OECD Case Study

Innovation in Fuel cell and Photovoltaic industry in Korea

Executive Summary

Innovation in fuel cell technology began in Korea in the 1980's when Korea Institute of Energy Research(KIER) began work on a basic research of fuel cell. The Government, by enacting measures such as the 'Promotion Act for the Development of Alternative Energy'in 1987, encourages and supports research and development of new and renewable energy including fuel cell and photovoltaics. From 1988 to 2002, US$ 63 Million was invested in the development of fuel cells and US$ 27.4 Million was invested in the development of photovoltaics.

Korean government modified "10-Year National Plan for Energy Technology Development" to concentrate on selective research areas. Fuel cell, photovoltaics, wind power have been selected as 3 high-priority areas and R&D budget of the government will be more concentrated on these areas. Korean government plans to invest approximately US$ 200 million in the development and dissemination of fuel cell from 2004 to 2011 and US$2.42 billion for the photovoltaics.

Government supported research organizations mainly involved in fuel cell and photovoltaics research and development and partnerships are currently being established between government organization and other players, such as academia and industry. In order to promote technology dissemination, government provide financial and institutional support to the distributed small power generation business. Continuous investment of the government and international collaboration are expected to promote innovation needed to achieve commercialization of technologies.

Introduction

As the Korea economy has rapidly grown, energy consumption increased. Korea stands tenth in the world in energy consumption and the total energy consumption of Korea is approximately 208.6 Mil. TOE. However, the overseas dependency rate of energy was 97.3%, and it costs to US$31.7 billion which accounted for 20.8% of the total inbound shipments.

	'97	'98	'99	'00	'01	'02
GDP Growth(%)	5.0	-6.7	10.9	9.3	3.1	6.2
Primary Energy Consumption Growth(%)	9.3	-8.1	9.3	6.4	2.9	5.2
Energy/GDP Elasticity	1.86	1.22	0.85	0.68	0.92	0.84
Overseas Dependency(%)	97.6	97.1	97.2	97.2	97.3	97.3

In 1987, the Government enacted the Promotion Act for the Development of Alternative Energy. The Alternative Energy Technology Development Plan was established, based on this Act, to develop and disseminate 11 major alternative energy technologies, including fuel cell and photovoltaic. Five percent of the total investment in these projects is tax deductible in order to promote and expand the use of new and renewable energy. Loans are provided at 5% interest for up to 80% of the total investment.

The Government has long supported the development of new and renewable energy technologies that could have economic value with great energy-saving potential in the near term. According to the 10-Year National Plan for Energy Technology Development, the Government is aiming at the supply of 3% of total energy demand by new and renewable energy by 2006 and 5% by 2011. To realize this plan, fuel cell, photovoltaics and wind technologies are selected as core technologies.

Drivers of innovation

Innovation in fuel cell technology began in Korea in the 1980's when Korea Institute of Energy Research(KIER) began work on a basic research of fuel cell. The Korean government, by enacting measures such as the 'Promotion Act for the Development of Alternative Energy' in 1987, encourages and supports research and development of new and renewable energy including fuel cell and photovoltaics.

National R&D Program

'National Energy Plan and R&D Program' were the initial driving force propelling fuel cell innovation.

Since the second oil crisis in 1978, the government has put great effort into developing and encouraging the use of indigenous new and renewable energy to reduce Korea's import-dependence on fossil fuels, such as petroleum.

In 1987, the Ministry of Commerce, Industry and Energy(MOCIE) enacted the 'Promotion Act for the Development of Alternative Energy'. The 'Alternative Energy Technology Development Plan' was established, based on this Act, to develop and disseminate 11 major alternative energy technologies, such as solar thermal, photovoltaic, bio-energy, small hydropower, fuel cells, wind power, coal gasification, waste recycling, geothermal, and hydrogen technology. . Following the success of the 'Alternative Energy Technology Development Plan', '10-year National Plan for Energy Technology Development' was made in 1997..

In October 2003, '**10-year Basic Plan for the Development and Dissemination of New and Renewable Technology**' was made to diversify of energy sources by increase of new and renewable energy supply and to promote technology research and development for coping with the United Nations Framework Convention on Climate Change (UNFCCC).

Basic directions of the Plan were to establish goals for NRE technology in consideration of present technological level, available funds and the likelihood of utilization, to designate priority R&D areas and formulate competitive R&D management systems by adopting 'top-down' R&D process, to expand infrastructure programs, to promote early commercialization and dissemination and to create an effective RD&D promotion system.

In order to maximize R&D investment effectly, 3 high priority areas such as fuel cell, photovoltaics and wind power were selected, and R&D efforts concentrated to these areas. R&D plan of 3 high-priority areas by 2004 is as followes,

. Photovoltaics : To Develop 3 ㎾ Generation System for Residential Houses

. Wind Power : To Develop 750 ㎾ Wind Power System

. Fuel Cell : To Develop 250 ㎾ MCFC (by 2006) and 3 ㎾ PEMFC System

In 1999, **'the 21st Century Frontier R&D Program'** was initiated with a vision to develop core technologies and to secure leading-edge technologies in promising areas by the Korea Ministry of Science and Technology (MOST). The government plans to select 21 projects and support about US$9 million a year for 10 years for each project.

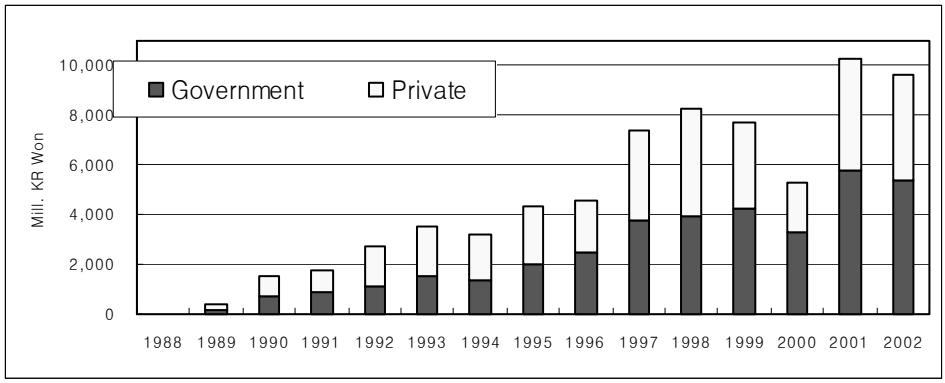
In order to respond positively to the UNFCCC and Kyoto protocol, Carbon Dioxide Reduction and Sequestration R&D Project was started in 2002. The goal of the project is 9 Million TC reduction of CO_2 by 2012 and major R&D areas are oxy-fuel combustion technology, integrated reaction and separation process technology, waste heat recovery technology and CO_2 sequestration technology

Hydrogen Energy R&D Project is started in 2003 to produce 190 K Ton of Hydrogen by 2015 and major R&D areas are hydrogen production and storage technology, hydrogen utilization technology including hydrogen engine, etc. and safe utilization technology of hydrogen including safety codes and standards.

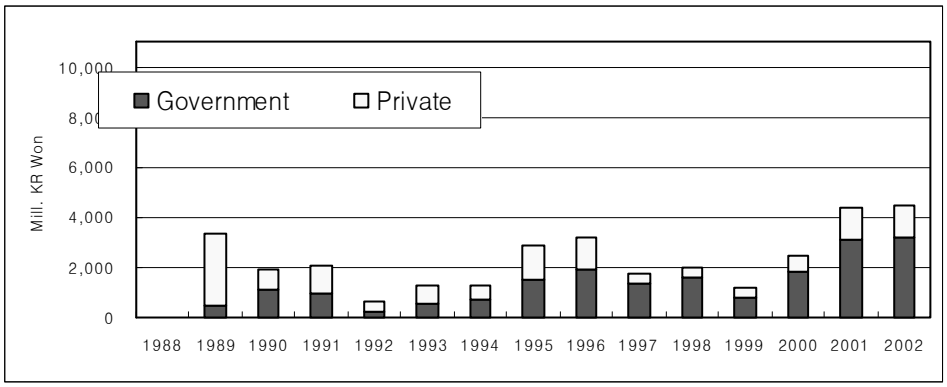
R&D Budget

From 1988 to 2002, US$ 63 Million(Government : US$ 34.7 Million, Private : US$ 28.3 Million) was invested in the development of fuel cells and US$ 27.4 Million (Government : US$ 16.1 Million, Private : US$ 11.3 Million) was invested in the development.

Fuel Cell



Photovoltaics



Promoting Measures

These measures for technology dissemination were a critical catalyst in the evolution of the Korean fuel cell and photovoltaics industry.

New regulation to mandate installation of new and renewable energy technologies to the public sector will begin in 2004. Since 2002, the government provide financial support (price-differential subsidy) to the distributed small power generation business.

In order to establish a cooperation mechanism among industry, academia, institute and government and to promote technology development and dissemination for rapid transfer to hydrogen economy, new organization, so called 'Hydrogen and Fuel cell Club' is established. Mission of the club is to discuss on the hydrogen/fuel cell technology development, dissemination and improvement of system. 22 members from government, industries, institutions and universities including the Minister of MOCIE are included in the club.

Factors that Influence Innovation

Energy technology development and its innovation process can sometimes be influenced by events that have not been anticipated. In Korea, external factors that has influenced the innovation are follows :

- **Switch of the Government Policy (R&D, the National Energy Strategy)**

Korean government modified "10-Year National Plan for Energy Technology Development" to concentrate on selective research areas and to switch the existing bottom-up approach to top-down approach. This switched policy is that R&D budget of the government is more concentrated on selected technology development (example: fuel cell, photovoltaic system, wind power plant) while the budget is shrunk on supporting the other technology. However, the priority of the government policy on R&D is generally on upward tendency, so the effect on innovation is positive. Especially, the government has selected 'Hydrogen Energy R&D Project' in 2003 following the 'Carbon Dioxide Reduction and Sequestration R&D Project' in 2002 as the '21st Century Frontier R&D Program', both of which are the major results of the switched government policy bringing the innovation of energy R&D.

○ **Change of Market Situation**

Network energy industry including power generation and gas companies, which was on the government leading monopolistic position so far, has been being reformed and privatized now. Therefore, the energy industry will seek the short-term profit and competitive power and rapidly curtail the investment on developing technology that demands the long-term investment with a high risk. To supplement this problem, the government has newly made 'Fund for Electricity Foundation' since 2002.

The government has executed the system for supplementing a difference between producing cost and selling price of grid electricity through amending the relevant law in order to innovate the technology of renewable energy and promote the spread of it since 2003. This system is expected to contribute toward the innovation of renewable energy technology.

○ **Regulations (Regulatory Constraints)**

Korea has enhanced the environmental regulations little by little like other advanced countries, which are very positive on the technological innovation. Korean environmental regulations on major pollutants are similar to the advanced countries' standard.

○ **Technological advances in other fields(IT, NT, BT)**

The development of high technology such as IT, NT, BT is predicted to influence on the innovation of energy technology. The joint of basic science and energy technology seems to bring a turning point of improvement of energy efficiency and the development of economical efficiency. Especially, the technology development of new energy materials applying NT is an essential factor to develop core energy technologies including hydrogen storage, fuel cell, and photovoltaic. Korean government that selected these technologies as core tasks has been promoting them.

Innovation system in the energy sector knowledge creation, diffusion and exploitation

Actors

The government, with the Ministry of Commerce, Industry and Energy (MOCIE), has pursued the development of short-term practical-application technologies, with the Ministry of Science and Technology (MOST) leading the development of long-term core technologies.

Government supported research organizations mainly involved in fuel cell and photovoltaics research and development and their participation in the sector is very significant component of the innovation system. Partnerships are currently being established between PRO and other players, such as academia and industry and patents and publications are being produced.

The followings are the most active Public Research Organizations in the fuel cell and photovoltaics research and development.

Fuel Cell	Photovoltaics
Korea Institute of Energy Research (KIER)	Korea Institute of Energy Research (KIER)
Korea Institute of Science and Technology (KIST)	Korea Institute of Science and Technology (KIST)
Korea Electrotechnology Research Institute (KERI)	Korea Electrotechnology Research Institute (KERI)
Korea Research Institute of Chemical Technology (KRICT)	Korea Research Institute of Chemical Technology (KRICT)
	Korea Research Institute of Standard and Science (KRISS)
	Korea Agency for technology and Standards (KATS)

List of universities involved in the fuel cell and photovoltaics research and development are as followes;

Fuel cell	Photovoltaics
Seoul National University	Seoul National University
Yonse University	Yonse University
Korea University	Korea University
Sogang University	Sogang University
Korea Advanced Institute of Science and Technology (KAIST)	Korea Advanced Institute of Science and Technology (KAIST)
Hankuk Aviation University	Kyunghee University
Chung-nam National University	Chung-nam National University
Hanyang University	Inha University

Kyung-book National University	Chunbook National University
Pohang University of Science and Technology (POSTECH)	Ajoo University
Inha University	Woolsan University
Hong-Ik University	Sungkyunkwan University
Dong-yang University	Pusan National University
Joongang University	Kunkook University
Hannam University	Inchon University
	Youngnam University

Private firms are playing very important role in fuel cell and photovoltaics research and development.

Fuel cell	Photovoltaics
KEPCO	Samsung SDI
Samsung SDI	Nescor Solar Co., Ltd.
Samsung Advanced Institute of Technology	Photon Semiconductor & Energy Co., Ltd.
LG Oils	LG Industrial Systems
LG Chemicals	Solar Tech.
LG Electronics	S-Energy
SKC	ATS Solar
SK Corp.	SOLAITEC
Hyundai Motors	KOREA SOLAR Co., Ltd.
Kukdong City Gas Co., Ltd.	Hae Sung Solar Co., Ltd.
Hankook Tire	Power Solartech Ltd.
RIST	S-Energy Co., Ltd.
CETI(Co.)	Gloval Hi-Tech Co., Ltd.
Fuel Cell Power	LSYSTECH Co., Ltd.
Twin Energy	SILTRON
LG Caltex	
Samsung Engineering	
Hyosung Industrial PG	

Current Technological Development

Most types of fuel cells in South Korea are currently in the development stage, but a 50 kW prototype of phosphoric acid fuel cell (PAFC) system was developed by LG-Caltex with the Korea Institute of Energy Research (KIER). KIER also developed a 5 kW unit of the proton exchange membrane fuel cell (PEMFC) for residential application. The Korea Institute of Science and Technology (KIST), the Korea Electric Power Corporation (KEPCO), the Research Institute of Industrial Science and Technology (RIST) and the Korea Heavy Industry (KHI) developed a 25 kW unit of the molten carbonate fuel cell (MCFC), and the Korea Electric Power Corporation (KEPCO), SamSung Eng. And HyoSung Heavy Ind. now developing 100kW MCFC. Hyundai

and Kia Motors in collaboration with the International Fuel Cell (IFC), are now developing a hybrid fuel cell car, targeting 2004 for market entry.

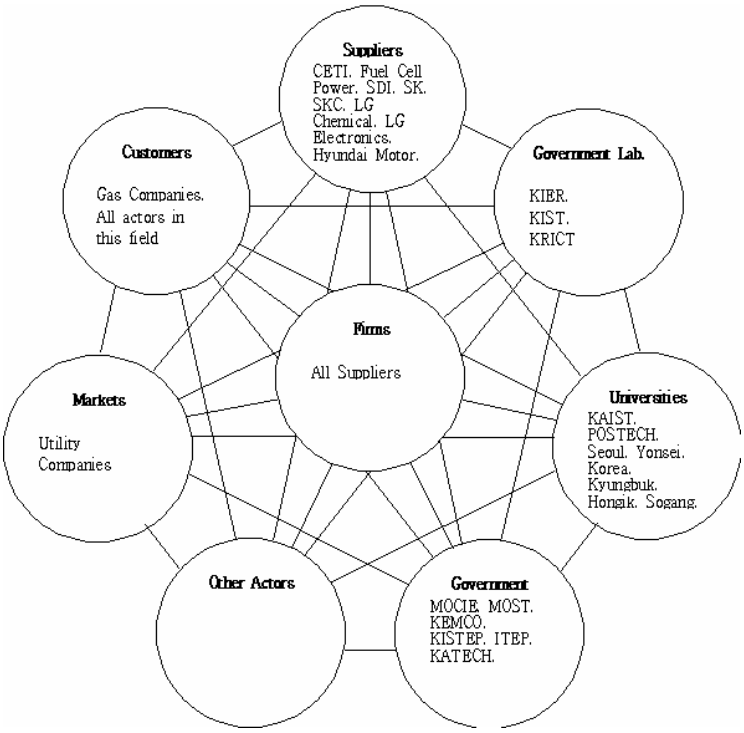
Current Technological Development of Fuel Cells in South Korea

Type of Fuel Cell	Current Technology	Developer/Manufacturer	Target (by 2006)
PAFC	- 50kW - Developing 100kW	- LG-Caltex, KIER	- Commercial Stage for 200kW
MCFC	- 25kW - Developing 100kW	- KIST, KEPCO, RIST (Research Institute of Industrial Science and Technology), Korea Heavy Industry	- Practical Stage of 100kW - Development of MW Capability
PEMFC	- 25kW (for transportation) - Developing 3kW for residential application	- Hyundai Motors - KIER,CETI	- Development of 25kW - development of 30kW for commercial buildings
SOFC	- Developing 100W		- 100kW prototype power plant
Vehicle Installed Fuel Cell	- Development of Hybrid Electricity Car (10kW and 25kW fuel cell/battery hybrid system) - Fuel Cell Car (75kW)	- KIER: 10 kW PEMFC system, DaeWoo : Electric Vehicle, with battery and Controller - KIST: PEMFC Stack SK Co.: Reforming Unit Hyundai/Kia Motors: 10, 25kW PEMFC stack Car Design & Manufacture - Co-developed by Hyundai/Kia Motors and IFC (International Fuel Cell)	- Gasoline-Fuel Cell Vehicle by 2002 (Hyundai/Kia Motors and IFC)

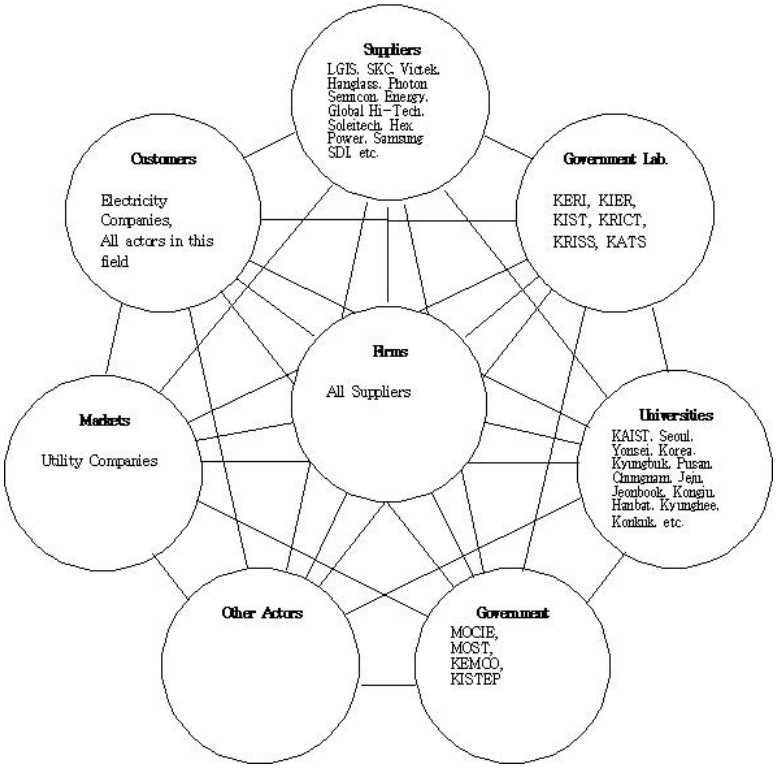
Source: Korea Institute of Energy Research (KIER). 2000. *Development of Alternative Energy in Korea.*

Organizational Network

Fuel cell



Photovoltaics



Markets

According to the projection by Korea Energy Economics Institute (KEEI)[1], the electricity generation capacity by fuel cells in Korea in 2020 would be almost zero in the BAU Scenario Case. However, in the Policy Commitment Scenario, the residential sector only would reach 120MW in 2010, 225MW in 2015 and 360MW in 2020, respectively. Residential fuel cell systems are expected to be installed in 10,000 houses in 2008 and 30,000 houses in 2015, respectively.

The cost of electricity generation by fuel cell and photovoltaics is also expected to decline. From 2005, electricity generation by fuel cell and photovoltaics is expected to contribute significantly as a distributed electric system.

Government plans to install 12,300 fuel cell systems (total 370MW, 30MW for residential sector, 20MW for building and 320MW for distributed power generation), and plans to install 3,210 photovoltaic systems(total 1.3GW, .3 GW for residential and 1GW for industrial sector).

[1] Source: KEEI. 2001. *Institutional Reform and Strategy for Promotion of Alternative Energies in Generating Electricity*

Public policy for innovation in specific sector/technology

Establishment of Infrastructure

In order to secure reliability of developed technologies before dissemination, the government has continued support for establishment of infrastructure.

'**Center for NRE Development & Dissemination'** is newly established under the KEMCO(Korea Energy Management Corporation) to promote R&DD of new and renewable energy technology in February 2003. A primary mission of the Center is to improve the efficiency of the government's R&D investment through programs that promote the efficient implementation of national research and development related to new and renewable energy initiatives.

'N&RE Demonstration and Evaluation Program' began to secure economy and reliability of N&RE equipments in 2001. Its main function is the connection to commercial use through evaluation and demonstration of technology performance. Demonstration project of technology performance is to ascertain the performance of developed equipments and to keep monitoring after installing the equipments in complexes (scheduled to operate two demonstration complexes in 2002). To evaluate the performance of N&RE equipments, the Performance Evaluation Center for solar thermal, photovoltaic and wind energy equipments was established in 2001 and took a role as national centers for new and renewable energy testing and evaluation. The Centers are going to contribute the quality improvement of the new and renewable energy products and technologies, and in consequence the promotion of commercialization and dissemination of them.

Measures for Technology Dissemination

The government supports several new & renewable energy dissemination projects for public organizations in order to attract public attention and to assure the credibility of R&D activities. To expand the N&RE market, the government supports low-interest bank loans for N&RE producers and facilities. Loans are provided at 4.75% interest rate up to 90% of the total investment.

Investment in the production and purchase of new and renewable energy facilities entails great expenses, which is a practical burden for manufacturers. Besides, small & medium enterprises may not have adequate access to normal banking channels. The preferential long-term loans and/or various tax incentives provided by the government may encourage voluntary participation in new and renewable energy investments. Loans are available for the production and purchase of new and renewable energy facilities at 4.25 percent interest rate with a three year grace and five year repayment period and US$22 Million was provided in 2003.

New and renewable energy-based electricity is purchased by a government-owned utility at the rate equivalent to the average retail price, which is set by the Electricity

Law. The government offers an income tax credit by compensating 10 percent of the total investment in new and renewable energy projects.

Since 2002, the government provide financial support (price-differential subsidy) to the distributed small power generation business. The government compensates the difference between power generation cost and sale prices. From May 2002, preferential prices program was applied to PV, Wind, Small Hydro, LFG, and fuel cell is included in 2003.

The government provides financial support for the local energy plan managed by local government in order to facilitate the use of new and renewable energy. The local energy plan consists of an Infrastructure Buildup Program and a Demonstration Project.

To secure the marketing of new and renewable energy after technology development, the government subsidizes 70% of the installation costs. US$6.2 million of subsidies by the government from 1993 to 2001.

The government is planning to establish the demonstration town 'Green Village' in Kwangju city and Taegu city to attract public attention and to assure the credibility of new and renewable energy facilities. Five more 'Green Village' will be established in the future.

New regulation to mandate installation of new and renewable energy facilities to public sector will be implemented from 2004.

Innovation performance and its assessment

Measuring innovation performance

In case of Korea, it is too early to measure and evaluate the result of the innovation meanwhile because the period from establishment to implementation of the national plan on energy technology development is relatively shorter than other countries.

The government recently evaluated the result of the past 5-year on "10-Year Plan for Energy Technology Development", and it was summarized as follows :

- Insufficient result based on the original plan for energy saving :

It was evaluated impossible realistically to achieve 10% saving of total energy in 2006, which had been the target of energy saving technology development project. The major reasons were the reduction of the actual investment based on the planned budget, the absence of systematical research management and strategy, and the absence of independent and objective evaluation on whole projects. Generally, the estimation of certain energy saving potential was successful, but the commercialization and spread of developed technology were unsatisfied.

- Change of investment portfolio by energy technology:

In investment portfolio of the original plan, energy saving technology had been selected as a best preferred target, but in practice, new and renewable energy based on the results was preferred.

- Insufficiency of the concentrated investment strategy on major areas:

Although top-down approach was supposed to be conducted on major areas in the original plan, in the implementing phase, it was not sufficient to select areas and concentrate on them. It was required to select the major technology areas and use the concentrated investment strategy on the situation of demand and supply.

- Necessity of enhancing the linkage of the general energy technology policy and UNFCCC :

The government should earnestly develop energy technology as a core scheme for UNFCCC. The government should utilize the reduction of greenhouse gas emission as an evaluation standard in selecting technology and expand the technology that is used in the areas of high reducing efficiency as a business target.

- Inefficient budget :

Because the actually practiced budget was just 58% of the original plan due to IMF, the implementation of the planned R&D was absolutely difficult. It is the prior task to expand the budget for energy technology.

- Necessity of the expansion of investment on infrastructure such as cultivation of experts and the international cooperation :

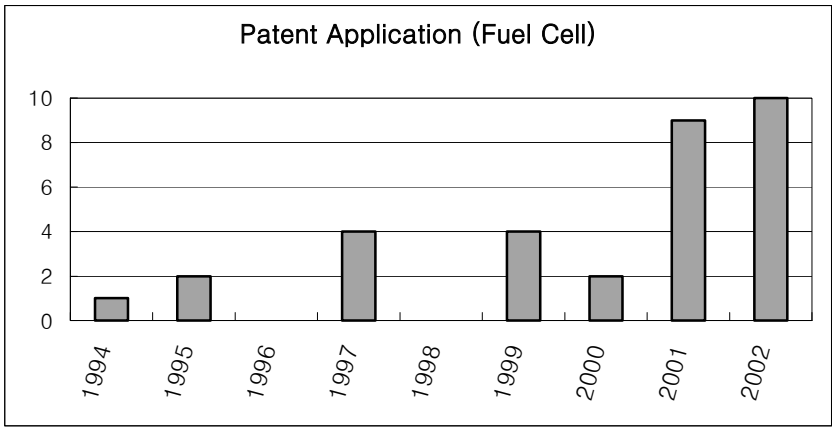
It was the most insufficient to invest on the establishment of foundation in comparison with the original plan so very difficult to secure the appropriate manpower. The security

of high professional and international manpower seems to be urgent because energy sector is very international and needs high technology.

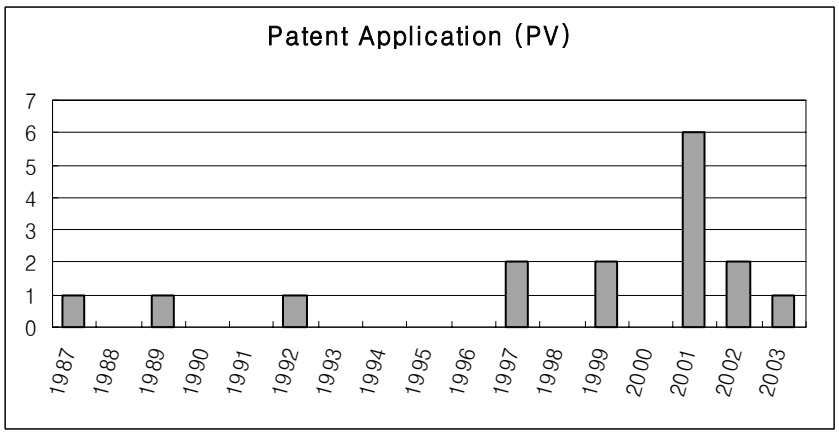
It is in the premature phase to analyze economic cost/benefit analysis on the results of technology development. According to the preliminary first-hand evaluation, the successful rate of commercialization of R&D projects was just 25%, the direct economic effect in practical fields (the effect of energy saving and import substitute) was 150% of investment scale, and the social profit rate was 376%. However, this quantitative analysis should be reevaluated in the basis of exact data and by precise approach afterward.

Bibliometric Analysis

- Patent (in KIPO)
  - Fuel cell : 34 since 1994

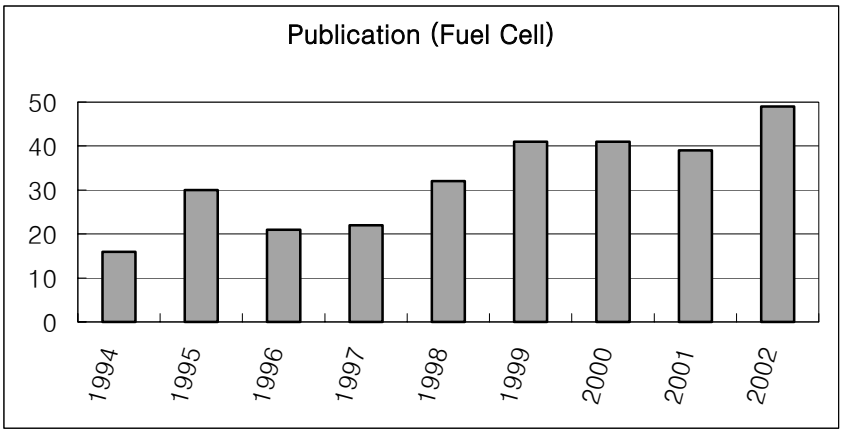


  - Photovoltaics : 17 since 1987

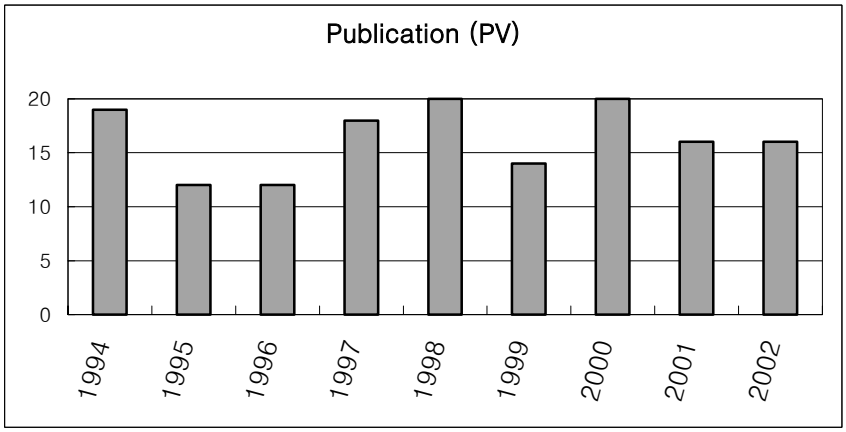


■ Publication (including non-academic publication)

- Fuel cell : 338 since 1994



- Photovoltaics : 147 since 1987



Assessment of Elements of Innovation System

■ Results of a Survey

Fuel cell

*** Factors influencing innovation processes**

- Factors in influencing the types or magnitude of innovative activities are to reduce production costs, to improve the performance or quality of existing products and to create new products

- Technical knowledge obtained from technical analysis of the products of competitors, joint/cooperative ventures, and public research institutes and universities are important

*** Access to research from public institutions & universities**

- New instrumentation/techniques and specialized or applied knowledge of public research institutes and universities are important to the innovative activities

- Research activities of the public research institutes are more important universities to the innovative activities.

- Joint research projects between your unit and an institute or university and hiring trained scientists and engineers are very important for learning about research conducted in public research institutes or universities.

- Lack of internal expertise and intellectual property rights are obstacles to absorb knowledge produced by public research institutes or universities.

* **Protection of innovations, IPRs and knowledge transfer**

- Secrecy and design registration are more important to prevent from copying or appropriating the product and process innovations

- Frequent technical improvements and technical complexity is important for making product and process innovations difficult or commercially unprofitable to imitate.

- From 1.5 to 5 years would a capable firm require to market a competitive alternative to a significant innovation.

- In the last three years, an application was made less than 19%.

- To prevent competitors from copying the invention and to improve the position in negotiations with other firms are the reasons for patenting new products/processes.

- In the last three years, the factors in influencing company's decision not to patent are the amount of information disclosed in a patent application and limits to the effectiveness of patents in preventing imitation.

- In last three years, factors in influencing a decision to publish research result in the open literature are giving signals to the public research institutes or universities about the company's research fields of interest and finding new R&D partners among public research institutes or universities.

- Policies and programmes of Korea such as subsidies (e.g. tax credits) and procurement programmes (civil, defense) are important in supporting the ability to innovate.

* **National innovation systems and globalization**

- Public procurement rules that favor local firms and incompatibility with local technical standards are obstacles in limiting the ability to profit from its innovations in home or foreign markets.

Photovoltaics

*** Factors influencing innovation processes**

- Factors in influencing the types or magnitude of innovative activities are external sources of information necessary for innovation and to improve the performance or quality of existing products.

- Technical knowledge obtained from public research institutes/universities and technical analysis of the products of competitors are more important to the innovative activities.

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- Specialized or applied knowledge and new instrumentation/techniques of public research institutes and universities are important to the innovative activities

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- From 1.5 to 3 years would a capable firm require to market a competitive alternative to a significant innovation.

- In the last three years, 20% to 59% of innovations was applied for a patent.

- To prevent patent infringements suits against your firm and to prevent competitors from copying the invention are the reasons for patenting new products/processes.

- In the last three years, the factors in influencing company's decision not to patent are the cost of applying for a patent and the limits to the effectiveness of patents in preventing imitation.

- In last three years, factors in influencing a decision to publish research result in the open literature are giving signals to the public research institutes or universities about the company's research fields of interest and finding new R&D partners among public research institutes or universities.

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