Monitoring of Green Technology Using GTNet Membership and Published Information in Korea

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***Abstract*—Green technology refers to an optimal technology that saves energy/ resources overall, and minimizes greenhouse gas/waste output such as greenhouse gas output reduction technology, efficient energy usage technology clean production technology, clean energy technology, resource circulation, and eco-friendly technology. GTNet is a website that provides information about the green technologies to the world non-stop and it is operated under a membership system. GTNet members can select their fields of interest and the provided green technology information are categorized by its field of green technology and labeled by its unique code. We used the membership and published information on GTNet to perform a cluster analysis amongst green technologies and discovered which fields of green technology share a lot of similarity. Also, we have performed a cross analysis on the relationship between high subscribed technological fields and their investment strategies as well. As a result, we have discovered that there are 5 major CNM clusters in green technology and members expressed interest in different clusters based on their affiliations.**

***Index Terms*—GTNet, CNM cluster, cross analysis, green technology.**

I. Introduction

The overall increase in demand for energy in the world, depletion of fossil fuels, and climatic changes have brought attention to green development as the new paradigm for national development. Green technology refers to technologies such as greenhouse gas reduction technology, efficient energy usage technology, clean production technology, clean energy technology, resource circulation, and eco-friendly technology(includes related combined technologies) which save energy/resources, and increase efficiency in terms of energy/resource spending in order to minimize the output of greenhouse gas and wastes (Framework Act on Low Carbon, Green Growth, Article 2, Clause 3, Enforcement Decree of the Patent Act Article 9, Clause 2).

The government has established an overall plan for green technology research and development in order to support green growth according to the laws mentioned above. The government has selected the 27 most important green technologies to complete and it strives to fully develop these technologies (Table I).

With the support of the Ministry of Education, Science and Technology as well as the Presidential Committee on Green Growth, the "Green Technology Information Portal (GTNet, www.gtnet.go.kr)" was established by the Korea Institute of Science and Technology Information (KISTI) according to Article 26 Section I of the Framework Act on Low-Carbon Green Growth, in order to provide information on relevant green technology, industry, market, policy, and national R&D, as well as to promote a green technology expert community. With the Presidential Committee on Green Growth leading, 10 liaison organizations for informational cooperation including KISTI, Korea Institute of Science and Technology Evaluation Planning, Korea Institute of Energy Research, and Korea Institute of Energy Technology Evaluation and Planning signed a contract with MOU for green technology information exchange and cooperation in order to put together relevant information and provide them to the government, research institutes, industrial experts, and the public through GTNet, thereby promoting cooperation among them [1], [2].

In this study, we have established a green technology network by using the relationship between green technologies looked up by GTNet members and we have also determined which technologies share the most similarities through cluster analysis. We have also analyzed which members look up what technology on the website based on their affiliation in order to analyze the level of industrialization for green technology.

II. Related Work

Network for theoretical modeling and empirical research has been mainly active in the field of statistical physics and applied mathematics, such as in the field of Science citation relationships, joint research status has been used. Many researchers in order to understand the complex systems that are interrelated network theory was used [3]-[7]. There are many ongoing researches to detect the patterns of relationships (commonly known as communities) within the network based on the network theory [8]-[10].

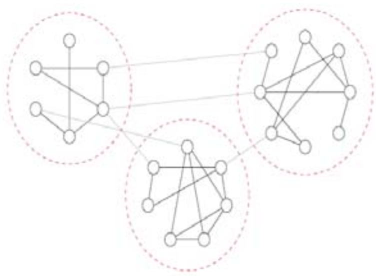

Fig. 1. A small network with clustering of type considered in this paper.

Normally, networks tend to have a few clusters and as Fig. 1 shows, we can see that there are 3 clusters when we grow them based on the linking density between nodes. In other

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words clusters are defined by the grouping of nodes that share high linking density in terms of network structure (Fig. 1) [11].

Analyzing and detecting methods of network clusters help understanding and visualizing the network structure/ This study has used CNM clustering in order to perform the clustering amongst green technologies.

TABLE I: GREEN TECHNOLOGY CLASSIFICATION

Large class	Intermediate class	Technology name
Energy source	Renewable energy	High efficiency, low cost technology of silicon solar cell
		Mass production and core source technology of non-silicon solarsystem
		Bioenergy production element technology and system technology
		Wind power energy
		Solar energy
		Hydraulic energy
		Ocean energy
		Geothermal energy
	Atomic power /Nuclear fusion	Advanced power reactor design and construction technology
		Environment-friendly nuclear non-proliferation fast reactor and cycling nuclear periodicity system development technology
		Fusion reactor design and construction technology
	Hydrogen-oxygen fuel cell	High efficiency hydrogen manufacturing and hydrogen storage technology
		Next generation high efficiency fuel cell system technology
	Environment-friendly agriculture	Environment-friendly plant growth facilitating technology
Increasing energy efficiency	Fossil fuel usability improvement, increasing efficiency	Integrated gasification combined cycle technology
	Increasing energy efficiency	LED for lighting, Green IT technology
		Electricity IT and electric device efficiency improving technology
		High efficiency secondary rechargeable battery technology
Greening of industry/ space	Improving efficiency in transportation	High efficiency low pollution vehicle technology
		Smart transportation, logistics technology
	Greener land	Eco-space construction and urban regeneration technology
		Environment-friendly low energy construction technology
	Environment-friendly manufacturing process, material efficiency improvement	Green process technology considering environment load and predicted energy consumption
Environment protection/ resource recycling	Weather change prediction, impact evaluation	Weather change prediction and modeling development technology
		Weather change impact evaluation and adaptation technology
		CO_2 collection, storage, treatment technology
		Non-CO_2 (Greenhouse gas other than carbon dioxide) treatment technology
	Water quality environment	Water system, water quality evaluation and management technology
		Alternative water resource securing technology
	Environment restoring	Harmful material monitoring and environment purification technology
	Waste treatment	Waste reduction, recycling, energy conversion technology
Non-pollution economic activity	Environment public health	Virtual reality technology

CMN clustering method was introduced by Clauset, Newman, and Moore. It is widely used as the clustering method for social network organizations. CNM clusters are based on the strength of connection between nodes and node separation method is used to perform the clustering.

This main advantage of CNM clustering is that modularity value can be calculated which can be used in clustering analysis. Modularity value ranges from 0 to 1 and the formula is below.

$$\text{Avw} = \begin{cases} 1 \text{ If verticies v and w are connected} \\ 0 \ \ \text{otherwise} \end{cases}$$

Suppose the vertices are divided into communities such that vertex v belongs to community *Cv*. Then the fraction of edges that fall within communities, i.e., that connect vertices that both lie in the same community, is

$$\sum_{vw} Avw\, \delta(Cv, Cw) / \sum_{vw} Avw = 1/2m \sum_{vw} Avw\delta(Cv, Cw) \quad (1)$$

where the δ-function $\delta\,(i, j)$ is 1 if $i = j$ and 0 otherwise, and m = $1/2\sum vw\ Avw$ is the number of edges in the graph.

This kind of quantity offers the advantage of expressing the standard of network division as a number despite the numerous nodes. In other words, when the network is sectored well, the modularity value should be very close to 1.

However, if we subtract from it the expected value of the same quantity in the case of a randomized network, we do get a useful measure. The degree *kv* of a vertex v is defined to be the number of edges incident upon it:

$$Kv = \sum_{\mathrm{w}} Avw \quad (2)$$

The probability of an edge existing between vertices v and w if connections are made at random but respecting vertex degrees is kvkw/2m. We define the modularity Q to be [12].

$$Q = \frac{1}{2m} \sum_{vw} [Avw - \frac{kvkw}{2m}] \delta(Cv, Cw) \quad (3)$$

Network density is measured based upon the concepts of inclusiveness and degree. Inclusiveness represents the number of actors interconnected in a network, and is calculated with the remaining numbers after subtracting the number of isolated nodes from the total number of nodes in the network. Degree signifies an extent that one node is connected to another node. In other words, the degree of a node indicates the number of other nodes directly connected to the specific node. To examine the accurate density of a network, inclusiveness and degree should be considered simultaneously. That is, in order to accurately measure density, the following two factors should be examined: how far the range of the network reaches; and how densely each node is connected to other nodes in the network.

This is expressed by the following formula:

$$\text{Network density} = \frac{k}{2g(g-1)} \quad (4)$$

K is the number of lines, and *g* is the number of nodes existing within the network. The denominator *g* (*g*-1)/2 are the maximum possible number of lines in the applicable network [13].

III. Method of Analysis

We have created the co-occurrence matrix table which is based on the fields of interest submitted by new GTNet members during registration as shown in Fig. 2–Fig. 3. in order to establish the network structure according to members' fields of interest. This is because GTNet operation system allows multiple overlapping selections for selecting fields of interest.

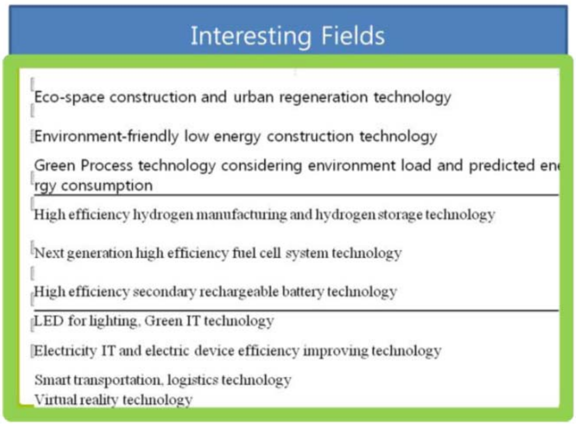

Fig. 2. GTNet operation system.

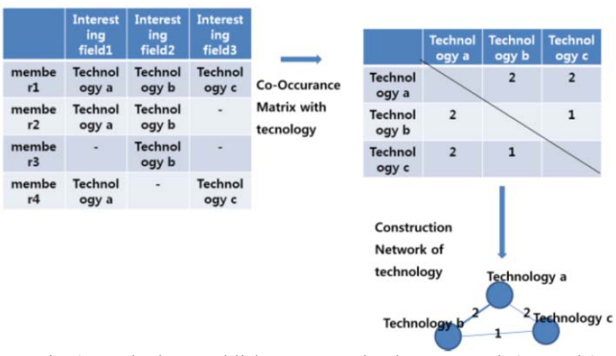

Fig. 3. Method to establish a green technology network (example).

CNM clustering and visualization of network structure was based on NetMiner 3.0 built by CYRAM. Currently, NetMiner is used for research in various social science fields such as social science, psychology, humanities, business administration, and economics. Also, it is used in fields of natural science and engineering such as physics, biology, industrial engineering, computer engineering, and natural science engineering. NetMiner is used for practicality in fields of organizational network such as personnel, organization, and knowledge management. It is also widely used for analyzing internet user networks such as SNS, and online communities (Fig. 2, Fig. 3) [14].

IV. Results of Analysis

We have determined through CNM clustering analysis on fields of interest that there are 5 clusters after removing independently categorized technologies. Cluster 1 is composed of green landscape, eco-friendly manufacturing process, and material efficiency improvement technologies. Cluster 2 is composed of battery cell technologies. Cluster 3 is composed of energy efficiency improvement technologies. Cluster 4 is composed of water quality, environment, waste processing, and energy generation technologies. Cluster 5 is composed of climatic change prediction and effect evaluation technologies (see Table II, Fig. 4).

TABLE II: Cluster Analysis of Green Technology Fields

Cluster Number	Field Code	Technological Field
1	GT030215	Eco-space construction and urban regeneration technology
	GT030216	Environment-friendly low energy construction technology
	GT030317	Green Process technology considering environment load and predicted energy consumption
2	GT010309	High efficiency hydrogen manufacturing and hydrogen storage technology
	GT010310	Next generation high efficiency fuel cell system technology
	GT020220	High efficiency secondary rechargeable battery technology
3	GT020218	LED for lighting, Green IT technology
	GT020219	Electricity IT and electric device efficiency improving technology
	GT030114	Smart transportation, logistics technology
	GT050127	Virtual reality technology
4	GT010105	Bioenergy production element technology and system technology
	GT010411	Environment-friendly plant growth facilitating technology
	GT040223	Harmful material monitoring and environment purification technology
	GT040224	Alternative water resource securing technology
	GT040425	Waste reduction, recycling, energy conversion technology
5	GT020112	Integrated gasification combined cycle technology
	GT040101	Weather change prediction and modeling development technology
	GT040102	Weather change impact evaluation and adaptation technology
	GT040121	CO_2 collection, storage, treatment technology
	GT040122	Non-CO_2 (Greenhouse gas other than carbon dioxide) treatment technology

Fig. 5 is network structure with green technology fields using GTnet member's interesting fields.

Density of network structure is 0.892. This means that Green technology fields have strong connection each other (Fig. 5).

We performed a cross analysis based on number of views on technologies in each cluster in order to analyze the relationship between clustered technologies and GTNet members' affiliation. As a result, p-value was 0.000 as Table

III shows, and we determined that there is a relationship between clustered articles and number of views by each members' affiliation (Table III).

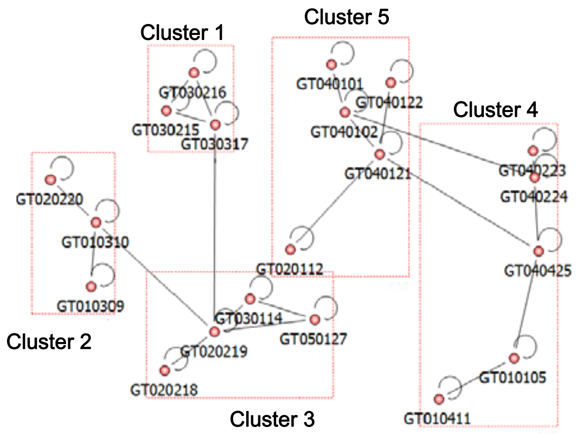

Fig. 4. Structure of green technological clusters.

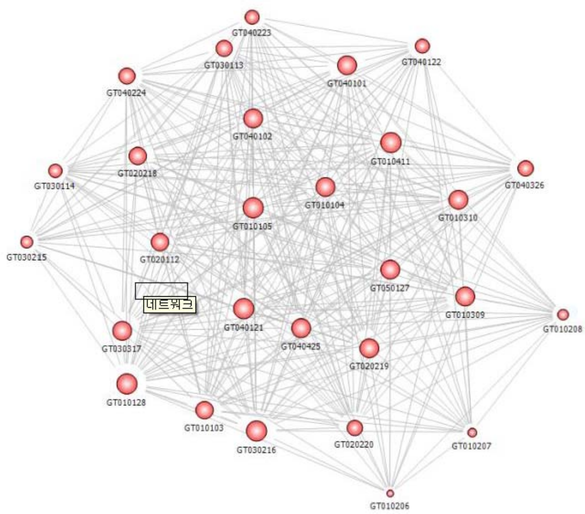

Fig. 5. Network structure with Green technology fields.

TABLE III: CHI-SQUARE TEST BETWEEN AFFILIATION AND CLUSTERS

	Value	Degree of Freedom	p-value
Pearson's Chi-square Test	166.74	16	.000
Fisher's Test	.000		.000

TABLE IV: CROSS ANALYSIS TABLE BETWEEN AFFILIATION AND CLUSTERS

Section		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Indust-ry	Frequency	3,844	5,429	8,448	5,409	3,134
	Expected Frequency	3,873	5,212	8,189	5,738	3,252
Resea-rch	Frequency	1,508	1,897	3,236	2,362	1,325
	Expected Frequency	1,523	2,050	3,220	2,256	1,279
Gover-nment	Frequency	317	415	685	377	286
	Expected Frequency	307	413	649	454	258
Acade-mic	Frequency	655	714	1,052	950	527
	Expected Frequency	575	774	1,215	852	483

TABLE V: CHI-SQUARE TEST BETWEEN INDUSTRY AND CLUSTERS

	Value	Degree of Freedom	p-value
Pearson's Chi-square Test	1,200.73	57	.000
Fisher's Test	.000		.000

If you look at the fields of interest by each type of member affiliation, Cluster 1 which contained green landscape, eco-friendly manufacturing process, and material efficiency improvement technologies was popular among the government and academic society affiliated members. This was determined by the fact that the frequency was higher than the expected frequency and Cluster 2 which contained battery technologies, was popular among industry and government affiliated members. Cluster 3 which contained energy efficiency improvement technologies, and clusters 4, 5 which contained environmental technologies, were popular among non-industry affiliated members (see Table IV).

We performed a cross analysis on specific fields of technology based on affiliation in order to determine the members' fields of interest for each cluster's specific technology. As a result, p-value was 0.000 and we determined that there was relationship between number of views by affiliation and each technological article (Table V).

If you look at the members' fields of interest by affiliation, industry affiliated members have expressed most interest in aquarium manufacturing/storage technologies, battery technologies, LED application, and electric IT technologies from Cluster 2, and 3. They also expressed interest in eco-friendly construction technology, and coal gasification as well. Researchers have expressed a lot of interest in toxic substance and substitute water resource technologies from Clusters 4, and 5. They have also expressed a lot of interest in eco-friendly and ecologically sustainable technologies from as well. Academic members expressed a lot of interest in green processing technologies, waste reduction and energization technologies, and climatic change's effect evaluation technologies. They have expressed a lot of interest in virtual reality technologies as well. The government members expressed a lot of interest in carbon dioxide output reduction technologies from Clusters 1, 4, and 5 (Table VI).

V. CONCLUSIONS

We have determined which green technologies share most similarities by performing a cluster analysis amongst green technologies using GTNet membership information and articles. Also, we have performed a cross analysis in order to determine the relationship between popularly subscribed green technological articles and investment strategies by each field of green technology. As a result, there were 5 clusters in green technology except the technologies that don't share any similarities. The interest level for each technological field varied by members' affiliations. Industry affiliated members expressed most interest in battery cell and IT technologies. Researchers and scholars mainly expressed interest in environmental fields. We can relate the timing of green technology industrialization to the period of green technology realization under the assumption that research bodies have different interests.

The secondary battery field has already been progressed commercialization and has been developed related Green vehicle, Green home and smart grid fields.

In this trend of research, Korea government has planning to construct “smartgrid test-bed” related secondary battery, rechargeable energy as wind power and solar cell in Jeju island. It has been started in 2008 and invested about 200 billion won and took a part in 12 consortiums composed of company related secondary battery field and rechargeable energy fields.

Fuel cell technology, is getting close to commercialization and the fuel cell businesses actually predict that fuel cells will be commercialized in 2015.

In the fuel cell field, Korea’s market has occupied mainly Korea’s industry as GS Fuel CELL, FUEL CELL POWER and Hyundai Hysco. Korea governernment has also supported cost of Fuel cell’s installation following “supply business of Green Home”.

In the field of construction technology, BEMS (Building Energy Management System) is rapidly being commercialized combined with solar cell technology field and LED lights are already developed to the point of commercialization with growing governmental support.

Non-carbon dioxide greenhouse gas reduction technologies, water quality and substitute water resource technologies, and climatic change prediction field is yet to be commercialized and these researches are mostly conducted by domestic laboratories.

The limitation of these results is that we only dealt with domestic professionals and therefore, it is very difficult to determine the overall trend of green technologies. However, this study was meaningful in the sense that we were able to analyze the level of industrialization and specialties of domestic green technologies through relationship analysis of clusters divided by number of views and their fields of interest.

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