kinds of knowledge spillovers it is more general, i.e. more diverse, than one which contributes to less than the four categories. Additionally, the more a technology contributes to external technological fields it lays the foundation for more distant knowledge increasing the probability of creating technologies which have a broader range of technological complementaries (Lipsey et al. 1998: 43). Therefore, the modularity and flexibility of the technological trajectory is encouraged making it less prone to a technological lock-in (van den Bergh 2008: 567).

All the above findings imply that technology and innovation policies should be carefully designed, if governments want to prevent a technological lock-in. The emphasis should be to create technological variety through a general knowledge pool rather than a specialised one which supports a narrow technological path. At the same time, specific policies for individual technologies should be designed paying attention to the suggested characteristic of knowledge spillovers of a technological field.

3.2.2 China

All the above studies base their research on datasets from OECD countries. No research has been done to my knowledge on knowledge spillovers between technologies from non-OECD countries. Specifically, for the Chinese case, the technological knowledge flows have not been measured nor characterised as of yet as of in the empirical work presented above which focuses on the relatedness of technologies. However, researchers have used patent data for the Chinese case to study the mechanisms of the technology transfers from created knowledge in economically developed countries to economically developing countries.

Examining the international transfer of climate change mitigation technologies, Dechezleprêtre et al. (2011) analyse a dataset of filed patent applications by 76 countries at patent offices worldwide. They focus on technologies in the fields of seven REN technologies (wind, solar, geothermal, marine energy, hydropower, biomass, and waste to energy), methane destruction, climate-friendly cement, thermal insulation in buildings, heating, electric and hybrid vehicles, and energy-efficient lighting. Their data shows that from 2000 to 2005, China is the receiving country for about 75% of technology transfers from OECD countries (and 25% go to other non-OECD countries) (Dechezleprêtre et al. 2011: 122). Additionally, their results show that China filed the most patents in the fields of cement, geothermal and solar energy. Based on patent counts, China is ranking 4th with 8.1% of global inventions, after Japan, the United States and Germany. However, when controlling for the quality of patents (i.e. the number of countries in which the patent is filed), China ranks 10th with 2.3% of global high-value inventions (Dechezleprêtre et al.: 116).

More research has been done concentrating instead on individual REN industries. De la Tour and colleagues (2011) analyse the solar industry. They find that Chinese inventors have a higher propensity to patent than their competitors because they want to send a signal to the Chinese authorities to receive continuing subsidies (p.767). This means that a higher number of patents does not necessarily translate into higher markets shares. Nevertheless, China was in 2008 the worldwide leader in the production of solar PV cells, exporting 95% of its production. The focus of the Chinese industry are improvements of the process which are rather protected by secrecy than patents.

Another paper looking at a specific REN industry in China is written by Lam et al. (2017), who study the deployment and innovation of the wind industry in China, identifying the main contributing factors of how this industry became what it is today. For the deployment of wind technologies, they found that the installation of wind capacity increased from as little as 400 MW in 2001 to 140 GW in 2015. The Chinese inventive contribution is studied through patents by inventors whose geographic location is in China. The authors compare the likelihood of Chinese patent citations, with patents being cited from their main competitors in Germany, Denmark, Japan and the US in the wind industry. Their findings show that the Chinese patents are less likely to be cited than their before mentioned counterparts (e.g. German patents are 2.3 times more likely to be cited and patents from the US are three times more likely to be cited). This is true for international PCT filings[5], patents granted at the European and the USA patent office between 1980 and 2014. The authors conclude that the Chinese wind industry was not able to drive down equipment prices through technological breakthroughs in the innovation process but through overcapacity.

[5] See Section 2.2.1 for PCT filings.

Chapter 4 Methodology

4.1 Data

The data for this research was extracted from the database called PATSTAT Online 2018 Spring. This database covers bibliographical and legal status patent data from patent offices of industrialised and 'developing' countries combining databases of the EPO (EPO n.d.). This means also that the EPO database contains Chinese patent data dating back to the start of cooperation of the EPO and CNIPA in 1985 (EPO 2014). The data was extracted using Structured Query Language (SQL) a commonly used programming language. The SQL commands are provided in Appendix D.

To be able to examine the Chinese contribution to technological change, the patent data was selected through the following criteria: All cited patents for which the first national application and the international PCT application[6] was filed at the CNIPA were included. The patent database does not indicate the nationality of the inventor (neither of the applicant). It only provides the correspondence address and the country of residence of the inventor which does not necessarily correspond with the nationality. Therefore, the assumption is that the first application of a patent is mostly the home country office of the inventor. Not to understate the activity of Chinese inventors the PCT filings are also included (Lam et al. 2017: 591). Additionally, due to the Chinese legal obligation my data is (partly) restricted to discoveries from within China. Until 2009, applications of invention and utility model patents had to be filed first with the CNIPA before they could be filed abroad. Since 2009, they have had to undergo a confidentiality examination before being filed abroad. Therefore, my dataset is restricted by assumption to inventions by Chinese innovators and by legal obligation to discoveries made within the territory of China.

Having defined the 'Chinese' criterion, the dataset was narrowed down based on four criteria: First, intra-family citations were excluded from the dataset because they refer to the same invention which has been granted in other countries. Therefore, they do not reflect true knowledge spillovers.

Second, 2000-2017 was selected as the period for the extraction of the data. The Chinese government announced to change its 'development mode' in its ninth five-year plan implemented from 1996-2000 (Gallagher 2014: 7) and started investing in REN technologies during the period of the tenth five-year plan (2001-2005) (Huang et al. 2012: 125). Additionally, global markets were created "for cleaner energy technologies beginning around the turn of the twenty-first century" (Gallagher 2014: 159). The year 2017 is the most recent year for which patent data is available in this database.

Third, forward citation data exhibits truncation issues. The dataset cannot include future patents. Additionally, patents that have not been filed recently have the opportunity to be overweighed in the dataset, since they have the chance of being cited for a longer period of time. Therefore, the data is truncated to a five-year window between the application filing year of the citing and the cited patent. In this way, the overrepresentation of older patents can be avoided. An potential limitation through the five-year window of citation is that the dataset ends in 2012 instead of in 2017.

Finally, only the cited patents identified as REN and FF technologies are included in the dataset. The choice of REN and FF technologies is based on Noailly's and Shestalova's

[6] See Section 2.2.1 for PCT applications.

(2013) research which includes the following renewable energy technologies: wind, solar, hydropower[7], marine, biomass, geothermal, waste[5] and electricity storage. The following technologies are categorised as FF sources producing fuel gases: carburetting air, steam engines plants, hot-gas or combustion-product positive displacement engine, steam generation, combustion apparatus, furnaces and improved compressed-ignition engines. To identify these technologies, I made use of International Patent Classification (IPC) codes which are an international categorisation of technologies provided by the World International Patent Office (WIPO). The approach for the categorisation of the IPC codes into the individual REN and FF technologies is the same as in Noailly's and Shestalova's (2013)[8] research. The IPC codes are proved in Appendix B Table B.10.

Potential biases in patent citation data can arise through the different sources of patent citations depending on whether the inventor or examiner added the citation (see Section 2.2). In my data 1% of the citations are added by applicants compared to 98% of citations added by examiners (94% coming from the search at the national patent office and 4% coming from international search reports for PCT filings). Since almost all citations are added by the examiners, it does not allow for a comparison of citations from inventors and examiners. Therefore, I need to be aware that my results are potentially biased towards external citations (Criscuolo and Verspagen, 2008: 1901).

4.2 Empirical model

My methodology is partly based on the research by Noailly and Shestalova (2017) (a later version of Noailly and Shestalova (2013)) which examines knowledge spillovers in REN technologies. To measure knowledge spillovers for REN and the interaction with FF technologies I use Noailly's and Shestalova's approach and empirical model adding one more variable to control for the quality of a patent.

To analyse knowledge spillovers the proxy of forward patent citations is used. The counts of forward citations indicate how many times the patent of a certain technology is cited in the patent of another technology. In other words, it signals how many times the knowledge of a technology serves as building block of another technology. The more a technology is cited the more it contributes to technological change. Therefore, the counts of backward citations are not used because they signal which knowledge is embodied within an invention and not how knowledge contributes to accumulation of other knowledge. However, since the former indicator reflects potential contributions to other knowledge and the latter the foundations of the technology, they both indicate the technological fields they are related to (Battke et al. 2016).

Forward citations can occur within the same technology (intra-knowledge spillovers), e.g. a wind technology is cited by another wind technology. Another possibility is that a REN technology uses the knowledge of another REN technology (inter-REN spillovers). E.g. a

[7] It can be questioned if hydropower and waste should be categorised as sources of renewable energies. The first one because of its immediate consequences for the environment and the surrounding eco-system (Wang et al 2011: 94). The latter one because its source is residual waste, which means waste which does not stem from animals or vegetables (REA n.d.). Nevertheless, these two sources are included because they are included in Noailly's and Shestalova's (2017) research.

[8] The authors chose these IPC codes following Johnstone et al. (2010) for REN technologies, and Johnstone and Haščič (2010) for storage technologies. Lanzi et al. (2011) and Haščič et al. (2009) provided them with the IPC codes for FF technologies.

wind technology is cited by a hydro technology. The second kind of inter-knowledge spillover[9] is when a FF technology uses the knowledge of a REN technology e.g. when a waste technology is cited by a FF technology. The fourth possible knowledge spillover is the external one, when a REN or FF technology is cited by a technology which is not covered by the definitions of the two electricity production fields of the renewable energies and FFs. This means e.g. a marine technology is cited by a technology within the field of engines, pumps and turbines.

Since the dependent variable is a count variable only including nonnegative integer values, the model will be estimated by a Poisson or a negative binomial regression. The name of the former approach stems from the assumption that the error term follows the Poisson distribution implying that the mean and the variance are equal (Winkelmann 2008: 8). However, with count data this equality is often not reasonable where the conditional variance is larger than the conditional mean (overdispersion) which the negative binomial approach allows for (Winkelmann 2008: 21). Testing for overdispersion through the likelihood ratio test (UCLA 2018) shows that the Null hypothesis of $\alpha=0$ can be rejected and therefore the data shows overdispersion. The negative binomial approach is chosen over the Poisson model and estimated in the following way:

$$FORWARDCITATIONS_{si} = \beta_0 + \beta_1\, GRANTED_s + \beta_2\, APPYEAR_s + \sum_{i \in REN} \beta_i\, TECHFIELD_i + \varepsilon_{si}$$

where $FORWARDCITATIONS_{si}$ are the number of forward citations per patent *s* from the technological field *i* within a five-year window. The $GRANTED_s$ status of a patent *s* suggests a higher quality of the patent *s* and takes on the value 1 if the cited patent was granted and the value 0 if it was not granted (yet). The $APPYEAR_s$ stands for the application filing year of patent *s* and controls for year effects. The year dummies correct for specific events occurring in a year, which would affect all technological fields. The $TECHFIELD_i$ is a binary variable which is equal to 1 if the patent falls into the technological category *i*. It is used to control for differences that may have an impact on the individual technologies which can be promoted through different policy support across the technological fields or tendencies to patent certain technologies. Specific REN policies are not accounted for. However, the technology dummies may capture that certain technologies received on average more policy support than other leading to more technological development. ε_{si} is the time-variant error term.

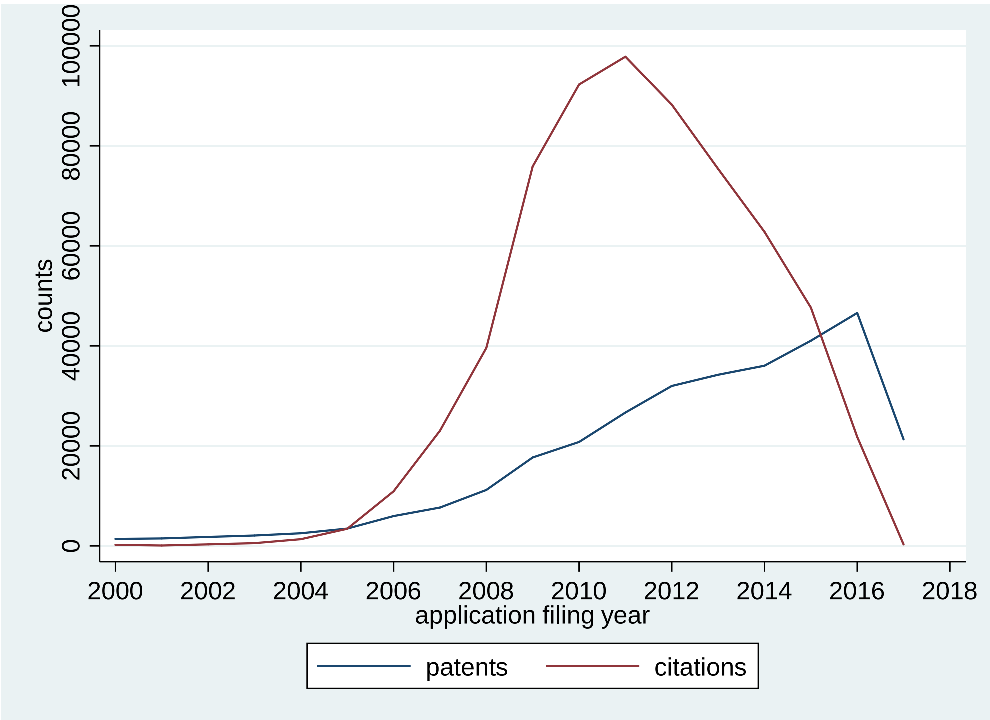
For the estimated regressions I made use of two datasets: cross-section A combines data on FF and REN technologies and cross-section B only includes REN technologies. The first dataset is used to compare the two main technologies and how they contribute to the different knowledge spillovers. The second dataset is used to compare the individual REN technologies and how they contribute to the different knowledge spillovers. Both datasets reflect the Chinese contribution to technological change since the data is narrowed down to Chinese cited patents. Different models will be presented with a changing dependent variable which is counts of forward patent citations within a five-year window: For each kind of citation

[9] This is also regarded as an inter-knowledge spillover because FFs are also part of the technological field of electricity generation.

group one separate regression is conducted and one regression with the total count of citations. For cross-section A six models and for cross-section B five models are estimated.

The two datasets are estimated for two different time periods: for the time period 2000-2012 and the time period 2000-2017. The former time period takes the truncation for the five-year window into consideration because patents which are applied for after 2012 have a lower probability of being cited. However, the number of observations more than doubles after 2012 reflecting the increasing Chinese patent activity. Graph 1 shows the development of the counts of Chinese patents and citations over time. It highlights that the increasing trends of the counts of citations decouple from the counts of patents after 2011 and that the counts of citations decrease drastically after 2012. Therefore, the data might be biased when including the years following 2012. Comparing the estimations of the two different time periods shows different results for some coefficients. In general, the relationships become weaker for REN technologies, which means that the positive relationships become weaker and the negative relationships become stronger. Some coefficients (e.g. marine) becomestatistically in- or significant depending on the model. The granted variable becomes mostly positively related. These changes could arise from not accounting for the full potential of the five-year window of citation. Henceforth, accounting for the truncation issue I will discuss in the text the estimations for the time period 2000-2012 and for transparency the descriptive statistics and the estimation results for the period 2000-2017 are provided in Appendix B.

Graph 1 Counts of patents and citations over time



Source: Own computation based on PATSTAT Online Spring version 2018

Chapter 5 Results and analysis

The descriptive and estimation section of Chapter 5 will each be separated into three parts to address the three research questions. First, the FF and REN technologies are compared. After the comparison, the individual REN technologies are analysed in more detail to examine China's contribution to technological change within the REN industry. The last part characterises the knowledge spillovers generated by the individual REN technologies to determine which technologies are potentially of general nature and can potentially foster a modular energy system.

The structure of the data is based on patents per technology. One patent can be based in different technological fields which means various IPC codes are ascribed to one patent. Consequently, one of the several technological aspects of the patent can be cited and therefore one patent can be categorised into several technological fields. This means, one patent can occur several times in the datasets, but can be ascribed to different technological fields[10].

5.1. Descriptive statistics

The descriptive statistics provide a initial picture of the comparison of FF and REN technologies, of the most represented REN technologies in the dataset and of the knowledge spillovers generated by REN technologies. For the descriptive statistics the data is separated into two datasets to obtain a clear overview about the two technologies for the following estimated analysis: one dataset for FF and one dataset for REN technologies.

5.1.1 Comparison of FF and REN technologies

Table 1 shows the summary statistics for the two datasets on FF and REN technologies. The FF dataset consists of 65,657observations[11] which are first filings at the CNIPA or international PCT filings at the CNIPA in the period 2000-2012. 59% of the dataset are non-cited patents and the average application filing year is the first half of the year 2009. 86% of the patents are granted. On average a FF patent is cited 2.7 times. Citations within the own technological fields are the most prevalent ones, followed by external technology citations. Both inter-technology citation categories occur to a much lesser extent.

The REN dataset contains 69,124 observations[9]. 53% of the patents are non-cited and the average application filing year is the middle of the year 2009. 76% of the patents are granted. On average a REN technology patent is cited 3.8 times. External citations occur almost as much as intra-technology citations. Both inter-technology citation categories are prevalent to a much lesser extent.

Comparing the two datasets shows that the means of all the listed variables are statistically significant from each other suggesting that the estimation results will point at differences in knowledge spillovers for the two technologies. The average application filing year is in the first half in the year 2009 for both datasets. The datasets differ in the following points. 3,467

[10] This means when referring to a citation "per patent", it is actually a citation per technological aspect of a patent.

[11] See Appendix C Table C.1 for further information on duplicate patents due to different technological aspects cited of a patent.

Table 1 Summary statistics for fossil fuel and renewable energy technologies

Variable	Observations	Mean	Std. Dev.	Min	Max
Forward citations (within a 5-year window)	**Fossil fuel**				
Total citations	65,657	2.66*	7.04	0	240
Intra-technology citations	65,657	1.21*	4.17	0	126
Inter-renewable energy technology citations	65,657	0.12*	0.87	0	35
Inter-fossil fuel technology citations	65,657	0.25*	1.29	0	48
External technology citations	65,657	1.07*	3.39	0	165
Explanatory variables	65,657				
non-cited patents	65,657	0.59*	0.49	0	1
application filing year	65,657	2009.29*	2.85	2000	2012
granted	65,657	0.86*	0.35	0	1
citation added by applicant	65,657	0.01*	0.10	0	1
Forward citations (within a 5-year window)	**Renewable energy**				
Total citations	69,124	3.75*	11.04	0	860
Intra-technology citations	69,124	1.79*	8.46	0	640
Inter-renewable energy technology citations	69,124	0.10*	0.71	0	26
Inter-fossil fuel technology citations	69,124	0.12*	1.00	0	72
External technology citations	69,124	1.74*	4.46	0	220
Explanatory variables	69,124				
non-cited patents	69,124	0.53*	0.50	0	1
application filing year	69,124	2009.44*	2.56	2000	2012
granted	69,124	0.76*	0.43	0	1
citation added by applicant	69,124	0.01*	0.12	0	1

Source: Own computation based on PATSTAT Online 2018 Spring. * signals the significant statistical difference of the means between the two main technologies.

(with duplicates) more REN patent applications have been filed in China in the period of 2000-2012 than FF patents. Moreover, the REN dataset includes 6% fewer non-cited patents than the FF dataset which may hint at the fact that REN technologies are more likely to serve as a knowledge base for other technologies and therefore contribute more to technological change. This is supported by the higher average number of total citations per REN technology compared to the average number per FF technology. The same holds for intra- and external technology citations where an average REN patent receives more citations than an average FF patent. The inter-technology spillovers are for both technologies to a much lesser extent relevant than the former two and do seem to play a minor role for the process of knowledge generation for both kinds of technologies. Furthermore, the FF dataset contains 10% more granted patents than the REN dataset suggesting that FF technologies are more likely to fulfil the three criteria of qualifying for a patent. The counts of citations are more dispersed in the REN dataset than in the FF dataset. The dispersion for the explanatory variable is very similar for both datasets.

5.1.2 Chinese contribution to technological change in the REN industry

Table 2 describes which technologies are represented the most in the dataset through patent applications and how many times they are cited. The number of patents and the number of citations seem to be related. However, it does not necessarily need to hold that the ranking of numbers of patents is the same like the ranking of numbers of citations like the example of waste technologies shows. Both indicators are the highest in the technological field of solar, waste and wind. Storage, hydropower, marine, biomass and geothermal technologies follow after wind in descending order exhibiting a substantial difference between the three top technologies and the rest of the technologies with geothermal as the least counts of patents and citations. E.g. the most prevalent technologies are solar which are represented by 23,653 patents and receive 82,394 citations, whereas only 733 patents represent geothermal technologies and being cited 1,535 times.

To assess the quality, i.e. if and how much a technology contributes to technological change, the number of citations is crucial because they show how many times a technology from a certain field serves as a base for the generation of other knowledge. At the same time, it should not be neglected that through a higher number of patents, the probability of a citation increases. Therefore, it is the ratio of the counts of citations and patents for descriptive statistics which can provide a better understanding of which technology seems to be crucial. The three most cited technologies are solar, wind and waste technologies with about four citations per patent. Storage, marine and geothermal follow them making hydropower technologies the least cited with about two references. In summary, the most contributing Chinese-invented technologies seem to be the fields of waste, wind and solar. The least contributing technological fields seem to be biomass and hydropower.

Table 2 Number of patents and citations for renewable energy technologies

REN technological field	Total number of patents	Total number of citations	Ratio
Solar	23,653	82,394	4.11
Waste	20,046	92,829	3.92
Wind	13,858	56,919	4.11
Storage	4,401	11,675	2.65
Hydropower	3,686	6,712	1.82
Marine	2,129	5,713	2.68
Geothermal	733	1,535	2.48
Biomass	618	1,488	2.03
Total	69,124	259,265	3.75

Source: Own computation based on renewable energy dataset downloaded from PATSTAT Online 2018 Spring.

5.1.3 Characterisation of knowledge spillovers

To compare the generated knowledge spillovers by FF and REN technologies, Table 3 shows the kinds of knowledge spillovers for the two kinds of technologies. These numbers support the findings in Table 1. For both technologies intra- and external citations are received the most. However, external knowledge spillovers stemming from REN technologies have a higher share of 46% compared to a 40% share stemming from FF technologies potentially suggesting that the utilisation of REN knowledge is more generally applicable than FF knowledge. Both groups of inter-knowledge spillovers play a minor role compared to intra- and external knowledge spillovers. However, FF technologies seem to promote knowledge accumulation within the FF-field to a larger extent than RE technologies in the RE-field

Table 3 Knowledge spillovers per main technology

Intra	Inter-ff	Inter-ren	External	Total
Fossil fuel				
46%	10%	5%	40%	100%
79,536	16,617	8,108	70,238	174,499
Renewable energy				
48%	3%	3%	46%	100%
123,849	8,632	6,663	12,0121	259,265

Source: Own computation based on PATSTAT Online 2018 Spring.

Table 4 shows what kind of knowledge spillovers are generated by each individual REN technology. The dominance of intra- and external knowledge spillovers inferred from Table 3 is also reflected when looking at individual REN technologies. Intra-technology spillovers are the most relevant for waste and wind. The most relevant REN technologies for external fields other than the electricity production by REN and FF sources to build their knowledge on are storage, geothermal, biomass, solar, hydropower and marine technologies. The two inter-knowledge spillover categories seem to be of minor importance. The inter-REN category seems to be the most relevant for biomass, marine, hydropower, geothermal and wind technologies. FF technologies seem to benefit the most of knowledge in the biomass, waste and geothermal field.

Even though the counts of inter-knowledge spillovers are overall for REN technologies rather moderate, the technological interrelatedness is looked at in more detail in Table 5. The technological relatedness to other REN technologies helps to cluster technologies and facilitate their diffusion (Grubler 2014: 42).

Table 4 Shares of knowledge spillovers per renewable energy technology

Renewable energy technology	Intra	Inter-ren	Inter-ff	External
Waste	52%	0%	6%	41%
Solar	46%	1%	3%	50%
Wind	55%	4%	0%	40%
Storage	16%	0%	0%	83%
Hydropower	32%	17%	0%	50%
Marine	35%	19%	0%	45%
Biomass	17%	21%	10%	53%
Geothermal	14%	11%	6%	69%
Total	48%	3%	3%	46%

Source: Own computation based on renewable energy dataset downloaded from PATSTAT Online 2018 spring.

As indicated in Table 4, biomass, waste and FF technologies share the burning processes as a common characteristic of the way in which they build their technologies (Noailly and Shestalova 2017: 8), which is reflected in the citations received by biomass and waste technologies invented by Chinese actors, with 10% and 6% for biomass and waste, respectively. In addition, geothermal knowledge informs the knowledge generated for the technological field of FF.

The distribution of inter-REN technology spillovers shows that hydropower, marine and wind technologies are interrelated since hydro and marine technologies have the highest shares of knowledge spillovers for the other two technologies respectively. Wind technologies are suggested to almost only benefit from the knowledge of the other two technologies[12]. Another technological interrelatedness exists between geothermal and solar reflecting their shared knowledge base of thermal processes. Furthermore, biomass technologies generate knowledge for waste technologies reflecting their similar knowledge base and complementaries with FF technologies.

Table 5 Shares of citation pairs by individual renewable energy technology

Origin	Destination								
	Waste	**Solar**	**Wind**	**Storage**	**Hydro**	**Marine**	**Bio mass**	**Geothermal**	**Fossil fuel**	**Other**
Waste	54%	0%	0%	0%	0%	0%	0%	0%	6%	39%
Solar	0%	47%	1%	0%	0%	0%	0%	0%	3%	49%
Wind	0%	1%	55%	0%	2%	1%	0%	0%	0%	40%
Storage	0%	0%	0%	16%	0%	0%	0%	0%	0%	83%
Hydropo	0%	0%	8%	0%	32%	9%	0%	0%	0%	50%
Marine	0%	1%	11%	0%	8%	35%	0%	0%	0%	45%
Biomass	21%	0%	0%	0%	0%	0%	17%	0%	10%	53%
Geothermal	2%	6%	3%	0%	0%	0%	0%	14%	6%	69%

Source: Own computation based on renewable energy dataset downloaded from PATSTAT Online 2018 spring.

As knowledge spillovers to external technological fields seem to be as relevant as intra-knowledge spillovers, their origins and destinations of the citations are analysed potentially revealing further technological complementaries. The external knowledge spillovers are categorised into 35 technological fields based on the technologies' IPC codes according the WIPO concordance table (Schmoch, 2008). Table 6 shows how the external destinations of FF and REN technologies are distributed. For a description of the main external technological fields see Appendix C Table C.2. A common main destination for both technologies is the thermal processes and apparatus field. It highlights the importance of burning processes

Table 6 Main external spillovers (>10%) per main technology

Technological field	Shares of external spillovers >10%
Fossil fuel	
Thermal processes and apparatus	28%
Material, metallurgy	18%
Basic material chemistry	11%
Renewable energy	
Electrical machinery, apparatus and energy	19%
Basic material chemistry	11%
Thermal processes and apparatus	10%

Source: Own computation based on PATSTAT Online 2018 Spring.

[12] Also, Nemet (2012: 1264) finds that find that wind and marine technologies are interrelated. Noailly and Shestalova (2017: 8) find that wind, hydro and marine technologies are intertwined.

(combustion) for FF technologies and heat exchange for solar and geothermal technologies (see Table 7) (Schmoch 2008: 15). Additionally, the field of basic chemical chemistry benefits of knowledge generation in both main technological fields. While the before-mentioned external technological fields are the same for both main technologies, they differ in one relevant external technological field. The knowledge of FF technologies serves as building block for the field of material and metallurgy. The knowledge of REN technologies lay foundations for the knowledge generation in the field of electrical machinery, apparatus and energy (specifically solar, wind, storage, hydro and marine, see Table 7). The technological relatedness to external fields seems to differ primarily in the extent (the share of an external field) but not so much to the kind of fields because the external technologically related fields seem to be similar.

Table 7 shows the technological fields with the most citations, i.e. a share above 10%, of external knowledge spillovers per individual REN technology. For a description of the main external technological fields see Appendix C Table C.2. Solar and geothermal technologies are suggested to receive the most citations from the technological field of thermal processes and apparatus reflecting their shared knowledge base. Waste and biomass technologies potentially receive the majority of their citations from the technological fields of basic

Table 7 Main external spillovers (>10%) per renewable energy

solar		**hydropower**	
Thermal processes and apparatus	23%	Engines, pumps and turbines	44%
Electrical machinery, apparatus, energy	14%	Civil engineering	14%
Semiconductors	12%	Electrical machinery, apparatus, energy	13%
waste		**marine**	
Basic materials chemistry	29%	Engines, pumps and turbines	30%
Environmental technology	19%	Electrical machinery, apparatus, energy	25%
Chemical engineering	13%	Transport	14%
Material, metallurgy	11%		
wind		**biomass**	
Electrical machinery, apparatus, energy	33%	Basic material chemistry	36%
Mechanical elements	14%	Chemical engineering	12%
Engines, pumps and turbines	11%	Environmental technology	10%
storage		**geothermal**	
Electrical machinery, apparatus, energy	80%	Thermal processes and apparatus	51%
		Civil engineering	22%

Source: Own computation based on renewable energy dataset downloaded from PATSTAT Online 2018 Spring.

materials chemistry, chemical engineering and environmental technology. The first and the third field indicate the technological relatedness of waste and biomass to FF technologies. The first field was also related to FF technologies in Table 6 and waste and biomass technologies serve as foundations for the field of environmental technology, which is related to combustion. Wind, hydro and marine technologies receive the most citations from the technological field of electrical machinery, apparatus, energy and engines, pump, turbines suggesting again their technological interrelatedness (as inferred from Table 3). The indicated external knowledge spillovers to the same technological fields of interrelated REN technologies reflect the combinatorial nature of the development process of technologies. The knowledge spillovers to external fields which are not shared among the REN technologies enforce this characteristic showing that some technologies are technologically related to a broader range of technological fields and are therefore inherently more combinatorial than others (Nemet 2012: 1268).

5.2 Estimation results

Table 8 and 9 show the regression estimation results for the pooled cross-section datasets A and B respectively. Each column in the two tables corresponds to a different model based on the dependent variable representing the counts of the different kinds of citations within a five-year window after patent application. The analysis is conducted at the patent level paired with the corresponding technological field including patents which did not receive any forward citations.

5.2.1 Comparison of FF and REN technologies

To address my first research question and, partly, my second research question, Table 8 compares Chinese-invented FF with Chinese-invented REN technologies, which means that the general and individual REN coefficients are interpreted compared to a FF technology.

Columns 1-3 present estimations for the general REN coefficient and the dependent variables of total citations, intra-technology citations and external citations respectively. The general REN coefficient in all three columns is statistically significant at the 1% level and has a positive relationship with the dependent variables. Column 1 indicates that REN technologies are overall more likely to be cited than FF technologies. This suggests that the mature technologies and saturated markets of the FF industry lead to fewer citations compared to the newer nature of the REN industry being characterised by a more dynamic innovation process. On average a REN patent is not only potentially more likely to be cited than FF technologies in total, but also within their own technological field and by external technological fields. These findings indicate that REN technologies are potentially of more general nature because they spill knowledge to a broader range of technological fields, namely within their own (Column 5) and to external fields (Column 6). It indicates a more diverse range of technological complementaries, which could be overestimated through the bias towards external citations because the majority of the citations are added by examiners (Criscuolo and Verspagen, 2008: 1901). However, this may only reflect again the increasing diffusion of REN technologies as implied by the results for total citations.

Columns 4-6 in Table 8 analyse the REN technologies more in depth by differentiating the technologies individually.

Table 8 Estimation results cross-section A: Comparison of renewable energy and fossil fuel technologies

Variables	Total citations (1)	Intra-citations (2)	External citations (3)	Total citations (4)	Intra-citations (5)	External citations (6)
Renewable energy technology	0.305*** (0.0146)	0.337*** (0.0212)	0.443*** (0.0155)			
Solar				0.217***	0.229***	0.422***
				(0.0177)	(0.0227)	(0.0211)
Storage				0.213***	-0.864***	0.911***
				(0.0487)	(0.0507)	(0.0486)
Wind				0.393***	0.600***	0.352***
				(0.0198)	(0.0244)	(0.0245)
Hydropower				-0.438***	-0.795***	-0.211***
				(0.0340)	(0.0439)	(0.0394)
Marine				-0.0370	-0.314***	0.0914**
				(0.0356)	(0.0354)	(0.0453)
Waste				0.500***	0.598***	0.555***
				(0.0254)	(0.0404)	(0.0214)
Biomass				-0.287***	-1.287***	-0.0285
				(0.0663)	(0.0571)	(0.0900)
Geothermal				-0.117*	-1.294***	0.406***
				(0.0673)	(0.0779)	(0.0751)
Granted	-0.368***	-0.310***	-0.394***	-0.353***	-0.282***	-0.382***
	(0.0188)	(0.0283)	(0.0186)	(0.0177)	(0.0253)	(0.0184)
Constant	-1.732***	-2.799***	-2.290***	-1.773***	-2.821***	-2.381***
	(0.192)	(0.213)	(0.242)	(0.193)	(0.218)	(0.232)
Observations	134,781	134,781	134,781	134,781	134,781	134,781

Citations: 5-years windows. The results of the negative binomial regression are interpreted as the likelihood of receiving a citation compared to a fossil fuel patent. Robust standard errors in parentheses: *p < 0.10 **p < 0.05***p < 0.01.

Column 4 shows the results of the dependent variable of total counts of citations. Almost all coefficients for the individual REN technologies are statistically significant at the 1% level which signals a strong relationship between the technologies and the generated knowledge spillovers. Only geothermal is statistically significant at the 10% level and marine is not statistically significant. After controlling for year effects and heterogeneity waste, wind, solar and storage technologies may be more likely to be cited than FF technologies. These technologies also received the most citations per patent in Table 2. On the other hand, geothermal, biomass and hydropower technologies may be less likely than FF technologies to receive citations. Marine technologies have a negative coefficient but are not statistically significant. Overall the data in Column 4 suggests that half of the REN technologies contribute more to technological change than FF technologies.

Column 5 estimates which technologies potentially develop from within their own technological field, which means that the dependent variable is the counts for intra-technology citations. All coefficients for the individual REN technologies are statistically significant at the 1% level. The coefficients of wind, waste and solar technologies suggest that they are more likely to receive citation from within their own technological fields than FF technologies and can therefore potentially establish their own technological linkages and promote themselves organically. These results support the descriptive statistics of Table 4. The coefficients for the remainder of the technologies suggest that they are less likely to be cited than

FF technologies from within their own technological fields. Intra-technology spillovers promote a certain technological path hinting at a higher potential for a technological lock-in. Therefore, it needs to be examined what types of other knowledge spillovers these technologies are characterised by to analyse if they are technologically related to other fields other than their own. If the latter is true, a technological lock-in is suggested to be less likely to occur.

Column 6 estimates the counts of external citations. Almost all the coefficients for the individual REN technologies are statistically significant at the 1% level except marine relates weaker at a significance level of 5%. Biomass is not statistically significant indicating a negative relationship to external citations. The coefficients for storage, waste, solar, geothermal, marine and wind technologies suggest that they are more likely to be cited by external technological fields outside the field of electricity production than FF technologies. Hydropower receives potentially fewer external citations than FF technologies. Again, the results for external citations could be overestimated because the majority of the citations are added by examiners (Criscuolo and Verspagen, 2008: 1901). At the same time, Column 5 indicates that generated knowledge within their own technological fields is more likely for four REN technologies than for FF technologies. These findings suggest that REN technologies may have a technological advantage compared to FF technologies because on one hand they are potentially able to develop from within their own technological fields. On the other hand, the knowledge of REN technologies seems to be more likely to find application outside the field of electricity production promising a wider use in the economy and complementing technologies with further technological distance than FF technologies.

The additional explanatory variable if a patent is granted is for all six models in Table 8 statistically significant on the 1% level, but they do not show the expected positive relationship with the number of citations. All columns show that if a patent is granted it may decrease the likelihood of being cited in general, of being cited within the same technological field and being cited by other technological fields than the field of electricity production (for the general REN and the individual REN coefficients). This may indicate that the three criteria of novelty, inventive step and industrial application may signal an impediment for technological impediment. Or granted patents by the CNIPA are not of high quality.

5.2.2 Chinese contribution to technological change in the REN industry

Table 9 compares only the individual REN technologies with each other. Each individual REN technology is estimated in comparison to an average solar patent. Solar as the reference category is chosen because it is the most dominant technology in the dataset. Column 1 shows the counts of total citations. All of the coefficients are strongly related to the dependent variable at the 1% significance level except storage, which is statistically significant at the 5% level. Chinese-invented waste and wind technologies seem to be more likely to receive citations than Chinese-invented solar technologies. The rest of the technologies receive less citations than solar technologies. Chinese-invented waste, wind and solar technologies (in descending order) seem to be the most valuable REN technologies for technological development as already indicated by Table 2 and Table 8. The results for storage technologies suggest that they are less likely to be cited than solar technologies implying that storage technologies experienced a slower pace of diffusion than solar technologies in the analysed period but faster pace of diffusion than FF technologies.

The negative relationship of hydropower technologies with total citations compared to solar (and FF in Table 8) technologies seems to reflect the mature character of this industry.

It is the oldest REN industry in China since it generates from the middle of the 20th century onwards electricity for its population (Zhang et al. 2012: 866). Biomass and geothermal technologies also indicate to have a negative impact on total citations compared to both technologies. However, in their case it does not reflect the more mature character of the industry but rather that they are in the very beginning of their diffusion process. Both REN sources have a large potential to be exploited in China (Zhang et al. 2012: 868). In the case of biomass technologies, it is surprising that the diffusion did not accelerate yet in comparison to waste technologies since they are both technologically related to FF technologies whose knowledge base is already more developed. Marine technologies also seem to contribute less to technological change than solar technologies. Compared to solar technologies the sign of their coefficient suggests having a negative impact. These findings indicate that marine technologies are in their introduction phase (ibid) where the industry is still dominated by uncertainty and experimentation (Grübler 1998: 52).

Table 9 Estimation results cross-section B: Comparison of renewable energy technologies to each other

Variables	Total Citations (1)	Intra-Citations (2)	Inter-REN Citations (3)	Inter-FF Citations (4)	External Citations (5)
Storage	-0.104**	-1.152***	-2.916***	-3.722***	0.390***
	(0.0416)	(0.0487)	(0.405)	(0.439)	(0.0429)
Wind	0.165***	0.351***	1.360***	-1.944***	-0.0693**
	(0.0217)	(0.0268)	(0.0854)	(0.142)	(0.0270)
Hydropower	-0.642***	-1.012***	1.923***	-2.746***	-0.622***
	(0.0356)	(0.0461)	(0.0941)	(0.300)	(0.0411)
Marine	-0.249***	-0.543***	2.454***	-2.002***	-0.330***
	(0.0373)	(0.0375)	(0.0960)	(0.411)	(0.0468)
Waste	0.277***	0.356***	-0.960***	1.234***	0.126***
	(0.0276)	(0.0430)	(0.125)	(0.0717)	(0.0247)
Biomass	-0.500***	-1.542***	2.325***	0.883***	-0.430***
	(0.0665)	(0.0577)	(0.116)	(0.199)	(0.0911)
Geothermal	-0.366***	-1.538***	1.779***	0.450**	-0.0531
	(0.0646)	(0.0776)	(0.143)	(0.187)	(0.0721)
Granted	-0.374***	-0.377***	-0.271***	-0.125*	-0.373***
	(0.0230)	(0.0345)	(0.0708)	(0.0753)	(0.0216)
Constant	-1.027***	-2.315***	-20.66	-5.507***	-1.367***
	(0.267)	(0.303)		(0.484)	(0.283)
Observations	69,124	69,124	69,124	69,124	69,124

Citations: 5-years windows. The results of the negative binomial regression are interpreted as the likelihood of receiving a citation compared to a solar patent. Robust standard errors in parentheses: *p < 0.10 **p <0.05***p < 0.01.

5.2.3 Characterisation of knowledge spillovers

Continuing with Table 9, Column 2 presents the findings for the dependent variable of counts of intra-technology citations. All coefficients are strongly related to the dependent variable at the 1% significance level. Waste and wind technologies potentially generate more citations within their own technological fields than solar technologies. The remainder of the REN technologies may be less likely than solar technologies to be characterised by intra-knowledge spillovers.

Column 3 shows the findings for inter-REN technologies citations. All coefficients are strongly related to the dependent variable at the 1% significance level. As Table 4 suggests marine, biomass, hydropower, geothermal and wind technologies are the fields which promote knowledge spillovers between other REN technologies. The potentially strong contribution of marine, hydropower and wind technologies to inter-REN citations indicates the interrelatedness of these three technologies depicted in Table 5. The coefficient for geothermal indicates that its contribution to REN technologies from Table 5 may have an impact on solar technologies. The same holds for the coefficient for biomass technologies which suggests that they contribute to the knowledge generation of waste technologies shown in Table 5. Storage and waste technologies are suggested to be less likely than solar technologies to be cited by other REN technologies field other than their own. In general, Column 3 potentially confirms the findings from Table 5. However, the coefficients are mostly very high and the year effects are not accounted for indicating that the small number of observations for which inter-REN citations are given, may have an impact and overestimate their effects. Nevertheless, these technological linkages are also suggested by Noailly and Shestalova (2017). Through the indicated technological interrelatedness of REN technologies policy support for one field may mean indirect support for another field.

Column 4 shows the findings for REN technologies cited by FF technologies. All coefficients are strongly related to the dependent variable at the 1% significance level. As suggested by Table 4 waste and biomass technologies may contribute to the accumulation of knowledge for FF technologies undermining the technological similarities and complementarities. The potentially positive contribution of geothermal technologies to FF technologies suggested by Table 4 is also undermined with these findings. The rest of the technologies are less likely to be cited than solar technologies by FF technologies. REN technologies which indicate to support the fossil-fuel based energy path should not receive (or receive less) policy support if technological change wants to be directed towards REN technologies.

Column 5 shows the findings for REN technologies cited by other technologies than the ones identified for the REN and FF technologies. Most coefficients are strongly related to the dependent variable of the counts of external citations at the 1% significance level. Only geothermal technologies are not statistically significant suggesting that they do not seem to be of relevance to create knowledge for external technological fields even though Table 4 suggests that geothermal technologies are characterised the most by external knowledge spillovers. As indicated by Table 8, storage and waste technologies exhibit probabilities of receiving more citations than solar technologies. The other five REN technologies are potentially less probably to be cited by external technological fields indicating that they are less likely than storage, waste and solar technologies to promote a diverse knowledge pool. Moreover, waste and solar technologies seem also to contribute to knowledge accumulation within their own fields promoting more diversity.

The characterisation of solar, waste and wind technologies seems to be appropriate since they seem to be at a similar stage of diffusion indicated by Column 1 (and being the most likely ones to be cited in the rest of the columns in Table 9). Waste technologies seem to contribute within their own and to external technological fields the most in comparison to solar and wind. Only storage technologies contribute more to external fields. Wind is more characterised by intra-knowledge spillovers than external ones indicating that its contribution is less likely to go beyond the field of RE. Solar is more characterised by external knowledge spillovers than wind. The remainder of the technologies seem to be diffused to a smaller extent which should be met with increasing policy support.

In general, the best option may be to promote REN technologies which are potentially characterised by external knowledge spillovers to promote knowledge in more distant technological fields which at the same time encourages a more general application of the combinatorial nature of knowledge.

Throughout all the columns in Table 9 granted patents have a statistically significant relationship at the 1% level with the different dependent variables. Granted patents are suggested to decrease the probability for a technology of being cited confirming the findings of Table 8.

5.3 Comparison to other findings

My results confirm and contradict the existing empirical literature. In the following sections, I will discuss which results do so and why.

5.3.1 Confirming results

Chinese-invented REN technologies receive more citations than FF technologies which indicates that the former technologies contribute in the period of 2000-2012 more to technological change than the latter. This could be attributed to the newer nature of the REN industry implying that this industry is in the process of increasing diffusion having a more dynamic innovation process. My results undermine the findings by Dechezleprêtre et al. (2014) who also find that clean electricity inventions are more likely to be cited than dirty electricity technologies for the time period of 1950-2005. Their dataset consists of patents filed all over the word. Supporting further findings of Dechezleprêtre et al. (2014) that clean inventions are more likely to be characterised by intra-technology spillovers than dirty inventions, I show that the probability of Chinese-invented REN technologies generating knowledge spillovers within their own technological fields is higher than for FF technologies.

Inter-REN knowledge spillovers are generated by Chinese-invented marine, biomass, geothermal, hydropower and wind technologies contributing more to the technological interrelatedness of the different REN technologies than solar, storage and waste technologies. Noailly and Smeets (2015) undermine these results by finding that past knowledge stock of REN technologies encourages innovation in other REN technologies. My results for inter-knowledge spillovers to FF technologies support the findings of Noailly and Shestalova (2017) for geothermal, biomass and waste technologies.

Similarly to my results, the analysis by Dechezleprêtre et al. (2014) suggests that clean inventions are characterised by inter-technology citations, which means other technological fields than their own. My estimations indicate that REN technologies spill more knowledge to external knowledge spillovers than FF technologies undermining their analysis.

The finding that REN technologies are more likely to be cited for intra and for external technological fields, indicates that REN technologies promote diverse knowledge spillovers. Promoting technological diversity suggests that REN technologies are of more general nature than FF technologies. This supports the results of Popp and Newell (2012) and Dechezleprêtre et al. (2014) who find that alternative energy patents (wind, solar, geothermal) and cleaner inventions respectively are more general than dirty ones. These findings could result from the fact that clean inventions in total experience increasing diffusion which is also reflected in spillovers to more distant fields instead of suggesting overall more generality.

5.3.2 Contradicting results

The results of Noailly and Shestalova (2017) find partly contradicting results compared to my results for the individual energy technologies across the different types of knowledge spillovers except for the inter-FF technologies knowledge spillover as shown in Section 5.3.1

where our results match exactly. When comparing the individual REN technologies with FF technologies and to solar technologies, my findings support and contradict the results of Noailly and Shestalova (2017) suggesting that the process of technological change for REN technologies has a globalised character. In general, the technologies, which are statistically significant and more cited than the reference category in their study, exhibit the same tendencies in my dataset. However, waste technologies dominate my dataset strikingly, whereas in the other study they do not seem to be as contributing as wind and solar technologies. There are other minor deviations between their and my results. The reason for these enforcing but also differing results is three-fold: Firstly, the dataset of Noailly and Shestalova (2017) is restricted to the year 2006, while the period regarded in this study lasts until they year 2012. For the REN industry especially more recent years are important because of the establishment of REN markets at the beginning of this century and an increasing implementations of REN policies around the globe. This may lead to an underestimation of the results by Noailly and Shestalova (2017). The dominance of the waste technologies in my dataset may simply reflect their increasing diffusion in more recent years after 2006. Secondly, the geographic locations of the patent offices where the patents in the datasets are filed, are different. They use only data of European patent offices and I use data based on patents filed at the Chinese patent office. Thirdly, my model includes one additional explanatory variable, which increases the explanatory power of the variation in the model and therefore the technological relatedness analysed by Noailly and Shestalova (2017) may be underestimated.

The results by Braun et al. (2011) indicate that solar and wind technologies benefit from intra-knowledge spillovers and wind does so for a larger extent. But only wind technologies seem to profit from inter-knowledge spillovers. Their results for wind technologies undermine mine. Whereas, their results for inter-knowledge spillovers, in my analysis external knowledge spillovers, contradict mine. My results suggest that solar technologies are more characterised by external spillovers than wind technologies. The reason is that the study by Braun and collegues (2011) use predefined IPC codes to construct the external knowledge stock which does not seem to grasp the more complicated and more diverse knowledge stock in the solar industry.

Furthermore, my results do not reveal technological relatedness between storage and other renewable technologies like the findings of Johnstone and Haščič (2010). They find that the knowledge stock of storage technologies has a positive impact on the development of biomass and waste, hydropower, wind, solar, geothermal and ocean technologies (in ascending order), whereas my findings do not exhibit any knowledge spillovers of storage to other REN technologies. Neither do the findings by Noailly and Shestalova (2017). The reason for these different findings may be that Johnstone and Haščič (2010) base their analysis on patent counts to construct past knowledge stock whereas Noailly's and Shestalova's (2017) and my analysis are based on patent citations to measure the likelihood of using certain knowledge as a building block for a technology. Nevertheless, my findings suggest that storage technologies contribute to knowledge accumulation particularly in the external field of electrical machinery, apparatus, energy which covers the 'generation, conversion and distribution of electric power' (Schmoch 2009: 7). This field also seems to be important in my dataset for intermittent technologies like solar, wind and marine technologies which are positively influenced by knowledge stock of storage technologies in the analysis of Johnstone and Haščič (2010). Therefore, solar, wind and marine technologies seem to have technological complementaries with storage technologies in my dataset but not direct linkages.

Dechezleprêtre et al. (2014) show, when only looking at the electricity sector (and not combined with clean transportation), that clean electricity inventions are less general than their dirty counterparts. However, these findings contradict my results because REN technologies in my dataset, as shown in Table 8 in the first three columns, are more likely to be characterised by different types of knowledge spillovers. The findings of their paper are based on time periods ending in 2005, whereas my time period ends in 2012. Therefore, they exclude important years during which the development of REN technologies worldwide accelerated underestimating their technological linkages.

Chapter 6 Conclusion

This paper contributes to the literature on technological change in the energy sector, in general, and the kind of role that knowledge spillovers generated by Chinese actors play, in particular. It is the first study to my knowledge to examine Chinese knowledge spillovers and to base its analysis on patent citations of energy patents filed at the CNIPA; moreover, it examined knowledge spillovers for a period as recent as 2000-2012, which to my knowledge has not yet been done.

As my findings based on the patent citations of Chinese-invented technologies suggest, the efforts of the Chinese government to promote innovation in REN technologies was (partially) successfully translated into diffusing technologies.

The results identify potential knowledge spillovers of Chinese-invented REN technologies in relation to Chinese-invented FF technologies and to each other. My estimations suggest that REN technologies contributed more to technological change through their total, intra- and external knowledge spillovers than FF technologies since the beginning of the twenty-first century until 2012. These findings could result from the accelerated (decreasing) rate of diffusion because of the newer (older) character of the REN (FF) industry, reflected in more (fewer) total citations. Especially waste, wind, solar and storage technologies seem to generate more knowledge spillovers in all three categories than FF technologies. The results for wind and solar match the fact that the Chinese solar and wind industry play an important role as global manufacturer.

To create a more comprehensive picture of the characteristics of knowledge generated by REN technologies, I compare only the REN technologies because they are all industries with a rather novel character. My findings suggest that waste, wind, and solar technologies experience an increasing diffusion. The knowledge of all three of them finds application within their own fields, whereas only waste and solar technologies serve as building blocks for technological fields other than their own. The latetr is also true for storage technologies. Through distant technological connections, the combinatorial nature of knowledge finds a more general application and suggests that they find a wide use in the economy, potentially supporting general productivity gains (Bresnahan and Trajtenberg 1995: 84). Based on these knowledge spillovers, the same level of policy support for waste, wind and solar potentially implies technologically narrower developments initiated by wind technologies. Waste and solar technologies may contribute to more general applications.

The inter-knowledge spillovers to other REN and FF technologies seem to be of minor importance compared to the other two categories. However, the potential technological relatedness within the field of electricity production may have implications for the way in which technological characteristics can promote an energy structure based on REN sources. My findings indicate that the knowledge base of wind, hydropower, marine and geothermal technologies serve as foundations for the development of other REN technologies. However, the knowledge spillovers of biomass technologies seems to encourage waste technologies, which in turn help to develop FF technologies. Additionally, biomass technologies themselves are suggested to aid the development of FF technologies. Therefore, if an energy structure based on REN sources is to be pursued based on the technological relatedness of these technologies, policies may neither support biomass, nor waste technologies. Furthermore, geothermal technologies seem to encourage knowledge accumulation for FF technologies, although to a much lesser extent than biomass and waste technologies. Consequently, based on the indicated findings of knowledge spillovers, the support for geothermal technologies should be carefully designed, because they support the foundation of solar technologies and potentially encourage knowledge accumulation for FF technologies.

My results are a snapshot of the development of the different technologies during the period 2000-2012. The analysis of patent citations reveals more specifically at what stage the different technologies are in the diffusion process, because the citations reflect whether their knowledge is applied to other technologies. However, the sign and the strength of the relationships can indicate which technologies are likely to be characterised by intra-, inter- or external knowledge spillovers, therefore suggesting to what kind of knowledge pool they can contribute. If technologies at the same stage in the diffusion process are compared, better conclusions can be drawn about their inherent characteristics. Furthermore, only patents filed at the CNIPA are examined, which restricts the implications for Chinese patents. Future research could extend the analysis to applications at patent offices in other countries to provide a more comprehensive picture of the diffusion process and inherent technological characteristics. Including the effects of implemented policies in the analysed period would improve the understanding of the way in which to design policies to diffuse REN technologies faster, and of the kind of policies that promote diversity in the knowledge pool to foster more technologies with general applications.

Overall, these findings suggest an accelerating diffusion rate of Chinese-invented RE technologies compared to FF technologies. Chinese-invented waste, wind and solar technologies seem to be the most-diffused REN technologies. Based on the indicated technological relatedness to FF technologies, waste technologies should not receive (as much) policy support as other REN technologies (the same holds for biomass technologies). Solar technologies, and with a stronger impact of storage technologies, serve as a foundation for technologically distant fields fostering a diverse knowledge pool. The emerging marine and geothermal REN technologies should receive more policy support to promote their diffusion. Policies differentiating between REN technologies in China can accelerate the global process of technological change to pave the way for an energy structure based on REN sources.

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Appendices (A-D)

Appendix A

Table A.1 Patents

Patent	Description
Inventions	“They are a new technical solution relating to a product, to a process or an improvement thereof” (Devonshir-Ellis et al. 2011: 7). These patent rights are granted for 20 years starting from the date of filing (Devonshir-Ellis et al. 2011: 8).
Utility models	Utility models “are new technical solutions related to a product’s shape, structure or a combination thereof, which is fit for practical use” (Devonshir-Ellis et al., 2011: 8). This means that processes and applications are excluded for these kind of patent (whereas this is the focus of invention patents). It is “required to meet a lower inventiveness requirement” (Feng 1997: 153). Utility model patent rights are granted for 10 years starting from the date of filing. Utility model rights do not experience the same in-depth examination as the patents rights for inventions and are therefore easier to be granted (Devonshir-Ellis et al. 2011: 8).
Designs	A design patent “is any new design for a product’s shape, pattern or combination thereof, as well as the color and the shape or pattern of a product, which creates an aesthetic feeling and is fit for industrial application” (Devonshir-Ellis et al. 2011: 8). Like in the case of utility models, they can only be granted for products and are granted for 10 years starting from the date of filing (ibid). A design patent focuses on the visual aspect of a product and does not focus much on technical progress. Nevertheless, it needs to be practically/industrially applicable, which is the connection to the other two kinds of patents. Its patentability is mainly based on the criterion of novelty (Feng 1997: 194). To file a design patent, a request, drawings or photographs of the product incorporating the patented design and an indication of the class to which the design belongs should be submitted (CNIPA 2014a).

Source: as indicated in table.

According to **article 22** of the Chinese patent law 1992 the **three criteria** for patentability are defined the following way:

“Novelty means that the invention or utility model concerned is not an existing technology; no patent application is filed by any unit or individual for any identical invention or utility model with the patent administration department under the State Council before the date of application for patent right, and no identical invention or utility model is recorded in the patent application documents or the patent documentations which are published or announced after the date of application. Creativity means that, compared with the existing technologies, the invention possesses prominent substantive features and indicates remarkable advancements, and the utility model possesses substantive features and indicates advancements. Practical use means that the said invention or utility model can be used for production or be utilized, and may produce positive results. For the purposes of this Law, existing technologies mean the technologies known to the public both domestically and abroad before the date of application.” (CNIPA 2013).

Appendix B

Table B.1 Summary statistics for fossil fuel and renewable energy technologies

Variable	Observations	Mean	Std. Dev.	Min	Max
Forward citations (within a 5-year window)	**Fossil fuel**				
Total citations	162,479	1.72*	5.37	0	240
Intra-technology citations	162,479	0.83*	3.29	0	126
Inter-RE technology citations	162,479	0.08*	0.69	0	35
Inter-FF technology citations	162,479	0.16*	0.99	0	48
External technology citations	162,479	1.07*	3.45	0	220
Explanatory variables	162,479				
non-cited patents	162,479	0.72*	0.45	0	1
application filing year	162,479	2012.65*	3.45	2000	2017
granted	162,479	0.79*	0.41	0	1
citation added by applicant	162,479	0.01*	0.08	0	1
Forward citations (within a 5-year window)	**Renewable energy**				
Total citations	151,513	2.40*	8.77	0	860
Intra-technology citations	151,513	1.19*	6.74	0	640
Inter-RE technology citations	151,513	0.06*	0.53	0	26
Inter-FF technology citations	151,513	0.09*	0.85	0	72
External technology citations	151,513	1.06*	3.44	0	220
Explanatory variables	151,513				
non-cited patents	151,513	0.68*	0.47	0	1
application filing year	151,513	2012.41*	3.37	2000	2017
granted	151,513	0.70*	0.46	0	1
citation added by applicant	151,513	0.01*	0.11	0	1

Source: Own computation based on PATSTAT Online 2018 Spring. * signals the significant statistical difference of the means between the two main technologies.

Table B.2 Number of patents and citations for renewable energy technologies

REN technological field	Total number of patents	Total number of citations	Ratio
Waste	50,978	138,210	2.71
Solar	46,088	112,205	2.43
Wind	25,389	66,599	2.62
Storage	7,403	12,348	1.67
Hydro	6,596	9,290	1.41
Marine	5,054	8,171	1.62
Biomass	2,273	2,324	1.02
Geothermal	1,332	1,559	1.17
Total	145,113	350,706	2.42

Source: Own computation based on renewable energy dataset downloaded from PATSTAT Online 2018 Spring

Table B.3 Knowledge spillovers per main technology

Intra	Inter-ff	Inter-ren	External	Total
Fossil fuel				
48%	9%	5%	38%	100%
134,172	26,267	13,403	105,075	278,917
Renewable energy				
50%	4%	2%	44%	100%
179,658	13,784	8,443	160,967	362,852

Source: Own computation based on PATSTAT Online 2018 Spring

Table B.4 Shares of knowledge spillovers per renewable energy technology

Renewable energy technology	Intra	Inter-ren	Inter-ff	External
Waste	53%	0%	7%	39%
Solar	48%	1%	3%	48%
Wind	56%	4%	0%	40%
Storage	18%	0%	0%	82%
Hydro	34%	15%	0%	50%
Marine	36%	18%	1%	45%
Biomass	19%	18%	8%	56%
Geothermal	17%	10%	6%	67%
Total	50%	2%	4%	44%

Source: Own computation based on renewable energy dataset downloaded from PATSTAT spring version 2018

Table B.5 Shares of citation pairs by individual renewable energy

Origin	Destination									
	Waste	Solar	Wind	Storage	Hydro	Marine	Biomass	Geothermal	FF	Other
Waste	55%	0%	0%	0%	0%	0%	0%	0%	7%	38%
Solar	0%	49%	1%	0%	0%	0%	0%	0%	3%	47%
Wind	0%	1%	56%	0%	2%	1%	0%	0%	0%	39%
Storage	0%	0%	0%	18%	0%	0%	0%	0%	0%	82%
Hydro	0%	0%	7%	0%	34%	8%	0%	0%	0%	50%
Marine	0%	0%	11%	0%	7%	36%	0%	0%	1%	45%
Biomass	5%	0%	0%	0%	0%	0%	19%	0%	8%	68%
Geothermal	2%	6%	2%	0%	0%	0%	0%	17%	6%	67%

Source: Own computation based on renewable energy dataset downloaded from PATSTAT spring version 2018

Table B.6 Main external spillovers (>10%) per main technology

Technological field	Shares of external spillovers >10%
Fossil fuel	
thermal processes and apparatus	30%
material, metallurgy	17%
environmental technology	10%
Renewable energy	
electrical machinery, apparatus and energy	18%
basic material chemistry	12%
thermal processes and apparatus	10%

Source: Own computation based on PATSTAT Online 2018 Spring

Table B.7 Main external spillovers (>10%) per renewable energy

solar		**hydro**	
thermal processes and apparatus	23%	engines, pumps and turbines	44%
electrical machinery	16%	civil engineering	18%
semiconductors	12%	electrical machinery, apparatus, energy	12%
waste		**marine**	
basic materials chemistry	24%	engines, pumps and turbines	28%
environmental technology	21%	electrical machinery, apparatus, energy	26%
chemical engineering	14%	transport	15%
material, metallurgy	10%		
wind		**biomass**	
electrical machinery, apparatus, energy	33%	basic material chemistry	31%
mechanical elements	13%	chemical engineering	18%
engines, pumps and turbines	11%		
storage		**geothermal**	
electrical machinery	79%	thermal processes and apparatus	52%
		civil engineering	26%

Source: Own computation based on renewable energy dataset downloaded from PATSTAT spring version 2018

Table B.8 Estimation results: Comparison of renewable energy and fossil fuel technologies

Variables	Total citations (1)	Intra-citations (2)	External citations (3)	Total citations (4)	Intra-citations (5)	External citations (6)
Renewable energy technology	0.225*** (0.0130)	0.271*** (0.0178)	0.375*** (0.0138)			
Solar				0.212*** (0.0161)	0.230*** (0.0202)	0.447*** (0.0192)
Storage				-0.0534 (0.0400)	-0.970*** (0.0409)	0.659*** (0.0403)
Wind				0.191*** (0.0191)	0.382*** (0.0226)	0.212*** (0.0231)
Hydropower				-0.622*** (0.0296)	-0.921*** (0.0362)	-0.307*** (0.0339)
Marine				-0.184*** (0.0294)	-0.462*** (0.0287)	0.0457 (0.0392)
Waste				0.436*** (0.0211)	0.556*** (0.0302)	0.470*** (0.0188)
Biomass				-0.476*** (0.0589)	-1.329*** (0.0502)	-0.0273 (0.0781)
Geothermal				-0.191*** (0.0598)	-1.165*** (0.0627)	0.389*** (0.0660)
Granted	-0.368*** (0.0188)	-0.310*** (0.0283)	-0.394*** (0.0186)	0.0919*** (0.0152)	0.220*** (0.0203)	-0.0859*** (0.0168)
Constant	-2.006*** (0.210)	-3.163*** (0.220)	-2.469*** (0.253)	-2.020*** (0.217)	-3.189*** (0.227)	-2.526*** (0.247)
Observations	313,992	313,992	313,992	313,992	313,992	313,992

Citations: 5-years windows. The results of the negative binomial regression are interpreted as the likelihood of receiving a citation compared to a fossil fuel patent. Robust standard errors in parentheses: *p < 0.10 **p < 0.05***p < 0.01.

Table B.9 Estimation results: Comparison of renewable energy technologies to each other

Variables	Total Citations (1)	Intra-Citations (2)	Inter-REN Citations (3)	Inter-FF Citations (4)	External Citations (5)
Storage	-0.391*** (0.0348)	-1.280*** (0.0405)	-2.935*** (0.377)	-3.705*** (0.379)	0.115*** (0.0371)
Wind	-0.0528** (0.0228)	0.113*** (0.0272)	1.441*** (0.0756)	-1.850*** (0.132)	-0.245*** (0.0262)
Hydropower	-0.834*** (0.0323)	-1.153*** (0.0395)	1.911*** (0.0883)	-2.658*** (0.244)	-0.746*** (0.0363)
Marine	-0.404*** (0.0322)	-0.710*** (0.0322)	2.593*** (0.0848)	-1.574*** (0.383)	-0.400*** (0.0415)
Waste	0.224*** (0.0246)	0.307*** (0.0339)	-0.909*** (0.105)	1.254*** (0.0594)	0.0274 (0.0228)
Biomass	-0.698*** (0.0610)	-1.603*** (0.0528)	2.198*** (0.130)	0.222 (0.156)	-0.457*** (0.0792)
Geothermal	-0.422*** (0.0614)	-1.406*** (0.0655)	1.981*** (0.150)	0.365** (0.170)	-0.0736 (0.0671)
Granted	0.0101 (0.0210)	0.0478* (0.0290)	-0.0701 (0.0610)	0.117* (0.0660)	-0.115*** (0.0207)
Constant	-1.080*** (0.303)	-2.479*** (0.329)	-23.94	-5.699*** (0.487)	-1.366*** (0.301)
Observations	151,513	151,513	151,513	151,513	151,513

Citations: 5-years windows. The results of the negative binomial regression are interpreted as the likelihood of receiving a citation compared to a solar patent. Robust standard errors in parentheses: *p < 0.10 **p <0.05***p < 0.01.

Table B.10 IPC codes

Technology	Description	IPC code
	RENEWABLE ENERGY	
Wind energy	Wind motors	F03D
Solar energy	Devices for producing mechanical power from solar energy	F03G6
	Use of solar heat, e.g. solar heat collectors	F24J2
	Drying solid materials or objects by processes involving the application of heat by radiation - e.g. from the sun	F26B3/28
	Devices consisting of a plurality of semiconductor components sensitive to infra-red radiation, light – specially adapted for the conversion of the energy of such radiation into electrical energy	H01L27/142
	Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation, specially adapted as devices for the conversion of the energy of such radiation into electrical energy, including a panel or array of photoelectric cells, e.g. solar cells	H01L31/042-058
	Generators in which light radiation is directly converted into electrical energy	H02N6
Geothermal energy	Devices for producing mechanical power from geothermal energy	F03G4
	Production or use of heat, not derived from combustion – using geothermal heat	F24J3/08
Marine (Ocean) energy	Tide or wave power plants	E02B9/08
	Submerged units incorporating electric generators or motors characterised by using wave or tide energy	F03B13/10-26
	Ocean thermal energy conversion	F03G7/05
Hydropower energy	Water-power plants; Layout, construction or equipment, methods of, or	E02B9; and not E02B9/08
	apparatus for; and not Tide or wave power plants	
	Machines or engines for liquids of reaction type; Water wheels; Power stations or aggregates of water-storage type; Machine or engine aggregates in dams or the like; Controlling machines or engines for liquids; and NOT Submerged units incorporating electric generators or motors characterized by using wave or tide energy	[F03B3 or F03B7 or F03B13/06-08 or F03B15] and not F03B13/10-26

Biomass energy	Solid fuels based on materials of non-mineral origin - animal or vegetable substances	C10L5/42-44
	Engines or plants operating on gaseous fuels from solid fuel - e.g. wood	F02B43/08
Waste-to energy	Solid fuels based on materials of non-material origin - sewage, town, or house refuse; industrial residues or waste materials	C10L5/46-48
	Incineration of waste - recuperation of heat	F23G5/46
	Incinerators or other apparatus consuming waste - field organic waste	F23G7/10
	Liquid carbonaceous fuels; Gaseous fuels; Solid fuels; and Dumping solid waste; Destroying solid waste or transforming solid waste into something useful or harmless; Incineration of waste; Incinerator	[C10L1 or C10L3 or C10L5] and [B09B1 or B09B3 or F23G5 or F23G7]
	Plants for converting heat or fluid energy into mechanical energy – use of waste heat; Profiting from waste heat of combustion engines; Machines, plant, or systems, using particular sources of energy – using waste heat. And Incineration of waste; Incinerator constructions; Incinerators or other apparatus specially adapted for consuming specific waste or low grade fuels.	[F01K27 or F02G5 or F25B27/02] and [F23G5 or F23G7]
Storage	lead-acid accumulators	H01M10/06-18
	alkaline accumluators	H01M10/24-32
	gastight accumulators	H01M10/34
	other types of accumulators not provided for elsewhere	H01M10/36-40
FOSSIL FUEL ENERGY		
Furnaces	Engines characterised by fuel-air mixture compression ignition	F02B1/12-14
	Engines characterised by air compression and subsequent fuel addition; with compression ignition	F02B3/06-10
	Engines characterised by the fuel-air charge being ignited by compression ignition of an additional fuel	F02B7
	Furnaces; kilns; ovens; retorts	F27
Ignition	Engines characterised by both fuel-air mixture compression and air compression, or characterised by both positive ignition and compression ignition, e.g. in different cylinders	F02B11

	Engines characterised by the introduction of liquid fuel into cylinders by use of auxiliary fluid; Compression ignition engines using air or gas for blowing fuel into compressed air in cylinder	F02B13/02-04
	Methods of operating air-compressing compression-ignition engines involving introduction of small quantities of fuel in the form of a fine mist into the air in the engine's intake.	F02B49
Coal	Production of fuel gases by carburetting air or other gases without pyrolysis	C10J
Engines	Steam engine plants; steam accumulators; engine plants not otherwise provided for; engines using special working fluids or cycles	F01K
Turbines	Gas-turbine plants; air intakes for jet-propulsion plants; controlling fuel supply in air-breathing jet-propulsion plants	F02C
Hotgas	Hot-gas or combustion-product positive-displacement engine; Use of waste heat of combustion engines, not otherwise provided for	F02G
Steam	Steam generation	F22
Burners	Combustion apparatus; combustion processes	F23

Source: Noailly and Shestalova (2013)

Appendix C

Table C.1 Numbers of patent duplicates by main technology

Number of duplicates	**FF**	**REN**
0	59,616	64,740
1	5,554	3,888
2	483	462
3	4	28
5	0	6
Total	65,657	69,124

Source: Own computation based on PATSTAT Online 2018 Spring

Table C.2 External technological fields

Technological field	Description
Thermal processes and apparatus	‘The field covers applications such as steam generation, combustion, heating, refrigeration, cooling or heat exchange’ (p.15).
Materials, metallurgy	‘This field covers all types of metals, ceramics, glass or processes for the manufacture of steel’ (p.14).
Environmental technology	‘This field covers a variety of different technologies and applications, in particular filters, waste disposal, water cleaning (a quite large area), gas-flow silencers and exhaust apparatus, waste combustion or noise absorption walls’ (p.14).
Electrical machinery, apparatus, energy	‘The field primarily covers the non-electronic part of electrical engineering, for instance, the generation, conversion and distribution of electric power, electric machines but also basic electric elements such as resistors, magnets, capacitors, lamps or cables’ (p.7).
Basic materials chemistry	‘This field primarily covers typical mass chemicals such as herbicides, fertilisers, paints, petroleum, gas, detergents etc’ (p.14).

Source: Schmoch (2008)

Appendix D

Wind

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SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'F03D%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F03D%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
```

Solar

```
SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'F03G   6%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F03G   6%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F24J   2%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE  'F24J   2%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F26B   3/28'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F26B   3/28'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'H01L  27/142'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
```

```
OR (i.ipc_class_symbol LIKE 'H01L  27/142'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'H02N   6%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'H02N   6%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'H01L  31/042' AND 'H01L  31/058'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'H01L  31/042' AND 'H01L  31/058'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
```

Geothermal

```
SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'F03G   4%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F03G   4%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
```

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AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F24J   3/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F24J   3/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
```

Marine

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SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'E02B   9/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'E02B   9/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'F03B  13/10' AND 'F03B  13/26'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'F03B  13/10' AND 'F03B  13/26'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F03G   7/05'
```

```
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F03G   7/05'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
```

<u>Hydropower</u>

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SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'E02B   9%'
AND i.ipc_class_symbol <> 'E02B   9/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'E02B   9%'
AND i.ipc_class_symbol <> 'E02B   9/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F03B   3%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F03B   3%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F03B   7%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
```

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AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F03B   7%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F03B  15%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F03B  15%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'F03B  13/06' AND 'F03B  13/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'F03B  13/06' AND 'F03B  13/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'F03B  13/10' AND 'F03B  13/26'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'F03B  13/10' AND 'F03B  13/26'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
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Biomass

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SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
```

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JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'F02B  43/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F02B  43/08'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'C10L   5/42' AND 'C10L   5/44'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'C10L   5/42' AND 'C10L   5/44'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
```

Waste

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SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'F23G   5%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F23G   5%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
```

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AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F23G   7%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F23G   7%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'C10L   1%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'C10L   1%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'C10L   3%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'C10L   3%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'C10L   5/00' AND 'C10L   5/40'
AND i.ipc_class_symbol BETWEEN 'C10L   5/46' AND 'C10L   5/48'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'C10L   5/00' AND 'C10L   5/40'
AND i.ipc_class_symbol BETWEEN 'C10L   5/46' AND 'C10L   5/48'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'B09B   1%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
```

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AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'B09B   1%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'B09B   3%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'B09B   3%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F01K  27%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F01K  27%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F02G   5%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F02G   5%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F25B  27/02'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F25B  27/02'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
```

Storage

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SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'H01M  10/34'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'H01M  10/34'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'H01M  10/06' AND 'H01M  10/18'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'H01M  10/06' AND 'H01M  10/18'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'H01M  10/24' AND 'H01M  10/32'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'H01M  10/24' AND 'H01M  10/32'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'H01M  10/36' AND 'H01M  10/40'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
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AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'H01M  10/36' AND 'H01M  10/40'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
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Fossil fuels

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SELECT DISTINCT cited.publn_nr, i.ipc_class_symbol ,ii.ipc_class_symbol, citeda.appln_filing_year, citeda.granted, citeda.docdb_family_size, j.citn_origin, cited.publn_kind, citeda.appln_auth
FROM tls211_pat_publn as citing
JOIN tls212_citation AS j ON citing.pat_publn_id = j.pat_publn_id
JOIN tls211_pat_publn AS cited ON j.cited_pat_publn_id = cited.pat_publn_id
JOIN tls209_appln_ipc AS ii on citing.appln_id=ii.appln_id
JOIN tls209_appln_ipc AS i on cited.appln_id=i.appln_id
JOIN tls201_appln AS citinga on citing.appln_id=citinga.appln_id
JOIN tls201_appln AS citeda on cited.appln_id=citeda.appln_id
WHERE (i.ipc_class_symbol LIKE 'F02B   7%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F02B   7%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'F02B   1/12' AND 'F02B   1/14'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'F02B   1/12' AND 'F02B   1/14'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'F02B   3/06' AND 'F02B   3/10'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'F02B   3/06' AND 'F02B   3/10'
```

```
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol BETWEEN 'F02B  13/02' AND 'F02B  13/04'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol BETWEEN 'F02B  13/02' AND 'F02B  13/04'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F02B  11%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F02B  11%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F02B  49%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F02B  49%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'C10J%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'C10J%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F02C%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
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AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F02C%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F02G%'
AND i.ipc_class_symbol <> 'F02G   5%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F02G%'
AND i.ipc_class_symbol <> 'F02G   5%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F22%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F22%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F27%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F27%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F23%'
AND i.ipc_class_symbol <> 'F23G   5%'
AND i.ipc_class_symbol <> 'F23G   7%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
```

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OR (i.ipc_class_symbol LIKE 'F23%'
AND i.ipc_class_symbol <> 'F23G   5%'
AND i.ipc_class_symbol <> 'F23G   7%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
OR (i.ipc_class_symbol LIKE 'F01K%'
AND i.ipc_class_symbol <> 'F01K  27%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.appln_id = citeda.earliest_filing_id
AND citeda.appln_auth='CN')
OR (i.ipc_class_symbol LIKE 'F01K%'
AND i.ipc_class_symbol <> 'F01K  27%'
AND DATEDIFF (day, cited.publn_date, citing.publn_date) < 1825
AND citeda.docdb_family_id<>citinga.docdb_family_id
AND citeda.receiving_office='CN')
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Non-cited patents: wind, geothermal, biomass, storage

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SELECT DISTINCT tls211_pat_publn.publn_nr, tls209_appln_ipc.ipc_class_symbol, tls201_appln.appln_filing_year, tls201_appln.granted, tls201_appln.docdb_family_size, tls211_pat_publn.publn_kind , tls201_appln.appln_auth
FROM tls201_appln
JOIN tls211_pat_publn on tls201_appln.appln_id = tls211_pat_publn.appln_id
JOIN tls209_appln_ipc on tls201_appln.appln_id= tls209_appln_ipc.appln_id
WHERE (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03D%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03D%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03G   4%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03G   4%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
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AND tls209_appln_ipc.ipc_class_symbol LIKE 'F24J   3/08'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F24J   3/08'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02B  43/08'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02B  43/08'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'C10L   5/42' AND 'C10L   5/44'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'C10L   5/42' AND 'C10L   5/44'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'H01M  10/34'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'H01M  10/34'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'H01M  10/06' AND 'H01M  10/18'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'H01M  10/06' AND 'H01M  10/18'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'H01M  10/24' AND 'H01M  10/32'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'H01M  10/24' AND 'H01M  10/32'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
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AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'H01M 10/36' AND 'H01M 10/40'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'H01M 10/36' AND 'H01M 10/40'
AND tls201_appln.receiving_office='CN')

<u>Non-cited patents: solar, marine</u>

SELECT DISTINCT tls211_pat_publn.publn_nr, tls209_appln_ipc.ipc_class_symbol, tls201_appln.appln_filing_year, tls201_appln.granted, tls201_appln.docdb_family_size, tls211_pat_publn.publn_kind , tls201_appln.appln_auth
FROM tls201_appln
JOIN tls211_pat_publn on tls201_appln.appln_id = tls211_pat_publn.appln_id
JOIN tls209_appln_ipc on tls201_appln.appln_id= tls209_appln_ipc.appln_id
WHERE (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03G 6%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03G 6%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F24J 2%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F24J 2%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F26B 3/28'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F26B 3/28'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'H01L 27/142'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'H01L 27/142'
AND tls201_appln.receiving_office='CN')

OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'H02N   6%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'H02N   6%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'H01L   31/042' AND 'H01L 31/058'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'H01L   31/042' AND 'H01L 31/058'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'E02B   9/08'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'E02B   9/08'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F03B 13/10' AND 'F03B 13/26'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F03B 13/10' AND 'F03B 13/26'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03G   7/05'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03G   7/05'
AND tls201_appln.receiving_office='CN')

Non-cited patents: waste, hydropower

SELECT DISTINCT tls211_pat_publn.publn_nr, tls209_appln_ipc.ipc_class_symbol, tls201_appln.appln_filing_year, tls201_appln.granted, tls201_appln.docdb_family_size, tls211_pat_publn.publn_kind , tls201_appln.appln_auth
FROM tls201_appln

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JOIN tls211_pat_publn on tls201_appln.appln_id = tls211_pat_publn.appln_id
JOIN tls209_appln_ipc on tls201_appln.appln_id= tls209_appln_ipc.appln_id
WHERE (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F23G   5%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F23G   5%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F23G   7%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F23G   7%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'C10L   1%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'C10L   1%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'C10L   3%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'C10L   3%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'C10L   5%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'C10L   5%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'B09B   1%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
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AND tls209_appln_ipc.ipc_class_symbol LIKE 'B09B   1%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'B09B   3%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'B09B   3%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F01K  27%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F01K  27%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02G   5%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02G   5%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F25B  27/02'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F25B  27/02'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'E02B   9%'
AND tls209_appln_ipc.ipc_class_symbol <> 'E02B   9/08'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'E02B   9%'
AND tls209_appln_ipc.ipc_class_symbol <> 'E02B   9/08'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03B   3%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
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AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03B   3%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03B   7%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03B   7%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03B 15%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F03B 15%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F03B 13/06' AND 'F03B 13/08'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F03B 13/06' AND 'F03B 13/08'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F03B 13/10' AND 'F03B 13/26'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F03B 13/10' AND 'F03B 13/26'
AND tls201_appln.receiving_office='CN')

<u>Non cited-patents: Fossil fuel</u>

SELECT DISTINCT tls211_pat_publn.publn_nr, tls209_appln_ipc.ipc_class_symbol, tls201_appln.appln_filing_year, tls201_appln.granted, tls201_appln.docdb_family_size, tls211_pat_publn.publn_kind , tls201_appln.appln_auth
FROM tls201_appln
JOIN tls211_pat_publn on tls201_appln.appln_id = tls211_pat_publn.appln_id
JOIN tls209_appln_ipc on tls201_appln.appln_id= tls209_appln_ipc.appln_id
WHERE (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02B   7%'

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AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02B   7%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F02B   1/12' AND 'F02B   1/14'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F02B   1/12' AND 'F02B   1/14'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F02B   3/06' AND 'F02B   3/10'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F02B   3/06' AND 'F02B   3/10'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F02B  13/02' AND 'F02B  13/04'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol BETWEEN 'F02B  13/02' AND 'F02B  13/04'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02B  11%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02B  11%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02B  49%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02B  49%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'C10J%'
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AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'C10J%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02C%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02C%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F22%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F22%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F27%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F27%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02G%'
AND tls209_appln_ipc.ipc_class_symbol != 'F02G   5%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F02G%'
AND tls209_appln_ipc.ipc_class_symbol != 'F02G   5%'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F23%'
AND tls209_appln_ipc.ipc_class_symbol  <> 'F23G   5%'
AND tls209_appln_ipc.ipc_class_symbol  <> 'F23G   7%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
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AND tls209_appln_ipc.ipc_class_symbol LIKE 'F23%'
AND tls209_appln_ipc.ipc_class_symbol  <> 'F23G   5%'
AND tls209_appln_ipc.ipc_class_symbol  <> 'F23G   7'
AND tls201_appln.receiving_office='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F01K%'
AND tls209_appln_ipc.ipc_class_symbol NOT LIKE 'F01K  27%'
AND tls201_appln.appln_id = tls201_appln.earliest_filing_id
AND tls201_appln.appln_auth='CN')
OR (pat_publn_id not in (select distinct cited_pat_publn_id from tls212_citation)
AND tls209_appln_ipc.ipc_class_symbol LIKE 'F01K%'
AND tls209_appln_ipc.ipc_class_symbol <> 'F01K  27%'
AND tls201_appln.receiving_office='CN')
```