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Eco - Innovation Strategies for Green Growth of Korean Manufacturing Industries

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Ⅰ. Introduction

Over the past decade, concern over the global environment has increased, especially focused on developed countries. It is recognized that increased greenhouse gases (GHG) have been causing global warming which is accompanied by rising sea levels, droughts, desertification, destruction of ecological systems, and unusual changes in weather. With the awareness of the global environmental crisis, international environmental regulations such as the Kyoto Protocol put constraints on GHG emissions and other pollutants and toxic materials.[1] However, there are different behaviors towards environmental regulations between developed countries and others which need more time to industrialize their economies.

In early 2008, the Korean government began to promote green growth (GG) as means to sustainable economic growth while resolving environmental problems. As a "bridge" country, Korea set up aggressive policies in response to global environment regulations. However, there are still problems,

1) As having legal force, Protocol set reduction targets for GHGs including CO2 and six pollutant gases which have been causing global warming. Protocol also declares in Section 3 that GHGs emission quantities should be reduced to at least 5.2% lower than those in 1990 in overall developed countries during from 2008 to 2012.

mainly from weaknesses in the private sector. It is also true that there is some confusion on the concept of and targets for green growth. From the perspective of eco-efficiency, there is no special difference between productive efficiency and environmental efficiency. Also, intermediate-suppliers have not faced serious environmental problems as producers of final goods would not enforce strict eco-efficiency standards on intermediate supply firms. This means that if producers of final-goods are not conscious of environmental problems, there might be no proper means to induce relevant firms to pursue eco-efficiency. In addition, markets have not recognized the importance of environment issues. Consumers are not overly concerned about environmental problems imposed on production firms but rather, are more concerned about the quality and prices of products. Hence, firms take account of environmental problems to the extent that their products or services can, at a minimum, meet environmental regulations.

In fact, the regulatory regime has shifted from the amount of pollutant or emission, to regulation levied on the products they sell. As examples, we noted ELV on cars and WEEE/RoHS on the electronic and electric appliances, which impose the environmental responsibilities on final products traded in the market.[2] This regulatory trend to-

2) ELV, WEEE, and RoHS stand for End of Life Vehicle, Waste Electrical and Electronic Equipment, and Restriction of Hazardous Substances, respectively.

wards the sustainable production and consumption implies that it becomes very important to manage the intermediate toxic materials and input resource quantities. In this paper I will provide several policy strategies by considering these regulatory trends and develop eco-innovation strategies for Korean manufacturers.

Ⅱ. Concept of Eco-Innovation

In general, Green Growth is defined as “sustainable economic growth” that accomplishes economic growth while resolving environmental problems. According to the situation and circumstances of each country, they have varying definitions and policy directions for GG. In Korea, in mid-2008, the government set up policy directions for GG by recognizing the importance of global environmental regulations and relevant economic issues. After that, the government has suggested applicable action plans through the MKE (Ministry of Knowledge Economy), the Prime Minister's office, and the GGC (Green Growth Committee). Recently the GGC submitted the GG National Strategies and 5-year Action Plan that synthesize government's policies and strategies for GG in its final policy report. In the report, most policies for GG were based on the eco-Innovation concept and supplements of traditional environmental policies.

This paper aims to introduce eco-innovation concepts and address policy instruments for the realization of such eco-innovation under Korean circumstances. Actually, eco-innovation has been dealt with many definitions. The EU defines eco innovation as “the production, assimilation or exploitation of novel products, production processes, services or in management and business methods, which

aims, throughout its life cycle, to prevent or substantially reduce environmental risk, pollution and other negative impacts of resource use (including energy)." (ETAP, Environmental Technology Action Plan) In Japan, Industrial Science Technology Policy Committee defines it as "a new field of techno social innovations that focuses less on products functions and more on [the] environment and people." (METI, 2007) Europe INNOVA defines eco-innovation as "the creation of novel and competitively priced goods, processes, systems, services, and procedures that can satisfy human needs and bring quality of life to all people with a life-cycle-wide minimal use of natural resources (material including energy carriers, and surface area) per unit output, and a minimal release of toxic substances." In the case of the OECD, the Oslo Manual clarifies the concept of eco-innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations." (OECD and Eurostat, 2005)

The concept of eco-innovation is constantly changing. The earlier approaches for eco-Innovation were centered on treatment, prevention, and management methods, which had limited effects in resolving environmental problems. In fact, in the treatment approach, non essential technologies are implemented, so they could not avoid "end-of-pipeline" solutions. That means that these approaches were only partial solutions, but not fundamental ones. However, fun-

damental and radical approaches have been adopted recently. Life-cycle approaches are extending environmental responsibility through CSR (Corporate social responsibility) and by considering GSCM (Green Supply Chain Management)

<Table 1> Conceptual development of eco-innovation

Pollution control	Treatment	Implementation of non-essential technologies (End-of-pipe solutions)
Cleaner production	Prevention	Modify products and production methods (-Process optimization: Lower resource input & output Subitution of materials: non toxic and renewable)
Eco-efficiency	Management	Systematic environmental management (-Environmental strategies and monitoring -Environmental Management Systems)
Lifecycle thinking	Expansion	Extending environmental responsibility (-Green supply chain management -Corporate social responsi- bility)
Closed-loop production	Revitalization	Restructuring of production methods (Minimizing or eliminating virgin materials)
Industrial ecology	Synergy	Integrate systems of production (-Environmental partnerships Eco-industrial parks)

Source : OECD(2009).

as SCM (Supply Chain Management) for efficient materials management.[3] Closed-loop production is moving to 'cradle-to-cradle' solution by restructuring production methods aiming at minimizing or eliminating raw materials. Moreover, industrial ecology is integrating the systems of production by coordinating environmental partnerships with stakeholders and establishing eco-industrial parks such as in the city of Kalunborg in Denmark.

In terms of the approach to eco-innovation, the OECD suggests that eco-innovation has three dimensions in which to earn efficient innovative effects: 1) Target: Products/Processes/Marketing methods/Organizations/Institutions 2) Mechanism: Modification/Re-design/Alternatives/Creation 3) Impact. In general, the concept of innovation should have a systematic and multi-dimensional approach, which should also be applied to eco-innovation and has been applied to real markets by global firms. Therefore, the heart of eco-innovation can not necessarily be represented by a single set of targets and mechanisms. Instead, eco-Innovation seems best created using an array of char-

3) SCM (Supply Chain Management) is a strategic approach which aims to maximize management efficiency and meet various demands from suppliers, customers, and inner organizations, by integrating and managing resource, information, money, and so on, from the overall perspective covering suppliers to customers. In comparison, GSCM (Green Supply Chain Management) or SCEM (Supply Chain Environmental Management) is to manage environmental parts of supply chains so as to resolve environmental problems.

acteristics-ranging from modifications to creations, across products, processes, organizations, and institutions. Such co-creative eco-innovation processes are often referred to as system innovations. Although the source of system innovations may arise from technological developments, technology alone cannot make significant differences. It has to be used in association with organizational and social structures, and human nature and cultural values. While this may highlight the difficulty of achieving large-scale environmental improvements, it also hints at the need for manufacturing industries to adopt an approach that seeks to integrate the various elements of the eco-innovation process in a way to leverage environmental benefits. The feasibility of these eco-innovative solutions would then be determined according to the organization's co-creative competency.[4)]

From the concept of eco-innovation, we see the implications of a proper systematic approach for eco-innovation in Korea. Moreover, we need to take account of eco-innovation strategies that accrue fundamental changes in not only technology but also organization, society, and cultural areas, which should be coordinated and work systematically. In order to secure efficient operation of eco-innovation, environmental policies should also provide assistance in the areas of material management, eco-Innovative activities by firms, and infrastructure establishment. In the

4) For more detail, refer to OECD(2009).

case of material management, it is necessary to set up targets for pollutants over the production and treatment process across all industrial sectors. There is also a need to support the operation of GSCM and the development of relevant converging technologies. In supporting eco-innovative firms, it is desirable to adopt market-based policy instruments including supporting the development and commercialization of technologies, setting up a beneficial tax system, and granting of subsidies. In terms of infrastructure, it is necessary to induce eco-innovation in private businesses through rebuilding the standardization system, strengthening education and training, and establishing cooperation and information networks.

Ⅲ. Eco-Innovation Case Study

1. The Cases of Global Firms

In response to global environment problems, global firms are driving eco-innovation through varying management instruments. In the car and transport industries, BMW, Toyota, and Michelin carried out vehicle's energy-efficiency

<Table 2> *Eco-innovative Companies*

Industry & company	Eco-innovation example
Automotive & transport industry	
The BMW Group	Improving energy efficiency automobiles
Toyota	Sustainable plants
Michelin	Energy saving tyres
Iron & steel industry	
Siemens VAI, etc.	Alternative iron-making processes
ULSAB-AVC	Advanced high-strength steel for automobiles
Electronics industry	
IBM	Energy efficiency in data centers
Yokogawa Electric	Energy-saving controller for air conditioning water pumps
Sharp	Enhancing recycling of electronic appliances
Xerox	Managed print services

Source : OECD(2009).

improvements, environment-friendly factory establishment, and energy-saving tire development, respectively. In the iron and steel industries, Siemens VAI adopted a new steel-production process, and ULSAB-AVC realized the development of high-strengthened steel for vehicles. In electronics, Yokogawa Electronics developed an energy-saving controller for water pumps of air conditioners, and Sharp improved the recycling of electronic appliances, and Xerox provided copier services. In copy services, Xerox has been providing services for consumers and maintaining ownership of their copiers. Consumers can use copiers instead of purchasing the copier itself.

These cases illustrate the patterns of eco-innovation strategies by global firms which change from the revision of products or processes to forms of creation. For example, targets for eco-innovation are not limited to products and processes, but extended into marketing or the organization. In the mechanisms of eco-innovation, they also present the application of new designs, the adoption of alternatives for production or marketing, and the creation of new business models. As for eco-innovation firms in Europe, there is a dramatic increase in cases where firms pursue non-technology changes for eco-innovation in areas of organization or marketing. Also, across manufacturing industries eco-innovators have carried out more non-technology changes rather than non eco-innovative firms. (Europe INNOVA, 2008)

2. Eco-innovation Policies of Developed Countries

Most developed countries established national eco-innovation strategies based on public opinion. They also provide incentives for green technology developments and eco-innovative activities of firms. The United States supports green technology development and the development and commercialization of green technologies by funding SMEs (Small and Medium Enterprises). In the UK, this strengthened the economic synergy effect by establishing an open cooperative network and thus encouraging firms to spontaneously participate in the relevant markets. In comparison, Japan has been operating several systems like environmental technology assessment programs, dynamic standardization systems, and environment management systems for SMEs. After assessing public opinion in response to environmental problems, France carried out eco-innovation strategies by adopting a functional approach and concentrating on core areas.

<Table 3> Eco-Innovation Strategies of Developed Countries

Countries	Contents of Strategies	Program
U.S.A.	*Formulation of cooperation strategies between private and public sectors for green manufacturing *Establishment of supporting center for eco-Innovation	*SMI(Sustainable Manufacturing Initiative) *NCEI(National Center for Environmental Innovation)
	*Assistance of green technology development and early stage of technology development by SMEs *Provision of various supporting policies for green technology development	*SBIR(Small Business Innovation Research), TCF(Technology Commercialization Fund) *Hydrogen, Fuel Cells & Infrastructure Technologies Program, R&D Continuum, Technology Innovation Program
UK	*Making of comprehensive industrial policies in response to environment (2009) *Establishment of cooperation committee of public and private sides for policy making (2007)	*Low Carbon Industrial Strategy *CEMEP(Commission on Environmental Markets and Economic Performance)
	*Building up of cooperation network open to spontaneous participation by firms *Support of green technology commercialization ·Varying cooperation networks	*NISP(National Industrial Symbiosis Program) *ETF(Environmental Transformation Fund), Carbon Trust *Centre of Excellence for Low Carbon and Fuel Cell Technologies, Energy Research Partnership, Knowledge Transfer Networks
Japan	*Setting half reduction target of GHGs emission up to 2050	*Cool Earth 50 Initiative
	*Green technology evaluation program, Product standard labeling system, SMEs' environmental management system etc.	*ETV(Environmental Technology Verification), Top Runner Program, Eco Action 21
France	*National opinion collection in response to environmental problem (2007~2008) *Establishment of committee for action plan making	*Environmental Roundtable *COSEI(Strategic Committee of Eco industries)
	*Support of green technology development, eco-innovation firm and SMEs, and technology commercialization funds	*PRECODD(Research Program on Eco-technologies and Sustainable Development, FCPI(Mutual Funds for Innovating Enterprises, FCP-ISR, Demonstrators Fund

Source : OECD(2009) and Europe INNOVA(2008).

Ⅳ. Eco-Innovation in Korean Economy

1. Industrial eco-innovation behavior

The manufacturing industries of Korea show relatively high consumption of energy concentrated on fossil fuels. The portions of energy consumption are 57.5% for industry, 20.4% for transportation, 19.8% for buildings, and 2.3% for the public sector. The national energy efficiencies of OECD countries are recorded as 0.13 (toe/thousand dollars) for UK, 0.15 for Japan, 0.16 for Germany, 0.16 for France.[5] By contrast Korea recorded 0.22 which passes the OECD average, 0.18. However, in early 2008, the Korean government began to heavily promote green growth as a sustainable economic growth while resolving environmental problems. After that, many environment-related policies were planned and put into practice. Before addressing Korean policies, this section shows the patterns of industrial response to global regulations like environmental management.

In Korea, at the firm level, many companies tried to meet international guidelines for environmental problems. As of 2008, 179 companies have been designated as Environ-

5) The dollars are on the basis of the PPP (Purchasing Power Parity) in 2000.

<Figure 1> Designation of Environmentally Friendly Companies

Source : ME's Environmental Statistics Portal

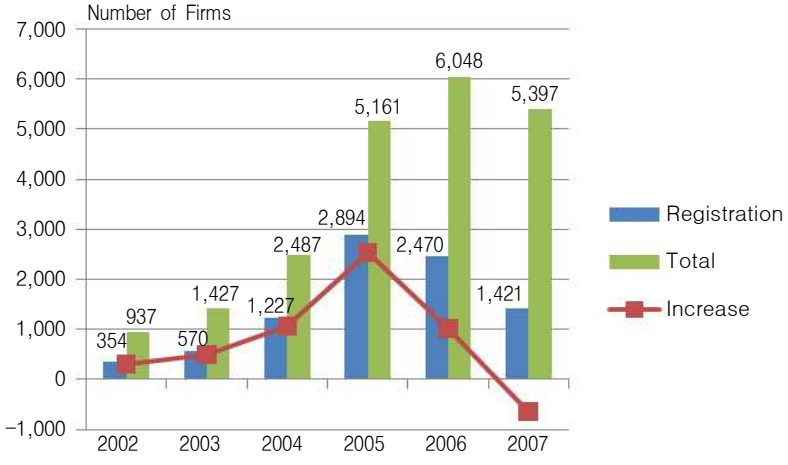
mentally Friendly Companies. The number of environmental friendly companies has been increasing since 1999 when Korea was recovering from the Asian financial crisis of 1997. In particular, after 2002, when WEEE and RoHS were enforced, the EFC numbers increased rapidly. Moreover, Korea adopted the Act on Environmentally Friendly Products and Promotion Act on Environmentally Friendly Purchasing in 2004. This made companies more aware of the importance of environmental management, which connects with the increased number of EFCs.

Another measure of environmental friendly companies is the ISO 14001 certificate, the increase of which did not appear until early this decade.[6] The following figure

6) The ISO 14000 is a standard for environmental management systems

shows that in 2005 there was the peak in the increase in the number of ISO 14001 certificate companies. This was influenced by the international and domestic regulations, namely WEEE and RoHS in 2002, and the Act on Environmentally Friendly Product and Promotion Act on Environmentally Friendly Purchasing adopted in 2004.

<Figure 2> ISO 14001 Certification Trend



Source : ME's Environmental Statistics Portal

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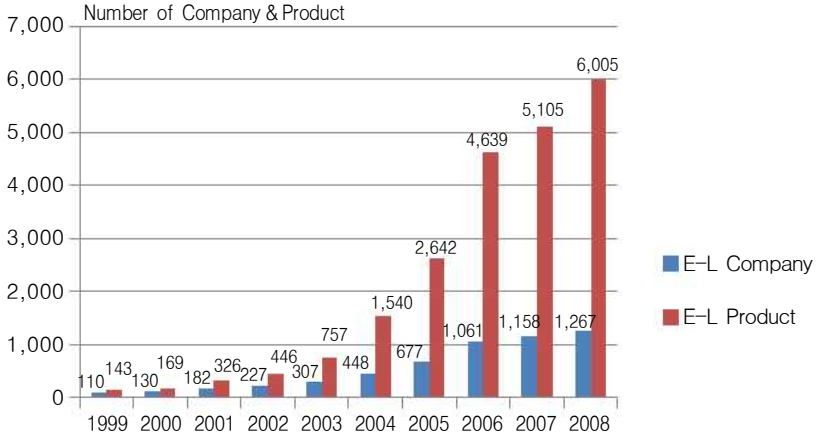
that is applicable to any business, regardless of size, location or income. The aim of the standard is to reduce the environmental footprint of a business and to decrease the pollution and waste a business produces. The most recent version of ISO 14001 was released in 2004 by the International Organization for Standardization (ISO) which has representation from committees all over the world. In order for an organization to be awarded an ISO 14001 certificate they must be externally audited by an audit body that has been accredited by an accreditation body. (Wikipedia)

<Figure 3> Eco-labeling Company and Product Trend

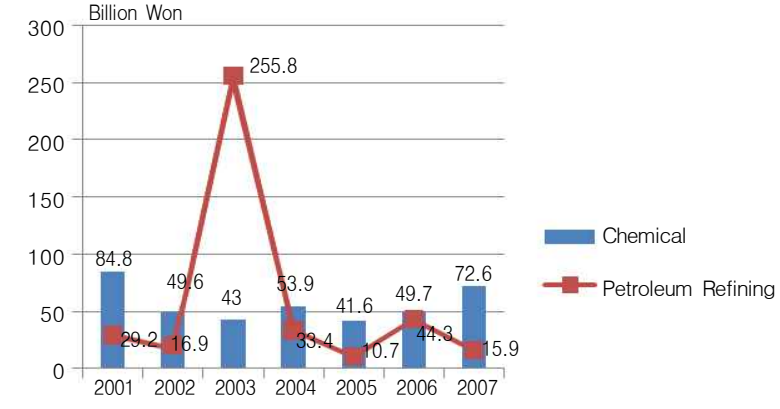


Source : ME's Environmental Statistics Portal

The trends of eco-abeling for companies and products also show rapid increases along with the strengthened regulations, as shown in Figure 3. In particular, the eco-beling of products has been increasing at higher rates compared with the eco labeling companies.

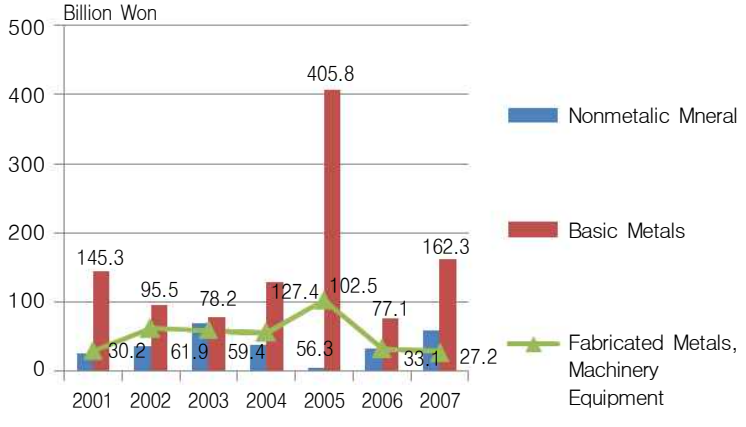
Figure 4, 5, and 6 show the investment in the protection of environmental pollution by major industries, 1) chemicals 2) petroleum refining 3) nonmetallic minerals 4) basic metals 5) fabricated metals, machinery, and equipment 6) transport 7) electronics 8) and ICT equipment. First, in Figure 4, the petroleum refining sector shows a peak in investment in environmental protection in 2003, which amounted to 255.8 billion won.

<Figure 4> Industries' Investment in Protection of Environmental Pollution - Chemical & Petroleum Refining



Source : ME(2008).

<Figure 5> Industries' Investment in Protection of Environmental Pollution - Nonmetallic Mineral, Basic Metals & Fabricated Metals.

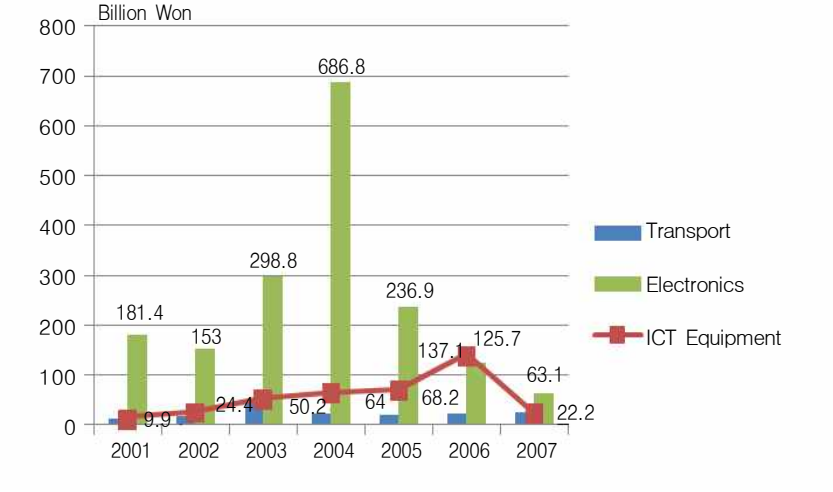


Source : ME(2008).

Figure 5 shows that the basic metals and fabricated metasl, machinery, and equipment industries have the highest investment in environmental protection in 2005, which amounted to 405.8 and 102.5 billion won, respectively. On the contrary, in the case of the nonmetallic mineral industry, the amount of investment in environemental protection was lowest in 2005.

In Figure 6, the sectors of transport, electronics, and ICT equipment show different investment in environemental protection. For example, the transport sector has kept a steady pattern of the investment in environmental protection. By contrast, the electronics sector peaked in their investment in environmental protection in 2004, which

<Figure 6> Industries' Investment in Protection of Environmental Pollution - Transportation, Electronics & ICT Equipment



Source : ME(2008).

<Table 4> Environmental Management Practices by Companies

		Environmental Management	No Environmental Management
Firm Size	Large	76.7%	23.3%
	Small and Medium	48.5%	51.5%
Industry	Manufacturing	72.5%	27.5%
	Non Manufacturing	39.0%	61.0%

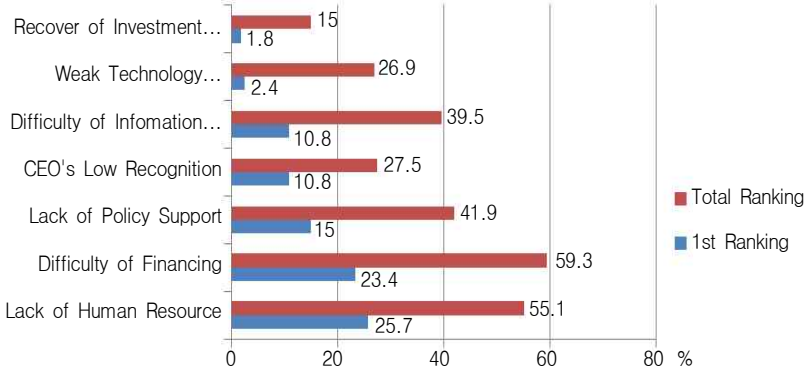
Source : ME(2007).

amounted to 686.8 billion won. In the case of ICT equipment, the highest amount of investment in environemental protection was recorded in 2006, which amounted to 137.1 billion won.

This section looks at corporate behavior toward Environmental Management in Korea. As shown in Table 4, large firms have a higher portion of carrying out environmental management practices, 76.7%. In contrast, SMEs have a comparatively lower rate of environmental management practices, 48.5%. The manufacturing sector also has a higher rate of environmental management activities, 72.5%, compared with 39.0% in the non manufacturing sector.

Figure 7 shows the reasons for no adoption of environmental management practices. According to rank, difficulty in financing had the highest response rate of reasons why the companies would not adopt environmental management activities, which amounts to 59.3%. The second most common reason was thelack of human resources,

<Figure 7> Reason for Not Adopting Environmental Management Practices

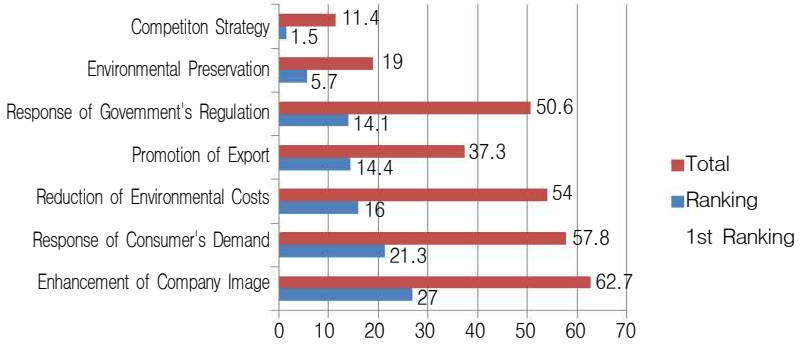


Source : ME(2007).

which amounts to 55.1%. However, the order of importance was reversed, that is, the difficulty of financing has 23.4% and lack of human resources was 25.7%. The lack of policy support was recorded by 41.9% of respond- ents, the third most common response.

In terms of their motive for environmental management, enhancement of company image, response to consumer de- mand, and reduction of environmental costs have 62.7, 57.8, and 54%, respectively. These priorities are no different in terms of total ranking and 1st ranking methods. Another common response was shown in response to government's regulation, which amounted to 50.6% as the fourth most common response in terms of total ranking.

<Figure 8> Motive for Environmental Management



Source : ME(2007).

Table 5 shows how manufacturing firms respond to global environmental regualtions. The most common response was 18.3% for RoHS regulations, compared with 6.8% for WEEE, 5.3% for Montoreal Protocol(CFC regulation), and 4.9% for ELV regulation. In contrast, in terms of 'adoption under way', the responding rate for REACH has the highest figure, which is 14.1%. Other common responses to global regulation are 11.8% for RoHS, 11.4% for Framework Convention on Climate Change, and 6.5% for WEEE. By contrast, companies with no recognition of global regulations were 24.7% for the Montreal Protocol(CFC regulations), 24.3% for REACH, 20.2% for ELV and 20.2% for the Framework Convention on Climate Change. Overall, companies have not made serious preparations for REACH, the Montreal Protocol(CFC regulation), the Framework Convention on Climate Change, or the ELV, in order of being written.

<Table 5> Adoption of Response System for Global Environmental Regulation

	Adoption of Responding System (%)		No Adoption (%)			Respond-ing Rate (%)
Environmental Regulation	Complete	Under way	Plann-ing	No Recognition	No Relation	
REACH(Registration, Evaluation, Autho-rization and Restric-tion of Chemicals)	4.2	14.1	15.2	24.3	42.2	31.7
RoHS(Restriction of Hazardous Substances)	18.3	11.8	8.4	15.2	46.4	56.2
WEEE(Waste Electrical and Electronic Equipment)	6.8	6.5	10.6	18.3	57.8	31.5
ELV(End of Life Vehicles)	4.9	4.2	5.3	20.2	65.4	26.3
Framework Convention on Climate Change	3.0	11.4	14.4	20.2	51.0	29.4
Montreal Protocol(CFC Regulation)	5.3	6.1	9.5	24.7	54.4	25.0

Source : ME(2007).

2. Eco-innovation policy and its limitation

In fact, eco-innovation can be measured or analyzed quanti-tatively by adopting several measure indices as follows: (1) Input measures: e.g. R&D expenditures, R&D personnel,

other innovation expenditures (such as investment in intangibles including design expenditures and software and marketing costs) (2) Intermediate output measures: e.g. the number of patents; numbers and types of scientific publications (3) Direct output measures: e.g. the number of innovations, descriptions of individual innovations, sales of new products from innovations (4) Indirect impact measures: e.g. changes in eco-efficiency and resource productivity.[7] Other measuring indexes for "greenness of national innovation systems" can be illustrated through environmental standards, environmental education, collaboration, venture capital, subsidy schemes and market based instruments. However, although such factors might help to measure the degree of eco-innovation, it is difficult to configure whether an eco-innovation system works well, or not, from the perspective of synergy effects. In this paper, we intend to point out some weaknesses in the eco-innovation strategies in Korea, in terms of synergy effects and system coordination.

First, eco-innovation policies focus on supply-side support, which can cause weak competitiveness of firms in relevant markets. The current manufacturing eco-Innovation policies mainly consist of R&D support, establishment of green clusters, green partnerships between major firms and SMEs, etc. However, these policies do not automatically guarantee success in manufacturing. In fact, it is

7) For more detail, refer to OECE(2009).

claimed that the concerns of firms reflect market demands more than overcoming supply-side difficulties including technology development. In Europe, 40% of eco-innovators recognize the demands of consumers as a decisive element of eco-innovation activities. (ZEW, 2007) Moreover, the eco-innovation policies have not properly supported non-technological eco-innovation, which comes from the fact that they take focus on technology elements in carrying out eco-innovation. Accordingly, it is necessary to support various non-technological innovation activities of firms including new business creation, and product service systems.

Secondly, policies for the development of green technologies are not efficiently operated in the way where we can expect synergy effect between the manufacturing industries. For example, the core areas of R&D are traditional green technologies, which are related to the utilization technologies of renewable energy, and clean energies. However, green technologies are expanded into the convergence of IT, BT, and NT or incumbent products or industries, so as to gain greater economic impacts. (MOSF et al, 2009) Basically, we should focus on the many opportunities to develop converging technologies between the inner or inter manufacturing sectors. These technologies can have greater effect on the manufacturing industries with the high utilization rate of technologies. Actually, the 27 core technologies suggested by the government are including the technologies associated with

wastes reduction, reuse, and transformation into energy which, in part, are involved in converging technologies. However, we need to extend R&D supporting technology areas, so as to strengthen the synergy effects of technology development in the manufacturing industries. The first step to creating synergy effects from technology development can be achieved by promoting inter industry sharing or utilization of resources, waste, and pollutants. Such cooperation with other companies provides opportunities to develop converging technologies which can enhance resource utilization between inner and inter industrial sectors. The government should be able to reflect new plans on technology development by providing incentives for cooperative R&D projects in forms of matching funds, subsidies, or taxation incentives.

Thirdly, the eco-innovation strategies do not provide proper incentives to induce the stakeholders to participate in eco-innovation fields. Even in establishing of eco-Innovation strategies for the manufacturing industries, there is no mechanism to induce spontaneous participation, which implies that it is difficult to expect practical effects of the policies. Therefore, it is necessary to guarantee relevant stakeholders spontaneous participation and free determinations, in establishing a national eco-innovation system including standardization, R&D, and an eco-labeling system. In the sense that such a strategy can ensure policy consistency and effectiveness, there is a weakness in green technology development policy. In the policy

making, three different actors are involved in the planning process, action planning, and coordination and management, respectively.[8] Such a policy making system might make it difficult to maintain the original intentions for technology development, for example, reflecting public opinion. Therefore, there is necessity for an open cooperation network and eco-labeling system which can provide various commercial opportunities through guaranteeing the companies spontaneous participation in determining policy and strategy.

8) In the government's overall green technology development policy, first the ministries altogether make a synthetic plan and then they will plan specific action plan individually, while NSTC (National Science & Technology Council) is supposed to coordinate the action plans by adjusting conflicting interests. (MOSF et al., 2009)

V. Eco-Innovation Strategies for the Manufacturing Industries

Environmental policies traditionally focused on the treatment of pollutions and wastes and this focus has been to a large extent on end-of-pipeline solutions. In order to avoid these problems, we should set up a well-organized eco-innovation system that will encompass the entire production and disposal processes. Such an overall approach should be adopted not only in the engineering field but also in the policy-making area. In this sense, it is not expected that Korean eco-innovation policies will have synergy effects because they have little correlation with other policies. In fact, systematic eco-innovation can solidify the cooperative relationships of stakeholders and their eco-innovation activities. The other important point is that, in order to carry out national eco-innovation efficiently, it is necessary to adopt a multi-dimensional approach for eco-innovation by extending cooperation networks even into different industries and strengthening political support for various non technologically eco-innovative activities. Of course, we also need to induce actors to participate in resolving environmental problems by guaranteeing interactive decision-making for eco-labeling and standardization system, so as to support the eco-innovation system.

1. Reinforcement of industrial symbiosis

In this paper, we suggest methods to attract industrial symbiosis that engages traditionally separate industries in a collective approach. In this view, SCEM needs to be broadly extended to a large scale within and between manufacturing sectors. In general, SCEM is applied to vertical integration between up and downstream firms within the same industry, which can maximize the efficiency of management by, from the overall perspective, integrating the management of the supply chain including resource, information, and money. This approach can be applied to the extended supply chain management between different industries through physical exchange of materials, energy, water, and by-products. This can alleviate the costs from the environmental regulations levied on vehicles (ELV) and electrical and electronic equipments (WEEE and RoHS) which mean that the regulations on the specific products aim at inducing markets to manage the usage of resources and toxicity of material. For example, car makers, chemical factories, and IT product makers can create synergy effects from integrating the management of resource sharing, reuse of emission and pollutant, and redesign of process for treatment of materials.

In supporting green technology development, SCEM is also applicable to the derivations of converging green technologies between different industrial areas. As promoting more SCEMs between industrial sectors, it can

naturally lead to more ideas on the development of green technologies benefiting several industrial sectors. In this view, the openness of SCEMs needs to be guaranteed in participating in the network with a technology development plan which might be supported by the government. However, although the environmental contribution of industrial symbiosis come predominantly from the perspective of the resource savings or reductions in pollution emissions, the approach could be linked to the perspective of regional innovation activities, in particular in relation to eco-innovation clusters. In addition, it would also desirable for eco-innovation clusters to be open to potential technology developers which can create synergy effects on other firms and industrial areas. Denmark has a good model for such an eco-innovation cluster, the Kalundborg eco-park. The park links a coal-fired power plant, refinery, pharmaceutical and industrial enzyme plant, plaster board factory, soil remediation company, and municipality through the town's heating facility, by exchanging 2.9 million tons per year across each operation. This park could be expanded into a broad sector-linked cluster by allowing free entry into the park for cooperation with other sectors to cope with the environmental problems for common benefits.

2. Promotion of non-technology eco-innovation

The adoption of more integrated and systematic methods

to improve sustainability performance has laid the foundation for non-technology innovation. As mentioned earlier, the importance of non-technology eco-innovation is being given more attention from the perspective of policy as well as from enterprise's strategy.[9] Non-technology innovative activities consist of organizational reform, creation of a new business model, green marketing, and product-service system. Such non-technology innovative activities need to be promoted by linking up with an eco-mark labeling system which should be able to reflect overall eco-innovative competency of firms. In order to reflect a firm's competency for eco-Innovation, an eco-mark labeling system should consider eco-innovation guidelines for not only technology innovation on products or processes, but also non-technology innovation activities. To achieve policy effectiveness, the support system, including taxation, financing, and subsidies, needs to be linked with the eco-mark labeling system.[10]

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9) Importantly, eco-innovators make more use of non-technological change than the average innovative company (across all sectors). This suggests that organizational and marketing innovations are an important element of eco-innovation.(Europe INNOVA, 2008)

10) Tax incentives for R&D and innovation may influence decisions to carry out innovation activities. In general, there are mainly two ways in which the national taxation system may influence innovation activity of firms: 1) R&D allowances: Firms may fully claim current R&D expenses in the year of their expenditure. 2) R&D tax credits: Tax credits allow firms to deduct a certain percentage of their R&D expenses directly from their tax burden. (Europe INNOVA, 2008)

Another integrated and systematic method to improve sustainability is product service systems (PSS).[11] Moving towards better environmental performance through material flow reduction has led to a more integrated approach of PSS. PSS encourages companies to increase the re-use and re-manufacturing of products. Whereas traditional manufacturing focuses on the production and supply of goods to consumers, a PSS focuses on the delivery of consumer utility and product functionality. For example, when producing and supplying photocopiers to their consumers, a company based on the PSS model retains product ownership by supplying the photocopier as a function such that consumers only purchase the copying service and not the product itself. This service system leads to internalizing the costs of product maintenance, retirement, and replacement for the producer's profit maximization objectives. Whereas companies need not sell more products to maximize profits, they can make profits by minimizing material consumption and increasing product re-use, recycling and re-manufacturing. Another environmental benefit of PSS could be gained from increasing product-use intensity, by sharing the same products among many consumers. The application of PSS, therefore, may lead to a radical reduction in the production of physical goods and

11) PSS is a business model which focuses on the delivery of consumer utility and product functionality instead of focusing on the production and supply of physical goods to consumers as seen in the traditional model. (OECD, 2009)

thus less material consumption and waste generation.

From the policy perspective, the government needs to provide consulting on new business model, PSS, reformation of organization and other non-technological eco-Innovation strategies. The information on non- technology Eco-Innovation strategies will be able to make firms realize eco-innovation in more creative ways. In particular, if the government can provide information on which businesses and firms are suitable to PSS and how they can organize PSS, such information will be so helpful to the firms trying to carry out eco innovation. Moreover, in order to heighten consumers' awareness of environmental problems, the government needs to apply PSS to public area. For example, the City of Paris in France introduced a self-service bike sharing system *Velib.*

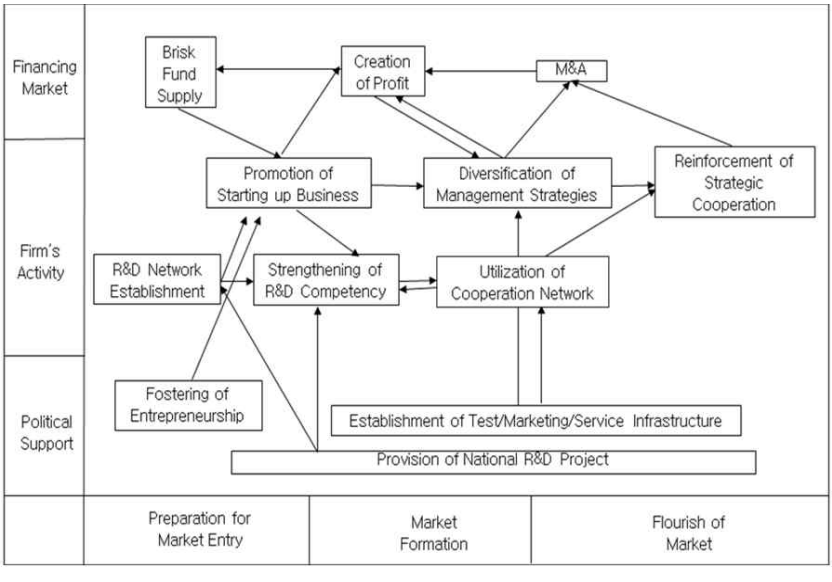
3. Dynamic approach to eco-innovation

In order to establish a synthetic eco-innovation system, we should consider a dynamic approach. Actually, a dynamic approach is being applied in part through the current government's plan. For example, green technologies are classified into three groups in accordance with the target time period, that is, short,-mid,-and long-term development strategy. We need to develop an approach which is applicable to the complicated market structures and firm organizations. In this paper, we present a dynamic approach that differentiates innovation strategies in

accordance with the development stages of markets and firms.

The dynamic innovation system can show how innovation works at each development stage and with each economic actor, as in Figure 8. At the stage of preparation for market entry, it is important to supply risk-management funds, and strengthen R&D competency in each firms by establishing an R&D network, and foster entrepreneurship so as to promote business start-ups. At the second stage of market formation, firms can create profit by diversifying management strategies and utilizing cooperation networks. From the policy perspective, it is necessary

<Figure 9> Dynamic Approach to Innovation - Industrial Policy



Source : KIET(2008).

<Table 6> Innovation Strategy Complying with Firm Development Stage

Stage / Sphere	Pre seed	Seed	Starting up business			Formation of Market	Flourishing Market
			Shortterm	Mediumterm	Longterm		
Financing	Individual funding	Angel capital		Venture capital		IPO	Loan
Tech-nology	Idea stage	Developmen t	Ownership	Dissemination		Commercializatio n	Varying tech. acquisition
Productio n			Production infrastructure establishment			In house production	Strategic cooperation
Marketing			Marketing infrastructure establishment				Strategic cooperation
Sale			Sale infrastructure establishment				Strategic cooperation
R&D	Basic research	Developmen t research	Applied research			Tech. combining	Tech. converging
Outside Network			Collaboration	Licensing out	Licensing in	Strategic cooperation	M&A
Innovation activities	Entrepreneur ship Know-ledge accu-mulation of basic science	Collaboratio n with aca- demy & public institute	Fund supply by venture capital Prod./marketi ng/sale infrastructure Human network extension	Fund supply by venture capital Expertise of tech. evaluation Cooperation structure with large firm		Tech. evaluation system Tech. trade market	Financing capital Inter discipline collaboration Deregulation on M&A International cooperation

Source : KIET(2008).

to establish test/marketing/service infrastructure and pro-vide national R&D projects to the firms. At the final stage of flourishing market, the firms need to reinforce strategic cooperation through diversifying management strategies and utilizing cooperation networks. These management strategies can be developed into M&A activities, which need to be promoted by supporting with policies and institutions.

In relation to the innovation system depicted in Figure 8, Table 6 shows that innovation strategies comply with firm development stages. In Table 6, the following activities are illustrated as important innovation strategies: entrepreneurship, knowledge accumulation of basic science, funds through venture capital, production/marketing/sale infrastructure, human network extension, financing capital, interdiscipline collaboration, and deregulation on M&A activities. These strategies are not entirely different from the innovation strategies applied to market development stages in Figure 8, apart from technology evaluation system, technology trade market, and international cooperation.

4. Market-friendly support system

In order to cope with environmental problems, we need to achieve dramatic innovation through future technologies. This is because of the characteristics of environmental technologies as mentioned in OECD (2009). "This is why there is relatively little environmental R&D. First is the importance of government policy in creating demand by regulatory and other environmental instruments. Second is the fact that R&D in environmental innovations is often very complex because it usually involves various scientific and technical disciplines and the necessary competence may not be available in the company undertaking the research." Therefore, in accordance of the characteristics of green technologies, we should establish proper a tech-

nology development support system.

One of the most important points in establishing an R&D system is to support for the high possibilities of market-failure of green technologies. The market-failure of green technology related R&D can come from high R&D costs connected to high prices as well as R&D competencies of firms. From this point of view, we need strengthening of company-centered cooperation or collaboration among companies, academies, and public institutes. The company-centered R&D system might be formed in the way where the companies take on a major role in drawing up the specifications of technologies, the academies and public institutes carry out R&D collaboration with the companies, and in the final stage, public institutes test and prove the performances of the developed technologies. For example, as illustrated in the OECD (2009), Econo-Pilot made it possible to control the pumping pressure of air conditioning systems. That is, Econo-Pilot can reduce the annual pump power consumption by up to 90%. Actually, Econo-Pilot was based on the technology devised by Yokogawa jointly with Asahi Industries Co. and First Energy Service Company. It was developed and demonstrated through a joint research project with the New Energy and Industrial Technology Development Organization (NEDO).

Another market-based R&D support policy instrument is to extend special fund for the development and commercialization of green technology by SME. Such com-

mercialization-oriented support can make firms closer to markets. In case of the U.S.A., The Department of Energy (DOE) provides Technology Commercialization Fund (TCF) so as to complement "angel" investment or early-stage corporate product development.[12] The OECD (2009) introduces the fund as follows: "The TCF brings the DOE's national laboratories and industry together to identify technologies that are promising, but face the "commercialization valley of death". It makes matching funds available to any private sector partner that wishes to pursue deployment of the technology identified." Besides support for SMEs, it also needs to support the development of next-generation technologies and preparatory activities for their commercialization including informing on technology benefits publicly. In the U.S.A., for example, the DOE's Hydrogen, Fuel Cells and Infrastructure Technologies Program supports the development of next generation technologies, and establishes an education campaign that communicates potential benefits.

5. Risk management on green technology development

Regarding green technology development, countries need to prepare for market failure which stems from the fact

12) The fund amounts to USD 14.3 million in fiscal years 2007 and 2008.

that R&D for green technologies comes with high costs. Therefore, we need a risk management system for green technology R&D, because depending solely on the markets could make it difficult to derive proper investment from the markets. In this paper, we suggest two market-based investment-inducing strategies as risk management on green technology R&D.

First, in order for a market-based innovation system to work well, it is important to promote start-up businesses based on their technology. Although it is easier to start up business with high potential technologies, non-technological barriers can make starting up a business difficult. As in the case of the U.S.A., financing is likely to face a capital "chasm" at the stage of start-up and early business. [13] Therefore, it is necessary to support financing by raising various funds at the early stage of starting up business. First, at the early start-up stage, technology-guaranteed financing should be supplied to firms so as to promote technology-based start up businesses. In the case of small enterprises, the main source of funding is government grants, it is necessary to diversify financing measures for

13) The traditional funding gap has been between seed and early stage investments at the $500,000 to $2 million range, where individual investors can no longer make investments. Recently, the gap has been widening as VC firms are shifting investments to focus on more mature firms with larger capital needs. Entrepreneurs report difficulty in raising money between $2 million and $5 million. (CoC, 2004)

<Table 7> Funding Gap in Risk Capital

Stage Funder	Pre Seed	Seed	Start up/Early	Mid	Later
Friends & Family	■	■			
Individual Angels		■			
Angel Networks/Funds			Capital Chasm		
Venture Funds				■	
Venture Funds					■
Investment Level	$25,000 to 100,000	$100,000 to 500,000	Between $500,000 and $5M	$5M and up	

Source : CoC(2004).

Note : The shaded cells indicate that investors are investing at the corresponding stages.

small-sized firms. For this end, various incentives should be provided to the private sector including policy funds, loan from commercial banks, increases in capital from newly issued stocks, and venture capital. For example, the government can help to develop financing routes by providing government grants or policy funds as some portion of seed money.

Another approach of alleviating risk from market failure is to adopt real option method in high technology projects like green technology R&D. In fact, the real option approach offers reactive flexibilities: an option holder can respond to environmental conditions and maximize his or her payoff, that is, they can decide whether to make the

investment and realize the payoff, and if so, when to invest.

The real option approach executes greater comprehensive valuation, by considering the time to expiry, the uncertainty of expected cash flows, risk-free interest rate, value loss over the duration of the option as well as the present values of fixed costs and expected cash flows. However, it is true that the NPV (Net Present Value) approach recognizes only two variables: the present value of expected cash flows and the present value of fixed costs. In making an early investment in radical innovation projects, the real option approach can help investors to enter into starting point of an investment in the projects. In order to adopt this approach, the government should also establish an assessment system for technology and investment value.

6. Inducement of market participation

In order to benefit from the effectiveness of policies, it is desirable to provide the market with incentives to participate voluntarily in standardization and e-marking scheme. In establishing a standardization system, first, it is necessary to adopt an adjustable one like Top Runner Program launched in 1998 by Japa's Ministry of Economy, Trade and Industry (METI). The program, first, sets performance targets for enterprises. It adopts a process of setting and revising standards by in principle taking the

highest energy efficiency rate of the products as a benchmark instead of setting fixed targets. This system can expect to create positive incentives and competition among manufacturers for quickly improving their product performance without the need for financial support or bias towards existing or outdated technologies that may cause innovation inertia. However, Nordqvist (2006) addressed its weakness as follows: "The most common critique directed at Top Runner in Japan is that the approach only encourages incremental technical improvements, while more radical innovations receive no incentives under the scheme." That is, if standard-setting procedures do not properly account for the actual technological potential, the program might run the risk of being sub-optimal. In this sense, it is important to consider the development of parallel policies to the scheme (e.g. labeling, green procurement laws, and green vehicle tax relief scheme in Japan). In this case, it might be effective to launch from the beginning, an entire package of coordinated policy instruments (Nordqvist 2006). In Japan, the program is supplemented by the eco-mark labeling scheme to help consumer choices at the point of sale. The program currently is being operated in selected 21 segments of markets for household and office appliances, vehicles, and vending machines.

Voluntary participation in the market can be reinforced by establishing a cooperation network which provides stakeholders with chances to exchange resources freely. The network needs to be open to companies of all sizes

from all business sectors. Moreover, the resources to be exchanged are not limited to technology or information. Actually, any resources can be put into the network including materials, energy and water and sharing assets, logistics and expertise. The network can also provide business with access to workshops and events and eco-Innovative management consulting from experienced practitioners. For example, the National Industrial Symbiosis Program (NISP) initiated in the United Kingdom, is an innovative free business opportunity program that aims to deliver bottom line benefits to its members. The NISP enables thousands of businesses to change how they practice and become more efficient with the disposal of waste resources. NISP consists in a network of 12 regionally based offices across England, Wales and Scotland. A point that is worthy of note is that each region works alongside a program advisory group which is made up of leading local industry and business representatives who help steer the regional scheme. Since the NISP was launched in April 2005, the NISP has made a significant impact on the UK economy.[14)]

14) Data as of February 2008 shows that NISP has more than 8,000 industrial member companies including multinationals, SMEs and single operators. And, NISP 1) helped to divert over 2.95m tons of industrial waste from landfill; 2) generated £119m in new sales for its members; 3) reduced CO2 emissions by over 2.9m tons; 4) saved its members over £97m; 5) eliminated 338,000 tons of hazardous waste; 6) created 618 new jobs and safeguarded an additional 807.(OECD, 2009)

Ⅵ. Concluding Remarks

In establishing eco-innovation strategies for manufacturing industry, first, it is very important to stimulate systematic innovation across overall manufacturing industries along with supporting firms' various eco-Innovation activities. In particular, non technology innovative activities need to be promoted by linking with an eco-mark labeling system which should be able to reflect organizational reform, creation of new business model, green marketing, and product-service system. In addition, the support system including taxation, financing, and subsidy needs to be linked with the eco-mark labeling system. For this end, the eco-mark labeling system should be able to present guidelines to assess overall eco-innovative competency of firms.

Second, in order to promote non technological eco-Innovation, the government needs to provide consulting on new business models, PSS, reformation of organizations and other non-technological eco-innovation strategies. The information on non-technology eco-innovation strategies will be able to make firms realize eco-innovation in more creative ways. In particular, if the government can provide information on which businesses and firms are suitable to

PSS and how they can organize PSS, such information will be helpful to firms trying to carry out eco-innovation. Moreover, in order to heighten consumers' awareness of environmental problems, the government needs to apply PSS to public areas.

Third, in order to establish a synthetic eco-innovation system, we should consider a dynamic approach. In the approach, at the first stage of preparation for market entry, it is important to supply risk-management funds in financing market, and strengthen firms' R&D competency by establishing R&D network, and foster entrepreneurship so as to promote starting up business. At the second stage of market formation, firms can create profit by diversifying management strategies and utilizing cooperation networks. From the policy perspective, it is necessary to establish a test/marketing/service infrastructure and provide national R&D projects to the firms. At the final stage of entering the market, firms need to reinforce strategic cooperation through diversifying management strategies and utilizing cooperation networks. These management strategies can be developed into concrete M&A activities, which need to be promoted by supporting with policies and institutions.

Fourth, important policy directions for efficient eco-innovation are needed to provide the market with some incentives to participate voluntarily in standardization and e-marking scheme. In establishing a standardization system, it is necessary to adopt an adjustable one which might adopt a dynamic process of setting and revising

standards by taking the highest energy efficiency rate of products as a benchmark instead of setting fixed targets. Then we can expect this to create positive incentives and competition among manufacturers for quickly improving their product performance. In fact, such a system can have greater impact on the market if it were linked with the eco-mark labeling scheme to help consumer choices at the point of sale.

Fifth, voluntary participation in the market can be reinforced by establishing a cooperation network which provides the stakeholders with commercial opportunities by exchanging resources with other parties. The network needs to be open to companies of all sizes from all business sectors. Moreover, the resources to be exchanged are not limited to something like technology or information. Actually, any resources can flow through the network, including materials, energy and water and sharing assets, logistics and expertise. The network can also provide businesses with access to workshops and events and even eco-innovation related consulting from experienced practitioners.

Sixth, in establishing R&D system, we should consider the high possibility of market-failure of green technology. The market-failure of green technology related R&D can come from high R&D costs connected to high prices as well as R&D competencies of firms. Accordingly, in this sense, we need strengthening of company-centered cooperation or collaboration networks, which might be formed

in such a way where companies take a major role in drawing up the specifications of technologies, the academies and public institutes carry out R&D collaboration with the companies, and in the final stage the public institute test and prove the performances of the developed technologies. Another market based R&D support policy instrument is to extend special fund for the development and commercialization of green technologies by SMEs. Such commercialization-oriented support can bring firms closer to the markets. Besides support for SMEs, there is also a need to support preparatory activities for their commercialization including announcing technology benefits publically, which can be expected to promote technology commercialization.

Finally, one of the most important approaches suggested in this paper is to the extended supply chain management between different industries through physical exchange of materials, energy, water, and by products. The SCEM can be expected to alleviate costs from environmental regulations levied on vehicles (ELV) and electrical and electronic equipments (WEEE and RoHS) which mean that the regulations on the specific products aim at inducing markets to manage the usage of resources and toxicity of materials. For example, car makers, chemical factories, and IT product makers can create synergy effects from integrating the management of resource sharing, reuse of emissions and pollutants, and the redesign of processes for treatment of materials. In addition, in supporting green

technology development, SCEM is also applicable to the derivations of converging green technologies between different industrial areas. The extension of SCEMs across industrial sectors leads to increases in idea creation on the development of green technologies. In this view, the openness of SCEMs needs to be guaranteed along with potential technology development. Industrial symbiosis can be linked to the perspective of regional innovation activities in relation to eco-innovation clusters. It is also desirable for eco innovation clusters to be open to potential technology developers which can have synergy effects on other firms and industrial areas.

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