論文 / 著書情報
Article / Book Information

Title	Can the conscious of technical characteristics overcome with harvesting local capability? International technology transfer of clean technologies focusing on technical characteristics
Authors	Kanako Nakayama, Yoshitoshi Tanaka
Citation	Proceedings of PICMET '11: Technology Management in the Energy Smart World, , , pp. 790-797
Pub. date	2011, 8
Note	This paper has been presented at PICMET'11 (Portland International Center for Management of Engineering and Technology) Conference on July 31 - August 4, 2011 in Portland, Oregon - USA, and published in the Conference Proceedings"

Can the conscious of technical characteristics overcome with harvesting local capability? International technology transfer of clean technologies focusing on technical characteristics

Kanako Nakayama, Yoshitoshi Tanaka
Tokyo Institute of Technology Graduate School of Innovation Management, Tokyo, Japan

***Abstract*--International technology transfer of clean technologies has been getting an important issue due to the rising international concern over climate change. By transferring clean technologies from developed countries to developing countries, developing nations need not go through the process of adopting dirty technologies, but can leapfrog over them, to install clean technologies which are already available in other countries and reduce the amount of greenhouse gases.**

Past field studies revealed that wind turbine technology proceeded with a successful technology transfer to China and India, where it is manufactured and also installed actively within the country. However, as for photovoltaic technology, those two countries quickly became one of the most active producers of solar panels, but most of the products are exported in foreign countries rather than installed domestically. This research aims to examine the differences of technical characteristics of two technical fields based on patent data, namely patent classification and characteristics of applicants. In order to enhance not only the manufacturing capacity but also the possibility of domestic adoption of clean products, the findings of this research will help the developing nations to absorb particular technologies with harvesting local capability of technology and market.

I. INTRODUCTION

A. Background and Objective

Since late 20th century, environmental issues such as climate change have become a big concern. Fig. 1 shows the transition of region based CO_2 emissions and future predictions. The emission of CO_2 from developing countries considered to rise dramatically due to the rise in energy consumption. China now overtook U.S. and became the largest emitter of CO_2, and India overtook Russia to become 4th biggest emitters after E.U.. It is very important internationally to minimize the energy consumption of these countries in order to reduce the amount of CO_2.

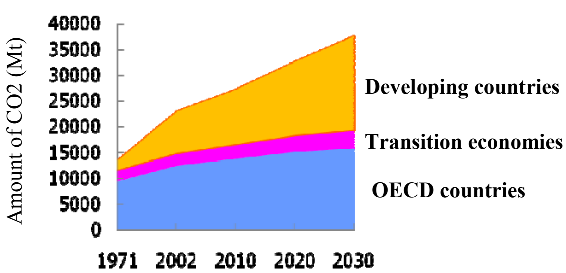

Fig. 1 Regional CO_2 emission trajectories
(IEA World Energy Outlook 2004)

Recently, "international clean technology transfer," transferring clean technologies from developed countries to developing countries, has drawn great attention as a tool to solve the climate change. Behind this discussion lies the concept of "leapfrogging." Developed countries have cutting-edge technologies for mitigating climate change, and if developing countries obtain those technologies, they can leapfrog over older dirty technologies and shift to the advanced clean energy societies. However, in reality, there are certain obstacles for technology transfer. Ueno and Sugiyama investigated 8 different environmental technologies and found out that some technologies diffuse within developing countries whereas others did not diffuse domestically and finished products are exported abroad, meaning the countries only became manufacturing bases [1]. The study shows the difference in the degree of transfer among different technologies.

This research examined the factors which affect the degree of environmental technology transfer from developed countries to developing countries. There are many ways to compare different technologies such as their installation policy and market demand. This study tries to use patent data to quantitatively compare the technical characteristics of clean technologies. Patent data is known to be a good tool to find technical characteristics of products [2]. It directly reflects companies' R&D activities and also it broke down technology into components for its examination purpose. As a comparison, we focused on photovoltaic power generation (PV) technology and wind power technology. These technologies were chosen because they are both one of the main new sources of energies, and also because several field studies have done on these technologies in the field of technology transfer [1][3][4][5][6][7].

PV technology was transferred and produced in developing countries but is not diffused well. As shown in figure 2, domestic production capacity of PV increased rapidly, but domestic installation capacity has not risen, causing a big gap between the two. Less than 2% of the finished PV products in China are used domestically, and most of them are exported to developed countries namely Germany and U.S [8].On the other hand, wind turbine is produced and also installed actively within the country. Until very recently, India and China did not have capability of producing wind turbines. However, by 2006, Indian company Suzlon and Chinese company Goldwind ranked in top ten of the world market share, breaking into European competitors

[9]. Domestic installations of wind energy have also been rising rapidly in both China and India, consisting up to 20% of world total installation in year 2008 by two countries. Case studies showed that the cost reduction resulted from domestic production and innovation contributed to the domestic installation. We compared these two types of technologies from patent data to find out the differences of technical characteristics.

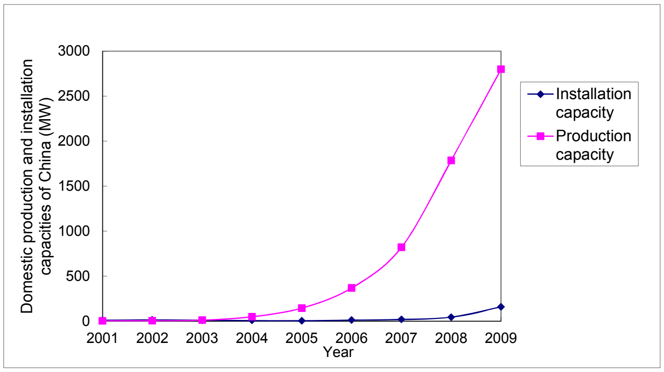

Fig. 2 Domestic production and installation capacity for PV in China (Data from Science Portal China [10])

B. Existing literature

The degree of technology transfer can be distinguished by a model offered by Bell(1990) as shown in figure 3 [11]. The model illustrates three different flows within the process of transferring technology from aspect of technological content. Flow A consists of transferring the capital goods and services necessary for creating physical facilities of a new production. Flow B transfers the skills and know-how for operating and maintaining those physical facilities. Flow C refers to the skills and knowledge which are needed for understanding, utilizing, and replicating the technology. This includes the capacity that eventually leads to creating new products. It can be assumed that without any obstacles, all flow A to C can be found within the transfer, but with more obstacles are found, it is harder to find complete transfer of flow C within the process of transfer.

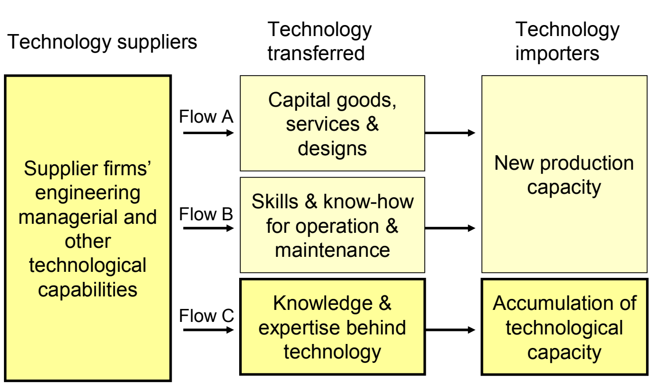

Fig. 3 Three flow found within the technology transfer (Oakwell(2010), referring to Bell(1990))

Past field studies found that for PV technology, domestic installation did not occur due to its high cost. Chinese domestic companies cannot innovate or reform existing technology enough to cost down to the level of its diffusion. It is considered that if the Chinese companies involve from the designing part of the PV production, the cost can be reduced up to 70% compared to the companies of other developed nations [7]. This suggests that the flow C of the technology transfer has not been occurred much in the case of PV. Only the production facilities and/or knowhow for its operation and maintenance (Flow A and B) have been transferred. On the other hand, wind power technology was considered to have been transferred not only flow A and B, but also flow C. Figure 4 is the relationship between involvement of flow C within the transfer and domestic diffusion is proposed by past researches.

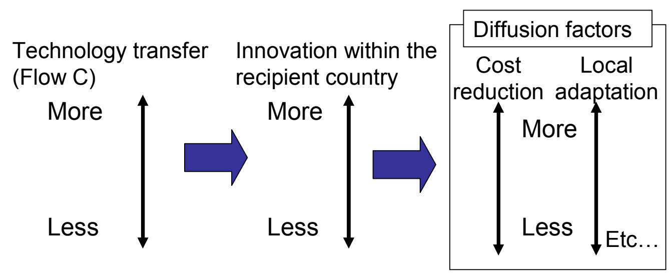

Fig. 4 Result of technology transfer in recipient country

Past studies have shown the difference in the degree of transfer among different technologies. However, most of the studies focused on the receiver's side of the transfer, and the researches are mostly done with case studies, without quantitative data. For financing transfer of clean technologies, it is important to quantitatively compare the technologies and choose the ones that easily diffuse in developing countries and can help reduce CO_2 effectively. This research tries to find out the obstacles of technology transfer, meaning the obstacles for transferring technology to the level of flow C, by comparing wind power and PV technologies. Study was analyzed using patent data in order to compare the data of two different technologies quantitatively.

There are some studies of inter-technology analysis using patent data. Tomita (1999) looked at IPC classification and their number of filed applications to compare agricultural field of technology of Germany and Japan [12]. Nakamura (2003) focused on three technologies; AI, LC, and biotechnology, and distinguished core technologies and other technologies using IPC patent classification [13].

This study also uses IPC patent classification, to subdivide technologies into component technologies.

II. RESEARCH METHODOLOGY

The concept of this research is shown in fig.5. Fig 4 looked from receiver's aspect (vertical axis) in detail. This study looked from provider's side (horizontal axis), focusing on technical characteristics. This figure shows the relationship between technological characteristics of the technology and degree of difficulty of technology transfer defined by flow C.

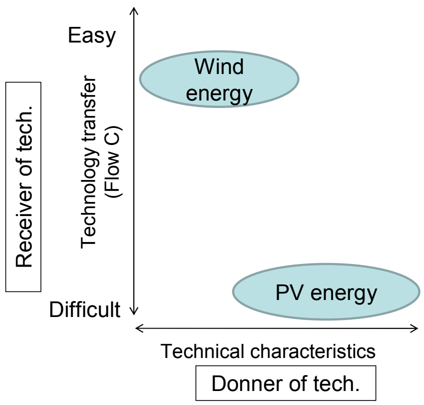

Fig. 5 The main framework for this research

IPC classification system and file index (FI) classification system[1] were used to breakdown PV and wind power technologies into component technologies.

First, two technologies were defined using IPC and FI classifications. Then, patents classified as those IPC and FI were extracted using JP-NET of Japan Patent Data Service Corporation (URL: http://www.jprom.co.jp/). Patent data used in this research were patent applications filed in Japan Patent Office during 2005-2009.

Three hypotheses were formed and examined through this research to find out the technical characteristics which act as obstacles for the technology transfer involving flow C. Hypothesis 1 looked at the relationship among component technologies of PV technology and wind power technology respectively, and analyzed whether each company that involves in these researches conducts R&D of single or several component technologies. Hypothesis 2 and 3 looked at the characteristics of each component technology. Hypothesis 2 examined the influence of other technology fields, whereas hypothesis 3 investigated the degree of research cooperation.

III. ANALYSIS OF PATENT APPLICATIONS OF PV AND WIND POWER TECHNOLOGIES AND DISCUSSIONS

A. Data extraction

First, PV and wind power technologies were defined by patent classifications and search keywords, using the reference of JPO and World Intellectual Property Organization (WIPO) [14][15]. For PV technology, H01L31/04 and H0131/042-055 for IPC, and H01L31/04, H01L31/06 for FI were decided as the technology scope. Keywords were chosen to eliminate the patents of solar heat panels. In addition, some noise applications were removed. For wind power technology, F03D01/00-11/04 for IPC and F03D1/00-11/04Z for FI were decided as the technology scope. Keywords were added for search in order to remove some noise applications. Among classifications that were chosen, classifications on crystallized silicon for PV and horizontal propeller type turbine for wind power were extracted for use as their component technologies. These were shown on Table 1 and 2. Classifications shown on Table 1 come below class 31/00, which is defined as follows: "Semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation; Processes or apparatus peculiar to the manufacture or treatment thereof or of parts thereof; Details thereof." Patent applications whose patent applicants are individual inventors were excluded from this research. Their patents need to be licensed or sold to companies in order to be used in the society. However, it is well-known that individual inventors in Japan rarely utilize their patents, thus we considered that the knowledge of the patents are not utilized in the society.

TABLE 1 FI CLASSIFICATION USED FOR THIS STUDY (CRYSTALLIZED SI SOLAR PANEL)

H01L31/04 adapted as conversion devices	31/04H Electrodes and substrates for single and polycrystal photoelectric power devices
	31/04L Joint construction for single and polycrystal photoelectric power devices(such as Schottky and MIS)
	31/04C Integrated single and polycrystal photoelectric power devices(module classified here)
	31/04Y Laminated single and polycrystal phtoelectric power devices (tandem types classified here)
	31/04X Manufacturing methods for single and polycrystaline films(Si, Ge)
	31/04F Antiglare films, obverse surface protection films, and reverse surface reflective films
	31/04G Lenses, reflectors, and filters
	31/04K Solar battery power circuits and testing devices

[1] FI classification is a system developed by Japan Patent Office (JPO) to refine the search of Japanese patent literature. FI classification is subdivided on the basis of IPC classification, with three digit numbers or/and one digit alphabet added to IPC code. Number of FI increases when patents are too concentrated in a particular classification, thus the structure of FI system implies the activeness of R&D in particular field of technology.

TABLE 2 FI CLASSIFICATION USED FOR THIS STUDY (HORIZONTAL AXIS PROPELLER TYPE WIND TURBINE)

F03D Wind motors	1/02 Wind motors with rotation axis substantially in wind direction: having a plurality of rotors
	1/04B having stationary wind-guiding means: air channel member in the horizontal direction
	1/06A Rotors:Propeller type windmill
	7/04E Regulation, i.e. controlling automatically: variable pitch control
	7/04K Regulation, i.e. controlling automatically: Azimuth control
	9/00 B Adaptations of wind mortors for special use; Combination of wind motors with apparatus driven thereby: Conversion of the wind force energy into another energy without the power
	11/00A Details, component parts, or accessories not provided for in, or of interest apart from, the preceding groups: related to the vane
	11/02 Transmission of power, e.g. using hollo exhausting blades

Two types of data set were used for this research. First one was a collection of patent applications which have FI listed on Table 1 as primary classifications. Second data was a collection of patent applications that have FI listed as any classifications, meaning not only primary but also as secondary classifications. These two different types of data set were shown on Fig.6. Both of these data set were grouped by their primary FI.

A. Hypothesis 1

From the past case studies, it is said that there are more integrated knowledge between component technologies for PV technologies. If companies that involve in the PV technology conduct R&D of several component technologies, this implies that there are environment to adjust multi-components to achieve the optimum performance. Thus, hypothesis 1 focused on the relationship among each component of the technologies, to examine the applicant duplications.

Hypothesis 1: Compared to wind power technology, companies involves in R&D of PV technology engage in several component technologies.

To verify hypothesis 1, "integrated ratio (IR)"index was defined. IR is calculated as follows.

$$\text{Integrated Ratio(IR)} = \frac{F(A \cap B)}{F(A \cup B)}$$

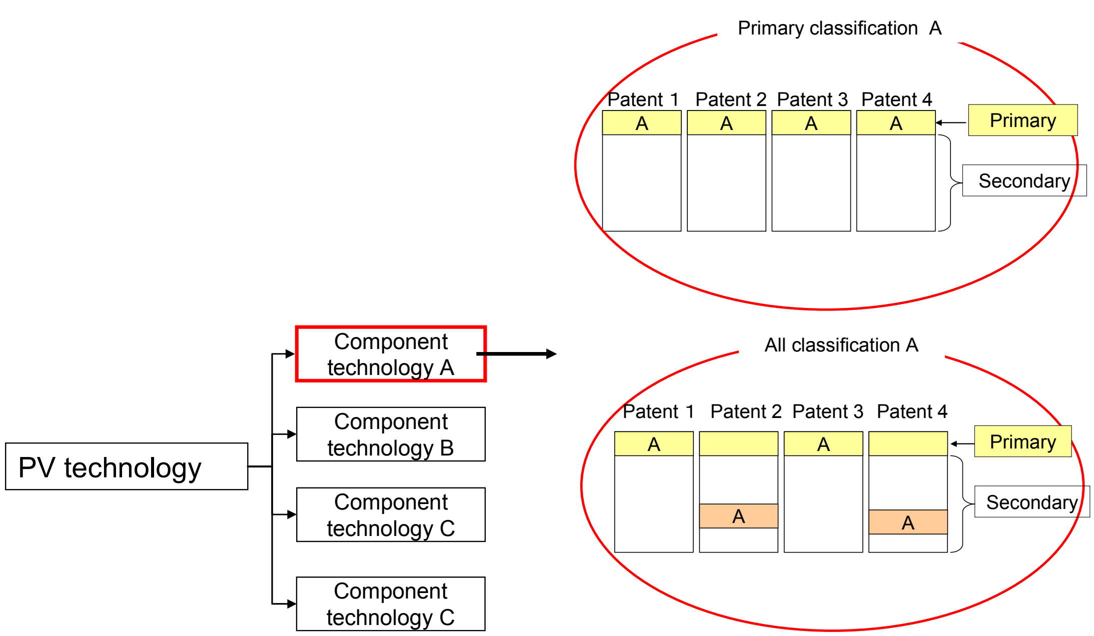

Fig. 6 Two sets of patent data used for analysis

F(x) is the number of applicants who filed applications in a classification (component technology) x. A and B are classifications within one technology. Upper set of data shown on Fig.6 (Primary classification) was used for this analysis. For each technology, IR between two components were calculated individually.(Table3, 4) Then for two groups of IR(PV and wind power), t-test was performed to verify the technological differences between the two. The result significantly rejected that two technologies came from the same technological samples (t (54) =-4.201, p<0.01), with higher IR for PV. This result shows that for PV technology, one company is engaged in R&D of multiple component technologies.

This implies the integrality among component technologies, because each company has the environment to adjust those components considering the mutual impact of one another, to achieve the optimum performance as a whole.

PV technology which has interdependence among component technologies may have needed to transfer all in one package. In this way, knowledge inside the package may not be transferred to the receiver. If the components have lower interdependence, like in the case of wind power technology, it is possible to transfer components one by one, individually, which possibly enhance the transfer of flow C.

For PV, H is considered to be a main component technology that most of the big solar panel companies engaged in. This component technology is related to cell production. Looking at relationship with this component technology, Y, X and G have lower IR value. This means they are researched independently with component H. This suggests that those companies involve in Y, X and G are specialized in those components. On the contrary, IR of control regulations (7/04) and blade (11/00 A) is high, which suggests that they are often done by the same company. These results mean that even though there seems to have tendency of higher IR for PV and lower IR for wind power, depending on the components, IRs are different within each technology.

B. Hypothesis 2

Hypothesis 2 looks into the characteristics of each component, to examine the influence of other technology fields. Past field studies noted that turn-key solution was introduced for PV technology because the technology possesses several production processes which makes it hard for technology to be transferred. It is predicted that with more production processes needed, the more variety of technical knowledge is needed. Thus, hypothesis 2 was formed as follows.

Hypothesis 2: Compared to wind power technology, each component technology of PV technology is influenced by several technological fields.

Lower set of data shown on Fig.6 (Primary and secondary classifications) was used for this analysis. For most of the patent in the data set, the primary classification was like patent 1 and 3 in the figure. However, some classifications had other patent classifications as primary classification. To verify the hypothesis 2, patents were grouped according to the primary classification, and the influence of those classifications of other fields was analyzed. For each component technology, Herschman-Herfindahl Index (HHI)[2] was applied for this patent data to understand the degree of influence. It was defined as Classification HHI (CHHI) which was calculated by following formula.

$$\text{CHHI} = \Sigma\,(\text{Amount of each main classification's filed application})^2$$

The result of CHHI was shown on table 5. T-test was used to verify that two set of data (PV and wind power) are different. The result proved that these technologies are different (t (14) = -1.843, p<0.1), with wind power having higher value. This means that wind power's component technology is more oriented to its technology, whereas for PV, other technological fields have some influence on each of the component.

TABLE 3 IR FOR PV TECHNOLOGY (2005-2009)

	31/04H	31/04L	31/04C	31/04Y	31/04X	31/04F	31/04G	31/04K
31/04H	–	0.135	0.156	0.055	0.096	0.168	0.088	0.143
31/04L		–	0.154	0.128	0.167	0.086	0.172	0.131
31/04C			–	0.082	0.150	0.134	0.110	0.161
31/04Y				–	0.068	0.040	0.054	0.062
31/04X					–	0.102	0.107	0.113
31/04F						–	0.081	0.131
31/04G							–	0.074
31/04K								–

TABLE 4 IR FOR WIND POWER TECHNOLOGY (2005-2009)

	1/02	1/04B	1/06A	7/04E	7/04K	9/00 B	11/00A	11/02
1/02	–	0	0	0.038	0.045	0	0.028	0
1/04B		–	0	0.032	0.077	0	0.053	0
1/06A			–	0.182	0.053	0.087	0.044	0.028
7/04E				–	0.217	0.067	0.113	0.098
7/04K					–	0.077	0.103	0.079
9/00 B						–	0.082	0.047
11/00A							–	0.108
11/02								–

[2] Herschman-Herfindahl Index (HHI) is the index used by Department of Justice in U.S. and fair trade commission in Japan which measure the oligopoly of product market. It is calculated by total sum of the square value of each company's share in the market. If the market is close to monopoly, HHI is high.

In PV, the result shows that component technology related to basic cell production process such as H, X and F, have quite low value. On the other hand, L, C and Y are for later stage of cell production (close to the module process) and their values are high. This suggests that early stage of cell production needs more knowledge of different technology fields. This is consistent with the fact that cell production knowledge has not been transferred well to China but later module process had already well transferred.

Next, IPC classification was used to subdivide the PV and wind power technologies, to examine the influence of other technological fields.

The method was the same, and the result was shown on Table 6. T-test was used to verify the difference of these two technologies, and two groups of component technologies were proved ($t(5)=-2.655$, $p<0.05$) to be different. The result showed that PV value is lower than that of wind power, which is the same trend with the result using FI classification data.

Then, the content of each dataset was observed. By looking at the actual content, degree of diversification of the technological field could be examined qualitatively. From the CHHI data using FI classification, classifications whose CHHI have value over 1×10^{3} were extracted and shown on figure 7 and 8. Component technologies of PV obtained more classifications than wind energy on average. Especially component technology used for cell production process (H and X) have several different technological fields. However, for C, Y and L, are not influenced much by other technological fields. Wind power has technology of other fields in some of the control regulation technologies. Overall, PV has technologies of Performing operations (class B), chemistry and metallurgy (class C), physics (class G), electricity (class H), and within the field of chemistry, it varies within single crystal, non-metal, and polymer. As for wind power, it only contains technologies of electricity (class H) and mechanical engineering (class F), suggesting narrower technological fields.

TABLE 5 CHHI VALUE USING FI CLASSIFICATION DATA (PATENT DATA 2005-2009)

Wind power technology	1/02	1/04B	1/06A	7/04E	7/04K	9/00 B	11/00A	11/02
	0.885	0.876	0.776	0.789	0.938	0.475	0.871	0.714
PV technology	31/04H	31/04L	31/04C	31/04Y	31/04X	31/04F	31/04G	31/04K
	0.523	0.829	0.887	0.848	0.237	0.580	0.578	0.436

TABLE 6 CHHI VALUES USING IPC CLASSIFICATION (PATENT DATA 2005-2009)

Wind power technology	F03D1/00-06	F03D7/02-04	F03D9/00	F03D11/00	F03D11/02
	0.798	0.652	0.511	0.679	0.714
PV technology	H01L31/04	H01L31/042-055			
	0.359	0.513			

31/04H	H01L(*)	H01L	H01B	C30B	C01B
	5.10E-01	6.63E-03	1.92E-03	1.71E-03	1.51E-03
31/04L	H01L(*)	H01L			
	8.26E-01	5.29E-03			
31/04C	H01L(*)				
	8.86E-01				
31/04Y	H01L(*)				
	8.46E-01				
31/04X	H01L(*)	C01B	H01L	C30B	
	1.36E-01	4.23E-02	3.14E-02	2.66E-02	
31/04F	H01L(*)	B32B	C08J		
	5.75E-01	1.44E-03	1.03E-03		
31/04G	H01L(*)	G02B			
	5.59E-01	1.72E-02			
31/04K	H01L(*)	H02J	G05F	G01N	
	4.22E-01	7.85E-03	1.78E-03	1.44E-03	

H01L(*)	PV technology	C08J	Organic macromolecular compounds; general process of compounding
H01L	Basic electric elements: Semiconductor devices	G02B	Optical elements, systems, or apparatus
H01B	Basic electric elements: Cables, conductors…selection of materials for their conductive, insulating, or dielectric	H02J	Generation, conversion, or distribution of electric power-circuit arrangements or systems for supplying or distributing electric power.
C30B	Single-crystal growth	G05F	Controlling, regulating-systems for regulating electric or magnetic variables
C01B	Inorganic chemistry: Non-metallic elements, compounds	G01N	Measuring ; investigating or analysing materials by determining their chemical or physical properties
B32B	Layered products i.e. products built-up of strata of flat or non-flat		

Fig. 7 Content of CHHI (CHHI>1×10^{3} for PV technology)

1/02	F03D		
	8.84E-01		
1/04B	F03D		
	8.75E-01		
1/06A	F03D	F16C	
	7.73E-01	1.89E-03	
7/04E	F03D	H02P	
	7.84E-01	3.27E-03	
7/04K	F03D	H02P	
	9.37E-01	1.04E-03	
9/00 B	F03D	H02P	H02K
	4.58E-01	1.30E-02	2.74E-03
11/00A	F03D		
	8.71E-01		
11/02	F03D		
	7.10E-01		

F03D	Wind motors
F16C	Engineering elements or units, general measures for producing and maintaining effective functioning of machines or installations: Shafts, rotary bodies other than gearing elements
H02P	Generation, conversion, or distribution of electric power: Control or regulation of electric motors, generators, or dynamo-electric converters, controlling transformers
H02K	Generation, conversion, or distribution of electric power: Dynamo-electric machines

Fig. 8 Content of CHHI (CHHI>1×10^3 for wind power technology)

It was shown that the components of PV technology have influence of other technological fields, and those fields vary greatly. The technology which has accumulation of various fields of knowledge is difficult for receivers to imitate or research by themselves. Also, through those complex researches, the technology should have incorporated knowhow of production. It is likely that these knowhow are hard to transfer. On the other hand, wind power technology has less influence of other technological fields. This suggests that with the technology transfer, it is easier for receiving companies to understand the technology, catch up and imitate.

C. Hypothesis 3

Hypothesis 3 also looks into the characteristics of each component, but examining the degree of joint research. The aims of joint researches are cost reduction, risk management, speed, and supplement of technologies among businesses [16].Thus, technologies generated from joint research is likely to have interaction with different industries and supplement each other within the process.

Hypothesis 3: Compared to wind power technology, each component technology of PV technology is researched by technological cooperation, involving multiple actors.

To measure the degree of joint research to verify hypothesis 3, ratio of co-applicant application was used. Table 9 shows the result for each component technology (FI classification).

On average, PV has more co-applicant applications than wind power. This suggests that research of each component technology of PV technology is done by multiple actors. During joint research, institutions are likely to share their internal resources to invent new technologies. It implies that each component PV technology is composed of knowledge of many actors.

These technologies are thought to be difficult to develop by developing countries' firms themselves, and also hard for them to imitate.

It is worth noting that the components which have lower value for analysis of hypothesis 2, meaning having the influence of many technological fields, tend to have higher ratios of co-applicant patent applications. This can be seen for 9/00 B for wind power, and 31/04H, 31/04 X for PV. This suggests that these components are complex as they may incorporate knowledge of different technology fields and actors. On the other hand, 31/04 Y has high ratio of co-applicant but analysis of hypothesis 2 shows it has narrow technology field, mostly of PV technology itself. This component has several co-application of university and company, thus it may be that the component incorporates basic and applied knowledge of the same technological field.

IV. CONCLUSIONS

This paper tried to find out the obstacles for technology transfer using patent data. This study stands on the position that not only technology itself and its operation knowhow, but also transfer of knowledge and expertise behind technology (flow C) is one of the key factors for clean technologies to diffuse within the developing countries and to contribute to the mitigation of climate change. By analyzing patent data of PV technology and wind power technology, three characteristics were derived which may act as obstacles for transferring process. Each of these characteristics can be put into x axis of Fig.9. With these obstacles, it is harder to transfer technology, which means less likely that flow C is found within the transfer. It is suggested that if technology has higher tendency of the characteristics on x axis (have high x value), then the technology transfer of flow C is more difficult (have lower y value).

TABLE 9 RATIO OF CO-APPLICANT APPLICATIONS FOR EACH COMPONENT TECHNOLOGY (2005-2009)

Wind power technology	1/02	1/04B	1/06A	7/04E	7/04K	9/00 B	11/00A	11/02
	0%	3.0%	0%	3.1%	0%	4.3%	5.1%	4.1%
PV technology	31/04H	31/04L	31/04C	31/04Y	31/04X	31/04F	31/04G	31/04K
	9.2%	4.4%	6.3%	8.8%	10.3%	4.8%	3.8%	4.4%

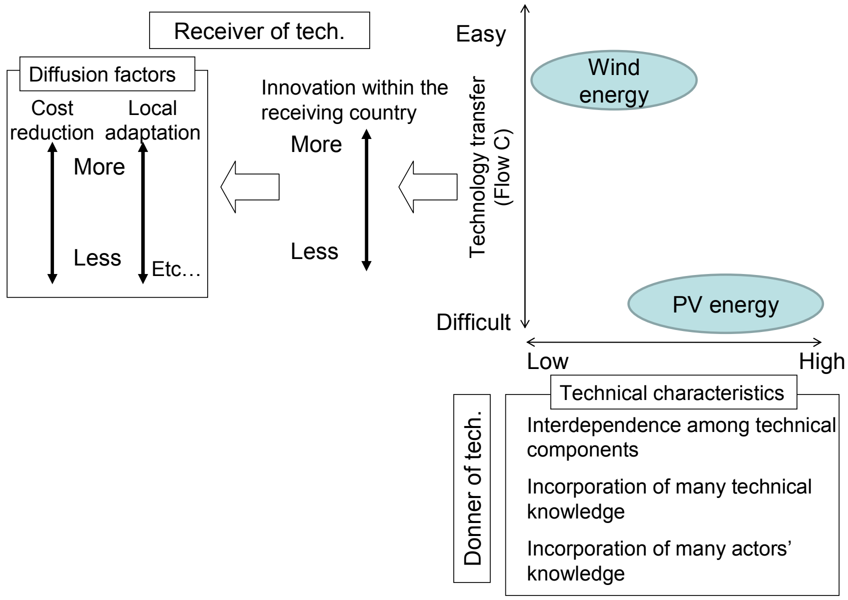

Fig. 9 Combination of past studies and result of this analysis

Recently, many programs for climate change mitigation try to finance the international clean technology transfer. It is necessary to finance the right technologies that actually do reduce the amount of CO_2 effectively. In that sense, it is important to choose the technology which are easier to be transferred. Three technological characteristics that are found in this paper can act as a guide to choose the right ones.

Also, within one technology, characteristic tendency differed among components. It is also worth thinking about which component to transfer when transferring specific technology to developing countries. For those components that are relatively easy to be transferred, we should encourage them to be transferred actively, whereas for more difficult ones, they can be imported in the beginning, so as to combat the problem of climate change most effectively with less cost.

For future research, patents of developing countries need to be investigated to verify that innovation of wind power technology is more active than that of PV power. This confirms the past field studies which this study stands upon, that flow C was involved in wind power technology transfer and not for PV. Also, more technologies should be analyzed to prove the relationship of three characteristics and the degree of transfer. Furthermore, this research used Japanese patent data for analysis, but investigating E.U. or U.S. patents would put in wider global trend of technology transfer.

REFERENCES

[1] Ueno, T. and Sugiyama T.; "Technology transfer of climate mitigation technologies –Analysis of cases of transfer to China-," *Socio-economic Research Center*, Rep. No. Y08023, 2009.

[2] Griliches, Z.; "R&D and productivity-The econometric evidence, " *The University of Chicago Press*, 1998.

[3] Lewis, J.; "Technology acquisition and innovation in the developing world: wind turbine development in China and India," *St Comp Int Dev*, Vol.42, pp.208-232, 2007.

[4] SPRU and TERI; "UK-India collaborative study on the transfer of low carbon technology: Phase II," *Institute of Development Studies*, 2009.

[5] Barton, J.; "Intellectual property and access to clean energy technologies in developing countries: An analysis of solar photovoltaic, biofuel and wind technologies-," *ICTSD Trade and Sustainable Energy Series* Issue Paper No.2. International Centre for Trade and Sustainable Development, Switzerland, 2007.

[6] Chen, H. and Pan, C.; "Organizational forms for knowledge management in photovoltaic solar energy industry," *Knowledge-Based Systems*, Vol.23, pp.924-933, 2010.

[7] Marigo, N.; "The Chinese silicon photovoltaic industry and market: A critical review of trends and outlook," *Progress in Photovoltaics: Research and Applications*,Vol.15, No.2, pp.143-162, 2007.

[8] JEPIC(Japan Electric Power Information Center); "Current situation and future prospect of photovoltaic power generation in China," *Kaigai Denryoku*, pp.83-86, 2008.

[9] Intergovernmental Panel on Climate Change; "Climate change 2007: synthesis report,"*United Nations Environmental Programme and World Meterological Organization*, 2007.

[10] Zuoxu, Z.; "Current situation and future prospect of Chinese photovoltaic industry," Retrieved 2009/3/31 World Wide Web, http://www.spc.jst.go.jp/hottopics/0904reuseenergy/r0904_zhai.html

[11] Ockwell, D., Watson, J., MacKerron G., Pal, P., and Yamin, F.; "Key policy considerations for facilitating low carbon technology transfer to developing countries", Energy Policy, Vol.26, pp.4104-4115, 2008.

[12] Tomita, T.; "Difference of climate and difference of technoogy-Comparisons and failure of transfers through patent-classifications and Beckmann's works," *Japan Society for Commodity Science,* Vol.50, No. 3-4, pp. 15-30, 2001.

[13] Nakamura, T.; "UsingJICST file and patent DB on a technology trend analysis-Using data-mining on inter-technology analysis-," *Journal of Information Processing and Management*, Vol.46, No.2, pp.97-106, 2003.

[14] World Intellectual Property Organization WIPO; "Patent-based technology analysis report-Alternative energy-,"2010.

[15] Japan patent office; "Patent application trends in 8 key fields-environmental technology and other 4 classifications", 2009.

[16] Goto, A. and Suzumura K.; "Japanese competition policy", *Tokyodaigakushuppan*, 1999.