Patent Analysis for Guiding Technology Transfer from EU/EEA to China: The Case of CO_2 Compressor in CCUS Cooperation

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Abstract--**Carbon Capture, Utilization and Storage (CCUS) technology is believed as an effective approach to control and reduce CO_2 emission in China. We take CO_2 compressor in CCUS as object of research and technological backgrounds to build up a patent analysis model in both statistics and bibliometrics approaches for guiding patent technology transfer. Patent bibliometrics analysis is more progressive compared with statistics analysis and goes further from the shallower to the deeper depth in technology analysis. We find patent analysis and technology transfer have internal theoretical relations and realistic relevance since patent analysis can play an unsubstitutable role in the preliminary stage of technology transfer in identifying IP ownership, technology gap, sources, distributions, characteristics and application domains. We compare these aspects on CO2 compressor in CCUS between EU/EEA and China from patent analysis view and define the necessities for technology transfer in clean energy context. Finally, we summarize IP policy implications and suggest patent technology transfer mechanisms based on the patent analysis model so as to ensure substantial achievements in future mutually beneficial cross-border clean energy technology transfer.**

I. INTRODUCTION

In the era of knowledge-based economy, the economic development of a region relies more and more on the progress of its technology. Thus, technology transfer is gradually regarded as a strategic choice to acquire technology progress for an organization [1]. As an academic concept, technology transfer per se has two theoretical mode definitions, one is called lateral transfer which means the technology transfers from one organization to another, the other one is vertical transfer which proceeds with the lifecycle of a technology from its original R&D to final commercialization [2]. In the context of cross-border technology cooperation, this research is constructed on the theory of technology vertical transfer. In this condition, technology transfer is a way to realize technology value and economic interests for technology suppliers which are mostly developed countries. While in another case, it is also an approach of technology catching-up for technology transferees which are mostly developing countries. This circumstance happens frequently in clean energy fields in international technology cooperation according to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol which matters much for the interests of all humankind.

Carbon Capture Utilization and Storage (CCUS) [1] technology is considered as a clean energy technology like solar energy, wind energy and clean vehicles, and considered to be one of the options for reducing atmospheric emissions of CO_2 from human activities [3]. In order to realize the goal of carbon emission reduction by 2020 and 2030 as compared to 2005, China's government pointed out from a strategic perspective that CCUS, as a new and promising technology, has the potential to become China's strategic technological choice in reducing carbon emission and safeguarding future energy security [4]. Considering the easy access to related data and materials and consulting technical experts' advices from China's Ministry of Science and Technology (hereinafter MOST) and technology managers from two large state-owned power groups from 4 interviews from 2013 to 2014, we take the ongoing Sino-EU/EEA Near Zero Emission Coal CCUS cooperation project which is between China and EU (including a non-EU country -- Norway) as a practical object for illustration.

In CCUS demonstration project, the captured CO_2 should be compressed, dried and transported before being "stored" under earth or utilized in real industry. CO_2 compressor is deemed to play a pivotal role in the process [5] (See Figure 1). In order to elevate the cost effectiveness of CCUS demonstration project, it is of great significance to research how to realize some key technologies' transfer in Sino-EU/EEA CCUS cooperation project for China. As a major output of R&D activities, patent contains abundant technological, commercial and legal information which serves as important data resource to study technology innovation [6]. At the same time, compared with other carriers of technology, patent has its superior advantages in its explicitness of legal ownership, evaluability of technological value and high-degree of market recognition. Therefore, patent technology transfer is a dominant form in present global technology transfer market [7]. To ensure the smooth progress of lateral technology transfer, patent analysis will play an important role. Obviously, patent analysis targeted at technology transfer should be more instructive and contains more comprehensive factors than conventional

[1] It is much common to find "CCS" rather than "CCUS" in previous international cooperation documents and technical reports. However, as China's science and technology minister Wan Gang pointed out in the No. 6 steering committee conference of China-US Clean Energy Research Center (CERC) on Jul. 2014, the segment of carbon utilization is the bottleneck of China's Carbon Capture and Storage (CCS) large-scale deployment. In another word, whether China's CCS projects can systematically work relies much on the effect of carbon utilization. So it is more feasible to use "CCUS" instead of "CCS" in China's circumstance.

patent analysis in guiding global and regional technology negotiation and transfer. Researches on the transfer of clean energy technology up to now mainly focus on the factors influencing technology transfer [8], mechanism selection [9], strategy analysis [10], etc. With the deepening of international cooperation, researchers come to recognize the complexity of intellectual property rights (IPRs) as a main problem hindering the smooth transfer of technology [11]. The complexity and barriers of technology transfer mainly exist in the following aspects:

a. Technology transfer, in most of current practices, is separated from IPRs transfer. The owner of technology usually tends to transfer its technical equipment as product to developing countries and equip it with their own specialists for operation. In some occasions, the quality and advancement of the technology is not that satisfying for transferees, several mandatory IP restrictions like no follow-up R&D and grant-back clauses in technology transfer agreement pose obstacles to substantial technology cooperation. However, the real essence of technology transfer, especially for clean energy technology, as the Technology Transfer Framework of Bali Roadmap pointed, should also include a function of assisting and supporting developing countries to development their own technical capacity.
b. Uncertain IPRs may pose significant risks to technology transfer. This situation happens when the owner of the technology doesn't have patent search and layout in transferee's country. Moreover, risks often occur when there is no clear engagement on the sharing mechanism of IP in joint research and development.
c. Weak IPRs provisions cannot ensure the effect of technology transfer. Weak IPRs provisions are also not helpful to build mutual trust. Patent analysis can be a tool to judge the technological background of cooperation otherwise the standpoint on IP for each side will be ambiguous.
d. Transferee is incompetent in IPRs capacity-building. Ordinarily, this is because the transferees are always technologically disadvantaged groups from developing countries and their IPRs capacities are sometimes misestimated.

Whether transfer of clean energy technology can be well executed directly affects the dual game between climate change and carbon emission reduction, and is of real interest to human being at large [12]. Therefore, the patent analysis research on this issue is prospective and constructive. A clear and in-depth understanding of patent-related issues so as to promote patent technology transfer is the key to deepen cross-border CCUS and other clean energy cooperation.

In order to build up a patent analysis model which can be effective for guiding cross-border technology transfer, the remainder of the paper is structured as follows to realize this goal. In Section 2, we review the theoretical background of related literatures including CCUS and CO_2 compressor technology, patent analysis approaches and the relationship between technology transfer and intellectual property in clean energy field. In Section 3 and 4 we present the combination of patent statistical analysis and bibliometric analysis and summarize several revealing results for patent technology transfer. In Section 5, conclusions and enlightenments from patent analysis for intellectual property policy-making and technology transfer mechanism construction in Sino-EU/EEA CCUS cooperation are raised.

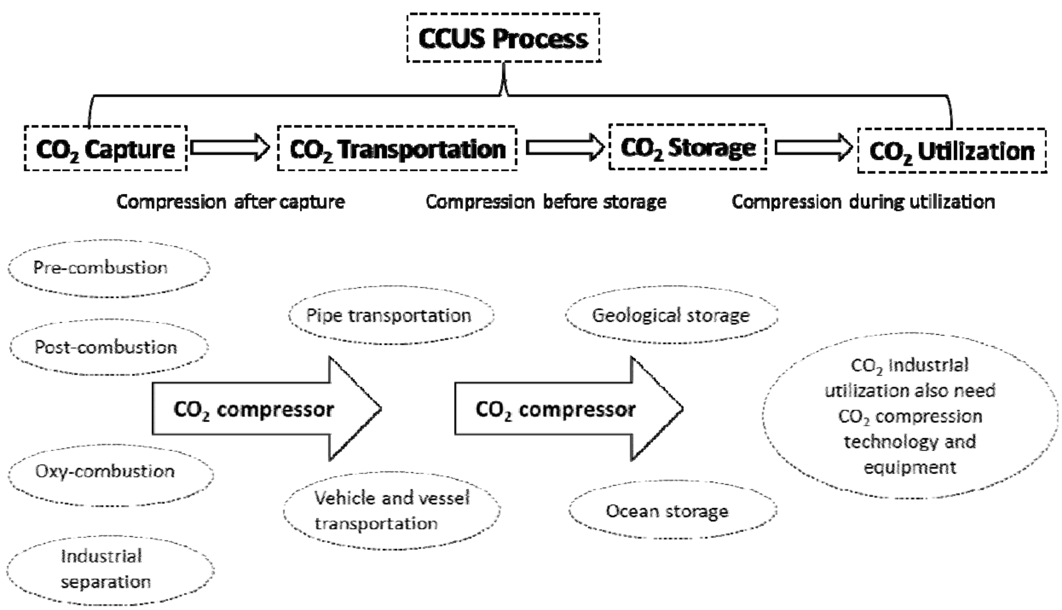

Figure 1 The pivotal role of CO_2 compressor in CCUS whole process

II. THEORETICAL BACKGROUND

A. The development of CCUS and the role of CO_2 compressor

To meet the global pressing needs for energy-saving and emission-reduction techniques, the researches and real practices based on CCUS has experienced a rapid progress, which is generally acknowledged as an effective way to decrease CO_2 generated by fossil fuel burning [13]. As a mega-science concept, CCUS covers a wide range of engineering and technology fields like energy conservation, environment protection, chemical materials, oil geology, machinery, electronics and so on. Therefore, the present CCUS-related research themes are distributed extensively into several different dimensions likewise, which generally contain CCUS integral system and process, technical know-why and operation, fundamental R&D and engineering practice [14].

During the 4 face to face interviews in the last 3 years, the indispensability of CO_2 compressor can be demonstrated from the following aspects: Firstly, the distinguishing thermal dynamics property of CO_2 at supercritical state determines that compressor is in need to ensure that the CO_2 turned from standard state to supercritical state is transportable and usable. Secondly, when dissolved in water, CO_2 can yield carbonic acid, which will erode compressor. To guarantee the stable and safe operation of the whole process of CCUS, the CO_2 compressor must be different from conventional air compressors. We choose CO_2 compressor as object of study from patent view out of following reasons: a. CO_2 compressor directly determines whether CCUS can be widely applied in demonstration projects in China; b. patent analysis is a major approach to investigate innovation situation; c. researches on CCUS sub-system, sub-unit and especially a single item of key technology from patent view are relatively few.

B. Patent technology transfer and intellectual property

Technology transfer, which refers to the transfer of systematic knowledge about manufacturing goods, application methods of production or providing services, is a process by which technology flows across countries or regions, between or inside industries [15]. The main forms of technology transfer include patent licensing, foreign direct investment, scientific and technological cooperation between governments, license trade, know-how agreement, etc. Compared with independent innovation carried out internally by R&D developers, technology transfer, which introduces innovation from outside, has obvious feature of externality and is more efficient and cost-effective. Patent, with its novelty, inventiveness, practical applicability, and clearly established legal and commercial attributes, has become the most common object of transfer in international technology trade [16].

Generally speaking, the modes of patent technology transfer (lateral transfer) have two embodiments. The first mode is realized through patent licensing. Regarding to the regionality of patent protection, this requires the patent owner of the technology, i.e. an EU company, to file patent in the transferee's patent office, i.e. the State Intellectual Property Office of China, before licensing. In this condition, patent layout is the beginning step of patent technology transfer before licensing. So here emerge the necessities for the original patent owner, i.e. the EU company, of knowing the overall situation of the technology from patent view in case of infringement or invalidation after filing the patent. Patent analysis can play a crucial role in this process. The second mode of patent technology transfer is reached by selling the patent and related know-how to the transferee whereas this is not quite common especially when the technology is important for the owner and technologically advanced.

The rationale for the transfer of Sino-EU/EEA CCUS technologies -- a representative clean energy technology -- originates from the statements about "common but differentiated responsibility of developed countries and developing countries in reducing carbon emission" and "the obligation of the developed countries to transfer clean energy technology to developing countries" stipulated in the UNFCCC and the Kyoto Protocol. That is to say, there exists a policy and international agreement oriented "compulsory" transfer intimation for clean energy technology from EU/EEA to China. Besides, both EU/EEA and China have strategic plans in the fields of clean energy that encourage clean energy technology transfer and carbon emission reduction from an institutional level, like the Europe 2020 Strategy and China's 12th Five-Year Plan, thus to structure a strategic docking and joint interest. Furthermore, a well-organized system of clear policies and legal regulations for guiding technology transfer of both sides is regarded to be a strong foundation for cooperation (Table 1).

TABLE 1 MAIN POLICIES AND LEGAL REGULATIONS FOR GUIDING TECHNOLOGY TRANSFER IN EU/EEA AND CHINA

	EU/EEA	China
Policy	Lisbon Strategy (2000); Partnership for Growth and Jobs (2005); Europe 2020 (2010); 7th Framework Program me (2007); Horizon 2020 (2014)	Outline of the National Medium and Long Term Scientific and Technological Development Plan (2006); National Technology Transfer Promoting Action Implementation Plan (2007); China's 12th Five-Year Plan (2011)
Legal regulation	Treaty of Rome (1957); (EEC) No 2380/74 (1974); (EC) 94/762 (1994); (EC) No 2897/95 (1995); European Patent Convention (2000); London Protocol (2000); (EC) No 1383/2003; (EC) No 772/2004 (2004); (EC) No 1906/2006 (2006); (EC) No 1908/2006 (2006); (EC) No 1172/2007 (2007); (EC) No 294/2008 (2008); (EU) No 1217/2010 (2010).	Regulations on the Administration of Technology Import Contracts (1985); Regulations on the Administration of Technology Import and Export (2002); Foreign Trade Law of China (2004); Patent Law of China (2009); Law on Promoting the Transformation of Scientific and Technological Achievements (2015)

C. Construction of Patent analysis Model

Patent analysis is an effective tool to discover, portray and utilize technological information from different knowledge bases [17]. With the development of patent analysis techniques and purposes, it is more and more worthwhile and vital to resort to for organizations in many circumstances. Patent analysts with different levels of expertise require patent analysis tools with versatile capabilities. From current literature review, the tasks and methods of patent analysis are summarized in Table 2. As we can find from Table 2, that various techniques have been developed to assist patent engineers, business managers, and technology experts to fulfill diverse requirements.

TABLE 2 REVIEW OF TASKS AND METHODS OF PATENT ANALYSIS

Tasks	Main methods	Related literatures
Analyzing technological trend	Patent statistics analysis and patent bibliometrics analysis	[18]; [19]
Analyzing technological cooperation network	Social networks analysis and patent citation networks	[20]
Forecasting technological developments	Delphi method and association rule mining	[21]
Determining technology novelty	Natural language processing and SAO based text mining	[22]
Identifying Infringement	Semantic analysis and logistic model	[23]; [24]
Mapping Technological road	Co-citation and k-means cluster	[25]; [26]
Determining patent quality	Back-propagation algorithm and fuzzy multiple criteria decision making	[27]; [28]
Identifying technological competitors	Patent statistics analysis	[29]
Identifying technological vacuums and hotspots	SAO based text mining and patent map	[30]

Actually, there is no apparent and consolidated classification for patent analysis, whereas patent text mining and visualization approaches can be one sort of classification [31]. As this summarization overlooks the most widely-used approach, namely conventional statistics analysis, this research points that patent analysis is composed of two approaches which are patent statistics analysis and patent bibliometrics analysis based on the review of literatures on patent analysis. Furthermore, patent statistics analysis can also be called descriptive analysis which is a mathematical patent data counting process [32] while patent bibliometrics analysis is a deep patent data process which includes both text mining and visualization approaches and defined by Norton as the measurement of texts and information [33]. Combining the evaluation results of the last column of Table 2 and the complexity in procedure, object, purpose and significance of technology transfer, we think the patent analysis for guiding technology transfer should at least cover following basic tasks which are describing the Status Quo of technology, identifying technology sources, comparing technology differences, identifying core patents, mapping technology development paths and finding technology transfer domains. (Figure 2)

In order to realize the goals of patent analysis, we exploit the method of multi-databases patent retrieval to make full use of the advantages of different patent databases. This article pioneered a model to utilize patent analysis for promoting clean energy technology transfer and meanwhile, considering the realistic demand of technology transfer, we try to make the results of patent analysis more precise and readable by adopting the theory of text mining and patent visualization so as to dig out more valuable technological information in depth from patent analysis and offer enlightenments for value judgment and risk evaluation of the transfer of these patents.

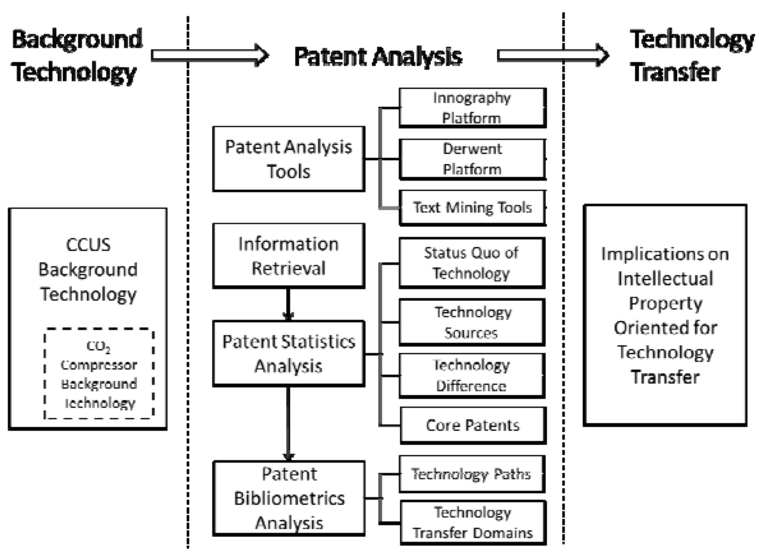

Figure 2 The patent analysis model in technology transfer (research framework)

D. Strategic implications from patent analysis

The afore-constructed patent analysis model for guiding technology transfer functions by reaching at least those 6 tasks. With regard to the task of describing the Status Quo of technology, no one can deny the fact that patent is best technological information and indication for R&D management and technology development evaluation [21]. It is with great value in drawing out technology development panoramic view from the analysis of strategy at a national level [18].

When investigating the source of technology transfer or a collaborating partner, apart from its technical strength measured in terms of patents, we also need to pay attention to some business information about it, such as the revenue and location of the enterprise, the litigation it takes part in, etc [34]. For example, if a patentee engages in a number of lawsuits as plaintiff, it can be inferred that the patentee has a strong patent early warning and attacking capability; while if a patentee often engages in the lawsuit as defendant, it suggests that the R&D path adopted by the patentee may be technological imitation.

In several researches of innovation, scholars find that technology advantage has strong regional diversity, different countries and regions have its own technology specialization [35]. Patent classification provides an easy and convictive tool to compare technology differences in patent analysis. As for the fourth task of patent analysis – identifying core patents, based on the theory of patent citation, it is an effective way to dig out the technology roots and evaluate the quality of patent by locating the patents with the highest citations and those on the knot or center of a citation network [20]. Also, some scholars establish index system to quantitively evaluate core patent, high strength patent, key patent and so on [36]. Besides, the development of technology has the effect of path dependence [37]. In order to expand the research scope of technology difference for guiding technology transfer among organizations and encouraging potential patent cross-license, the investigation on technology path can be applied to map the road of their development and to explore the technological gap and overlap among them. Finally, in accordance with the connotation of the patent system, one of the most important purposes of patent technology transfer is to commercialize the patent and bring economic interests to patent owners [38]. Assisting patent owners to identify potential transferring and commercial industrial domains of the patent is not only theoretically significant but also with indispensable practical use.

III. PATENT STATISTICAL ANALYSIS

Technology transfer, as a complex commercial activity, requires statistical analysis of patent because it reveals development trend of technology and collects technological, legal and commercial information about patent necessary for substantive negotiations on technology transfer. Innography patent platform mainly designed for analyzing commercial information is used to conduct patent statistical analysis oriented for technology transfer. Considering the logical operation characteristics of Innography and the distinguishing features of the object of technology transfer as well, the patent retrieval query are constructed as: @(abstract,claims,title) ("CO2 compress*" or "carbon dioxide compress*" or "CO2 pump*" or "carbon dioxide pump*"). 1311 granted patents since 1995 are retrieved, and after integrated filtering and artificial screening, 1279 are left to form a database of CO_2 compressor patents.

A. Comparison of number of patents among nations

As greenhouse effect aggravates globally, countries all over the world are making unremitting efforts to reduce carbon emission. The pressing need for countries to reach the carbon emission reduction goal set in the Kyoto Protocol by the end of the “first commitment period” (2008-2012) and the pre-feasibility study and deployment of numerous large-scaled demonstration projects of CCUS all over the world bring about substantial researches on CO_2 compressor, a core device in CCUS. As for the number of patents related to CO_2 compressor, EU and EEA countries, with a number of 349 patents, are slightly ahead of United States, which has 300 patents. And Germany, with 171 patents, takes the lead in EU countries. China and Japan follow with 265 and 187 patents respectively. (See Table 3)

TABLE 3 COMPARISON OF NATIONS IN NUMBER OF CO_2 COMPRESSOR-RELATED PATENTS

Countries and Regions			Number of Patents	Percentage
EU/EEA	Germany	171	349	31.70%
	Britain	54		
	France	46		
	Italy	37		
	Holland	18		
	Denmark	12		
	Sweden	6		
	Norway	5		
United States			300	27.25%
China			265	24.07%
Japan			187	16.98%

B. Comparison of patentees

To figure out the patentees of CO_2-compressor-related patents is the key to identifying technology sources. As shown in Table 4, Alstom, a French company holding 69 patents, overtakes other companies in the number of patents, suggesting its comparative advantage in technical strength and making it a powerful candidate for technology supplying. Royal Dutch Shell is well above other countries in terms of comprehensive strength by rating 100 percent points in this indicator, which means that equipped with potent financial strength, it has strong acquisition ability and has the potential to become patent licensee. General Electric, an American company, takes part in 270 patent litigations, the most of all patentees.

TABLE 4 TOP 10 COMPREHENSIVE STRENGTH OF PATENTEES OF CO_2 COMPRESSOR

Patentee	Number of Patent	Capital Reserve	Number of Lawsuits in America	Patent Index Score (% Patents + % Classifications + % Citations)	Comprehensive Strength Score (% Revenue + % Locations + % Litigation)
Alstom SA	69	$28,200,350,000	15	100	25.34
General Electric Company	54	$145,715,000,000	270	98.54	44.13
Mitsubishi Heavy Industries	48	$27,699,888,190	5	65.62	14.26
Saudi Arabian Oil Company	33	$199,756,000,000	6	33.77	41.6
Zexel Valeo Compressor Europe	29	-	0	35.61	4.396
Air Liquide	27	$21,182,890,000	25	45.85	12.97
Royal Dutch Shell	26	$451,235,000,000	62	32.03	100
Air Products & Chemicals	21	$10,180,400,000	14	34.21	8.602
Central Road Research Institute	16	-	0	23.91	2.198
Liaohe Petroleum Exploration Bureau	14	$2,640,489,000	0	24.65	2.719

TABLE 5 TOP 5 PATENTEES IN EU/EEA AND CHINA

EU/EEA Patentees			China Patentees		
Patentee	Number of Patent	Percentage	Patentee	Number of Patent	Percentage
Alstom SA	69	31.63%	Liaohe Petrolum Exploration Bureau	14	24.14%
Zexel Valeo Compressor Europe	29	14.80%	Dalian University of Technology	8	13.79%
Air Liquide	20	10.20%	Shanghai Jiaotong University	6	10.34%
General Electric Company	19	9.69%	Panasonic Appliances Cold Chain (Dalian) Co.Ltd.	5	8.62%
Royal Dutch Shell	15	7.65%	China Huaneng Group	5	8.62%

As shown in Table 5, the number of patents held by patentees from China and EU/EEA vary greatly. The top 10 patentees from Europe own a total of 196 patents related to CO2 compressor, over three times more than those held by their Chinese counterparts. The top 3 patentees from Europe are, from high to low in rank, Alstom of French (69), Zexel Valeo Compressor of Germany (29) and Air Liquide of French (20). Then, an analysis of the technical strength of background patents (or background IPRs) of each company shall be made during the next stage of cooperation before finally determining one from which we apply for patent license and introduce technology.

C. Statistical comparison of patent classification

In order to optimize existing patent classification scheme based on the International Patent Classification (IPC) and coordinate and harmonize the patent classification systems by European Patent Office (EP0), United States Patent and Trademark Office (USPTO) and other major patent offices all over the world so as to improve retrieval efficiency and user experience, EPO and USPTO jointly initiate the Cooperative Patent Classification (CPC) as an extension of the IPC. Incorporating the entry of emerging technologies such as new energy and environmental protection, the CPC can be easily used for statistical analysis of patents involved in Sino-EU/EEA CCUS technologies. According to CPC, the top 3 sections into which CO_2 compressor-related patents of EU/EEA countries fall are B67 D1 (Apparatus or devices for dispensing beverages on draught), F04 B27 (Multi-cylinder pumps characterized by number or arrangement of cylinders specialized for elastic fluids) and B01 D53 (separation of gas or steam). The top 3 sections into which CO_2 compressor-related patents of China fall are C01 B31 (carbon and its compound), C07 C273 (preparation of urea or its derivative) and B01 D53 (separation of gas or steam). China's patents are distributed in five sections (A-Human necessities; B-Performing operations; transporting; C-Chemistry; metallurgy; E-Fixed constructions; F-Mechanical engineering; lighting; heating; weapons; blasting engines or pumps), while European patents are only distributed in two sections (B and F), which reflects that China's patents on CO_2 compressor are less concentrated than those of EU/EEA countries (See Table 6). This can be explained that the entry in new market by new innovators (in this case China) are still exploring various paths while mature innovators (EU) are already specialized (and probably locked in) in a specific technological trajectory. As EU/EEA and China have different technological advantages by the comparison of patent classification, patent cross-license between the two sides could be a possible choice of way for promoting technology transfer.

TABLE 6 TOP 10 CPC CODE COMPARISON OF CO_2 COMPRESSOR-RELATED PATENTS BETWEEN CHINA AND EU/EEA

EU/EEA Patent Statistical Analysis			China's Patent Statistical Analysis		
CPC	**Number of Patent**	**Percentage**	**CPC**	**Number of Patent**	**percentage**
B67 D1	25	16.78%	C01 B31	15	18.07%
F04 B27	23	15.44%	C07 C273	15	18.07%
B01 D53	23	15.44%	B01 D53	12	14.46%
F01 K13	20	13.42%	E21 B43	12	14.46%
F01 K23	14	9.40%	F25 B29	7	8.43%
C07 C29	11	7.38%	C08 G64	6	7.23%
C07 C273	10	6.71%	C11 B9	4	4.82%
F25 J3	8	5.37%	F25 J1	4	4.82%
C10 L3	8	5.37%	F04 B39	4	4.82%
B01 J19	7	4.70%	A61 K9	4	4.82%

D. High-strength patent

In Innography, set the patent strength as 3 to 10 points, and we can get 301 high-strength patents related to CO_2 compressor (See Table 7). The indicators used to evaluate the strength of a patent include forward citations and backward citations, patent claim, the revenue from patent licensing and patent litigation, etc. The European patentees holding high-strength CO_2-compressor-related patents are Alstom, France (14 high-strength patents), Royal Dutch Shell (11 high-strength patents) and Air Liquide, France (8 high-strength patents). So far as the number of high-strength patents being held is concerned, the United States outstrips other countries with 120 high-strength patents, followed successively by Germany (45), Japan (40), Great Britain (15), France (15), Canada (13) and China (13) (See Table 8). Take a patent named "CO_2 capture and compression device" (patent number US20110304155) for example, it is an active high-strength patent owned by Alstom, a company of EU/EEA countries. Its backward citations is 28 and forward citation 5. The backward citation helps to identify technological source and development history of the patent, while the forward citation predicts technological prospects and development trend. A follow-up study found that Rolls-Royce, Florida Turbine Technology, Mitsubishi Heavy Industry and Doosan Heavy Industry cited the patent and conducted R&D activities to improve it. (See Figure 3)

TABLE 7 TOP 10 PATENTEES HOLDING HIGH-STRENGTH PATENTS

Patentee	Country Origin	Number of Patent	Percentage
Alstom SA	France	14	15.38%
General Electric Company	United States	13	14.29%
Air Products & Chemicals	United States	11	12.09%
Royal Dutch Shell	Holland	11	12.09%
Mitsubishi Heavy Industries	Japan	9	9.89%
Air Liquide	France	8	8.79%
Central Road Research Institute	India	8	8.79%
Clean Energy Systems	United States	6	6.59%
Greatpoint Energy	United States	6	6.59%
Tecumseh Products Company	United States	5	5.49%

TABLE 8 TOP 10 COUNTRIES OWNING HIGH-STRENGTH PATENTS

Country	Number of Patent	Percentage
United States	120	42.55%
Germany	45	15.96%
Japan	40	14.18%
Britain	15	5.32%
France	15	5.32%
Canada	13	4.61%
China	13	4.61%
Sweden	11	3.90%
Italy	7	2.48%
Holland	3	1.06%

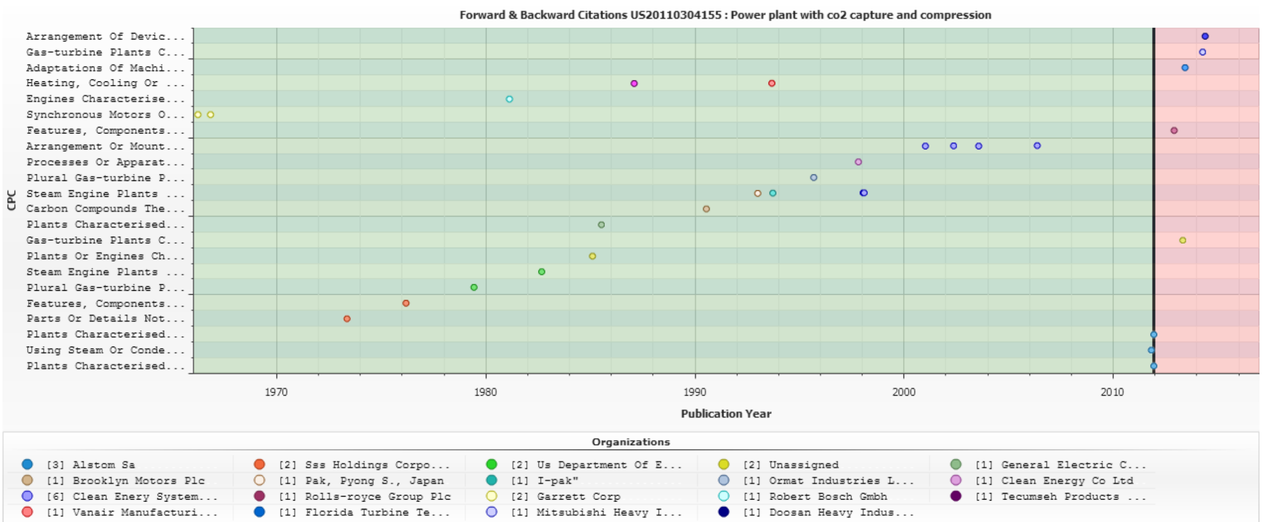

Figure 3 Citation map for one of Alstom's high-strength patent (No. US20110304155 A1)

IV. PATENT BIBLIOMETRIC ANALYSIS

In order to mine more patent information useful for technology transfer of CO_2 compressor, we CiteSpaceIII knowledge visualization software to make a bibliometric analysis based on the concept of "co-citation" [39], with a view to obtaining a panorama of patent dynamics by identifying the development path and research hotspot of CO_2 compressor through cross-database retrieval method. Firstly, to make sure the patent data format compatible for CiteSpace III, we download CO_2 compressor patent data from Derwent Innovation Index (DII) based on the same retrieval strategy and query with that in Innography. What's more, we clean these data one by one to make sure that they correspond perfectly to the 1279 items of patent data obtained from Innography. Secondly, input these patent data in txt form into CiteSpaceIII for knowledge visualization. Finally, read and explain the analyzing results generated from CiteSpaceIII. This kind of patent analysis approach targeted at technology transfer is one of the highlights of the paper.

A. Clustering and co-occurrence analysis by Derwent Manual Codes

Select data in the timespan from the year of 2000 to 2014 in CiteSpaceIII. The slice length is two years, the threshold values are (2, 2, 4; 4, 3, 6; 4, 3, 3). Comparing with IPC and CPC, Derwent Manual Codes (DMC) is more oriented for practical application of a technology and much easier for engineers to understand. Using DMC to conduct clustering and co-occurrence analysis for the abstracts of Chinese and European patent documents concerning CO_2 compressor, a DMC co-occurrence map for Sino-EU/EEA patents related to CO_2 compressor is generated (Figure 4 and Figure 5). Then with the distribution of color blocks (clusters) in the figure and the extracted technology classification codes, we can make a comparison in the general characteristics of CO_2 compressor patent citation clusters between China and Europe. And the future research direction for CO_2 compressor can be predicted with the aid of text mining results. China's CO_2-compressor-related patent citations are concentrated in the following five fields: q69 (Storing/distributing gas/liquid), q52 (Reaction engines: External combustion; Gas turbines; Rockets), e31 (Non-metallic elements, metalloids and compounds), m24 (Metallurgy of iron and steel) and a41 (monomer and distillate). Patent citations by EU/EEA countries are mainly concentrated in: a41 (Monomer and distillate), x22 (Automotive electrics), q14 (Vehicle accessories), q69 (Storing/distributing gas/liquid), e19 (Other organic compounds) and a26 (Other polyconsendates). These hotspots of patent citation co-occurrence of China and EU/EEA in Figure 4 and 5 indicate the differences of research hotspots between the two sides which support the technology difference analysis just by CPC classification comparison in 3.3 from the perspective of DMC.

Citation count is an indicator to reflect the attention received by the patent, and the centrality reflects the technical impact of the patent by quantifying the significance of nodes. Combining these two indicators for retrieving, we can dig out some core patents vital to technology transfer (See Table 9). Combining with the abovementioned high-strength patents in Innography, we can verify the final results of core patents which are technologically valuable, legally active and also owned by European patentees within this project.

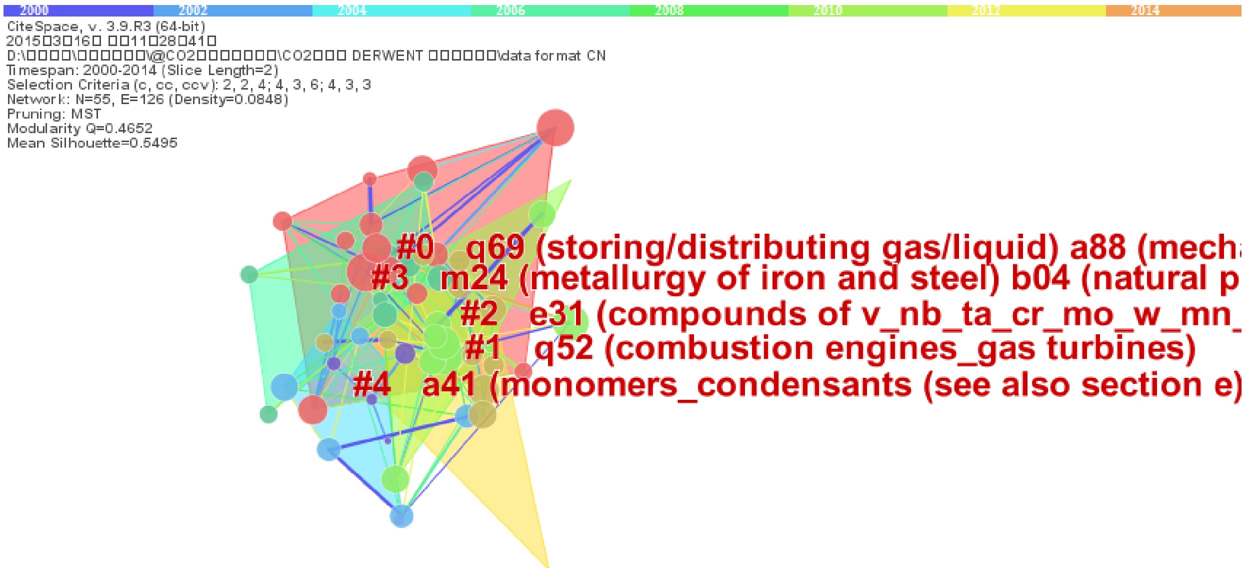

Figure 4 Derwent Manual Codes clustering and co-occurrence map of China's CO_2 compressor-related patents
(Data source: http://apps.webofknowledge.com, Patent Data from 2000 to 2014)

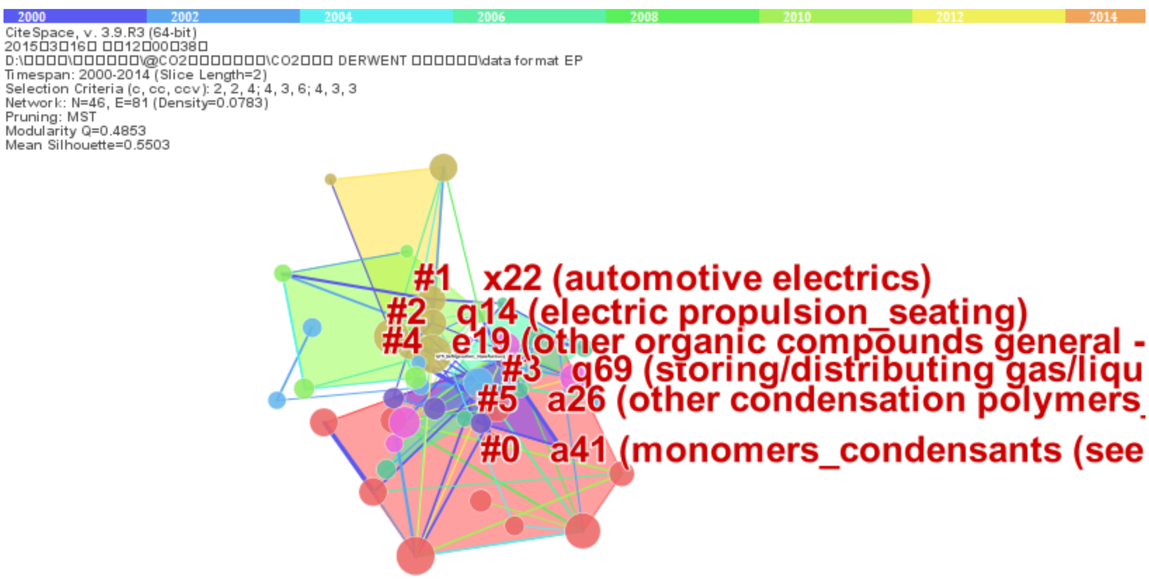

Figure 5 Derwent Manual Codes clustering and co-occurrence map of EU/EEA countries' CO_2 compressor-related patents
(Data source: http://apps.webofknowledge.com, Patent Data from 2000 to 2014)

TABLE 9 PATENT LITERATURES WITH TOP 5 CITATION COUNTS AND CENTRALITY

Citation Countrs	Document	Centrality	Document
20	Golomb DS, US5724805	0.32	Wilkes C, DE3101098A1
17	Stahl CR, US4434613	0.26	Stahl CR, US4434613
12	Stahl CR, GB8413003D0	0.26	Stahl CR, GB8413003D0
11	Anderson RE, US6637183	0.15	Aycock LW, US7383686
10	Bartlett MA, JP2005028529	0.10	Wiant BC, US6430915

B. Evolution path for cutting-edge CO_2 compressor technology of China and EU/EEA countries

By analyzing 3 years' time slice for Chinese and European CO_2 compressor from 2000 to 2014, we can determine the technological fields with highest Burst value in CiteSpaceIII, on the basis of which the comparison of the evolution path for CO_2 compressor technologies between China and European countries can be drawn. As shown in Table 10, China's technologies have undergone an evolution path from refrigeration and liquefaction (2000-2002), to positive displacement fluid machines/pumps/compressors (2003-2005), power generation and high-power machine & fuel products and coal gasification (2006-2008), non-fossil fuel electrical generating system (2009-2011) and drying (2012-2014). In contrast, EU/EEA technologies have undergone an evolution path from refrigeration and liquefaction & separation (evaporation and crystallization) (2000-2002), combustion equipment and process (2003-2005), power generation and high-power machines & catalytic chemical/physical process (2006-2008), and fermentation industry and purification & treatment of waste gas (2009-2011). As far as the technologies related to CO_2 compressor used in CCUS projects are concerned, China start earlier than European countries in positive displacement fluid machines/pumps/compressors (q55), while Europe runs ahead of China in catalytic chemical/physical process and purification (j04) & treatment of waste gas (p43). In the field of power generation and high-power machines (x11), China and Europe run neck and neck with each other. However, we should admit a fact that the analysis in this part is based on the patents which are granted by China's State Intellectual Property Office (patent number started with "CN") and European Patent Office (patent number started with "EP"). The results doesn't stand for technology capability of both sides but the technology evolution path in China and EU/EEA countries since a great part of the patentees are not locally in China and EU/EEA countries.

C. Identification of potential domains of patent technology transfer

After comparing a series of Natural Language Processing tools, we select AlchemyAPI developed by IBM for the semantic extract and analysis of the titles and abstracts of CO_2 compressor-related patent documents. The advantage of this software lies in its powerful semantic recognition and complete lexicon system. Inputting the titles and abstracts of CO_2 compressor patents retrieved by DII platform into AlchemyAPI for semantic analysis and using the lexicon information and notional word classification function of AlchemyAPI, we extract notional words relevant to different industries, and on this basis generalize the potential industries that these patents may find application. Results of word frequency analysis show that there are 11 industrial domains to which the patented technology may be transferred, including carbon dioxide (Relevance: 0.944), methane (0.473), natural gas(0.438), energy consumption (0.417), gas storage (0.305), air conditioner (0.282), coal fueled power plant (0.282), carbon capture (0.254), portable equipment (0.223), carbon sequestration (0.212) and electrical energy (0.207). This kind of analysis guide direction for technology transfer in Sino-EU/EEA CCUS joint project and subsequent projects, and patentees concerned shall attach importance to it.

V. CONCLUSIONS AND POLICY-MAKING IMPLICATIONS

As mentioned before, patent analysis targeted at guiding technology transfer is more instructive in practical technology cooperation compared with conventional patent analysis, since it embodies particular function of providing technical information for promoting global and regional technology cooperation, transfer and negotiation [40] [41]. It can be seen from the patent analysis above, EU/EEA countries has sharp edge over China in patents related to CCUS technologies represented by CO_2 compressor. Therefore, developed countries shall take the lead in meeting the binding commitment of "common but differentiated responsibilities" and transfer related technologies to developing countries. CCUS, as a cutting-edge clean energy technology for large scale demonstration, is encumbered with fierce patent competition. To explore the issues concerning intellectual property involved in the transfer of CCUS technologies can provide instructive enlightenment and suggestion for decision and policy making.

TABLE 10 EVOLUTION PATH FOR CO_2 COMPRESSOR TECHNOLOGY IN CHINA AND EU/EEA COUNTRIES (PATENT DATA FROM 2000 TO 2014)

	2000-2002	**2003-2005**	**2006-2008**	**2009-2011**	**2012-2014**
China	q75	q55	x11 & h09	x15	q76
	refrigeration and liquefaction	positive displacement fluid machines/pumps/compressors	power generation and high-power machine & fuel products and coal gasification	non-fossil fuel electrical generating system	drying
EU/EEA	q75 & j01	q73	x11 & j04	d16 & p43	
	refrigeration and liquefaction & separation(evaporation and crystallization)	combustion equipment and process	power generation and high-power machines & catalytic chemical/physical process	fermentation industry and purification & treatment of waste gas	--

A. Patent technology gap

The technology gap between the two parts can be examined by patent analysis oriented for technology transfer since it is the first step of technology cooperation. There is a gap between China and EU/EEA countries in the proprietary patents related to CCUS technologies represented by CO_2 compressor, especially in high-strength patents, which may confront China with problems such as patent barrier and technology dependence. Therefore, it is necessary for us to make a patent warning analysis oriented for technology transfer, which can help China to avoid the risk of introducing redundant, backward, outdated technologies from other countries.

Technology transferee countries like China shall strengthen efforts in creating tracking and warning mechanism for patent related to critical technologies and equipment, and bring into full play the function of patent information analysis in guiding technology transfer. As revealed in patent information analysis, China should increase support for the research and development of advanced technologies such as CO_2 compressor technology and critical technologies that may cause a bottleneck in large-scale deployment of CCUS. Transferee countries also shall attach great importance to patent portfolio of key technologies and keep a close eye on foreign countries' patent portfolio. Enterprises of transferee countries shall be encouraged to lay out patent in foreign countries to pave way for cross-licensing negotiations.

To meet the trend of increasing integration of patent and technical standard, Transferee enterprises shall be encouraged to take an active part in cooperating with other countries in the compilation and amendment of CCUS or other clean energy technology related standards to avoid the risk of being put at a disadvantage when bargaining with developed countries over key patent technologies and technology standards. Great efforts shall be focused on resolving key technical problems in demonstration projects and making technical breakthrough, such as the manufacturing process and technology of high-parameter and large-capacity centrifugal pump and compressor with CO_2 stream in CCUS case.

It is important to keep in mind that the ultimate goal of introducing clean energy technology from other developed countries lies in promoting developing countries' domestic technological strength in drastically cutting CO_2 emission level. Therefore, when technology transfer is being considered, a clear distinction shall be made between introduction of technology and introduction of patent, and a technology transfer pattern is not desirable if it pays more attention to how to operate equipment or technical process and how to raise technical effect than to enhance independent innovation capacity for carbon emission reduction.

B. Suggestions on Patent Technology Transfer

Clean energy technology transfer which can be defined as a fast way to deliver innovation and accelerate deployment of clean energy project like CCUS to scale in developing countries. Considering the low cost of labors and materials, less obstacles of legal restrictions on deployment and more incentive policies on the encouraging the use of clean energy technology in developing countries, large scale clean energy technology transfer especially CCUS related transfer to developing countries has great potential in the near future. Nevertheless, the major concerns and often-cited barriers in climate change negotiations lie in IP [42]. Developing countries claim that the threshold of access to clean energy technology owned by developed countries is too high, namely strong IP protection and unaffordable price. Meanwhile developed countries argue with their unbalanced input & output ratio in cooperation and fear with the loss of their core interests (including IP). To confront with this situation, we conclude with the following suggestions on patent technology transfer from patent analysis in this case.

1) Build up mutual trust on IP information analysis capacity. From one perspective, by the patent analysis model, several aspects of technology comparison among participating sides have been undertaken and some valuable and hidden technological information in patents have been dug out. For transferee countries, it is possible to identify key technology, alternative technology and so on by patent analysis for negotiation with transfer countries so as to lower the threshold and price of targeted technology. For transfer countries, the patent filing strategy, patent infringement monitoring and cross-licensing bargaining can be realized by patent analysis.

2) Encourage cross-licensing, interest-sharing, mutual learning and other mutually beneficial mechanism. Technology transfer should be established on the principle of mutual beneficial. For example, the identification of industrial domains in patent analysis just fits for this principle. Usually, a patented technology can be industrialized not only in one industry sector, by this process of identification, transferee countries can provide more industry information and preferential policies in these domains to transfer countries to catalyze other commercial transfers of their patents as economic compensation.

3) Develop joint research mechanism in common-concerned technology fields. Technology specialization analysis is an important part of the analysis model which includes technology differences and technology path analysis. Different countries have their own advantages and disadvantages in different technology fields. Joint research is the best way to make up for each other's deficiencies, save R&D cost, integrate resources and maximize cooperation achievements. In this condition, an IP agreement for cooperation as a rule of conduct is highly needed to implement the up-mentioned propositions.

C. Intellectual Property Agreement

As China and Europe have not yet signed any intellectual property agreement or clause within this cooperation, the two parties still face a risk of intellectual property disputes, making it hard to carry out substantive technological cooperation and technology transfer. Although the international cooperation treaties on climate change contain some "soft provisions" to oblige developed countries to help transferring clean energy technology to developing countries, in reality, effective patent technology transfer is usually hard to achieve due to the attribute of intellectual property, especially patent, as a kind of private rights and the unwillingness of developed countries to transfer for the sake of their own interest.

Considering this, an intellectual property agreement or a Technology Management Plan (TMP) on intellectual property shall be signed for all this kind of clean energy joint projects and other cross-border technology cooperation to avoid patent disputes and to promote cooperation in a pragmatic way. The agreement or plan shall:

1) clearly define background IP and project IP (chiefly patent). The cooperation parties are required to provide a list of their background IP and timely update it which is the base of cooperation. Patent analysis based on the framework in Figure 2 can play an irreplaceable role in defining background IP and project IP. Measures and provisions to protect background IP are important for international technical cooperation and is the key to establish mutual trust between cooperation countries in joint project. The definition of project IP will directly or indirectly affect the formulation of rules concerning the transfer, protection mechanism, dissemination, publication, exploitation, and interest sharing of IP.

2) The rules about owning and disseminating the IP arising from the project shall be clarified. For example, *the Horizon 2020* of EU works with a guiding intellectual property principle that "protecting IP rights while encouraging dissemination". EU is one of the stakeholders for CCUS demonstration projects, but as the project is being deployed in China, it shall comply with China's Patent Law, which stipulates that unless specially specified, the party actually performing invention or creation should own the IP, regardless of the stakeholder. Other issues to be agreed upon include the acquisition for the IP arising from the project (e.g. patent application), the maintenance for the IP (e.g. payment of annual fee) and the abandonment of right, etc.

3) The use rules concerning IP shall be lay down, mainly including the assignment, licensing and profit allocation of intellectual property. For example, Article 50 Clause 4 in the *Rules for Participation in Horizon 2020* stipulates that "the contracting authorities shall enjoy at least royalty-free access rights to the results for their own use and the right to grant, or require the participating contractors to grant, non-exclusive licenses to third parties to exploit the results under fair and reasonable conditions without any right to sub-license. If a contractor fails to commercially exploit the results within a given period after the pre-commercial procurement as identified in the contract, it shall transfer any ownership of the results to the contracting authorities" [43]. For further reference, relevant statements about ownership, licensing, pricing and consultation mechanism about intellectual property of "jointly funded research programs" stipulated in the Technical Management Plan signed by three parties of China-US Joint Clean Energy Research Center. As shown in the above cases that the ownership, dissemination and exploitation of intellectual property place a very important role in international technical cooperation treaties as it may directly affect the interest of the participating parties and the cooperation effect of project.

D. Building of intellectual property capacity

Some of the transferee countries' participating parties are inadequate in building intellectual property capacity, which is mainly manifested by: the lack of patent warning system and inadequate experience in mining technique; the insufficient awareness and experience in patent licensing, patent evaluation, the exploitation of patent information analysis in guiding innovation; the lack of channel, mechanism and approach to share knowledge with foreign counterparts; the varying ability of the staff to comprehend and execute intellectual property policies; more emphasis being put on requesting aids from other parties than on strengthening protection over their own intellectual property.

To build up the capacity in IP requires concerted efforts of government, enterprises and individuals. At state level, participating countries' and regions' governments like Chinese and EU's in CCUS cooperation shall deploy IP strategy throughout the whole process of the project, making prospective evaluation of hidden risks of intellectual property disputes. Some enterprises in developed countries like China do not know how to respond appropriately, or even feel at loss, when faced with several so-called "overbearing clauses" enacted by foreign parties about patent grant-back, invention of improvement, cross-licensing, etc. This is unfavorable for the deployment of overall strategy of developing countries' clean energy technology. Therefore, participating enterprises of developing countries shall establish IP protection and management mechanism and organize training or seminars to enhance the enterprises' and individual's capability concerning IP. The ultimate goal is to reduce global carbon emission for all human kind through promoting transfer of clean energy represented by CCUS technologies on the premise of safeguarding interest of both parties.

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