Chapter 1 Science and Technology Carving out a Future and Solving Challenges

The globalization of international community has been in progress at an ever increasing pace due partly to development and infiltration of information and communications technologies, lower costs of transportation, economic development of emerging countries, etc. and international competition has been intensifying, and we are facing the risk of a problem of one country to develop into the global problems. In such circumstances, there are significantly more problems for which international coordination and cooperation are essential to solve. Some of the examples of the global problems becoming significant in recent years include global warming, climate changes, natural disasters, environmental pollution, infectious diseases, etc. (Table 1-1-1)

Table 1 1 1 Major global problems

○Climate change (global warming, change in precipitation, local downpour, etc.)	○Water pollution (river, sea, ground water)
○Sea level rise, disappearing land	○Tight water supply
○Urban heat island	○Further desertification
○Acid rain	○Decrease and deterioration of forests
○Destruction of ozone layer	○Pollution and deterioration of soil
○Frequent disaster (flood, landslide, tsunami, etc.)	○Reduction in cultivated acreage
○Air pollution	○Tight food supply
○Cross-border movement of toxic substances	○Decreasing biodiversity
	○Ecological effect of invasive species
	○New infections

Source: Prepared by MEXT based on data provided by Center for Research and Development Strategy

In Japan, there are concerns about the quality of people's living and security has been in doubt these days due to the problems of progress in low birth rates and aging society, natural disasters such as large-scale earthquakes, tsunami, wind, flood, etc., serious traffic accidents, frauds that have shaken people's confidence about safety of food, etc. As a consequence, more people are calling for measures to realize a society in which people can make their living safely and in peace. According to the "Public Opinion Survey on the technology"[1] conducted by the Cabinet Office in Japan in January 2010, those who affirmed the questions "Development of science and technology is necessary to enhance international competitiveness." and "The new problems in the society, such as resources, energy, environment, water, food, infections, etc. will be solved as a result of the development of science and technology." accounted for 86.7% (rose 8.4% compared with the previous poll) and 75.1% (rose 13.0% compared with the previous poll) respectively, showing that the citizens' expectations for science and technology are very high. (Figure 1-1-2)

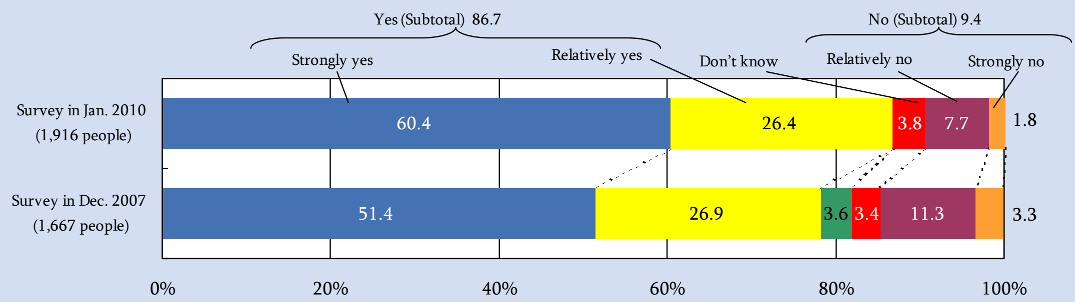
For the purpose of responding to such social calls and meeting the citizens' expectations, it is

1 The poll was conducted by interviewing 3,000 adult (men and women) in January 2010, from which 1,916 responded effectively. (effective response rate: 63.9%) See the Cabinet Office website at http://www8.cao.go.jp/survey/h21/h21-kagaku/index.html

necessary to promote science and technology, which are considered to be the sources of national strength and the platforms to provide support for growth, and to open up the future of the country and of human beings.

Figure 1 1 2 Citizens' expectations for development of science and technology (Public Opinion Survey on the Technology)

Q: Opinion on S&T: "The new problems in society, such as resources, energy, environment, water, food, infections, etc. will be solved as a result of the development of science and technology."



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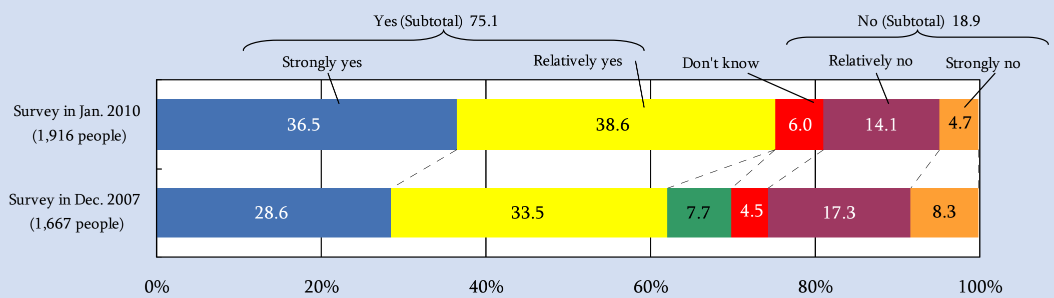


Source: Public Opinion Survey on the Technology [Polled in Jan. 2010 (Published in Mar. 2010]

For this purpose, it is important to generate new intellectual properties by promoting basic research activities as the sources of human wisdom and knowledge as well as to accumulate as a consequence ample knowledge. It is also important to create innovations by promoting research and development that may contribute to addressing some global problems, such as global warming, environmental pollution, etc. and to solving other domestic problems, such as diseases, food, economic growth, etc.

To address the difficult problems that we are now facing and to become a "model country" to provide solutions to such problems prior to anybody else in the world may be directly connected to our goal of enhancing the Japanese capacity in the field of R&D and the financial strength of Japanese corporations, which may result in increasing potential demands once these problems are solved in the future. Thus, Japan should consider this "crisis" as a "chance" to promote the following two things: one is "green innovations," which is to change our corporate activities and private life styles into ones that do not require so much carbon consumption, and the other one is "life innovations," which is to create a society where people can maintain their health throughout their lives. Thus, importantly, Japan should aim to become a "problem-solving country," in which problems are solved by means of science, technology (Japan ranks around the top in these fields), and of human power.

Considering the points stated above, Chapter 1 illustrates the current state of Japan and a summary of future prospects in relation to the science and technology contributing to creation of a low-carbon society, the science and technology necessary for citizens to live high-quality lives safely, and the efforts to enhance the basic science capability.

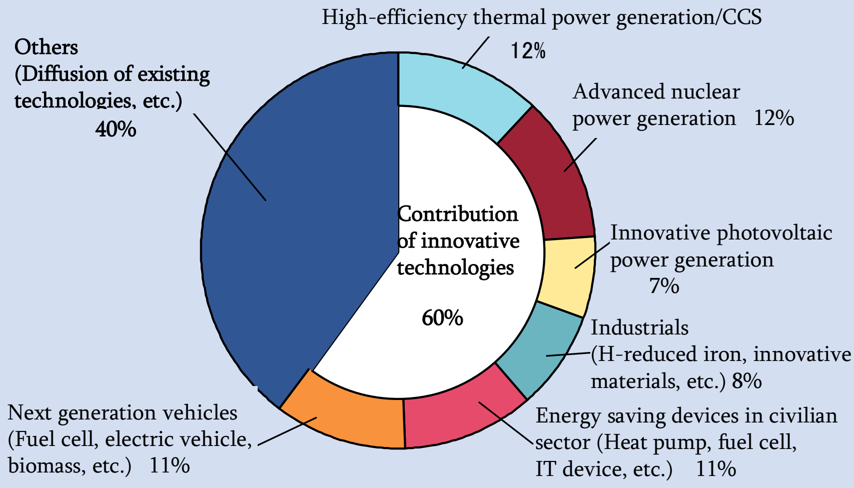
Section 1 Science and Technology Contributing to Creation of a Low-Carbon Society

Research and development of innovative technologies consist of a series of elements essential to the creation of a low-carbon society. For instance, Ministry of Economy, Trade and Industry (METI) has selected 21 innovative technologies to be focused on in order to halve the emission of carbon dioxide (CO_2) generated by energy consumption by the year 2050, estimating that about 60% of the CO_2 reduced can be attributed to the application of these technologies. (Figure 1-1-3)

Global warming is an issue requiring measures from the global standpoint and every country has been making a variety of efforts to solve the problem while setting targets, for example, how much they will reduce the emission of CO_2 and other greenhouse gases[1]. In the meantime, Japan has set a mid-term goal to reduce the emission of greenhouse gases by 25% compared with 1990 by the year 2020 on the assumption that a fair and practical international framework will be structured and all the major countries will agree with a will on such targets. In addition, Japan has a long-term goal to reduce the emission of the gases by 80% by the year 2050 compared with 1990, attempting to share the goal of halving, at least, the amount of the gases emitted by the whole world with all countries. Japan has also presented the policy toward becoming world's top-level environment and energy power, implementing all kinds of policies, including promotion of science and technology, to address the global warming problem and to contribute to economic growth while encouraging to utilize top-level environmental technologies in Japan.

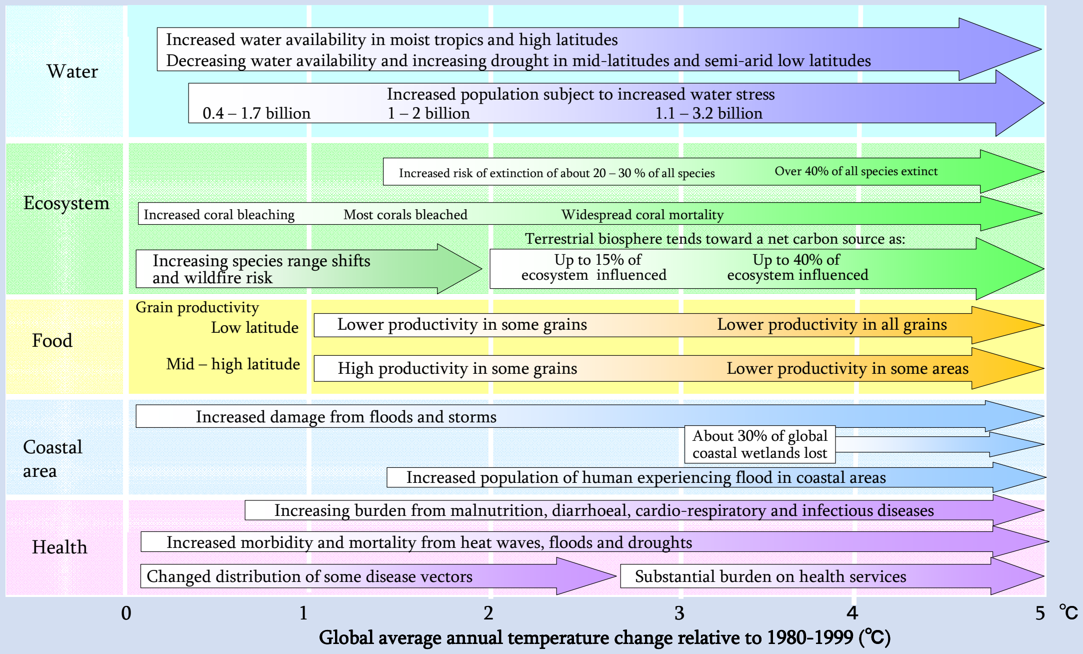
1 Gases that may cause greenhouse effect. In the Kyoto protocol, carbon dioxide, methane, nitrous oxide, and some of the fluorocarbons have been set as the target greenhouse gases to be reduced the emission.

Figure 1-1-3 Innovative technologies contributing to global CO_2 reduction (estimate)



Note: This chart illustrates how much each technology contributes to reduction of CO_2 on the assumption that the global CO_2 emission will be halved by 2050.
Source: Prepared by MEXT based on METI "Cool Earth-Innovative Energy Technology Program"

Figure 1-1-4 Possible examples of impact of increase in global average temperature



Note: The impact may differ depending on adaptability, the pace of temperature change, and the socioeconomic paths.
Source: Prepared by MEXT based on "Climate Change 2007, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Summary for Policymakers"

On the other hand, in the Fourth Assessment Report, written in 2007, of IPCC[1], consisting of experts from the member countries, the panel points out that no matter how hard we try to reduce

1 Intergovernmental Panel on Climate Change

the emission of greenhouse gases, the global average temperature would still increase[1] by the end of this century and that global warming would be inevitable for the next couple of decades, so that it is not sufficient to implement only measurements to restrain the emission of greenhouse gases but some adaptive measures to the near-term impact will especially be necessary (Figure 1-1-4). With this observation in mind, in order to implement measurements against global warming, research and development will be necessary simultaneously for the technologies to mitigate global warming by reducing the emission of greenhouse gases (mitigation technologies), and the technologies to predict climate change and its impact to the society and others and to adapt to the impact (adaptive technologies). In addition, in order to create innovations from the outcomes of the research, these technologies should be encouraged to be utilized practically in the society while working on the elimination of bottlenecks for the implementation.

This section illustrates the current state and an outlook of Japan and of the world in relation to the science and technology contributing to the creation of a low-carbon society.

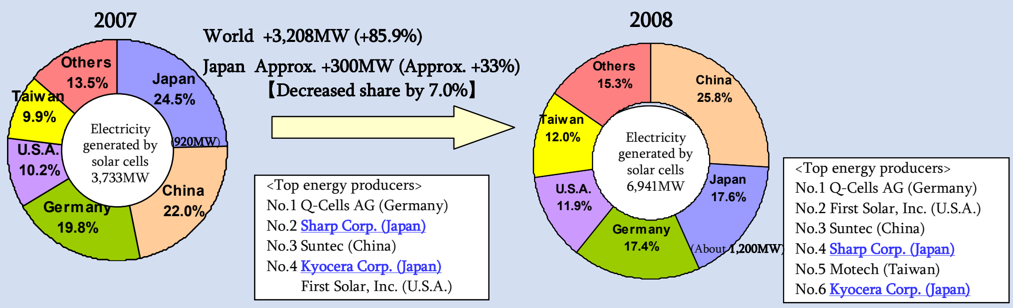
1 Status of R&D to Overcome the Global Warming Problem

(1) Movement over global warming countermeasure technology

There are more active moves to solve the problem of global warming and to create a low-carbon society in the countries around the world. According to UNEP[2], the market size of global environment-related businesses was about €1 trillion (about ¥150 trillion) in 2005 while it is estimated to more than double by 2020, reaching about €2.2 trillion (about ¥300 trillion)[3]. In Japan, we have experienced many pollution problems and two oil crises so that we have focused on energy conservation, which has resulted in our world's highest-level environmental technologies, but such advantage has not been fully utilized in the international competition for environmental technologies. For instance, in the photovoltaic industry, companies in China, Germany, and U.S.A. are currently increasing their production. While the global production is increasing significantly, Japanese companies are also increasing their production and Japan, as a whole, still ranks higher in the global share, but the individual shares of Japanese companies are decreasing (Figure 1-1-5). The same can be said of the lithium battery industry, which is one of the major electricity storage technologies, and some of the Japanese companies rank higher in its production, but their shares are decreasing due to the rise of Chinese and Korean companies.

1 The temperatures in the 2090s are estimated (best estimation) to be between 1.8 and 4.0 degree Celsius (Scenario B1 and scenario A1F1 respectively) based on the years 1980 through 1999, and increase was predicted to be seen in all the six scenarios used by IPCC.
2 United Nations Environment Programme
3 The euro sums of 2005 and 2020 were converted into Japanese yen based on the purchasing power parity of 2005 and 2008.

Figure 1-1-5 Production of solar cells of selected countries (2007 and 2008)



Source: Prepared by MEXT based on papers provided by METI

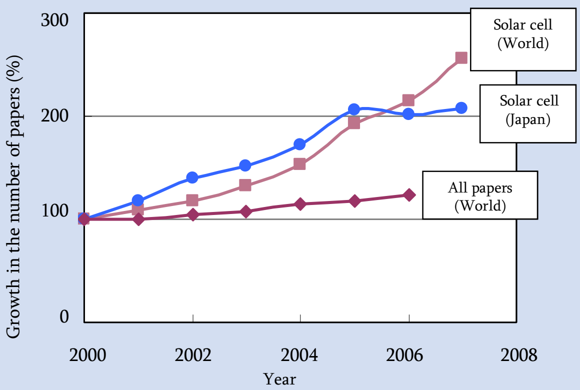
In terms of R&D, countries around the world are working more actively on the technologies to address the problem of global warming. In terms of R&D, countries around the world are working more actively on the technologies to address the problem of global warming. For example, as indicated in Figure 1-1-6, the number of papers related to solar cells and fuel cell power systems[1] are increasing in recent years both globally and in Japan, suggesting that the R&D in relation to such technologies are carried out more actively in the world. In addition, there is a significant increase in the number of papers on dye-sensitized and organic solar cells, which are expected to be the technologies of next generation, suggesting that the R&D in these fields has also been activated. The growth of Japan in the number of papers is smaller compared to that of the world in the fields of both solar cells and fuel cell power systems, but it is definitely increasing mainly in the field of the next generation technologies. The share of Japan in the papers on solar cells ranks the second after the U.S.A. and in fuel cell power systems, it is the third after the U.S.A. and China. This fact shows that Japan still has significance in these fields.

1 It refers to a device to generate "electricity" directly from the chemical reaction of "hydrogen" and "oxygen." It is a synonym for "fuel cell."

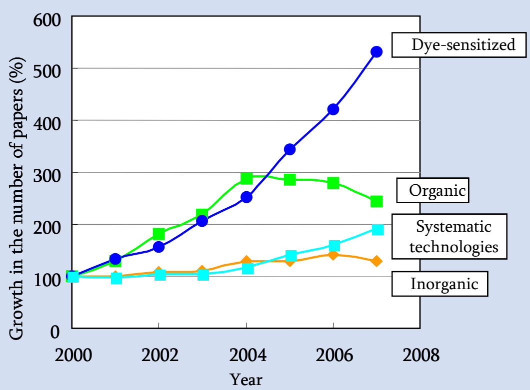
Figure 1-1-6 Increase in the number of papers in the world and in Japan in relation to solar cells and fuel cell power systems

1) Solar cells (100 = the number of papers in 2000)

(1) Increase in the number in the world and in Japan

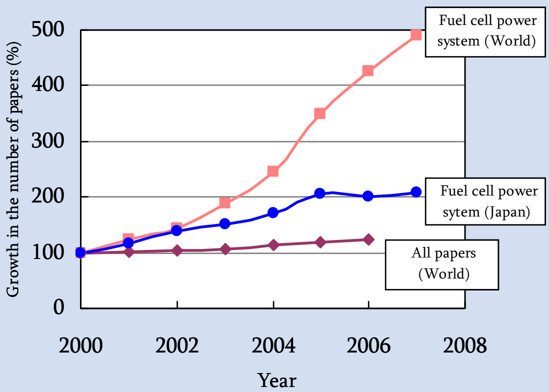


(2) Increase in the number in the world for different types of cells

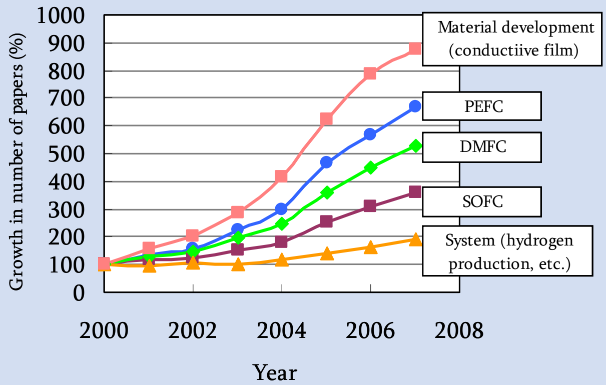


2) Fuel cell power systems (100 = the number of papers in 2000)

(1) Increase in the number in the world and in Japan



(2) Increase in the number in the world for different types of technologies



Note: 1. Innovation Policy Research Center at the University of Tokyo organized the data based on the SCOPUS customized data of Elsevier B.V.
2. 3 year moving average. i.e. the number of 2006 is the average of 2005, 2006, and 2007.

Source: Prepared by MEXT based on the materials provided by Innovation Policy Research Center at the University of Tokyo

The analysis of JST/Center for Research and Development Strategy shows that the current levels in which Japan is positioned in many technical areas are relatively high from the global standpoint regarding the research done by universities, national research institutions, and corporations, and the corporate capacity for R&D in relation to the technologies related to global warming. (Table 1-1-7)

Table 1 1 7 National level of science and technology in relation to technologies related to global warming

		Technology to stop global warming on the energy consumer side			Technology to stop global warming on the energy supplier side					
		Industrials (Industrial processes, etc. such as steel, cement, etc.)	Transportation (Vehicle (hybrid, electric, light weight, etc.), storage battery, fuel cell, etc.)	Building, household (Home solar power generation, heat pump, high-efficiency lighting, home insulation, etc.)	Traditional energy (petroleum/coal thermal power, hydraulic power, nuclear power, etc.)	New energy, renewable energy, biomass energy (Photovoltaic power, winder power, bioethanol, etc.)	Carbon dioxide Capture and Storage technology	Absorbing technology in forest and soil (Afforestation/deforestation technology, forest monitoring, etc.)	Technology to stop global warming in agriculture (Restriction of fertilizer, energy-saving technology, etc.)	Prediction/evaluation technology (Climate change projection model, super computer, data grid, etc.)
Japan	Level of research	B	B	A	–	A	A	A	A	A
	Level of technical development	A	A	A	A	A	A	A	B	A
	Capacity of industrial technology	A	A	A	A	B	A	B	C	B
United States	Level of research	B	A	A	–	A	A	A	A	A
	Level of technical development	C	B	A	A	B	A	A	A	A
	Capacity of industrial technology	D	B	A	B	B	A	A	C	A
Europe	Level of research	B	A	A	–	A	A	A	A	B
	Level of technical development	A	B	A	B	A	B	A	B	A
	Capacity of industrial technology	B	B	B	B	A	A	A	A	B

"A" in red indicates the areas in which Japan is advanced significantly.

Note: Given 4 absolute evaluations to different technical areas by several experts according to the following 3 phases.
"Level of research": Level of research at universities and national research institutions,
"Level of technical development": Level of research at corporations
"Capacity of industrial technology": Capacity for R&D at corporations
Criteria for the 4 absolute evaluations are as follow:
"A": very advanced, "B": advanced, "C": behind, "D": very behind
Source: Prepared by MEXT based on JST/Center for Research and Development Strategy "International Comparisons of Technologies and R&D for environment and agriculture 2009"(May 2009)

With these facts in mind, in terms of technologies related to global warming, Japan has international advantage in R&D not only at corporations but also at universities and other institutions to a certain degree, so it can consequently grow up in the future by creating innovations while taking such advantage in these fields. However, while the environment-related businesses are expected to be growing worldwide, other countries are also involved more actively in the commercial and R&D activities related to the technologies related to global warming, resulting possibly in ever intensifying international competition in the field of research and development.

(2) Research and development efforts on global warming countermeasure technology in Japan

In order for Japan to lead the world in the field of global warming countermeasure technology, all concerned parties such as the national and local governments, research institutions, and private-sector businesses are required to work together and further promote research and development of global warming countermeasure technology.

In this field, the Ministry of Education, Culture, Sports, Science and Technology (MEXT), the Ministry of Economy, Trade and Industry (METI), and the Ministry of Agriculture, Forestry and Fisheries (MAFF) have been conducting various research and development for the purpose of basic research, practical use, demonstration of technology, and regional science and technology.

Here are cases about research and development efforts on global warming countermeasure technology

1) Greenhouse gas emission mitigation technology

a) R&D of next generation solar cells

Trial solar cell applying new principles (Dye-sensitized solar cell)
Photo: National Institute for Materials Science

Solar cells are considered to be one of the most promising technologies to reduce emission of greenhouse gases with their high installability and maintainability at power plants, office buildings, and at homes, among all types of renewable energy[1]. However, conventional solar cells made of silicon still have some issues such as enhancement of conversion efficiency in photovoltaic power generation, reduction of costs, etc. Thus, innovative technologies need to be developed, including next generation solar cells, in order to be widely used in daily life.

In 2009, Japan Science and Technology Agency (JST) has started several projects, including Basic Research Program "Creative Research for clean energy generation using solar energy" (Research supervisor: Masafumi Yamaguchi/Principal Professor at Toyota Technological Institute), to promote basic research for problem solving in team work and individual research by young researchers to participate in the development of dye-sensitized solar cells, organic solar cells, quantum structure solar cells, and others cells for practical use while making full use of the state-of-the-art nanotechnology, for the purpose of enhancing the conversion efficiency and the life of solar cells, which is considered to be a breakthrough in the modern technology.

National Institute for Materials Science has started to construct "R&D Center for Environmental Technologies" in 2009 to accelerate the research and development of innovative environmental technologies, including dye-sensitized solar cell, in partnership with some companies.

METI designated the University of Tokyo Research Center for Advanced Science and Technology and National Institute of Advanced Industrial Science and Technology as the international bases for innovative solar cells and progressing with the R&D of highly efficient and low cost innovative solar cells while working together with universities and companies in Japan and also with some of the most prestigious research institutions in the United States and in Europe.

b) Biomass energy

The technology of biomass[2] energy is one of the most promising technologies to generate renewable energy, with a possibility of realizing "local production for local consumption" for the energy generated from wood biomass, which can be obtained in an isolated island, etc.

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1 A general term for the energy generated from the phenomena that can be repeated in the natural environment, for example sunlight, biomass, wind, terrestrial heat, solar heat, etc.

2 A substantial amount of bioorigin resources which can be utilized in the form of energy and materials (without crude oil, gas originated crude oil, natural gas and coal,)

50kW gas engine test plant of the Norin Biomass the Third (Isahaya, Nagasaki)
Photo: Nagasaki Institute of Applied Science

In 2004, a research team led by Dr. Masayasu Sakai, professor at Nagasaki Institute of Applied Science, developed "Norin Biomass the Third," a new system to supply thermal and electrical energy using biomass plants, as part of an attempt to minimize biomass plant with portability while reducing cost and enhancing efficiency, in partnership with National Agriculture and Bio-oriented Research Organization (abolished), under the contract with MAFF. They repeatedly tested the 50kW gas engine test plant while carrying out the basic research for property evaluation of gas chemical reaction of biomass plants as part of the "Academic Frontier Promotion Project for Private Universities," applying the outcomes from the promotion project to the test. In 2009, they started another project with grant under MAFF to develop practical plant with capacity of as much as 250kW that can produce methanol fuel and to test the technology.

In Tokachi Area, Hokkaido, the Exterior Tokachi Foundation is carrying out an experimental research project to produce bio ethanol from sugar beet and other major crops harvested in the region with the support of METI, MAFF, etc., aiming to utilize bioethanol[1] practically as an alternative fuel for petroleum. In 2009, several companies in the region worked in partnership to execute a large-scale experiment with the support of MAFF on the operations from procurement of ingredients through production and sales, utilizing a production facility that can produce 15,000 kilo litters of bioethanol annually.

In 2008, as part of the project to accelerate the process of paying back to the society in relation to the use of biomass promoted by the Cabinet Office, MIC, MAFF, METI, Ministry of the Environment, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), all working in cooperation, research and experimental verification were started regarding procurement and production of raw materials of bio fuel, development of production technology, and application of bio fuel to automobiles and others machines, and at the same time, discussions are being held to revise the regulations and the standards in relation to bio fuel.

Regarding the technology of biological generation of energy, JST inaugurated a project in 2008, as part of the Basic Research Programs, to conduct research on the green algae[2] that photosynthesize almost the same oil as light crude from carbon dioxide in the atmosphere with the leadership of Dr. Makoto Watanabe, professor at the University of Tsukuba, who discovered the algae, and the project is working on improvement of the algae species, enhancing the efficiency of oil extraction and refining methods, and R&D in relation to the mass cultivation system for the plant to enhance the efficiency in the oil production.

1 A type of biomass energy expected to be used as fuel for automobiles.
2 Microalgae, like any other terrestrial plants, carry out photosynthesis and contain many oil producing seeds. Its oil productive efficiency is significantly high in comparison to that of oil-producing plants. Makoto Watanabe, professor at the University of Tsukuba, is currently making progress with developing an excellent high alkaline culture strain that produces high productivity and breeding of hydrocarbon using green algae, Botryococcus capable of producing hydrocarbon of high quality oil.

C) R&D in relation to technologies of energy storage

The technologies related to the storage of energy with storage batteries and others are indispensable in our society while being practically used as small rechargeable batteries for cellular phones and storage battery for hybrid vehicles and also to be used in the future for electric vehicles, which are expected to be used, and for local electric power conditioning in the community or in the household once renewable energy are in practical use, and people are also hopeful about these technologies because it may result in expansion of the market in the future. On the other hand, conventional storage batteries have problems of low energy density and cost, so there are calls for some innovative technologies for energy storage, including raw materials and systems, in preparation for future use.

New Energy and Industrial Technology Development Organization (NEDO) started a project called "Development of High-performance Battery System for Next-generation Vehicles," aiming to develop high-performance low-cost rechargeable batteries, which are to be used in future hybrid vehicles and electric vehicles, with Toda Kogyo Corporation, Panasonic Corporation, Tokyo University of Science, Tohoku University, and National Institute of Advanced Industrial Science and Technology (AIST), promoting R&D for new lithium-ion batteries and others to meet the requirements regarding performance and costs (energy density 100 Wh/kg, power density 2 kW/kg, cost 30,000 yen/kWh) by 2015, when the practical use of electric vehicles is expected to be in the first phase.

JST launched a research project in 2008 with Dr. Yoshiharu Uchimoto, professor at Kyoto University, as a representative leader of the research team, as part of the Basic Research Programs, aiming to create new batteries with longer lifetime and high energy density made from magnesium, calcium, and aluminum to be used as a post-lithium-ion battery.

In Mie prefecture, a research project was inaugurated by Mie University, Mie Prefecture Industrial Research Institute, Mie Industry and Enterprise Support Center, and local companies in 2009, as part of the City Area Program, to research and develop polymer lithium rechargeable batteries [1] with some new properties such as safer, thinner, bendable, etc. using solid macromolecules as electrolytes. So far, for the first time in the world, this project has been successful in producing rechargeable batteries experimentally using solid polymers that function under the room temperature or below, and this technology may be applied in a wide range of products in the future, used as batteries for flat panel displays, electronic paper, etc.

d) R&D on fuel cell power system

A fuel cell power system is one of the promising technologies to be applied to vehicles, household, offices, etc. since it has a variety of advantages such as more efficiency than conventional internal combustion engines, no emission of carbon dioxide and nitrogen oxide, a substance that pollutes atmosphere. In Japan, commercial use of the fixed fuel cell power system has just begun in 2009 to be used as heating and electricity supply systems for home use, but there are still some issues with

1 A kind of lithium-ion batteries. Currently, regular lithium-ion rechargeable batteries apply fluid electrolytes, so certain measures must be taken against leak. Lithium-ion batteries with solid electrolytes in polymers are advantageous since there is no risk of leak.

the system, such as to lower the cost, to save resources, to enhance durability, to minimize hydrogen for production, storage, and for transportation, and to build distribution infrastructure, etc., so that development of an innovative fuel cell power system, including new resources, is needed.

Taking advantage of having some experiences through "Next-generation Fuel cell Project" hosted by MEXT," NEDO started a research project in 2008 to find new materials to be used to establish a basic technology for the fuel cell power system that can realize high performance, high reliability, and low costs at the same time, as a university-industry collaboration headed by Dr. Masahiro Watanabe, professor of University of Yamanashi. So far, they have been successful in developing the reforming catalyst to extract hydrogen more efficiently with less cost from coal gas, biomass, etc. and electrode catalyst with more durability, and they also have presented the developmental guidelines for new electrolyte films. In this research project, they are ultimately aiming to develop a new membrane electrode assembly (MEA)[1] that can function under low temperature or high temperature with less humidity without consuming so much resource and cost (reducing the amount of platinum as electrode catalyst to 1/10) to create a fuel cell with performance required for the practical use of hydrogen vehicles by the end of 2014 (energy efficiency: 64%, operating time: 5,000 hours, durability: 60,000 times of start and stop).

Column 1 Science & Technology to Reduce CO_2 Emitted from Our "Daily Life"

Japanese government has studies a variety of matters for the purpose of reducing the emission of carbon dioxide, and some aspects of people's individual living are in focus now, such as at home or in the office (public welfare) and transportation, as targets of CO_2 reduction.

For instance, in relation to the public welfare, people can consider (1)utilizing renewable energy with photovoltaic power generation or solar water heating or installing a home fuel cell power system, (2)utilizing LED and other highly efficient illumination, highly efficient air conditioner, TV, and other energy-saving devices, (3) applying well heat insulated house to save thermal energy (double glazed window, high heat insulator, etc.) or utilizing heat pump water supply, (4) utilizing IT network to visualize the amount used or installing a device control system to utilize energy efficiently at home or in the office.

In relation to transportation, (1) using an electric vehicle, a plug-in hybrid vehicle, etc., (2) improving public transportation, such as electric busses, etc.

By taking advantage of a variety of science and technology, including the innovative technologies mentioned above, it may be possible to reduce an significant amount of carbon dioxide emitted from our "daily living" without downgrading our comfortable living space and the quality of life. It may also be possible that the utilization of various technologies can trigger people's voluntary actions to change their life styles into low-carbon lives.

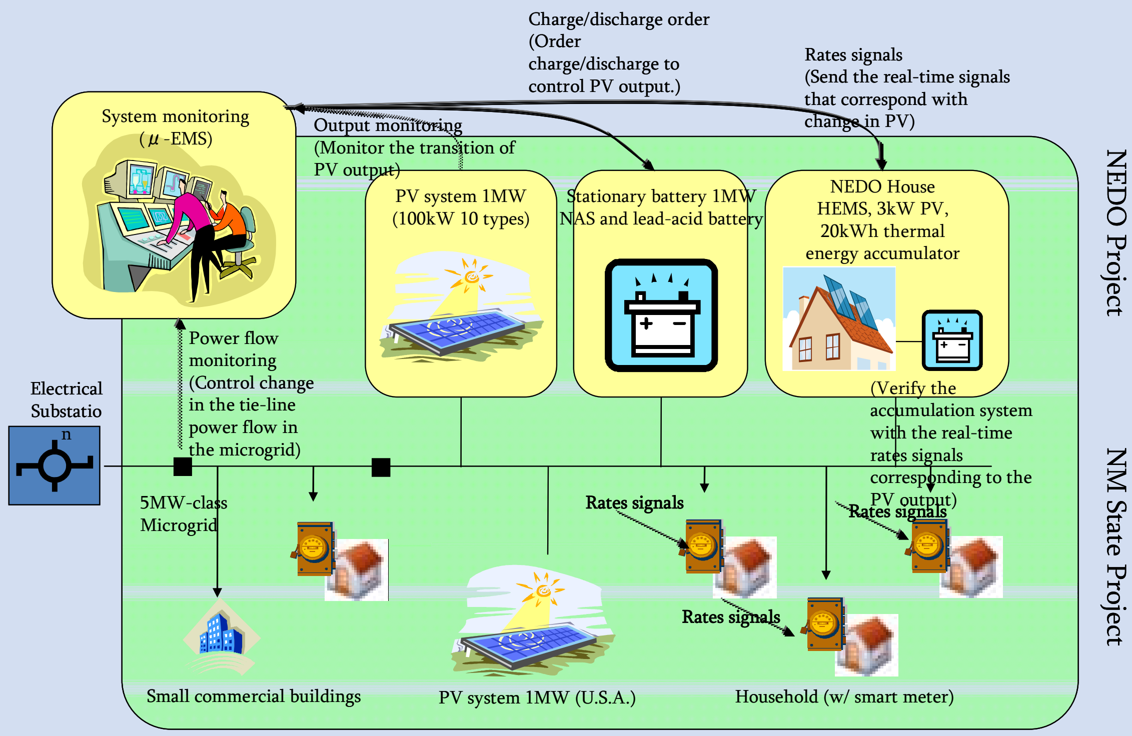
e) Smart grid technology

When renewable energy, including photovoltaic power, is introduced at a large scale, there are some risks of voltage change in the area and unstable frequency. Therefore, a power transmission and distribution network is attracting considerable attention to balance supply and demand efficiently by utilizing information technology for a stable supply of electricity. It is "Smart Grid."

1 The heart of the electricity generator in the cell connecting catalyst layer of hydrogen electrode (cathode) and oxygen electrode (anode) with the both sides of an electrolyte film that conducts positive electricity (hydrogen ion). When hydrogen and the air is supplied from outside to the EMA, voltage is generated. The more layers it has, the higher the voltage generated.

NEDO has established a joint experimental research program with the state of New Mexico in the United States to carry out technological experiment not easily executed in Japan due to regulations, to carry out trials of the technologies on the U.S. power grid, and to participate in the move of standardizing smart grid in Japan. Toshiba Corp., Hitachi Ltd., Kyocera Corp., and some other companies joined this project and they are now carrying out experiment on introducing solar cells and storage cells in the power system, residences, and buildings and analyzing the impact on transmission line systems. (Figure 1-1-8)

Figure 1-1-8 Illustration of experimental micro grid in Los Alamos, NM



Source: New Energy and Industrial Technology Development Organization (NEDO)

f) Carbon dioxide capture and storage (CCS) technology

The CCS technology, a technology to separate and capture the carbon dioxide generated at a thermal power plant and others and to store underground or underwater, is expected to reduce significantly the carbon dioxide in the atmosphere. The CCS technology is currently tested globally for the purpose of establishing the technology to be put into practical use by 2020.

Aiming to put the CCS into practical use by 2020, METI has launched a program to experiment the comprehensive system applying the series of technologies constituting the system while storing the CO_2 (about 1,000 m underground) captured at large-scale sources, such as thermal power plants, etc., and to develop technologies to capture CO_2 with lower costs, and to research and develop a stricter safety evaluation system.

2) Adaptation to global warming and impact prediction

a) R&D on the adaptive technologies to global warming in agricultural production activities

Since the activities of agricultural production are subject to the impact of climate change, it is important to research and develop an agricultural technology that can adapt to the change in climate and other environment due to the global warming. As part of the contribution to stable production of agricultural produce and of livestock products while adapting to global warming, National Agriculture and Food Research Organization (NARO) is conducting R&D on the technologies of growing new varieties of crops and of cultivation management for the purpose of predicting the impact of global warming on the crop and the quality of the agricultural produce as well as on the production of livestock and feeds, and of taking measures against sun burnt mandarin oranges, which is currently a problem in Japan, and other heat injuries. It is also working on R&D in relation to the technologies adaptive to temperature rise for the livestock industry. So far, NARO has been successful in suggesting cultivation methods, including the time to plant rice and the method of controlling the water levels in rice paddies to minimize the incidents of cracked rice.

b) Projection and evaluation of the impact of global warming

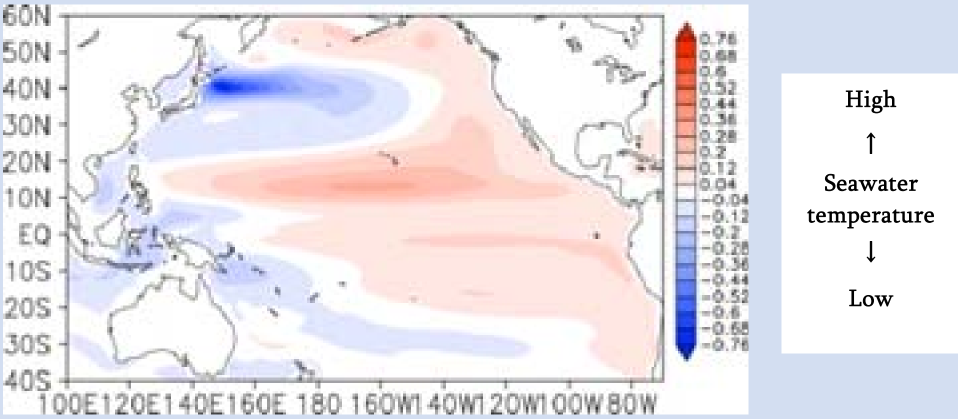
To predict any climate change as precisely as possible is necessary when taking measures against global warming.

A research team, led by Dr. Masaaki Sumi, professor of the University of Tokyo, engaged in development of a model to predict climate change utilizing the Earth Simulator, one of the most prestigious computers, and in conducting experiment on making predictions using this model, in the "Project for the Sustainable Coexistence of Humans, Nature and the Earth". The consequent analysis of the causes of increase in global average temperature and the prediction of long-term climate change by the end of the 21st century contributed to the creation of the Fourth Assessment Report of the IPCC. Based on this achievement, they are currently contributing to the next assessment report of the IPCC, and the team led by Dr. Masahide Kimoto, professor of the University of Tokyo, currently conducting "Innovative Program of Climate Change Projection for the 21st Century," is now working on development of a comprehensive model combining the model of the carbon cycle, circulating around land, sea, and air, and that of ecosystem, including marine animals and plants, with the conventional climate model, and experiment and other activities to predict with more prevision of climate change (Figure 1-1-9). In addition, further upgrade of the supercomputer is also expected in the future to make highly sophisticated and complex predictions on climate in a short period of time.

At Ministry of Environment (MOE), the "Project for Comprehensive Projection of Climate Change Impacts," led by Dr. Nobuo Mimura, professor of Ibaraki University, conducted a quantitative projection of the impact of climate change in major categories, such as water resources, forestry, agriculture, coastal areas, and health. Currently, while applying the outcomes of the experiment, they are proceeding with the research to provide more detailed prediction of the impact of global warming specifically for each region.

Figure 1 1 9 Sample of the outcomes obtained by Innovative Program of Climate Change Projection for the 21st Century

The simulation shows a typical pattern of "the Pacific decadal oscillation," regular shifts in the distribution of seawater temperature every 10 to 20 years in the Pacific Ocean. (The figures illustrate the distribution of late 1970-2000, and currently highs and lows are reversed in these periods) This has proved the validity of the projection model, so that the prediction experiment will be conducted starting as early as 2010 until around 2030.



Source: JAMSTEC, Atmosphere and Ocean Research Institute, the University of Tokyo

c) Global environment observation technology

When clarifying weather phenomena and examining highly accurate projections and countermeasures, it is essential to grasp accurate trends in changes of the global environment in accordance with climate change, and analytical observations will be necessary on a global scale in relation to greenhouse gas, water cycle, forest distribution, etc.

The Greenhouse Gases Observing Satellite (GOSAT) "IBUKI," developed jointly by Japan Aerospace Exploration Agency (JAXA), the Ministry of Environment (MOE), and NIES, was launched in January, 2009, and it is observing the distribution of the concentration of carbon dioxide and methane over most parts of the Earth's surface, beginning to offer the observational data to the public. The methods to accumulate and analyze observational data are expected to be improved while further enhancing the accuracy of the analytical data in order to be utilized as scientific data in discussions of IPCC.

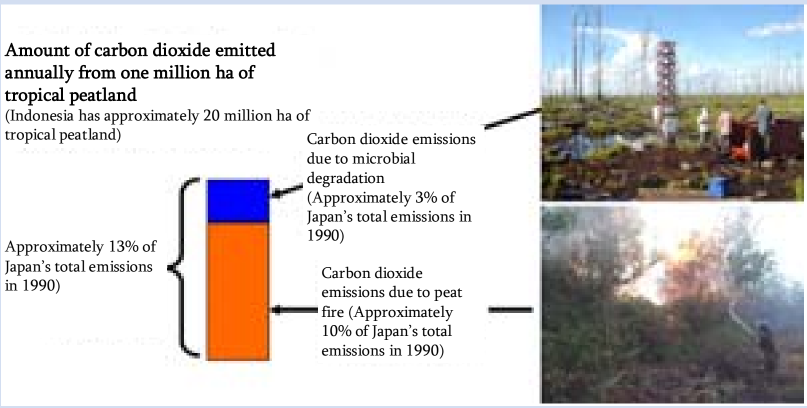
3) International collaboration research contributing to solving the global warming problem that other countries are facing

a) Peatland management in Indonesia

The Indonesian government reported that a large amount of carbon is accumulated in Indonesia's tropical peatlands, and the country is the world's third largest producer of greenhouse gas emissions after China and the U.S., including the emissions from forest loss and peatland devastation. Also, through research exchange activities between the research group consisting of researchers mainly from Hokkaido University and the Indonesian Institute of Sciences supported by the Japan Society for the Promotion of Science (JSPS), it is shown that carbon dioxide, which are 13 percent of CO_2 emissions in Japan in 1990, are emitted from 5 percent (a million hectares) of peatlands across

Indonesia per year. In Indonesia, peatland management becomes a significant issue related to global warming. (Figure 1-1-10)

Figure 1-1-10 Amount of carbon dioxide released annually from one million hectares of tropical peatland



Source: Center for Sustainability Science, Hokkaido University

Furthermore, since 2008, taking advantage of networks and knowledge cultivated through this research exchange activities, a research team led by Dr. Mitsuru Osaki from Hokkaido University has developed a system to detect and predict peat fire in Indonesia's tropical peatlands by using data from the Japanese Advanced Land Observation Satellite (ALOS), also called Daichi, in the Science and Technology Research Partnership for Sustainable Development (SATREPS), a joint project between the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA). Also, in cooperation with five organizations in Indonesia, the team has been conducting research and development of an optimal system to control and manage carbon released from the peatlands based on the measurement of carbon dioxide balance and the control of water levels and afforestation around the peatlands.

b) Prediction of abnormal weather in the southern African region associated with climate variations

Due to complex interplay of the Indian Ocean Dipole (IOD)[1] and other phenomena of climate variations, there are many incidents of drought and flood that cause damages in the southern African region. As the global warming progresses, the abnormal weather may occur more frequently. Thus, it is our challenge to establish a skill to accurately predict complex climate variations around this region.

Prof. Toshio Yamagata of the University of Tokyo discovered the IOD phenomenon, which can trigger abnormal weather worldwide, during the research conducted at "Frontier Research System for Global Change", Japan Marine Science and Technology Center (former) in 1999. Afterwards, in the "Project for the Sustainable Coexistence of Humans, Nature and the Earth" and other projects,

1 The Indian Ocean Dipole (IOD) is a coupled ocean-atmosphere phenomenon in the Indian Ocean. It is normally characterized by anomalous cooling of SST in the south eastern equatorial Indian Ocean and anomalous warming of SST in the western equatorial Indian Ocean. Associated with these changes the normal convection situated over the eastern Indian Ocean warm pool shifts to the west and brings heavy rainfall over the east Africa and severe droughts/forest fires over the Indonesian region.

his group conducted research using an accurate seasonal prediction model ran on the Earth Simulator and produced many outcomes. In 2005, the team was the only one in the world, which successfully predicted the serious drought that occurred in Australia in 2006.

Taking advantage of the above experiences, they have started a bilateral project in 2009 with the Republic of South Africa in the framework of "Science and Technology Research Partnership for Sustainable Development (SATREPS)" of JICA/JST, with the professor as the leader on the Japanese side. This project aims to enhance the capacity of seasonal climate prediction in the Republic of South Africa so that it can be applied to management of environmental problems in the southern African region. More specifically, utilizing the Earth Simulator, they will clarify mechanisms of climate variations that influence the southern African region, perform global-scale climate prediction with about one-year lead using their highly accurate coupled ocean-atmosphere model, conduct regional prediction of abnormal weather, and utilize these prediction results.

2 Trends in R&D in the United States and European Countries

In Europe and in the United States, governments have progressed further with moves to strengthen research and development on the technologies in relation to global warming. In recent years, there is also a global trend of moves to promote R&D activities with the participation of researchers from multiple fields.

In the United States, the Obama administration have carried out a drastic review on the U.S. energy research strategies, including the enhancement of the research in the fields outside the military and defense sector. In such circumstance, the U.S. Department of Energy (DOE), under the direction of Energy Secretary Steven Chu, is taking a leadership in the field of the technologies related to measures against global warming executing various projects as following:

1) To build a network connecting 46 research centers to establish Energy Research Centers (EFRCs) to promote a variety of problem-solving basic research.

2) To start providing grants by the Advanced Research Projects Agency-Energy (ARPA-E) for high-risk research of a variety of levels from the Valley of Death to Darwinian Sea[1] or more

3) To establish an energy innovation hub to be the basis of interdisciplinary research and development carrying out from the basic research through the industrial development necessary for commercialization, with the participation of researchers from a variety of fields, such as natural sciences, energy strategies, economics, etc.

4) To start RE-ENERGYSE for the purpose of training about 8,500 researchers and technicians involved with clean energy by 2015, implemented under the partnership of National Science Foundation (NSF), Department of Education, Department of Labor, etc.

The FY 2011 President's Budget indicates that such efforts will be further reinforced. (Figure 1-1-11)

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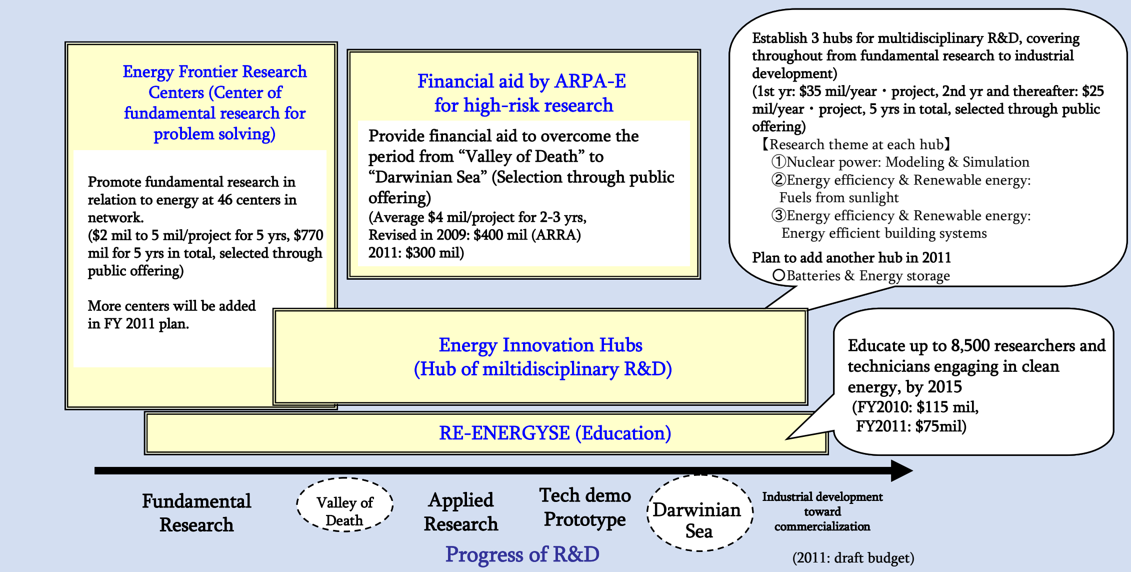
[1] In order to create innovation, in between the basic research to development of application stage, due to inadequate funds the researchers fall into what is called "Valley of Death" and to aim for a success in industry, there is a stage called "Darwinian Sea" where harsh competition is taking place against other competitors.

Figure 1 1 11 Major R&D measures of energy at DOE



Source: Prepared by MEXT based on JST/ Center for Research and Development Strategy

European Union (E.U.) has been aiming to build a European research zone and deploying the policy emphasizing on R&D activities to address global warming issues, as shown in the Seventh Framework Programme for Research and Technological Development (FP7), which is implemented mainly to support joint research across the member countries. In addition, under the leadership of the industry, with the participation of experts and stakeholders in companies and universities, eight research areas have been promoted, such as solar power generation, biofuel technology, smart grid technology, and fuel cell power generation system, etc., as the European Technology Platform (ETP), which is to discuss each area's future visions and road maps. The European countries also issued a policy to focus on R&D related to global warming technology, promoting the R&D activities. For example, in Germany, the "Helmholtz Network Regional Climate Change (REKLIM[1])" was established in October 2009 to carry out R&D with the 8 institutions under the Helmholtz Association in partnership, spending about 32.2 million euro (about 5 billion yen) for the 5 years from 2009 on the investigation to understand the interactions of atmosphere, sea, and ground surface and the climate change associated with the interactions, to conduct research on prediction of the impact of such phenomena to Germany, and to provide optimal choices of both adaptive and easing measures. In U.K., too, new investments were made in 2009 for R&D projects carried out by several institutions established by the collaboration of industry, academia, and government, including the "Low Carbon Vehicles innovation Platform competition" for the purpose of supporting industry-led collaborative projects focused on development of supply chains while strengthening the U.K. capability in relation to R&D of low-carbon vehicles.

[1] Regionale Klimaänderungen

Column 2 Energy Frontier Research Center

U.S. Energy Frontier Research Center (EFRC) is a problem-solving basic research program targeting 10 focal research areas related to energy, establishing 46 centers in universities and national research institutions, inviting applications from the public, and started in 2009. Each center, in partnership with other research institutions, conducts R&D activities related to at least one focal research area utilizing nanotechnology and other advanced technologies, and about 700 senior researchers and about 1,100 young researchers and technical assistants, including post doctors participate in this program as a whole. In addition, all of the over 100 research institutions participating in this program consist of the nation-wide network.

In the phase prior to the inauguration of this program, DOE Office of Science examined the program with the participation of more than 1,500 experts of universities, the industry, research institutions, etc. in total in for about 8 years, from 2001 until 2008, summarizing issues to be overcome and focal areas to be researched, looking at the year 2050.

10 Focal Research Areas	
1. Hydrogen Economy 2. Solar Energy Utilization 3. Superconductivity 4. Solid-State Lighting 5. Advanced Nuclear Energy Systems 6. Clean and Efficient Combustion of 21st Century Transportation Fuels	7. Geosciences: Facilitating 21st Century Energy Systems(Geological disposal of radioactive waste and carbon dioxide) 8. Electrical Energy Storage 9. Materials under in Extreme Environments (High temperature, high pressure, high magnetic field, etc.) 10. Catalyits for Energy

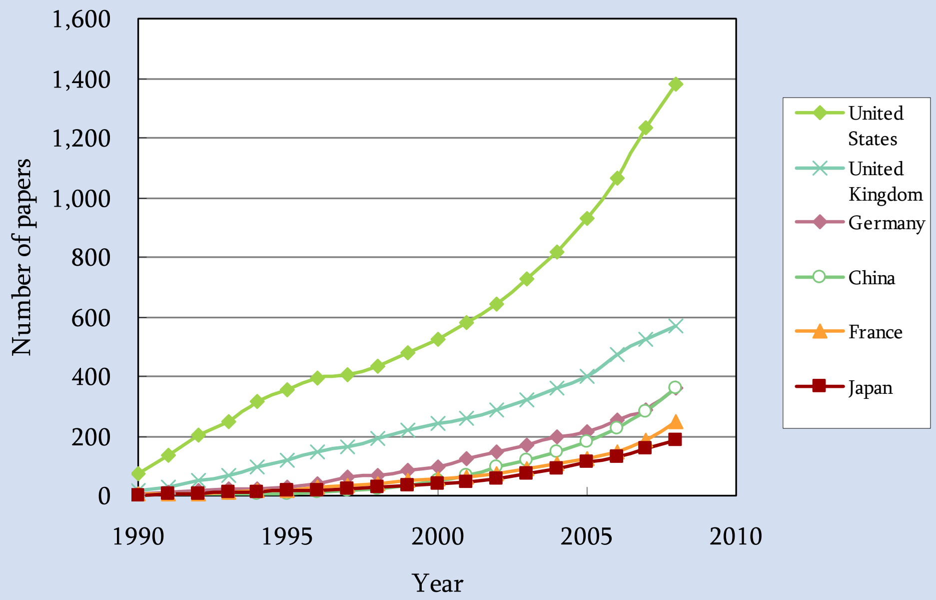
3 Knowledge Integration for Low Carbon Society

Global warming and other global problems are not merely energy problems but have become very complicated and large scale beyond the rage someone can handle individually with their component technologies, involving all the areas related to human activities, such as resources, international politics, economy, technology, etc. In addition, a wide-range of knowledge is required to solve the problems, and under such situation, it has become too complicated for one person to grasp the overall picture of the problems. Therefore, when promoting the R&D of the technologies against global warming, it has become more and more important to work on R&D not only in a single specialized and segmented research area but also with integral knowledge of researchers and technicians of other related areas.

On the other hand, in Japan in general, it is said that such R&D that integrates different areas is not sufficient. For example, looking at the world trends in the number of papers with the terms “sustainability” or “sustainable,” which are the keywords in the integrated research area in relation to the global warming problem and other environmental problems, written in each country, the number of each country in the world has increased significantly whereas in Japan, it still tends to be increasing but the number itself and the pace of increase are smaller than other countries, illustrating a part of the current situation surrounding Japan. (Figure 1-1-12)

In order to promote R&D of technology against global warming, more talented researchers, especially basic scientists, are expected to become interested in the creation of a low carbon society or in the global warming problem and to participate actively in solving the problems. Then, it is important for such researchers to gather to share the goal of realizing a low-carbon society, to execute comprehensive projects with the participation of the researchers not only form the research areas closed related to this goal but also from a variety of areas, including completely different ones, such as natural, cultural, and social sciences, and to promote smooth partnership and network among researchers and research institutions across multiple areas.

Figure 1 1 12 Trends in the number of papers related to "sustainability" in selected countries



Note: 1. Innovation Policy Research Center, the University of Tokyo developed the data based on Elsevier SCOPUS Custom Data.
2. 3-year moving average. For example, the values of 2006 are average of 2005, 2006, and 2007.
Source: Prepared by MEXT based on the materials of Innovation Policy Research Center, the University of Tokyo

Furthermore, in order to realize economic growth while addressing the problem of global warming, it is essential to promote widespread application of the outcomes of R&D and it is also necessary to implement or revise systems (tax, subsidy, and other systems), to regulate, or to deregulate. Therefore, there is a growing importance of projects integrating natural sciences with different areas in cultural and social sciences, including sociology, economics, psychology, etc. Japan has also started attempts of research in the integrated areas of natural sciences and cultural/social sciences, and the following are some of the examples.
1) "Integrated Research System for Sustainability Science" was established in 2005 by five Japanese universities, including the University of Tokyo, with the support of Special Coordination Funds for Promoting Science and Technology, to conduct studies on sustainability science, which aims to solve problems on global warming and other problems from the viewpoint of sustainability, and it engages not only in research activities but also in communications with the society, training of human resources in research and education, issues of international journals, international cooperation, and other activities in a wide range.
2) Research Institute for Humanity and Nature (RIHN), which was founded in 2001, has started to indicate the guidelines to integrate the outcomes from the research activities with a variety of subjects, such as water cycle, atmosphere, climate, oceans, groundwater environment, islands,

ecological systems, etc., which have all been on the process of research, and to combine them beyond the framework of cultural, social, and natural sciences as global environmental studies, and they are promoting joint research among universities and research institutions inside and outside Japan. (Figure 1-1-13)

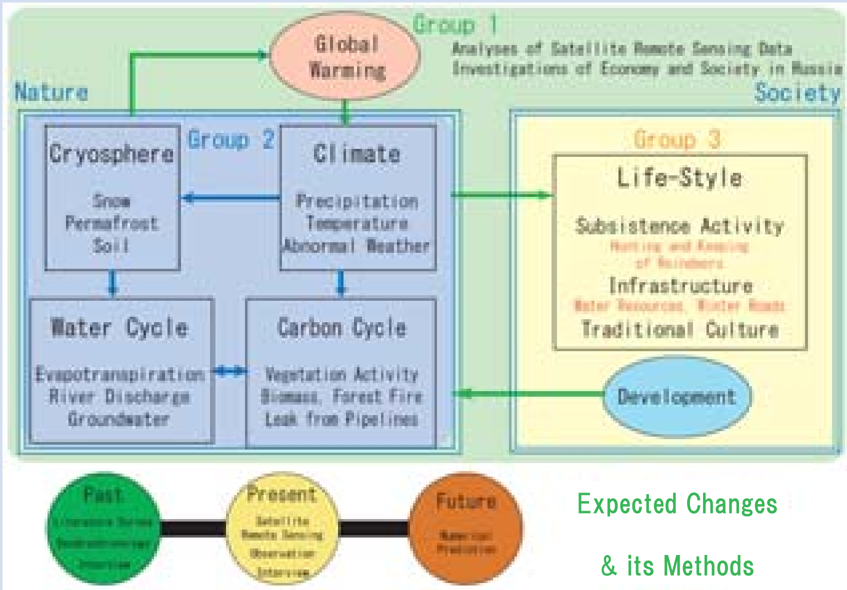
3) The Ministry of Environment started a new research program about environmental economics and policy studies in FY 2009, to study impacts of the efforts of environmental preservation to the economy or those of economic moves to environment.

In addition, the MEXT has established the JST/Center for Low Carbon Society Strategy to promote comprehensive efforts by combining research and development on social scenarios and easing/adaptive technologies, with the participation of researches and other related people in the fields of natural, cultural, and social sciences, and they have just started a full-scale research activity in 2010 in relation to quantitative social scenarios for the purpose of creating a low carbon society.

In order to realize a low carbon society, it is essential to implement comprehensive projects that include even the viewpoints of cultural and social sciences while integrating areas within natural sciences.

Figure 1-1-13 Case Study at Research Institute for Humanity and Nature (RIHN)

"Nature and people in the warming of Siberia- Adaptation of society to changing water environment and other terrestrial ecosystem"
This study aims to clarify the impact of global warming and development on indigenous people and others in urban and rural areas in Siberia through changes in water environment and ecosystems (including greenhouse gas balance), by means of research with satellites and on the ground or the studies of history and culture of indigenous people.



Source: Research Institute for Humanity and Nature

Section 2 Science and Technology Contributing to Safe and Sophisticated Human Life

Japan is facing problems to be solved, such as low birth rates and population aging, as well as the issues that threaten people's lives and need countermeasures, such as natural disasters, infection, water problems, etc.

For people to enjoy their health and high quality of life, it is necessary to promote R&D and innovation that enable advanced medical supplies and nursing care techniques and stimulate further growth of the country while considering the industries based on the scientific technologies related to healthcare and nursing as Japan's leading industries. It is also important to eliminate the causes of the threat against people's lives by means of science and technology. Thus, it is important to promote science and technology used for the measures against natural disasters, crimes, terrorism, as well as for stable supply of food, water, etc. to create a society in which people in the country can live comfortably and safely.

Although R&D in such areas plays an important role in establishing the basis of safety and high quality of life for people, it sometimes takes significant time and effort to bring out industrial outcomes, and in other times, it is not easy to bring out results in a short period of time, so the national government need to be actively involved with the projects. So far, the Cabinet Office, Ministry of Education, Culture, Sports, Science and Technology (MEXT), and Ministry of Health, Labour and Welfare (MHLW) have conducted a variety of R&D projects through ""Funding Program for World-Leading Innovative R&D on Science and Technology (Cabinet Office)," "World Premier International Research Center Initiative (MEXT)," and "Super Special Consortia for Supporting the Development of Cutting-edge Medical Care [Cabinet Office, MEXT, MHLW, and Ministry of Economy, Trade and Industry (METI)]," a program to stimulate development and commercialization of advanced medical treatment, medicines, and medical instruments.

This section is an overview of the current state of R&D in relation to the science and technology that will contribute to people's health and to safe and peaceful life in the society.

1 Science and Technology Contributing to Human Health

To maintain the health of people continuously in the future, enhancement of applied research and R&D based on the development of basic research, which is the seed of innovation. In addition, to bring out creation of a number of innovative medicines and medical instruments from the outcomes of Japanese excellent R&D activities, it is necessary to promote development of a powerful system to execute translational research, clinical research, as well as clinical trials, and quick screening and approval of medicines and medical instruments.

To date, challenging R&D have been conducted in a wide range of areas outside of life science, from the basic research of understanding life functions and causes and conditions of diseases to R&D of new medicines, medical instruments and medical and nursing techniques. The following section provides some of the case studies in relation to R&D for people's health.

(1) Research to Understand Living Bodies and to Develop into Future Therapies

1) Clarifying biological mechanisms of pathogen recognition in living bodies

A living body protects itself against pathogens by means of innate immunity, which is a transient defensive reaction of living body of nonspecific nature, and acquired immunity with strong and long-lasting effects by producing specific antibodies and others. However, the detailed mechanism and the relationship between natural immunity and acquired immunity have so far not been fully elucidated.

Dr. Shizuo Akira, professor of Osaka University, clarified that the Toll-like receptors (TLR) on the cell surface recognize the unique structure of the pathogen and activate itself, resulting in immune response and inducing acquired immunity. They are currently working on clarifying the detailed mechanisms of how innate immunity can activate acquired immunity. In addition, they are aiming to visualize the immune response in living animal bodies through the integrated research of immunology, imaging (visualizing) technology, and bioinformatics to clarify the whole picture of the immune system. They are in partnership with RIKEN Research Center for Allergy and Immunology and Institute for Frontier Medical Sciences, Kyoto University in Japan, and overseas, with U.S. National Institutes of Health (NIH), Harvard University, New York University, California Institute of Technology, Stanford University, University of California, San Francisco, and the Institute for Systems Research.

The findings are expected to be applied to elucidation of causes and conditions of infectious diseases, autoimmune disease, etc., development of their remedies, and development of anti-allergy medication, cancer vaccines, and other medicines.

2) Developing drugs and medical technologies for disease research using genetically modified primate

It is normal for modern medical research to prepare animal models, such as a modified mouse with a gene responsible for human disease to be used to elucidate causes and conditions of diseases and to develop remedies. However, a human (primate) and a mouse (rodents) have a variety of different aspects although these two are the same mammals, so the results obtained from mice cannot frequently be applied directly to human beings. Thus, there were calls for development of transgenic animal primates, but the technology was not established.

Dr. Hideyuki Okano, professor of Keio University, successfully developed a technology to modify primates genetically, and he announced it in 2009 (Figure 1-1-14). Modified genes have been verified to be passed down from the next generation. This research on the genetic modification of primates started in around 1970 in partnership with the Central Institute for Experimental Animals, focusing on the Common Marmoset[1], a small primate with high reproductive capacity. The Institute established a standardized high quality laboratory animal with common marmoset in 1991, and since 1992, they have been devoted in developing technologies of reproduction engineering, such as generation of ES cells and establishment of in vitro fertilization. In the future, transgenic animals with genes for Parkinson’s disease and other incurable diseases are expected to be prepared to be utilized in research and therapy development.

Development of basic technologies supporting research activities, including the preparation of laboratory animals, takes many years before its completion, it is very important for enhancement of cutting-edge research.

1 Common Marmoset belongs to the genus Callithrix in the Callitrichidae family.

Figure 1 1 14 Genetically modified Common Marmoset

Note: The research was published in the Nature magazine and featured on its cover. Sasaki et al. Generation of transgenic non-human primates with germline transmission, Nature, 459(7246):523-527, 2009.
Source: School of Medicine, Keio University

(2) Research on innovative medical technologies for the treatment of heart disease, cancer, and dementia

1) R&D for the regenerative medicine using iPS cells, etc.

The method to generate iPS cells (induced pluripotent stem cells) was found by Dr. Shinya Yamanaka, professor at Kyoto University, and others. These iPS cells, which can be induced or differentiated[1] freely into a variety of cells, have enable the study to clarify the cause and the conditions of diseases and to assess the safety and efficacy using the cells of tissues and organs derived from iPS cells of patients, instead of conducting traditional experiment on humans when evaluating side effects and effectiveness in drug discovery. This is expected to bring us safer and more efficient R&D of innovative medicines and medical technologies. It is further expected that regenerative medicine will be realized by transplanting various cells derived from human iPS cells to regenerate the lost function of the affected tissues.

Currently, the research outcomes are being accumulated in the laboratory about iPS cells and ES cells induced and differentiated into cardiomyocytes, blood cells, pancreatic β-cells, corneal neural progenitor cells, etc. to be transplanted to animal models with myocardial infarction or spinal cord injury, and in addition, research and development in relation to the safety of iPS cells and the techniques to evaluate the cells' functions in various universities and research institutions in Japan for the purpose of clinical application. On April 1, 2010, Kyoto University established the world's first "Center for iPS Cell Research and Application" as a global hub to start research for the purpose of clinical application of iPS cells. In addition, "MEXT iPS Network" was established in April 2008, consisting of researchers and research institutions participating in the R&D related to iPS cells, etc., receiving support from MEXT and JST, to develop a virtual research promoting system to share centralized information related to the research outcomes and assets for the purpose of promoting the research on iPS cells and other stem cells and on regenerative medicine in whole Japan.

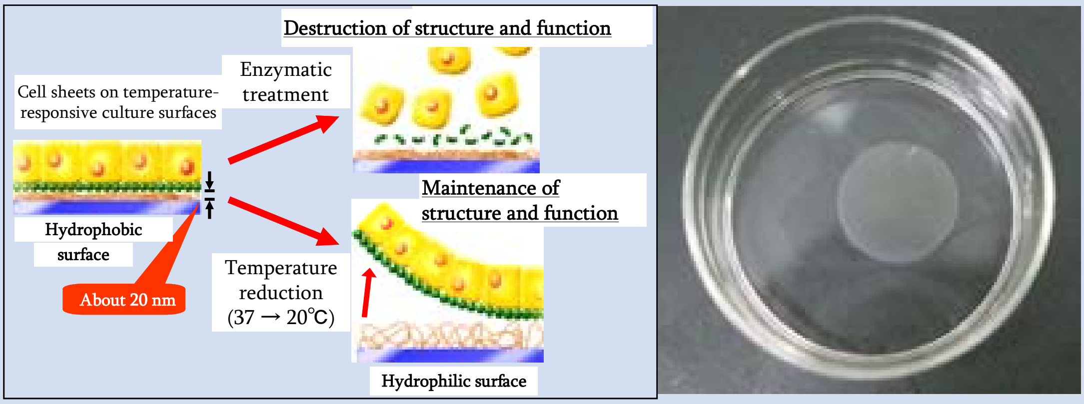
1 Differentiation means the phenomenon of cells changing into distinct shapes of a living creature, whereas induction means the changes of the cells caused by certain substances made by the genetic material during the process of differentiation.

2) Regenerative medicine applied to the innovative tissue engineering

Cells do not exist solely in a living body, but cells are closely coupled with each other in structural and functional manners to constitute an organization. In addition, tissues and organs have unique three-dimensional structures.

Dr. Mitsuo Okano, professor of Tokyo Women's Medical University, developed a culture dish that changes its surface property in hydrophobic or hydrophilic according to the temperature (temperature-responsive culture dishes) for the purpose of developing a cell sheet that mimics the structure of a living body. Then, they made a single-layer cell sheet while culturing cells to be transplanted to the damaged part of a tissue or an organ, enabling regeneration of a lost function (Figure 1-1-15). A world leading clinical research has already been started with corneal epithelial cell sheets made with the corneal epithelial stem cells or from the cells taken from the oral mucosa of the patient, transplanted into his/her cornea. Clinical studies have also been started on the myocardium. They have also been successful in developing basic technologies related to regeneration of tissues of skins, bladder, esophagus, blood vessels, lung, livers, etc. These studies are conducted in partnership with the National Center for Child Health and Development, Nagasaki University, Osaka University, Tohoku University, Dai Nippon Printing, Co., Ltd., CellSeed Inc., Olympus corp., Hitachi Ltd., etc.

Figure 1 1 15 Cell sheet



Note: The right is a cell sheet for heart muscle.
Source: Tokyo Women's Medical University

3) New cancer drug treatment: Development of peptide vaccine therapy

Dr. Hiroshi Shiku, professor at Mie University, started the R&D of complex cancer vaccines in 2009, combining the cancer vaccines with immunity enhancement technologies using genetically modified T-cells in partnership with Sapporo Medical University, Keio University, Takara Bio Inc., etc.

Dr. Yusuke Nakamura, professor of the University of Tokyo, is working on the development of the peptide vaccine for cancer therapy and its clinical application in partnership with Kurume University, Sapporo Medical University, National Cancer Center Hospital East, and the University of Tokyo. The peptide vaccines cancer therapy is a medical therapy to attack cancer cells by injecting a peptide vaccine[1] to enhance immunity, restraining growth of the cancer, reducing it, etc. Currently, they are conducting clinical studies on lung cancer, esophageal cancer, hepatitis C, liver cancer, etc.

In the Kurume region in Fukuoka prefecture, the Knowledge Cluster Initiative (to develop a global hub) was started in 2009 for the purpose of forming a development base for high-tech world leading medicine with the cancer peptide as the core of the project, and 29 institutions, including Kurume University as a leader, along with Kyushu University, Kyushu Sangyo University, Fukuoka Biotechnology and Food Research Institute, Fukuoka Industrial Technology Center, etc. are currently conducting the R&D activities.

4) Research on elucidating the cause of cognitive dysfunction

Parkinson's disease is an incurable disease that frequently occurs in elderly people with the symptoms of trembling limbs due to lack of brain neurotransmitters (dopamine), and the number of the patients is increasing with the progress of aging society. Parkinson's disease was traditionally said not to have significant cognitive impairment, but there have been cases in which the patients demonstrates the symptom of dementia with the progress of the disease. Thus, it is attracting many people's interests in the correlation with the dementia.

A group of researchers from National Institute of Radiological Sciences (NIRS) and Chiba University clarified using the positron emission tomography (PET) while examining the image of the brain, that the cognitive function in the cholinergic nervous system[2] in the brain of the patients with Parkinson's disease is already in decline compared to healthy people at the early stage of the disease, at which the symptoms of dementia are not recognized yet, with a remarkable tendency as the degree of cognitive impairment worsens. The outcomes of the research are expected to contribute to the determination of the causes and development of treatments of Parkinson's disease.

(3) R&D Connected to New Medical Devices and Support to Provide Services

1) R&D of radiation therapy equipment to treat while tracking the cancer automatically

With advances in equipment diagnosis, the effectiveness of radiotherapy of malignant tumors is enhancing because of greatly improved technology to track the precise position of the tumor, enabling intensive radiation on the malignancy and minimization of damage to surrounding normal tissue. However, since the location of tumors always moves a few centimeters in the body due to breathing and heartbeat, except for brain, the techniques to conduct diagnostic imaging and radiation therapy accurately in a timely manner are necessary to pinpoint the radiation to the tumor.

Dr. Hiroki Shirato, professor of Hokkaido University, conducted three times the continuous real time calculation of the location in three dimensions, resulting successfully in the tracking radiation therapy, in which radiation is applied only when the coordinates of the planned radiation and those

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1 A small protein consists of 9 to 10 amino acids and it has been developed to suppress the cancer cell to proliferate by increasing the immunity of the patient.

2 Cholinergic nervous system and should involve the nervous system neurotransmitter called acetylcholine, that happens hypothesis that cognitive dysfunction in this disorder.

of the calculation have matched. Currently, based on this research, they are conducting R&D of a radiation therapy device equipped with the functions to track malignant tumors in the body and to apply radiation automatically. In addition, they are working in partnership with Hitachi Ltd. and Mitsubishi Heavy Industries, Ltd. to develop radiation treatment apparatus equipped with PET, which can visualize malignant tumors in the body.

NIRS is conducting R&D of the radiation technology combining the technology to fill along the outline of a tumor utilizing high dose distribution of the heavy iron beam therapy to apply radiation in accordance with the movement of breathing.

2) Life supporting service robot

With the progress of aging society, there are more households in which people are forced “elderly-to-elderly nursing,” or the situation in which an elderly person has to nurse another elderly person, and especially in relation to caregivers, the problem of not only the increasing emotional burden but also the physical burden has become a significant social problem. With these backgrounds, in recent years, robots (service robots) are under research and development to support caregivers and careers to secure freedom of actions.

Dr. Yoshiyuki Sankai, professor of University of Tsukuba, has developed the wearable robot suit “HAL” for the purpose of enhancing and amplifying the physical functions of human being. Further R&D will be conducted to advance the robotic suit so as to move as people think to be applied to rehabilitation and assistance to elderly people’s living. It is intended to be industrialized by the year 2018. A university venture, CYBERDYNE Inc. was also founded in 2004 to conduct R&D of equipment to support human functions while utilizing the above-mentioned research.

METI launched “Life Support Robot Commercialization Project” in 2009 to promote commercialization of robots that serve nursing, welfare, housework, safety, security, etc. (Figure 1-1-16) The project aims to establish personal safety in the practical use of the life support robots as well as to pass the international standards in five years, while collecting and analyzing the data in relation to safety to develop safety technologies of the robots.

Figure 1 1 16 Transport Assistance Robot wheelchair to support independence and help elderly people (Robotic bed)

Note: The shape can be changed in flat bed mode, back rest up, wheelchair separated from the bed.
Source: Panasonic Robot Business Promotion Center

(4) Efforts on Health Sciences with Collaboration of Different Areas, Including Cultural and Social Sciences

1) Research and education center to address interdisciplinary research on aging society

In order to solve a wide range of complex issues in an aging society, it is necessary to develop a new academic discipline comprising of medical sciences, nursing, biology, engineering, laws, economics, sociology, psychology, ethics, pedagogy, etc. new disciplines.

In April 2009, the University of Tokyo established a new interdisciplinary research and education center, "Institute of Gerontology," so that Japan can gain the initiative to address issues of the aging society. The research of the institution is based on fundamental understanding of aged individuals and the aging societies as well as the technological R&D to support the lives of the elderly, conducting research projects for issues taken from the community or the society, in cooperation with the community and companies (Figure 1-1-17). Also, based on the idea that the interdisciplinary study of gerontology[1], which is developed to deal with the problems of the elderly and the aging society, is very useful for the future no matter in what areas they are going to be specialized in, a gerontology program was launched for the first time in Japan with the inter-disciplinary classes in the curriculum.

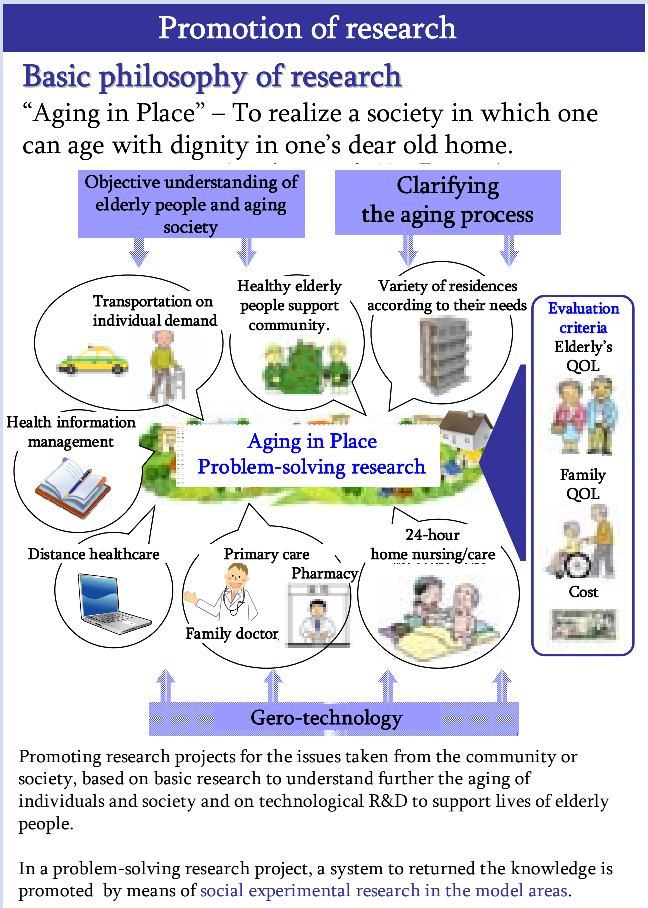
2) Suggestion on policies under the collaboration of industry and academia: Silver New Deal

In February 2010, Todai Policy Alternatives Research Institute and Council on Competitiveness-Nippon (COCN)[2] released the advocacy, "Silver New Deal for Active Aging Society," a collaboration of the industry and the academia to realize a society in which everybody, including the elderly, can live peacefully, while taking full advantage of the ability of elderly people. It explains that the Silver New Deal is "to create new industries and employment, while solving the problems arising as the society ages, by connecting the potential demand of an aging society, not limiting to domestic one, and the power of the suppliers of new technologies, ideas, business models, local resources, etc. that exist in Japan." In view of promoting the Silver New Deal, some of the suggestions were presented, including establishment of an aging society grants to support the overall concept of the fusion of culture and sciences, experiment and verification of urban living models in limited regions under the industry-academia and public-private partnership, and creation of national framework to develop a society in which elderly people are set as the standards.

1 Gerontology includes medical sciences, nursing, physical sciences, engineering, laws, economics, sociology, psychology, ethics, pedagogy, etc., encompassing a wide range of disciplines. (Institute of Gerontology, the University of Tokyo)

2 Council on Competitiveness-Nippon (COCN) was established in 2006 by industry volunteers with a deep interest in Japan's industrial competitiveness.

Figure 1 1 17 Institute of Gerontology



Source: Institute of Gerontology, the University of Tokyo

3) Health promotion in collaboration with the community

Shinshu University conducted a health project for local residents in cooperation with local governments and corporations, in the educational and research field of comprehensive preventive medicine at Matsumoto College of Physical Education for Middle-age People, and established an NPO, "Jukunen Taiikudaigaku Research Center (Research center of college of sports for middle-age people)" with the president Dr. Hiroshi Nose, professor of Shinshu University in 2004.

This is a university-industry and public-private collaborative project initiated by Shinshu University, Matsumoto City, corporations in the private sector, and citizens, and in addition to the activities for the community, they are conducting such activities as providing know-how of the health promotion projects based on scientific grounds (EBH: Evidence Based Health-promotion), mainly of sports, for local governments, groups, hospitals, corporations in Japan, and as a result, 11 local governments, 11 hospitals, and 17 corporations have participated. Interval walking was developed in the project, alternating between slow walking and brisk walking. Records are retrieved automatically with the equipment attached to the waist, and the data are forwarded to the center, enabling the result of the analysis regarding caloric consumption, muscular strength, endurance, etc. returned to the individuals via the Internet along with the guidance on exercise, nutrition, and mental health.

University of Tsukuba started a health project for the elderly incorporating strength training, etc. in collaboration with the government of Taiyo Mura (currently the City of Hokota) in Ibaraki in 1996, developing an effective system for health promotion for elderly people. In 2002, for the purpose of disseminating scientific evidence-based systems for local health program community, the university established a university venture, "Tsukuba Wellness Research " (President: Shinya Kuno, Associate Professor of University of Tsukuba), providing the system of personalized health care assistance program utilizing IT technology for more than 30 municipalities and companies across the country up to date. The high-performance pedometer automatically records the user's daily activities, which assists in the health management appropriate for each individual by combining the physical test results conducted on a regular basis with the data, for the purpose of preventing lifestyle-related diseases and bedridden.

Nagasaki Prefecture, which has the islands and remote areas with highly aged societies, is working on the project to promoted industry-academia-government collaboration in urban areas under the leadership of Nagasaki University for the purpose of developing a preventive home care system for the residents. In cooperation of healthcare facilities and nursing homes in the islands and remote areas and of Nagasaki University Hospital, they are working on commercialization of health-check equipment, such as a blood sugar meter utilizing non-invasive sensing technology, a lung sound checking system, a urine management system, etc., while aiming to develop a preventive home care system connecting the medical network and the above-mentioned equipment through mobile phones, etc.

The University of Tokushima established the Centers for Diabetes in 2007 to overcome the extremely high mortality of diabetes in Tokushima Prefecture, promoting further epidemiological survey targeting the residents in the prefecture, while establishing the Diabetes Clinical Research Center in 2009 to conducting R&D in relation to prevention and treatment. In addition to this, Tokushima Prefecture started the "Medical Tourism" that combines treatment of diabetes and tourism, in partnership with Tokushima University Hospital, aiming to establish the diabetes treatment center, which is expected to increase its number in Asian countries in the future.

As mentioned above, efforts to promote people's health have begun in partnership with universities and community. Such activities are expected to increase further in the future since that leads to the reduction of regional medical costs.

2 Science and Technology for Social Safety and Security

While building a society in which people's safe and secure lives are maintained, it is necessary to prepare measures to prevent or, if not possible to prevent at all, to minimize the damage from the matters considered to bring an enormous impact on our lives.

The following are examples of the measures applying science and technology against the main incidents that are considered to threaten safety and security of people's lives.

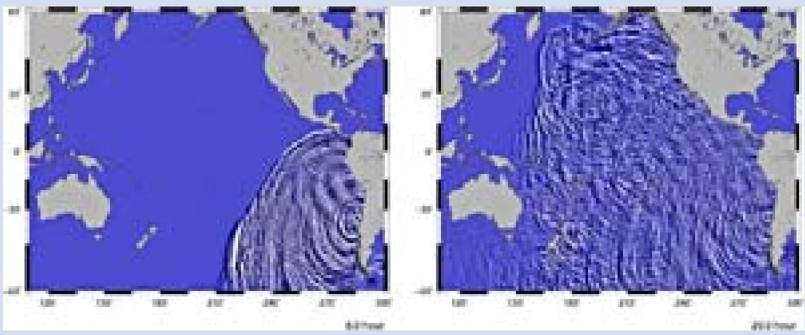
(1) Science and Technology in Relation to Prevention and Reduction of Natural Disaster

Japan is prone to disasters such as earthquakes, tsunamis, typhoons, floods, etc. due to its geographical conditions, weather, and other natural conditions. The number of those who die in natural disasters is on the decline every year, but a large-scale natural disaster can cause a significant number of victims. Since it is difficult to prevent natural disasters completely, the science and technology are needed to be applied to reduce damage to minimal level by taking measures in advance while predicting accurately and immediately the occurrence of disasters through daily observation and monitoring.

In relation to weather, there is a next-generation system to monitor heavy rain and strong wind (X-band Weather Radar Network), and it is tested in metropolitan areas. Intended to assist in the development of urban disaster prevention system, under the leadership of National Research Institute for Earth Science and Disaster Prevention (NIED), the radars for research at Chuo University, National Defense Academy in Japan, Japan Weather Association, Central Research Institute of Electric Power Industry, and Japan Meteorological Research Institute are all connected to the network to develop models to predict rainfall of several hours ahead. The Japan Meteorological Research Institute conducts research on the techniques to assimilate observation data, numerical weather prediction models, prediction of the path and the intensity of typhoon, urban climate, weather statistics, and so on.

R&D for early detection of earthquakes and tsunamis and enhancement of the accuracy of such prediction are conducted by the Meteorological Research Institute, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC), and others. In relation to the development of the system of real time observation targeting Tonankai earthquake and the enhancement of the earthquake forecasts model, JAMSTEC and other institutions are aiming to set up 20 observation points in the area that the epicenters of Tonankai earthquake might fall in, conducting a project to place seismometers and water pressure gauges (tsunami gauges) and to connect all the observation points with submarine cables to form a network. A new project will be started in FY 2010 to form a submarine network in the area that the epicenters of Nankai earthquake might fall in. Japan Meteorological Agency is monitoring earthquakes and tsunamis using the data collected by the collaborators.

Figure 1 1 18 Analysis of tsunami wave propagation occurred in Chile in 2010 (image)



Source: Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

(2) Science and Technology to Maintain Stable Food Supply: Aquaculture Technology

Consumption of tuna in Japan accounts for about 20% of the world consumption, but nearly half the tuna consumed in Japan are imported. However, there is a continued restraint of tuna catch for the viewpoint of the protection of biological resources, so there are high expectations for aquaculture technology.

Fisheries Laboratory of Kinki University began research for complete culture of coastal tuna using fish preserves in 1970 and they succeeded in 2002. Complete culture is a technology to grow artificially incubated tuna until they become adults in order to collect their eggs and then to incubate the eggs artificially, which allows cultivation from one generation to another without relying on natural resources. In 2003, a venture business A-marine Kindai Co., Ltd. was established, selling the fish cultivated applying the fish farming techniques developed by Fisheries Laboratory of Kinki University (10 fish including tuna, red sea bream, white trevally, etc.). Currently, they conduct the research on farming techniques not stressing the natural environment and on improvement of meat quality of cultivated fish, and the development of aquaculture business model.

A group led by Dr. Nobuhiko Akiyama, professor of Tokai University, is conducting research on tuna farming on land utilizing underground seawater[1] in partnership with a venture business, WHA. Since 2006, they have been developing an environmentally friendly system to grow bluefin tuna, growing a fry as heavy as about 12 kilograms in 18 months. In addition, it has become possible to control the fat content of tuna meat by adjusting the flow rate of the tank.

In the future, based on improved understanding of the ecological technology of fish, branded tuna and other fish particular to specific areas are expected to be supplied on the table.

(3) Science and Technology to Detect Terror and Other Danger

International terrorism is a major threat, and Japan should also be well-prepared. According to the Annual White Paper “Defense of Japan 2009,” among world incidents of terrorism in 2008, the Middle East region accounted the most, or 5,748 cases, followed by Asia and Oceania 4,110 cases. Compared to Europe’s 719 cases and North and Latin Americas’ 352 cases (90 percent in Colombia), there are relatively large number of incidents in the above-mentioned regions.

Among the materials used in terrorism are chemical agents, biological toxin, microbial organisms, radioactive materials, nuclear materials, explosives, etc. In particular, terrorist attacks using nuclear materials and explosives can damage people in a shorter time, almost in an instant when it happens, so it is important to develop technologies for pre-detection.

In relation to the “Walkthrough Explosive Detection System (Hitachi Ltd.),” one of the projects adopted for the year 2007 as part of the MEXT’s “Project on Science and Technology for a Safe and Secure Society,” a new explosive detection system is under development to enable high-speed inspection during a passage through the gate or others by limiting the inspection time to under 3 seconds, which used to take about 20 seconds, for the purpose of preventing terrorist attacks and

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1 It is the groundwater penetrated from the sea. In Shimizu area in Shizuoka, you only have to dig out about 20 - 40 meters to obtain the water. The water temperature is constant throughout the year and it is suitable for breeding fish since no anaerobic bacteria exist.

crime with explosives, introducing the system in mass transportation systems, commercial facilities, event sites, etc. Similarly, R&D is conducted in relation to the technologies to detect liquid explosives, toxic organisms, nuclear materials, etc. In addition, the technologies to detect nuclear materials are under development mainly by Japan Atomic Energy Agency (JAEA) in partnership with other related organizations and ministries, coordinating with International Atomic Energy Agency (IAEA), the U.S. government, and others for the purpose of preventing nuclear terrorisms to realize a world free of nuclear weapons.

(4) Measures against Emerging and Reemerging Infectious Diseases in Conjunction with the Overseas Institutions

The emerging infectious disease is a recently found infection that can be a problem of public health, and a reemerging infectious disease is an ever present and once decreased infection, but recently increasing again or showing potential to be problematic in the future. Examples of emerging infectious diseases include severe acute respiratory syndrome (SARS), human immunodeficiency virus (HIV) infection, highly pathogenic avian influenza, etc. and the examples of reemerging infectious diseases are malaria, tuberculosis, rabies, and others. In addition, in 2009, the novel swine influenza A (H1N1) was confirmed in Mexico spreading around the world in a twinkle. Emerging and Reemerging Infectious Diseases cannot be predicted, always requiring prompt actions after the occurrence. Therefore, it is important that we continue to conduct extensive research on these matters.

The National Institute of Infectious Diseases (NIID) collects and analyzes the information of the incidences of infectious diseases (patient, pathogens, and epidemiological information) and the information is available to the public. In addition, they are exchanging information with overseas institutions related to infectious diseases, conducting epidemiological studies on group infection, and training professional epidemiologists.

MEXT is collecting basic knowledge about emerging and reemerging infectious diseases through joint research programs of Japanese universities with overseas research centers established at 12 locations in 8 countries in Asia and Africa, and also promoting training of human resources.

(5) Science and Technology to Solve Water Problems in the World

Water is the resource necessary for all organisms on Earth, including humans, to maintain our lives and societies in a sustainable way. However, the presence of water around the globe is 97.5 percent in seawater, whereas fresh water exists only about 2.5 percent. In addition, freshwater that exists in the forms of groundwater, rivers, lakes, and marshes is only about 0.8 percent and the rest is glacier. Thus, it is necessary to think about planned use of water resource. In the world, it is widely recognized that ensuring safe sanitary water and the impact of climate change on water usage are important issues.

Japan Science and Technology Agency (JST) established “Innovative Technology and System for Sustainable Water Use” (Supervised by Dr. Shinichiro Ogaki, president of National Institute for Environmental Studies) in 2009 to reduce water problems aggravating due to climate change, etc. as part of their Basic Research Programs and to create innovative technologies that enable sustainable water use, initiating the research on the integrated management system of water treatment, urban water use systems, water management in the farmlands and resource recycling .

In September 2009, "Funding Program for World-Leading Innovative R&D on Science and Technology" (Cabinet Office)" adopted the research program of Mr. Masaru Kurihara, advisor at Toray Industries, Inc., "Mega-ton Water System," to develop an energy-saving seawater desalination system and a sewage treatment system with the world's largest capacity, utilizing the membrane water treatment technology, which are expected to bring out solutions to the global water shortage problem.

New Energy and Industrial Technology Development Organization (NEDO) started "Water-saving Environmentally Friendly Water Cycle Project" in 2009 to develop an environmentally friendly water circulation system that can save water utilizing Japan's advantageous water treatment technology, and to reinforce the industrial competitiveness by disseminating this system inside and outside Japan. In FY 2009, introduction of the water treatment system in Thailand, Vietnam, China, and the Middle East enabled the investigations and studies of the usability of rivers that was not used in the past as the source of drinking water and the feasibility of water supply systems mainly by corporations.

Section 3 Enhancement of Basic Science Capability

1 Importance of Basic Research

The achievements of basic research in Japan has been shown a strong presence in the world for the past 10 years, during which there have been 8 Nobel laureates in the fields of natural sciences since 1999, ranked next to the United States. Furthermore, in the article entitled "Breakthrough of the Year" in Science Magazine, "Reprogramming Cells Based on the Research on iPS cells" by Dr. Shinya Yamanaka, professor of Kyoto University, and others and "Discovery of Fossil of a 4.4 million year-old Ardipithecus (Early Hominid Species)" by an international research team led by Dr. Gen Suwa, professor of the University of Tokyo were selected as the No.1 of the top 10 breakthrough of the year 2008 and 2009 respectively.

The beginning of discovery of fossils of Ardipithecus ramidus, which lived about 4.4 million years ago, started in 1992 when Dr. Suwa discovered a peace of molar. (Photo is a restored skull of the Ardipithecus.)
Photo: Dr. Gen Suwa, University of Tokyo

Humanity's understanding about the origin of matters and the universe and the evolution of life, etc. have been based the research arisen from the intellectual curiosity and inquisitive mind of human beings. New principles and phenomena discovered as a result of steady, serious pursuit of truth and of trial and error were organized and systematized into knowledge over the years, accumulated as the common asset of mankind, such as classical mechanics, quantum mechanics, and molecular biology. In addition, this research has given a significant impact on people's view of nature and their philosophy of life, changing drastically the individual behavior and the presence of society. Abundance of such assets means the wealth of citizens or mankind.

Basic research has given birth to human wisdom and is the source of knowledge, creating knowledge as the sources of innovation. In the modern society with increasing diversity and continuous rapid change, the promotion of basic research plays an important role as a source of all kinds of science and technology underlying all human activity, and its importance will be further heightened in the future.

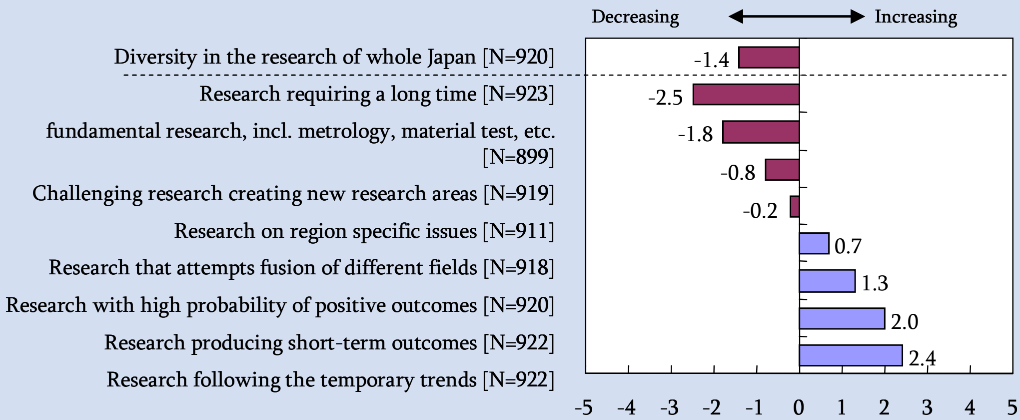
The Japanese government has been promoting research activities by means of basic expenditures, the Grants-in-Aid for Scientific Research to proceed with basic research, particularly the research activities based on free ideas of researchers. The Third Science and Technology Basic Plan (Cabinet decision in March 2006) indicates that the research based on free ideas of researchers will be conducted in order to proceed with various types of research from the early stage and to inquire the universal knowledge from the long-term standpoint.

In relation to this point, "Analytical report for 2009 Expert Survey on Japanese S&T System and S&T Activities by Fields (March 2010)" (Hereafter "Teiten Fixed Point Survey 2009"[1]) shows that "the diversity in the basic research of whole Japan" has decreased compared to around the year 2001, In addition, there are significant number of respondents answering that "research conducted over a long time," "fundamental research such as metrology, materials testing, etc.," and "challenging research creating new research fields" have been in decline (Figure 1-1-19). In the same survey, some also pointed out that the decrease in funding for the fundamental expenses could also inhibit the original and creative research of young people very likely to produce the world's top class achievements[2].

1 The fixed point survey 2009 was conducted every year from 2006 targeting Japanese major researchers and experts, and it is an attitude survey to ask the current state of Japanese science and technology by giving the same questionnaire to the same respondents. This survey consists of two types of questionnaire; a fixed point survey on Japanese S&T system and a fixed point survey on S&T activities by fields. The targets of the former are about 420 people, including those who have been in the positions of president of a university or have an experience of being involved with policy making in relation to science and technology, such as a committee member of council. The targets of the latter included those who are in the 4 priority fields to be promoted and the 4 fields to be promoted with recommendation of the Academic Society, totaling about 120 people in each field. (The sum of the 8 fields is about 960 people.)

2 Opinions contributed to the Q3 "Overall opinion about research funding" in the fixed point survey 2009 (fixed point survey on Japanese S&T system.)

Figure 1-1-19 Diversity in the basic research (comparison to around 2001)[1]



Source: Prepared by MEXT based on NISTEP "Analytical Report for 2009 Expert Survey on Japanese S&T System and S&T Activities by Fields"

Basic research is not necessarily intended to have a direct objective to apply acquired knowledge to the development of practical technologies, but some achievements took more than 20 years of R&D period to be used practically or commercialized, so it also functions as the source of innovation in the economy (Table 1-1-20). For example, in 2009, Dr. Charles Kao, former dean of the Chinese University of Hong Kong, was awarded the Nobel Prize in Physics for "study lead to the commercialization of optical fiber[2]." Dr. Kao and his fellows theoretically proved in 1966 that the causes of attenuation of light in the glass fiber were scattering or absorption by the impurity, so loss of light could be reduced by removing impurity. Afterwards, a U.S. company successfully developed the fiber-optic cable of one kilometer based on the presentation of Dr. Kao, bringing the prediction into reality. In 1988, the undersea optical cable[3] was laid between the United States and Europe, extending about 6,000 km, and it was rapidly commercialized.

1 The items on the surveys have not been conducted every year since 2006 but done as additional research in FY 2009 survey. In addition, this figure is the sum total of both fixed-point surveys on scientific and technological systems and on different fields. In the fixed point survey on scientific and technological system, there was also a question about the presence of actual feeling, and those who answered that they "had actual feeling" were aggregated as the target of the statistics. Answers were to be selected for the one that seems most appropriate (a scale of 6 answers). The answers of 6 different levels were indexed of 10-point scale, setting 0 as the middle point on a scale of -5 to 5.
2 Thin glass fiber used to transmit light when transferring information by means of light.
3 The fiber optic cable is cable covered with protective coating.

Figure 1 1 20 Major Examples of Nobel Prize-awarded Achievements Leading to Practical Applications

Practical applications	Nobel Prize
MRI (Magnetic Resonance Imaging)	Bloch et al. (Physics1952)
	Lauterbur and Mansfield (Physiology Medicine 2003)
Semiconductor (Transistor)	Shockley, Bardeen, et al. (Physics 1956)
Insulin	Sanger (Chemistry 1958)
Semiconductor (Electron tunneling)	Leo Esaki, et al. (Physics 1973)
CT (Computed Tomography)	Cormack, Godfrey, et al. (Physiology Medicine 1979)
Monoclonal antibody	Jerne, Köhler, et al. (Physiology Medicine 1984)
Conductive polymer (Backup battery for mobile phones)	Hideki Shirakawa, et al. (Chemistry 2000)
Asymmetric synthesis (Synthesis of menthol)	Ryoji Noyori, et al. (Chemistry 2001)
Protein mass spectrometry	Koichi Tanaka, et al. (Chemistry 2002)
GMR head (A head to read HDD)	Fert and Grünberg (Physics 2007)
Knockout animal	Capecchi, Evans, et al. (Physiology Medicine 2007)
GFP marker	Osamu Shimomura, et al. (Chemistry 2008)
CCD (Charge Coupled Device)	Boyle, Smith, et al. (Physics 2009)
Optical fiber	Kao (Physics 2009)

Source: Prepared by MEXT

2 Towards Enhancing Basic Science Capability

(1) Japanese Basic Science Capability Viewed in the Papers

One of the indicators to understand the capacity in basic science of each country is the number of papers, the number of times cited, and the productivity of papers, often seen in the number of papers per number of researchers.

Recently, Dr. Shizuo Akira, professor of Osaka University, ranked the researcher who had the most papers which were cited many times for 2004-2005 and 2005-2006[1], for the study on the innate immune function, and Dr. Yoichi Kamihara, research fellow at Tokyo Institute of Technology, published a paper on iron-based high-temperature superconductor that was cited the most in the world in 2008[2].

In addition, taking into consideration that methods for R&D expenditure and the number of researchers differ by country, National Institute of Science and Technology Policy (NISTEP) enhanced the accuracy of international comparison on the number of researchers and papers in the higher education sector in Japan, the United States, United Kingdom, and Germany, and conducted an analysis of the productivity of papers per researcher in relation to the higher education sector[3], which is supposed to play an important role for basic research in Japan[4].

As a result, the number of papers per researcher in the higher education sector in Japan,

[1] Published by Thomson Reuters. Ranking is based on the top 0.1 percentile of the papers cited during the past 2 months sorted in each field among the papers published in the past two years.

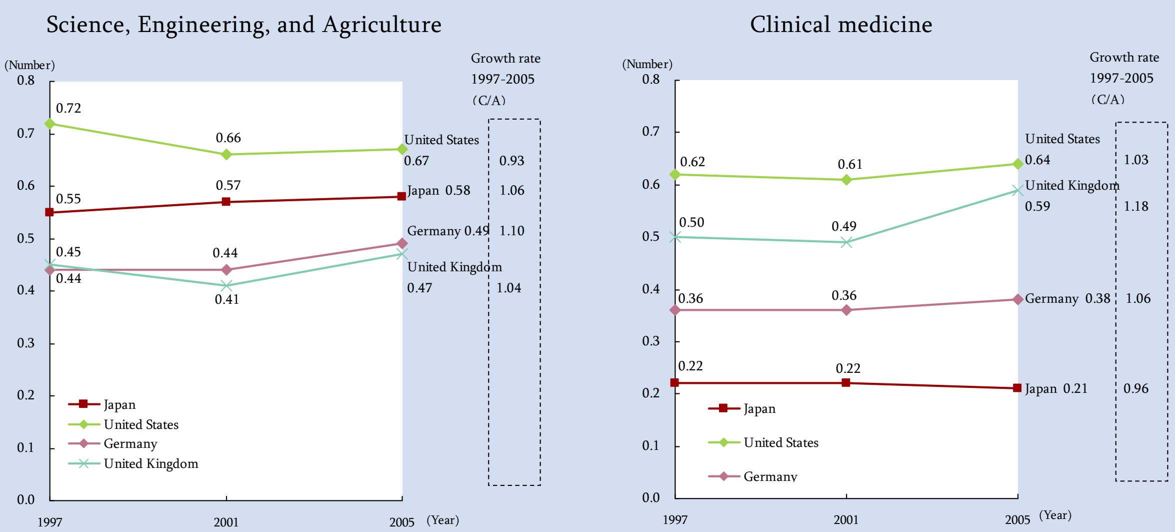
[2] Published by Thomson Reuters. The most cited papers in 2008 among those published in the same year.

[3] In this survey, the number of researchers in the higher education sector was calculated by arranging the data for the U.S.A., U.K., and Germany to be equivalent to the data of full-time researchers in the undergraduate schools (including research department of graduate schools) cited in the Report on the Survey of Research and Development in Japan, using the educational statistics and others.

[4] In previous research, the productivity per research paper of the higher education sector in Japan is pointed out to be lower than that of the United States, the United Kingdom, and Germany. Since there are aspects of education are many talented people through the creation of the paper, it should be noted that the index of activity in universities is not only the number of papers.

particularly in physical sciences, engineering and technology, and agricultural sciences, increased from 1997 through 2005, and in 2005, the number exceeded that of United Kingdom and Germany, which was 0.58, proving to be not too bad[1]. The number of papers per researcher in clinical medicine was declining, 0.21 in 2005, and Japan is the only country with declining number compared to the United States and Germany. (Figure 1-1-21)

Figure 1 1 21 Trends in the number of papers per researcher in higher education



Note:
1. NISTEP organized the data based on the SCOPUS customized data of Elsevier B.V.
2. 3 year moving average. i.e. the number of 2006 is the average of 2005, 2006, and 2007.
3. Number of researchers in Japan Statistics Bureau, “Survey of Research and Development” by. Other Science and Technology Policy Institute based on the aggregate national statistics.
4. In the United Kingdom, the number does not include University Hospital researchers.

Source: NISTEP “Comparative Analysis of input and output of major countries and Japan relating to the follow-up study of the Third Science and Technology Basic Plan”

(2) Towards Enhancing Basic Science Capability of Japan

Major countries are implementing projects to enhance their basic research while setting numerical targets of the budget, etc. The Obama administration of the United States is positioning the basic research as one of the three most important elements to produce sustainable growth and to create jobs of high quality in “Innovation Strategy” announced in September 2009 with an underlying concept that science is important for country’s prosperity and safety, security, and health of American people. In addition, the strategy indicates the plan to double the budget for research institutions [NSF, DOE Office of Science, National Institute of Standards and Technology (NIST)] from 9.7 billion dollars (2006) to 19.5 billion dollars (2017) to support high risk, high return research and young researchers, while conducting comprehensive efforts to enhance basic research, including making the tax credit for experiment/research funds permanent, and supporting Science,

[1] According to the report, the growth in the number of natural sciences, engineering and technology, and agricultural sciences of Japan was 1.19 times from 1997 through 2005, exceeding all of the United States, United Kingdom, and Germany. On the other hand, the growth in the number of papers in clinical medicine was 0.99 in the same period, which was a slight decline.

Technology, Engineering, and Mathematics (STEM) Education.

In EU, the Seventh Framework Programme for Research and Technological Development (FP7), which provides support for joint research activities among member states, has a target to increase the research budget by 65% on annual average[1] compared to FP6[2]. In relation to grants to individual researchers via the European Research Council (ERC), 7.46 billion Euros will be supplied to support in total until 2013, which is expected to make great contribution to enhancement of European basic science capability. More specifically, Concrete support applies mainly to young researchers and advanced and high-risk research including basic research, the competition rate of support screening is very high.

Meanwhile, MEXT had intensive discussions in “Committee for Enhancing Basic Science Capability,” consisting of experts, for the purpose of enhancing Japan’s basic science capability, organizing “Suggestion to Enhance Basic Science Capability” in August 2009. In the suggestion, basic conception to enhance basic science capability, including significance and characteristics, etc. of basic science is stated, and at the same time, considering the conception, it refers to how to enhance basic science capability from the three different points of views; training of human resources, radical expansion of public funding, and research promotion system. In the future, it will be essential to unite investment to basic research, development of research basis, and efforts of human resource training, etc. as a series of scientific and technological system while aiming to elevate the education and research capacity in Japanese universities and research institutions to the top level and “to lead the world with the scientific and technological power.” Then, in Chapter 2, the current state and issues in relation to the scientific and technological system of Japan will be illustrated.

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[1] Periods of FP6 and FP 7 are 2003-2006 and 2007-2013, respectively.

[2] The Sixth Framework Programme for Research and Technological Development

Column 3 Research Funding System to Support Advanced Research

Dr. Hideo Hosono, professor of Tokyo Institute of Technology was elected to be the main researcher in the Funding Program for World-Leading Innovative R&D on Science and Technology. We have asked about the paths and difficulties until he produced the outcomes and how the Research Funding System should be to support advanced research.

Photo: Dr. Hideo Hosono
Professor of Tokyo Institute of Technology

-Paths and Difficulties until Producing Research Achievements

I completed undergraduate and graduate studies (doctoral course) in Tokyo Metropolitan University in 1982, and took the current position in 1999 after working as an assistant and an assistant professor at Nagoya Institute of Technology. I have researched on expression of light and electronic functions of ceramics, with the support of Grants-in-Aid for Scientific Research (1-20 million yen) and private funding (1-3 million yen). In 1998, the results of my research caught the eyes of representatives of Japan Science and Technology Agency (JST) and doctors at the Academic Society, and they offered me (then assistant professor at Tokyo Institute of Technology) to do the presentation for a big basic research project called "ERATO (Exploratory Research for Advanced Technology) funded by JST. I took the plunge and wrote the ideas I had had during my research. It was a presentation of a technology to change ceramics, white powder without conductivity, into semiconductor. To my surprise, my presentation passed it although it was highly competitive. And "Hosono Transparent Electro-Active Materials Project" started in 1999. It was hard to believe that they chose me as the general project manager of ERATO at that time because I was not from a so-called famous laboratory and I only had rough ideas and a few papers (These papers were cited in a leading journal.) to be the basis of the project. I imagine it was such a brave decision. The ERATO, named after the researcher, is one of the largest projects for a competitive research fund of about 300 to 400 million yen per year, characterized not only by the conception of the general manager of the research but also by the fact that it is a project to take a chance on the individual researcher because he/she will take all the responsibility in relation to the research, such as selection of the personnel, procedures, etc. When I was selected, I remember beginning this project with a determination, saying to myself, "So what? This may be once-in-a-lifetime chance. I should do what I want to do without being afraid of failing."

As a result of concentrating myself on the project with the recruited young researchers, I successfully transformed cement into transparent conducting metal. It means that I successfully turn a substance made from major insulators, lime and alumina, into electrically conductive. Then, new conception occurred to me that it may be possible to turn ordinary substances to have the attributes that were only expressed in rare elements, depending on how creative you can be. This lead to "Strategy for Rare Elements," a policy unique to resource-poor Japan.

In addition, we made an attempt to turn glass into semiconductor, realizing transistors with the capacity 20 times as large as those driving current LCDs, TVs, etc., and this technology will be applied to the next-generation LCD TV in around 2010. Some say that the market size is about 3 trillion yen.

The most-talked topic in the world, among others, is the discovery of an iron-based superconductor. It was a common knowledge among researchers that iron cannot be a superconductor, but we found an iron compound that showed a superconductive property under even considerably high temperature. Researchers in the world immediately responded to the discovery at once, and our paper became the world's No.1 cited paper among all papers published in 2008[1]. Research projects are established with government aids in many countries. What is different from the moves of 20 years ago is the fact the competitors are not only the Western countries but now we have tougher rivals, such as China, India, etc. We have acquired the honor of "discoverer" but we still have to compete to win by pursuing a substance that functions in a higher temperature.

1 It is the same fact as the world's most cited papers of Dr. Yoichi Kamihara, as stated in Part 1, Chapter 1, Section 3, 2 (1)

-How research funding systems should be to support the advanced research

We keenly feel the following important points while looking back our history.

(1) Support for research needs to have different characteristics according to the times. During the germination period, such supports as Grants-in-Aid for Scientific Research and other aids from private foundations are effective because the funds can be used because the concepts are not restrained. Big money is not necessary.

(2) When there is a new leaf that seems to grow larger, it is necessary to work intensively in an organizational structure. JST Basic Research Programs may be appropriate. The above-mentioned research on application of transistors to displays would not have been developed so quickly even if we had Grants-in-Aid for Scientific Research many times.

(3) When the prospects of industrialization have become clearer, it is necessary to conduct organizational research for application in partnership with corporations. Publicly-recruited Grant-in-Aid for research funded by NEDO is appropriate.

New achievements are not returned to the public unless there are many different kinds of research funding systems (fund). This does not mean that to have three different kinds is a waste, but it is absolutely contrary.

Commentary Current situation in Japan Viewed in the Papers

Each indicator related to papers used in Chapter 1, such as the number of papers and the number of times cited, has advantages, disadvantages, and even limits, so it is necessary to be careful when making an interpretation. On the other hand, these indicators are considered to offer fundamental information to understand the current state surrounding scientific and technological systems explained in Chapter 2, describing one of the aspects of the level of Japanese science and technology. This section is an explanation on some of the points to be noted when making an interpretation of the number of papers and that of cited papers, while over viewing the current state of Japan utilizing a variety of indicators related to papers.

01 Quantitative Indicators Using Papers

The following are examples of quantitative indicators that focus on scientific papers as one of the outputs of research activities;

- The number of papers [e.g. number of papers in Country A (number of papers produced in institutions in Country A)]
- The share of papers [e.g. the share of the numbers of papers of Country A (Percentage of the number of papers of the country in the world)]
- The number of times cited (The number of times cited from other papers)
- The share of the times cited (e.g. percentage of the times cited in Country A against those in the world)
- The numbers of top 10% papers (Number of the top10% highly cited papers in each field and year)
- The share of top 10% papers
- Relative Citation Impact (Normalized values of the times cited per paper in each country divided by the times cited per paper in the world)

The following points should be noted, for example, when making interpretations of the above-mentioned indicators.

- It is reasonable to think in general that the papers that generally attract attentions of researchers tend to be cited more frequently. Therefore, the indicators based on the times cited are often used aside from the number of papers and the share of the numbers of papers.
- The citation database used for each indicator in this White Paper includes only papers at lease with authors and abstracts written in English, so the papers with authors and abstracts written only in Japanese are not included. Each indicator cited in this White Paper is subject to the influence of the language used in the paper listed in the citation database.
- Academic journals and papers to be listed in the citation database differ depending on the types of the database, so the distribution of fields and the share of the number of papers differ.
- The number of papers and the times cited differ depending on the fields. For example, in mathematics, it is noted that they tend to write longer papers with less frequency, compared to other fields. In physics and other similar fields, the average number of papers on experimental research tends to be larger than that of theoretical research.
- In some research fields and organizations, the results of works such as creation, writing books, etc. are more highly evaluated than writing papers.
- The languages used in papers may differ depending on the field of research. In some fields, English is more frequently used, and in other fields, such as area studies, it is frequent that the local languages are used in the papers.
- The papers include articles, letters, notes, reviews, and other various written materials. In some

cases, the number of papers and the number of times cited may differ depending on the types of literature to be surveyed.

Some points out that each paper has different scientific value, so there is a limit in evaluating only with the number of papers.

In addition to the above indicators, there are indicators with specific targets as follows:

<Examples of indicators targeting academic journals>

Impact Factor (An indicator called IF, indicating the impact of academic journals. The IF of the academic journal A in the year X is "the average of times cited during the year X of the paper cited in the academic journal A for the past two years, i.e. the year X-2 and X-1.")

<Examples of indicators targeting researchers>

h-index (An indicator showing simultaneously the relation of the number of papers and the times cited of the particular researcher. The h-index of the researcher is "h" when there are h papers cited more than h times, among the group of papers written by the researcher.)

However, it is necessary to note the following;

Some points out that the impact factor is not an appropriate indicator for researcher's individual evaluation because it is generally an indicator to illustrate the impact of academic journals, not to show the state of papers individually.

Some points out that the h-index is influenced by the field to which the researcher belongs and the length of his/her research career. (It tends be higher for the elderly.)

In this white paper, the indicators are calculated based on the two citation database (Web of Science (Thomson Reuters) and SCOPUS (Elsevier)). Both databases list up the information of the papers cited on the academic journals that meet certain standardized criteria, such as the names of the authors and abstracts in English, regular issuance, review process, etc. Each database covers different academic journal, so the distribution of the fields and the share of the papers by countries regarding the cited papers are different as shown in Table 1 and Table 2. In addition, the number of academic journals on science and technology or medical sciences published in Japan is said to be about 10,000[1]. That means that the Japanese academic journals in the citation databases are less than 5%[2].

Table 1: Distribution of papers by field in SCOPUS and Web of Science

	SCOPUS	Web of Science
Chemistry	7.2%	12.2%
Material science	3.8%	4.7%
Physics & Space science	7.8%	11.4%
Computer science & Mathematics	6.4%	5.6%
Engineering	12.1%	8.5%
Environment/ecology & Geoscience	7.1%	5.5%
Clinical medicine & Psychiatry/Psychology	30.0%	24.6%
Basic biology	22.3%	24.2%
Other	3.3%	3.4%

Note: 1. 2004-06 average.
2. SCOPUS: Prepared by NISTEP based on the SCOPUS customized data of Elsevier B.V.
3. Web of Science: Prepared by NISTEP based on the Thomson Reuters "Web of Science"
4. Classification of papers is based on the classification of fields for academic journals.
5. In each field, the category with more accepted papers is highlighted.
Source: NISTEP "Follow-up Study on 3rd Science and Technology Basic Plan Report/ Comparative Analysis of R&D Inputs and Outputs between Japan and major Countries"

1 Citation from Japan Science and Technology Agency (JST).

2 For instance, according to "Follow-up Study on 3rd Science and Technology Basic Plan Report/ Comparative Analysis of R&D Inputs and Outputs between Japan and major Countries" (NISTEP Report No. 118), the academic journals published in Japan between 2004 and 2006 amounts to 376 among the journals in the SCOPUS.

Table 2: The number and the share of papers in SCOPUS and Web of Science

	SCOPUS		Web of Science		Share ratio
	The number of Papers	Share (S)	The number of Papers	Share (W)	S/W
Japan	89,607	7.1%	67,805	7.4%	0.96
United States	320,698	25.5%	235,243	25.7%	1.00
United Kingdom	78,701	6.3%	55,938	6.1%	1.03
Germany	68,972	5.5%	54,624	6.0%	0.92
France	48,831	3.9%	38,894	4.2%	0.92
Rep. of Korea	26,818	2.1%	22,641	2.5%	0.86
China	136,559	10.9%	62,160	6.8%	1.60
World	1,255,477	100.0%	916,534	100.0%	1.60

Note: 1. 2004-06 average.
2. Fractional counts for each institution to which author belongs. In each country, the result with higher share is highlighted.
Source: NISTEP "Follow-up Study on 3rd Science and Technology Basic Plan Report/ Comparative Analysis of R&D Inputs and Outputs between Japan and major Countries"

Recently, many of the papers written by Japanese researchers tend to be contributed to the academic journals in other countries. This shows that the researchers in Japan tend to have desire to contribute to a journal with high evaluations among researchers internationally.

While it is one of the major issues of Japan to create an internationally prestigious academic journal, Institute for Materials Science publishes "Science and Technology of Advanced Materials (STAM)," aiming to create an academic journal in English that is internationally well known in the field of material science. The journal has been attracting more attention from the world, raising its IF by converting itself into an open access journal.

02 Domestic/International Situations on the Number and the Share of Papers

The following section demonstrates the analysis of the Web of Science.

Among the papers published in the world's major academic journals, the number of papers published by the Japanese research institutions increased from 40,900 to 69,300 in 20 years from 1988 to 2008, or approximately 1.7 times. Looking at the country-specific number of papers, Japan ranked the world's second 10 years ago (1998) whereas it is the world's fifth recently (2008). (Table 3)

Then, looking at the percentage of the number of papers of each country among the total number of papers around the world (share of papers), while foreign countries have all been increasing their numbers of papers since 1980s, the number in China has jumped since the second half of the 1990s, ranking the second in the world in the share of papers of China in 2008, or 10.5%. Meanwhile, Japan's share of papers in the same year was 7.0%. With increasing number of papers in China, the shares of papers of major countries, such as Japan, the United States, United Kingdom, Germany, etc. have decreased. (Figure 4)

Table 3 The number of papers by selected countries/regions (Top 25 countries/regions)

1988		1998		2008	
United States	192,730	United States	210,357	United States	275,625
United Kingdom	48,107	Japan	60,347	China	104,157
Germany	41,818	United Kingdom	60,289	United Kingdom	75,914
Japan	40,990	Germany	54,632	Germany	73,849
Russia	37,631	France	41,367	Japan	69,300
France	30,701	Canada	28,467	France	53,707
Canada	25,214	Italy	26,399	Canada	44,379
Italy	15,630	Russia	24,316	Italy	43,528
India	14,219	China	21,098	Spain	35,716
Australia	11,975	Spain	19,126	India	35,437
Netherlands	10,989	Australia	17,945	Australia	30,085
Sweden	9,546	India	16,086	Rep. of Korea	30,016
Spain	8,468	Netherlands	15,742	Russia	25,166
Switzerland	7,756	Sweden	12,925	Brazil	25,081
China	6,742	Switzerland	11,577	Netherlands	23,981
Israel	6,109	Rep. of Korea	9,105	Taiwan	19,882
Poland	5,710	Belgium	8,358	Turkey	18,623
Belgium	5,411	Taiwan	8,221	Switzerland	18,051
Denmark	4,568	Israel	7,912	Sweden	16,633
Czech Republic	4,138	Brazil	7,683	Poland	14,885
Finland	3,682	Poland	7,169	Belgium	13,386
South Africa	3,575	Denmark	6,561	Iran	11,171
Austria	3,479	Finland	6,008	Israel	9,956
Brazil	2,907	Austria	5,746	Denmark	9,421
Hungary	2,905	Turkey	4,409	Greece	9,353
World	560,724	World	666,982	World	987,497

Note: 1. Prepared by NISTEP based on the Thomson Reuters "Web of Science"

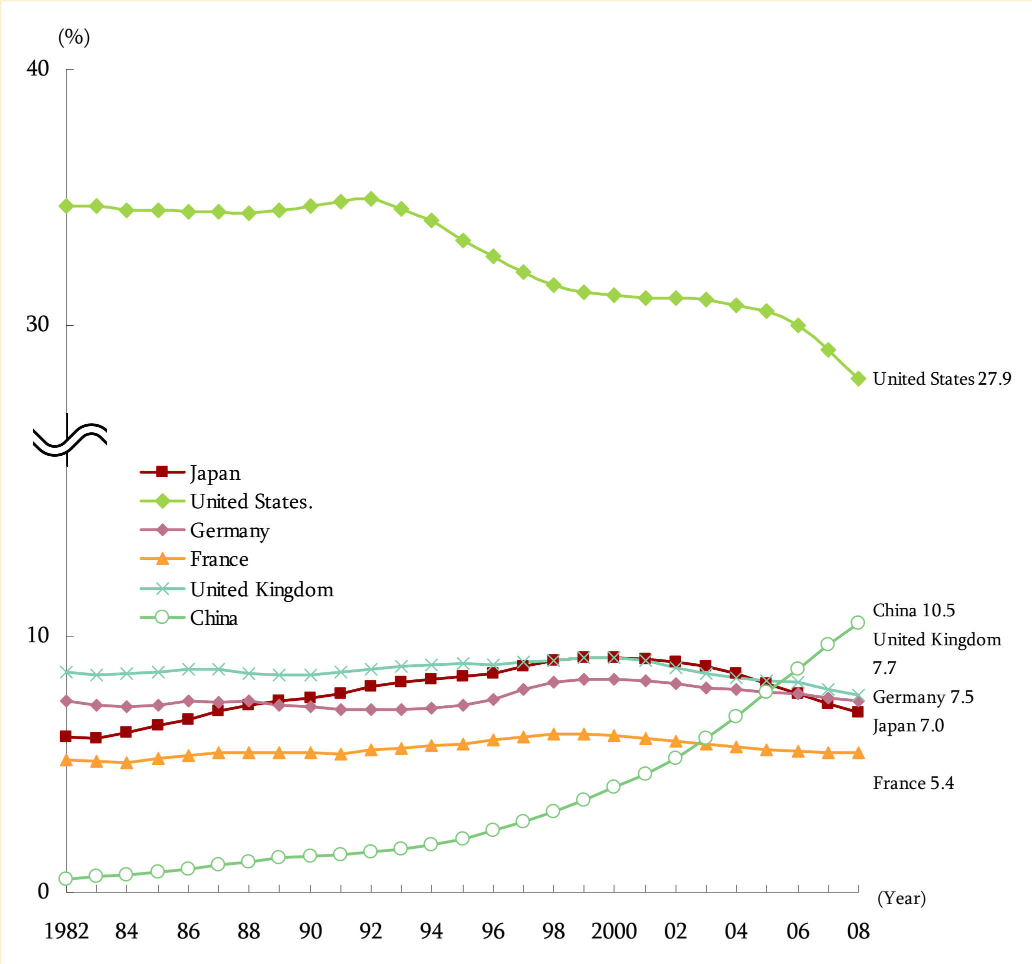
2. Articles, letters, notes, and reviews are counted by the whole counting method[1].

3. 3 year moving average. i.e. the number of 2008 is the average of 2007, 2008, and 2009.

Source: Prepared by NISTEP

[1] In this method, when papers are co-authored by several institutions, (e.g., co-authored by Country A and Country B), it is counted as one to Country A and one to Country B and this would give some indication to "the degree of participation to research activities in the world" of each country. With international co-authored papers, this method would give a count to several countries and the countries with more international co-authors, the number of papers tend to exceed actual contribution.

Figure 4 Trends in the share of papers in major countries



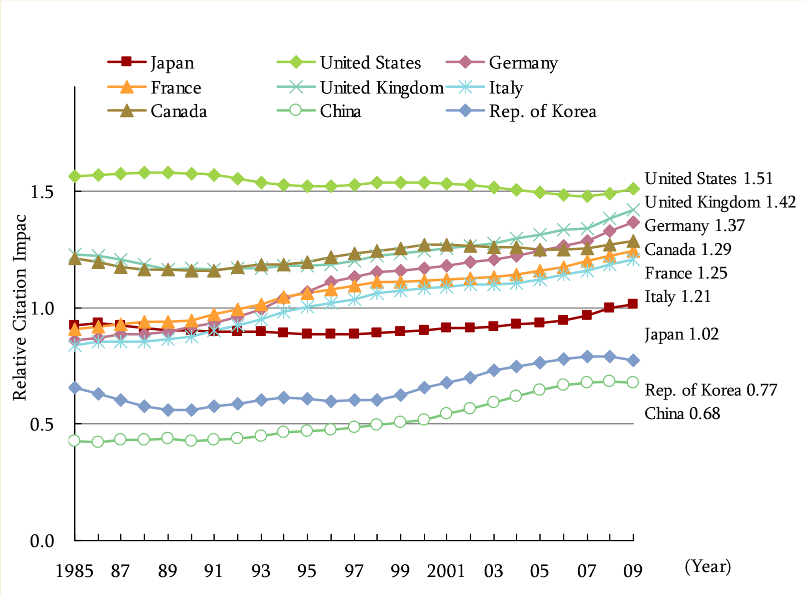
Note: 1. Prepared by NISTEP based on the Thomson Reuters "Web of Science"
2. Articles, letters, notes, and reviews are counted by the whole counting method.
3. Percentage of 3 year moving average of the share of the top 10 % papers in all fields. i.e. the number of 2008 is the average of 2007, 2008, and 2009.
Source: Prepared by NISTEP

03 Domestic/International Situations on the Times Cited

Relative Citation Impact[1] of the papers published in Japan continuously increased from 0.89 in 1998 to 1.02 in 2009, exceeding the world average 1 for the first time (Figure 5). In addition, some analyses show that the number of the top 10 % papers in all fields of Japan increased from 3,470 to 5,283 in 20 years from 1988 to 2008[2]. On the other hand, in relation to the share of top 10 % papers, China has demonstrated a significant increase since the latter half of the 1990s, reaching 8.0% in 2008. The share of top 10 % papers in Japan, however, is 6.4%. While China increases the number of the top 10 % papers, Japan and the United States decreased their shares. (Figure 6)

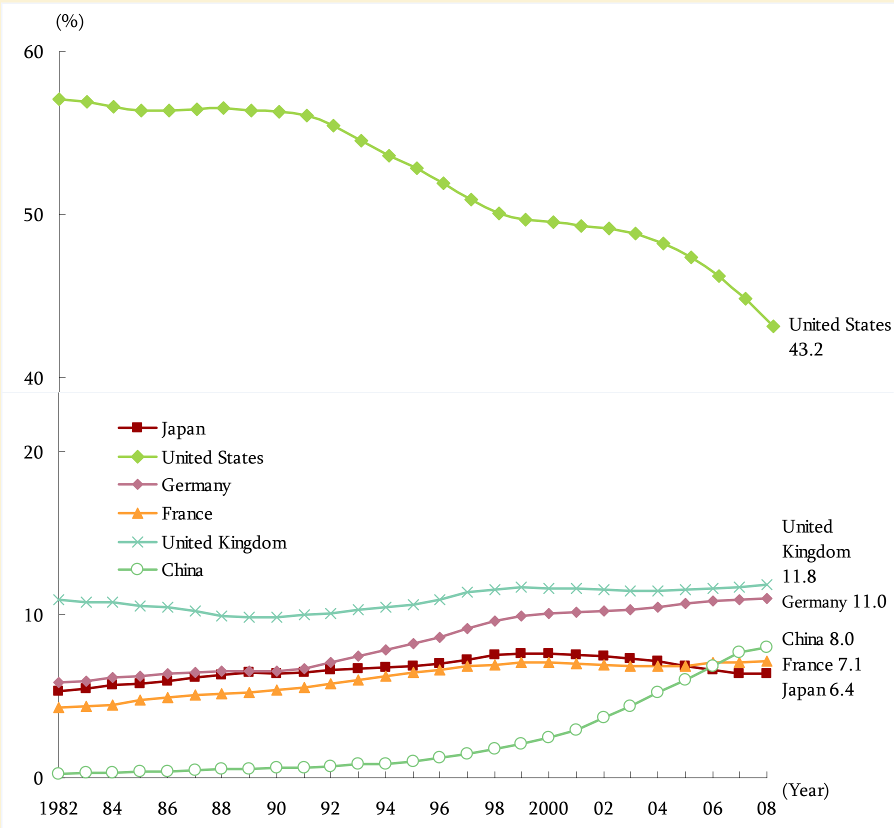
1 It is a standardized value of the times cited per paper in each country divided by the times cited per paper in the world.
2 Surveyed by National Institute of Science and Technology Policy (NISTEP)

Figure 5 Trends in Relative Citation Impact in selected countries



Note: Prepared by NISTEP based on the Thomson Reuters "Web of Science
2. Articles, letters, notes, and reviews are counted by the whole counting method.
3. Each figure is a 5 year cumulative number. i.e. the number of 1985 is the cumulative number of 1981-1985.
Source: Prepared by NISTEP

Figure 6 Trends in the share of top 10% papers in selected countries

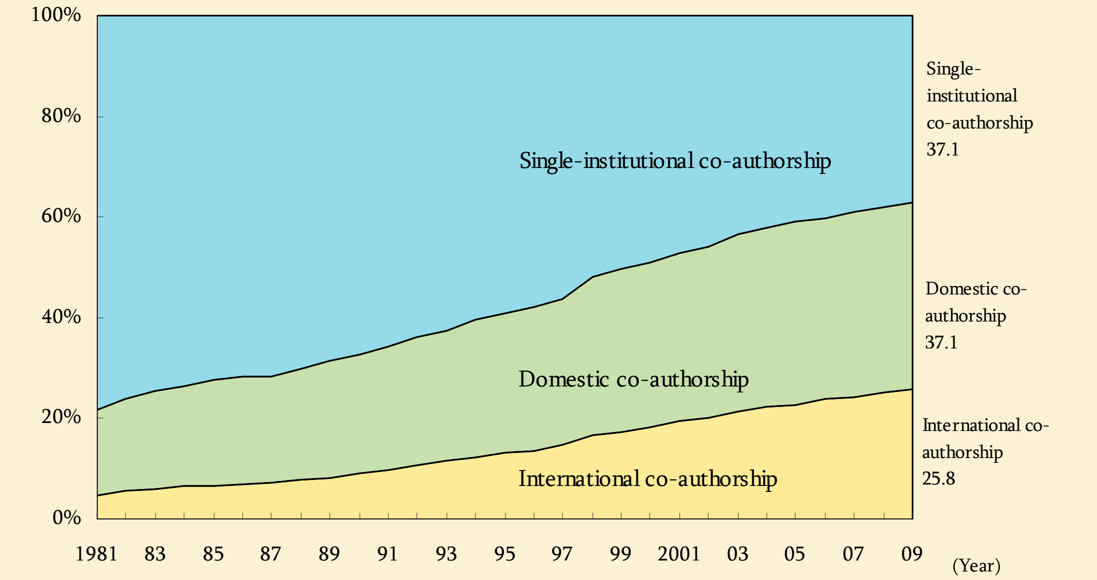


Note: Prepared by NISTEP based on the Thomson Reuters "Web of Science"
2. Articles, letters, notes, and reviews are counted by the whole counting method.
3. Percentage of 3 year moving average of the share of the top 10% papers in all fields. i.e. the number of 2008 is the average of 2007, 2008, and 2009.
Source: Prepared by NISTEP

04 Change in the Forms of Co-authored Papers

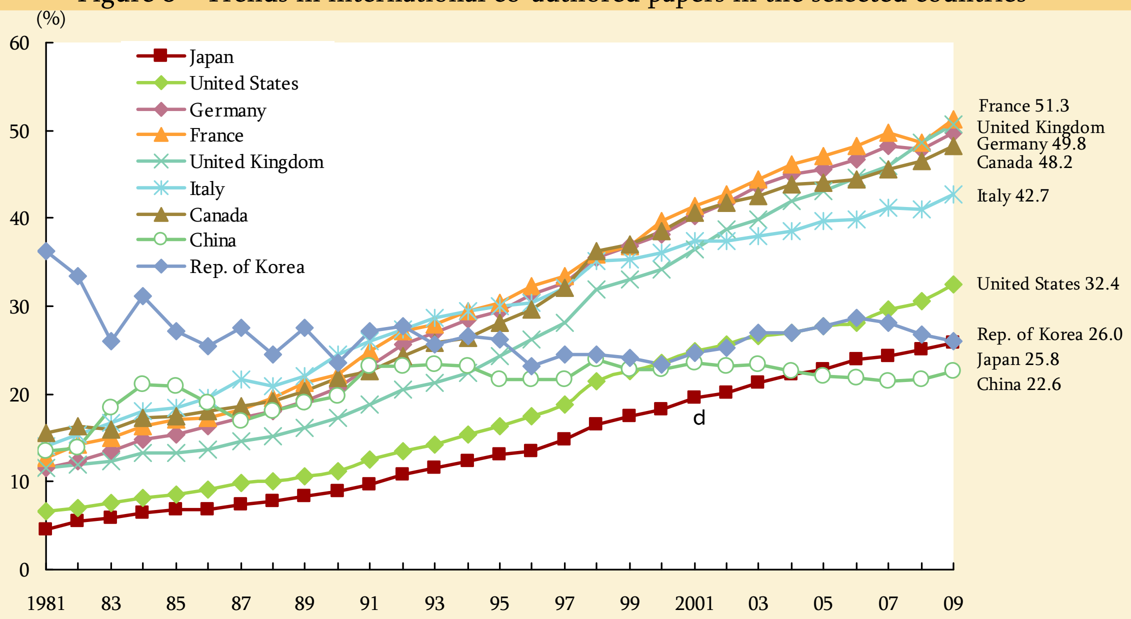
In foreign countries, the forms of joint papers have changed from individuals to groups, and from a single country to multiple countries. In particular, in France, United Kingdom, and Germany, about half of all the papers are internationally co-authored (Figure 8). In Japan, however, co-authored papers among domestic institutions can be spotted, but the growth in the share of internationally co-authored works is slow compared to other selected countries. (Figure 7 and Figure 8)

Figure 7 Change in the forms of co-authored papers in Japan



Note: 1. Prepared by NISTEP based on the Thomson Reuters "Web of Science
2. Articles, letters, notes, and reviews are counted by the whole counting method.
Source: Prepared by NISTEP

Figure 8 Trends in international co-authored papers in the selected countries

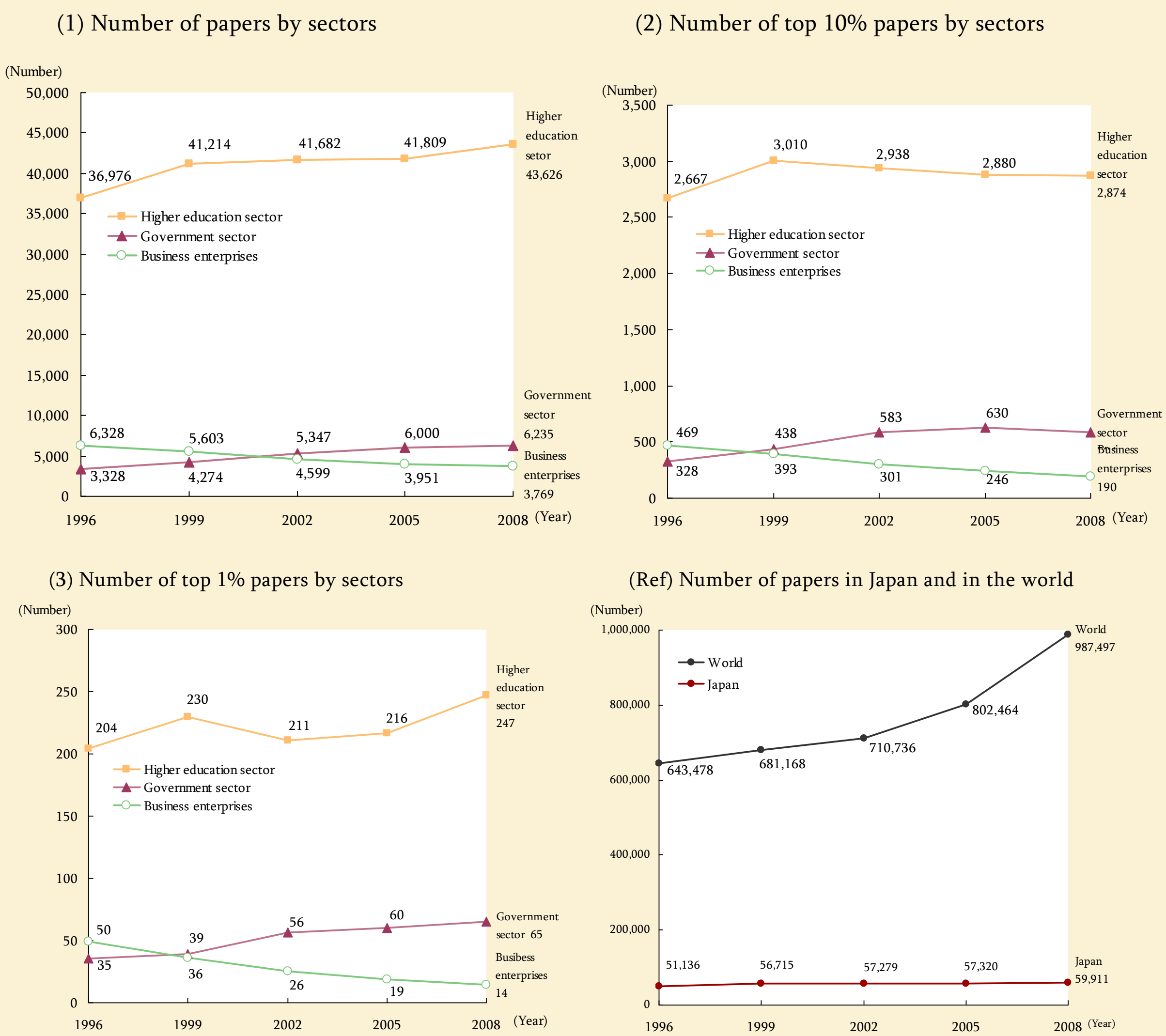


Note: 1. Prepared by NISTEP based on the Thomson Reuters "Web of Science
2. Articles, letters, notes, and reviews are counted by the whole counting method.
Source: Prepared by NISTEP

05 Trends in the Number of Papers by sectors in Japan

Figure 9 illustrates the total number of papers, the top 10 % paper, and top 1% paper from Japan, sorted by the types of organizations, i.e. higher education sector, the government sector including IAI (formerly National Laboratory), and business enterprises.

Figure 9 Trends in the Number of all papers, top 10% paper, top 1% paper (Fractional count[1])



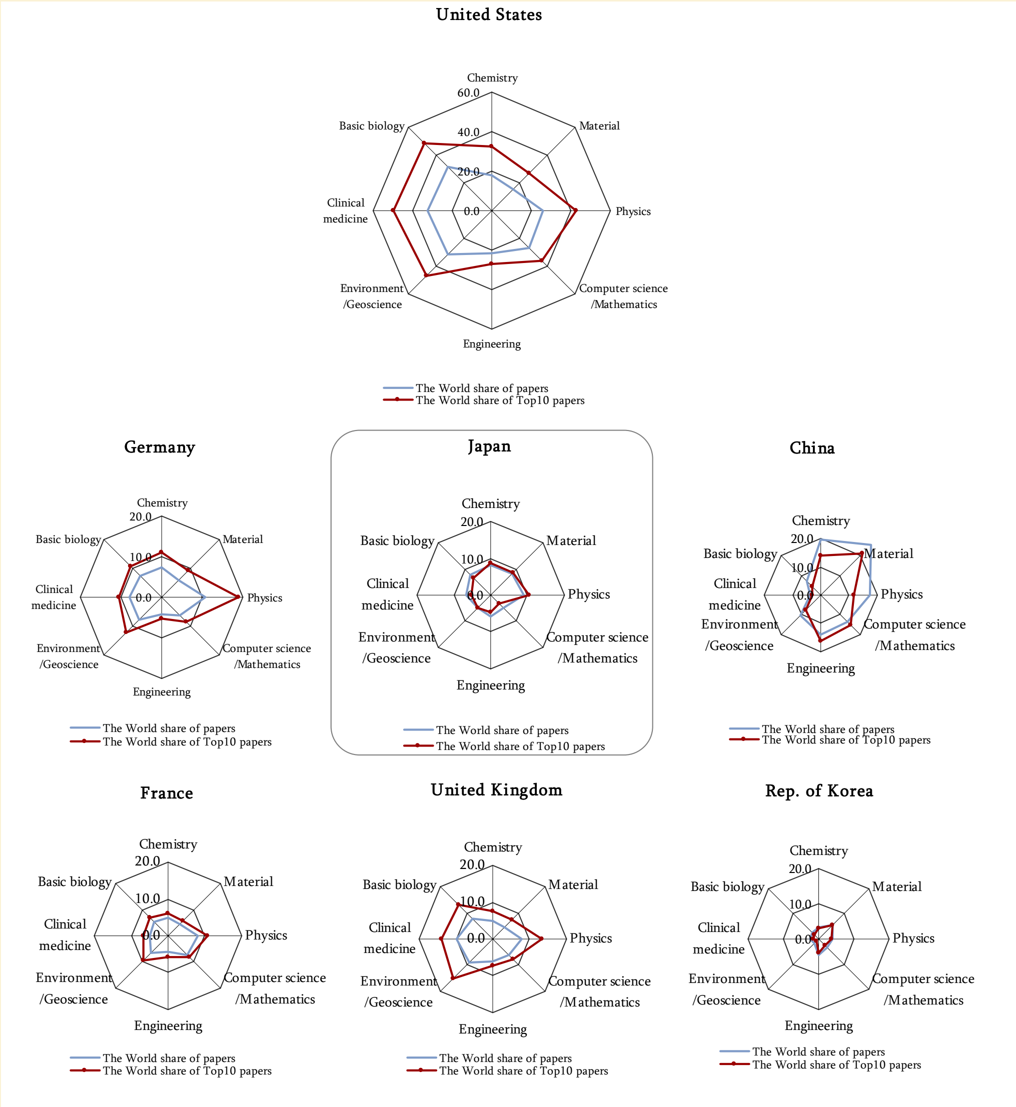
Note: 1. Higher education sector include national, public and private universities, technical colleges, inter-university research institutes. Government sector include institutions such as IAI (incl. former National Laboratory) and other facilities.
2. Total Number of papers sorted by organizations in (1) and the Number of papers in Japan in (Ref) do not correspond.
3. Prepared by NISTEP based on the Thomson Reuters “Web of Science
4. Articles, letters, notes, and reviews are counted by the whole counting method.
5. 3 year moving average. i.e. the number of 2008 is the average of 2007, 2008, and 2009.
Source: Prepared by NISTEP

1 In this method, when papers are co-authored by several institutions, (e.g., co-authored by A University and B Institute), 1/2 is attributed to A University and the other 1/2 is attributed to B Institute, according to which it is possible to grasp “the degree of contribution to paper production” of each institution. In this statistics, the fractional count method was applied to compare such contribution of each sector to the paper production.

06 Domestic/international Situations of the Number of Papers Sorted by Fields

Looking at the share of papers of Japan and that of top 10 % paper in the world, (2007-2009), Japan shows higher share in the fields of chemistry, material science, physics, and space science. (Figure 10)

Figure 10 Share of papers, of top 10% papers by fields in the selected countries



Note:
1. The numbers in the table are percentage and the average numbers of 2007-09.
2. Prepared by NISTEP based on the Thomson Reuters “Web of Science
3. For the fields in the figure, the papers listed in Thomson Reuters “Web of Science” are re-categorized into the 22 fields of Essential Science Indicators, and then sorted into the following 8 categories, excluding economics & Business, multidisciplinary, social sciences, general.
(1) Chemistry: chemistry, (2) Materials: materials science, (3) Physics: physics, space sciences, (4) Computer science/mathematics: computer science, mathematics, (5) Engineering: engineering (6) Environment/Geoscience: Environment/Ecology, geosciences, (7) Clinical medicine: clinical medicine, psychiatry/ psychology, (8) Basic biology: agricultural sciences, biology & biochemistry, immunology, microbiology, molecular biology & genetics, neuroscience & behavior, pharmacology, plant & animal science (Left is the category in the figure, and right is the field in the source)
4. Articles, letters, notes and reviews are analyzed by the whole counting method.
5. Values plotted on each axis demonstrate the share of papers and the share of the top 10 % papers in each field in each country. If the chart is close to circle, it means that the country has the similar proportion of the share to that of the world in each field.
Source: Prepared by NISTEP