Science and Technology Trends —Quarterly Review

2008 April No. 27

ISSN 1349-3671

Science & Technology Trends

Quarterly Review

Science & Technology Foresight Center, NISTEP

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Science & Technology Foresight Center of NISTEP

Foreword

This is the latest issue of "Science and Technology Trends — Quarterly Review".

National Institute of Science and Technology Policy (NISTEP) established Science and Technology Foresight Center (STFC) in January 2001 to deepen analysis with inputting state-of-the-art science and technology trends. The mission of the center is to support national science and technology policy by providing policy makers with timely and comprehensive knowledge of important science and technology in Japan and in the world.

STFC has conducted regular surveys with support of around 2000 experts in the industrial, academic and public sectors who provide us with their information and opinions through STFC's expert network system. STFC has been publishing "Science and Technology Trends" (Japanese version) every month since April 2001. The first part of this monthly report introduces the latest topics in life science, ICT, environment, nanotechnology, materials science etc. that are collected through the expert network. The second part carries insight analysis by STFC researchers, which covers not only technological trends in specific areas but also other issues including government R&D budget and foreign countries' S&T policy. STFC also conducts foresight surveys periodically.

This quarterly review is the English version of insight analysis derived from recent three issues of "Science and Technology Trends" written in Japanese, and will be published every three month in principle. You can also see them on the NISTEP website.

We hope this could be useful to you and appreciate your comments and advices.

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NISTEP has moved to a new office

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Executive Summary

Information and Communication Technologies

1 Petascale Computing Trends in Europe

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"High Performance Computing (HPC)" means the calculations with numerous high-end computational complexities used in the simulation of natural phenomena such as weather and climate, astrophysics and plasma analysis, and life-science applications. According to the TOP500 list, which ranks the speeds of the world's top 500 supercomputer systems (HPC systems) that perform high performance computing, Europe is seen to be emerging in its strive for ownership of HPC systems following behind the overwhelming ascendancy of the United States. While it is a fact that the European HPC systems rely on hardware that is sourced almost entirely from overseas, software technology development and technological application of HPC systems are very highly advanced whereby the grid networking of pan-European HPC systems has efficiently accelerated application capabilities even further.

The shift in responding to HPC systems is hitherto apparent in Europe. This trend focuses on the research and development into petascale computing (HPC computing based on supercomputers with petaflop/s capability) that has been carried out in the United States and Japan. In order to expand developments in science and technology, it is necessary to respond to changes towards large-scale, high-precision, high-speed advancements; therefore, the fastest HPC systems are required. In Europe, the deployment and usage of 'European Supercomputer System' with petaflop/s performance are considered essential and the e-Infrastructure programme of the Seventh Framework Programme for European Research and Technological Development (FP7), active since January 2007, has ranked 'Supercomputer System Deployment' as a new category in addition to the grid infrastructure intensified in FP6.

In June 2006, the 'High Performance Computing in Europe Taskforce (HET)' – made up of HPC systems specialists from 11 European countries – was inaugurated. The purpose of this taskforce is to propose strategies and actions in order to achieve HPC systems integration (HPC ecosystem) that are sustainable within Europe, considering the highest performance HPC systems, infrastructures available in each country and software development. HET attaches importance to high-end resources with petaflop/s computing performance and the methods for applying these systems successfully. One of the proposals put forward by the taskforce in January 2007 was to split the HPC systems into a three layers based on their performance. Focusing on the 'European Supercomputer System' at the apex, the proposal features the objectives of its usage in science and technology, coordinated deployment with the existing infrastructures through the grid, funding and utilization models and the selecting process of the programs operated in the system.

Owing to their activities, the 'European High Performance Computing Service' was incorporated as one of 35 projects in the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap which holds a great influence on European sciences. Furthermore, in April 2007, the 'Partnership for Advanced Computing in Europe' (PRACE) initiative was formed by supercomputing centers in 15 European countries for the purpose of materializing these HET proposals.

Europe has made great strides towards the deployment and application of petascale computing. It would be worthwhile to follow closely the prospects of Europe where excellent achievements in software development and application technologies have been realized.

(Original Japanese version: published in October 2007)

Environmental Sciences

2 Current Situation and Problems of Contiguous Water

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Water is essential to sustaining life. There are numerous challenges concerning water including problems such as increasing local water supply associated with lifestyle changes, increasing water usage due to expansion in food production associated with increasing population, the virtual water issues related food self-sufficiency in Japan, growing demand for bottled water due to concerns over safety of tap drinking water, increasing demand in agricultural water utilization associated with increasing biomass production such as corn, etc., and regionally distorted water demands due to population intensification of urban areas.

During the last twenty years or so, droughts have occurred at least once a year almost everywhere in Japan. The stoppage of water supply due to droughts not only bears a great impact on daily life, it also damages farm produce, raises prices of vegetables, etc., and obstructs the operation of manufacturing plants. While the technology for desalination of seawater is available, it requires a huge amount of energy. Therefore, since water shortage is linked to increased energy demands, there are added concerns over the problem of global warming. In addition, Japan imports 60% of food which water is needed for its production overseas. The issues facing this type of virtual water are also numerous.

The purchasing of bottled water that is safe and pleasant tasting is recently on the increase. While the cost of tap water varies from region to region, the national average cost per cubic meter is approximately 170 JPY. Although the water contained in a 1.5 liter bottle costs approximately 200 JPY, costing 500 to 1000 times more than tap water, the consumption of not only domestically produced bottled water but imported products is also on the increase. The results of opinion polls indicate that there is a widespread sense of distrust regarding tap water. However, in actual fact, there are 18 inspection control items for the raw water used in the production of bottled water such as mineral waters, etc., whereas there are 50 items for tap water that are applicable by waterworks law. Therefore, there is a significant difference in numbers of inspection items and the water quality of tap water is controlled more strictly than bottled water.

In June 2007, the mayor of San Francisco issued a permanent ban on the purchasing of bottled water in the city for the purpose of saving taxes and protecting the environment. Trial calculations show that 40 million gallons of oil are consumed per annum in producing container materials for bottled water purchased by its citizens. Furthermore, because this also generates the problem of disposing of the containers, there are also many controversies concerning this matter.

In order to alleviate the impact on the environment, from now on it will be necessary to reuse reclaimed wastewater, utilize thermal energy of water, and raise public awareness towards tap water. One such example is the bottling of highly purified tap water in Tokyo city, and selling it under the brand of “Tokyo Water.” From the viewpoint of saving energy also, it would be desirable to distribute the sophisticated water processing technologies which Japan has developed, water-saving technologies that are applied to general households, reclaimed wastewater reuse systems, and utilization of water as a heat source, etc., around the world. Also, the effective utilization of waste reverse osmosis membranes in seawater desalination plants, byproducts of hardness reduction processes and granular activated carbon used in high purification processes, in addition to actions such as the introduction of small-scale hydroelectric power plants, etc., serve as a reference for regions that have limited natural water resources.

The water problem is not merely a problem of water demand. It is necessary to understand that it is linked to heterogeneous energy and environmental issues and in particular to improve the image of tap water. Activities that will enable us to reacknowledge the importance of contiguous water are expected.

(Original Japanese version: published in November 2007)

3 Waste Recycling Technologies Required by a Sound Material-Cycle Society

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The waste problem has attracted considerable interest due to the impact of waste on the environment, among other reasons. However, because large amounts of waste are generated in everyday life, and the enormous social stock represented by buildings and structures ultimately becomes waste, waste can be considered one symbol of modern material civilization. The formation and emission of dioxins in waste incineration processes, which became a social problem in the latter 1990s, had a direct effect on improvement of element technologies for incineration treatment, and was also one factor that gave impetus to the creation of a sound material-cycle society. In a sound material-cycle society, efficient removal and treatment/disposal of waste is an essential urban service of a comfortable society. Realization of a recycling society in harmony with the environment is also stated as one key policy issue in Japan's Third Science and Technology Basic Plan.

In recent years, the 3Rs (Reduce, Reuse, Recycle) have become keywords. The technologies that are envisioned as promoting the 3Rs are technologies that realize the formation of a sustainable society, which includes securing diverse energy supply paths, against the background of preventing global warming. The recent sharp rise in crude oil prices and concern about its depletion has led to a further recognition of the necessity of reducing dependence on fossil resources, resulting in heightened interest in biomass energy utilizing biomass as even a material. Due to its relatively low efficiency, biomass had not necessarily attracted attention in the past. Today, however, there is pressure to accelerate the implementation of global warming countermeasures in all fields, and reduction of carbon dioxide (CO_2) emissions by actively utilizing biomass, etc. is an urgent matter. Because much biomass is waste-type biomass, efforts related to waste treatment are demanded. Furthermore, circulating use of resources also plays an important role in reducing consumption of virgin natural resources. Some waste treatment technologies required by a sound material-cycle society have already been partially realized. For example, when recycling is considered, one focus is kitchen waste and food product waste, which have comparatively low rates of circulating use. Methane fermentation has attracted attention in this connection, but because methane fermentation processes produce liquid and solid residues after the methane gas is recovered, technical development is required in order to ensure that treatment and disposal are performed in an environmentally-sound manner. Methane fermentation can only be considered an environmentally-responsible recycling technology when improvements have been realized in this respect. Gasification is also possible by pyrolysis (thermal decomposition). Some gasification and reforming technology processes have been realized, which extract combustible gases such as hydrogen that can be used in energy and other applications, and research and development are underway aiming at more advanced processes. Recovery of valuable organic materials and the realization of high speed processes applying supercritical and subcritical technologies is also being studied.

Together with technologies for recycling, one important requirement for waste recycling is effective utilization of the recycled material. That is, a resource circulation cycle is only realized when users are secured. Because the raw material composition of wastes is not homogeneous, a pretreatment process may be necessary. Moreover, a total technology must also include treatment/disposal of any residues generated after treatment. If a technology does not satisfy these conditions, it cannot be considered complete as an environmental technology. Accordingly, this paper makes the following recommendations for technical development and policy.

i) System design should be carried out from a comprehensive viewpoint, including safety. Therefore, it is necessary to recognize that a technology should be a total system, which includes pretreatment and residue treatment, as well as heightened consideration of safety. ii) Treatment and recycling efficiency should be considered. From this viewpoint, guidance to ensure appropriate evaluation based on an estimate of the energy and cost requirements of recycling is necessary. iii) Use of the recycled product should be expanded. For this, the application of recovered/recycled materials should be expanded by removing restrictions on use as far as possible, based on a scientifically-sound evaluation of safety.

(Original Japanese version: published in December 2007)

Nanotechnology and Materials

4 Japan's Policies to be adopted on Rare Metal Resources

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Rare metals are raw materials that are used extensively in value-added products manufactured in the materials, machinery, and electronics industries. Rare metals are 31 types of non-ferrous metals which exist on the earth only in limited quantities or are economically and technologically difficult to extract in pure form. Rare metals are mineral resources that are essential to peoples' lives and industrial activities together with the base metals such as copper, lead,zinc and so on. However, at the present time, the only mineral resource that Japan is self-sufficient in is sulfur. For all other mineral resources, Japan is dependent on imports. In recent years, anxiety of securing a stable supply of resources in Japan is growing due to the increasing scarcity amidst the rapidly growing consumption of non-ferrous metals in the world's emerging countries together with a high dependency on specific producing countries in unevenly distributed production regions.

One of the future issues to be addressed in the short term – since mineral resources differ from energy resources – is the reusable and recyclable process. In order to boost the utilization efficiency of resources, a confluent resource system in which three groups in resource supply and recycling process (upstream position: supplying information on geological features and resources, etc., downstream position: utilization and consumption, etc., and backflow position:

recycling, etc.) share risks is required for each individual rare metal element. As a nation, in addition to promoting this type of system, it is necessary to quickly ascertain the world's mining situation by gathering and analyzing resource data for the relevant industries. In reviewing the development of land-based resources, due to recent growing demand, it is necessary to reexamine the small-scale mines that have been abandoned out of necessity.

From 2007, as a long-term measures for securing a stable supply of rare metal resources, the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Economy, Trade and Industry have respectively launched the 'Elements Strategy Project' and the 'Development Project on Rare Metals Substitution Materials' in the field of 'Nanotechnology and Materials' which is one of the four main promoting fields of the 'The 3rd Science and Technology Basic Plan'. Cooperation to implement effective research and development has progressed from the public subscription stage by establishing a support system that can be developed over a broad range from laying the groundwork to practical utilization.

In the development of seabed resources, the 'Basic Ocean Law' implemented in July 2007 indicates the positive utilization of oceans including the development of ocean resources for the purpose of developing socioeconomic health in Japan by comprehensive and systematic promotion of ocean-based strategies. It has been found that Japan's exclusive economic zone is exceedingly large and its national oceans and underwater seamounts are endowed with expansive cobalt-rich crusts that include platinum, cobalt, copper, and magnesium of the finest quality available on the earth. In addition, as sea-floor hydrothermal deposits exist in comparatively shallow seabeds and they have regenerative high-grade resources, making repeated mining possible, profitably viable resource development is favorably anticipated. While there are technological issues such as ore excavation methods, anti-pollution measures, and metallurgical methods – in addition other larger economic concerns – once these systems are established, it is plausible that several resource fields can be mined reciprocally.

In the future, materials researchers will not only focus on individual substances and materials, they will also need to consider a broader range of substances and materials to accommodate the increasing demands of research outcomes and the viability of having a stable supply of raw materials. It is vital that research work utilizing substances and materials, for which the supply is unstable, will have to go back to relearn the basics of condensed matter physics in order to search for potential substitute materials that are likely to yield a constant stable supply.

(Original Japanese version: published in October 2007)

Social Infrastructure

5 New Problems in the Study of Disaster Prevention Based on Disaster Risk Governance

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Recently in Japan, earthquakes causing heavy damage occur frequently in areas with low probabilities of occurrence. There is also an imminent danger of the occurrence of large-scale earthquakes in Tokai, Tonankai, Nankai, and Minamikanto regions, and those with an epicenter in metropolitan Tokyo. The Intergovernmental Panel on Climate Change (IPCC) predicts that flood and storm damage caused by global climate changes like earth warming will increase. It also forecasts that the risks of tsunamis/storm surges, volcanic eruptions, snows and ice, tornadoes, etc. will be unavoidable, indicating that some regions may need to take measures to control multi-hazard risks. Combined with increasing uncertainty about disaster risks as mentioned above, changes in social structures, such as a rapidly aging population, a declining birthrate, and weakening communities, are pressing to revolutionize existing disaster prevention policies and strategies.

Taking account of the uncertainty of disaster risks and changes in social structures, we need to change the subjects of disaster prevention policies and the methods of disaster risk management to those based on the viewpoints of multiple networks (dealing with the uncertainty taking advantage of the diversity of major concerned bodies and the multiplicity of networks in disaster prevention) and the comprehensiveness and integrity of disaster prevention policies (comprehensively addressing individual disaster measures and integrating them taking account of other related policies). The concept of disaster risk governance should be established as a new framework to create innovative disaster prevention policies. Disaster risk governance is defined as "cooperative administration through the social interactions (risk communication based on disaster risk information) and the formation of social networks of various major concerned bodies. The materialization of disaster risk governance requires the following three conditions: (1) Multiplicity of disaster risk information and its community-wide sharing, (2) Social decision-making based on deliberate communication and discussions between various stakeholders, (3) Establishment of horizontal and non-institutional cooperative frameworks consisting of various organizations and individuals in society through the use of social relations and personal incentives.

The research and development of "the disaster reduction technology integrated with the social science" based on the concept of disaster risk governance will become important. Corresponding to the three conditions of disaster risk governance, the research and development should be carried out in an integrated way focusing on the following issues: (1) Integrated risk assessment methods, (2) Participatory disaster risk communication methods, (3) Comprehensive and integrated disaster measures and disaster response measures, (4) Technologies and methods of social operation for decentralized and interoperable disaster risk information platforms.

The above research and development should be carried out in an integration with the application research of "disaster risk information platforms" based on the Innovation 25 with a mission of giving the benefits back to society in an early stage. Research and development oriented Independent Administrative institutions and universities should take initiatives to promote new research and development with a strong social mission, working in close cooperation with related administrative agencies, local governments, enterprises, NPOs, resident organizations, and so on.

(Original Japanese version: published in December 2007)

Frontier

6 Disaster Management Satellite System Development and International Cooperation Promotion in Asia

p.93

Japan is a country that is frequently damaged by natural disasters due to earthquakes and typhoons, and possible large-scale disasters due to causes such as ocean trench-type earthquakes are one of Japan's most serious concerns. With regard to other parts of Asia, the giant earthquake off Sumatra in Indonesia and the resulting December 2004 Indian Ocean Tsunami are still fresh in our memory.

It is impossible to prevent natural disasters from occurring, and quick rescue operations and damage mitigation measures through disaster risk identification are important. Since earth observation satellites can, without being affected by disasters, quickly observe disaster areas over a wide range, their data, if combined with information from instruments such as aircraft and helicopters, are expected to assist us in realizing disaster damage condition assessment that would make rescue operations more effective. Since earth observation satellites can visit and observe the same area regularly, their data could be used for disaster risk identification.

The Sectoral Promotion Strategy, formulated by the Council for Science and Technology Policy based on the Third Science and Technology Basic Plan, has selected a Technology to Monitor and Manage National Land to Mitigate Disaster, one of whose elements is a Disaster Monitoring Satellite Application Technology, as one of the strategically prioritized science and technology areas. The goal of the Disaster Monitoring Satellite Application Technology is to establish a satellite observation and monitoring system by JFY2015, and to continuously provide observation data useful for disaster management and mitigation, thereby ensuring the safety and security of the Japanese people. To study the application of earth observation satellites to disaster management, disaster management demonstration activities using the “DAICHI” Advanced Land Observing Satellite of the Japan Aerospace Exploration Agency (JAXA) are being conducted, and new application technologies such as satellite image maps and hazard mapping have been developed, verified, and gradually introduced into disaster management activities. Starting from October 2006, images obtained by “DAICHI” and other data have been distributed via the internet to Asian countries, which, like Japan, are damaged by earthquakes, typhoons, and other natural disasters, under the framework of “Sentinel Asia.” There may be cases in Asia when it is difficult to assess disaster damage conditions because of, for example, being an island country, or road and communication network conditions, and earth observation satellites could be an effective means to assess damage conditions in such cases. The fact that 51 agencies from 20 countries and eight international organizations in Asia and Oceania are members of Sentinel Asia as of September 2007 suggests that Asian countries are highly interested in this framework. It is difficult to download large volumes of data quickly in regions where broadband services are not available, and low-resolution image data are also provided. Since the “KIZUNA” super high-speed internet satellite to be launched soon[Note1] carries an antenna for Southeast Asia, and enables large volume data transmission, Sentinel Asia plans to utilize this satellite for such data transmission.

The European Union also plans to use earth observation satellites to support emergency response activities, and the three core services of land and marine monitoring as well as emergency response will start around 2008. The European Commission plans to establish a governing structure through which it will use data obtained from satellites developed by the European Space Agency as well as from satellites owned by European national governments and private sector to provide European national government agencies, the United Nations, and other organizations with information for assessing damage conditions, identifying disaster risks, and other disaster management purposes.

Japan’s efforts to promote international cooperation with Asian countries in the application of earth observation satellites to disaster management, and to maintain and strengthen friendly relationships with them should serve Japan’s national interest. Using earth observation satellites and super high-speed internet satellites, which should therefore be regard as one of its tools for science and technology diplomacy, Japan should push forward with its space diplomacy, and should contribute to disaster management activities not only in Japan but also in Asia.

[Note1] "KIZUNA" was successfully launched on February 23, 2008 (JST).

(Original Japanese version: published in November 2007)

1

Petascale Computing Trends in Europe

MINORU NOMURA
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1 Introduction

"High Performance Computing (HPC)" means the calculations with numerous high-end computational complexities used in the simulation of natural phenomena such as weather and climate, astrophysics and plasma analysis, and life-science applications by using supercomputers and grids. Supercomputers are Ultra High Performance Computers with diverse architectures that are adapted according to their utilization in performing highly computationally-intensive calculation tasks in science and technology. Various systems exist that have their performances ranked from high to low. The generic term for such supercomputers is called as 'HPC System' in this report. A Grid is an ecosystem with a large number of computational assets such as computers, storage devices, visualization systems, large-scale experimental observation devices, and data sources distributed throughout a network in which the component units of the system are utilized as a single virtual computer.

According to the TOP500 list,[1] which ranks the performances of the world's top 500 high performance supercomputer systems (HPC systems), Europe is seen to be emerging in its strive for ownership of HPC systems following behind the overwhelming ascendancy of the United States. Recently, further changes in responding to HPC system have been noticed in Europe. These shifts are focused on the government backed research and development of petascale computing (petaflop/s*1 performance supercomputer based HPC) carried out in the United States and Japan. Active deployment of the fastest HPC systems capable of handling large-scale, high-precision, high-speed simulations that are vital for advancing science and technology has also become necessary in Europe. Europe considers that acquiring and utilization of HPC system with petaflop/s performance, hereafter called the 'European Supercomputer System', is necessary and the e-Infrastructure programme of the Seventh Framework Programme for European Research and Technological Development (FP7), active since January 2007, has ranked 'Supercomputer System Deployment' as a new category in addition to the grid infrastructure intensified in FP6.

Relative to this development, the 'High Performance Computing in Europe Taskforce (HET: HPC in Europe Taskforce)' was inaugurated in June 2006. HET is comprised of HPC systems specialists from 11 European countries. HET was set up to propose strategies and actions in order to build a HPC ecosystem (integrated HPC systems) that is sustainable within Europe considering the highest performance HPC systems, infrastructures available in each European country, software developments and the requirements of capacity development in computational science. In January 2007, HET delivered the results of this research.

This article introduces these HET proposals. To begin with, the current situation regarding HPC within Europe is outlined in chapter 2. The proposals submitted by HET are shown in chapter 3; whereas the points that are worth particularly mentioning are described in chapter 4.

2 European high-performance computing (HPC)

2-1 European-owned HPC systems in TOP500 list

The TOP500 list is a list ranking computer power based on the LINPACK Benchmark.*2 Although it does not necessarily reflect the performance of

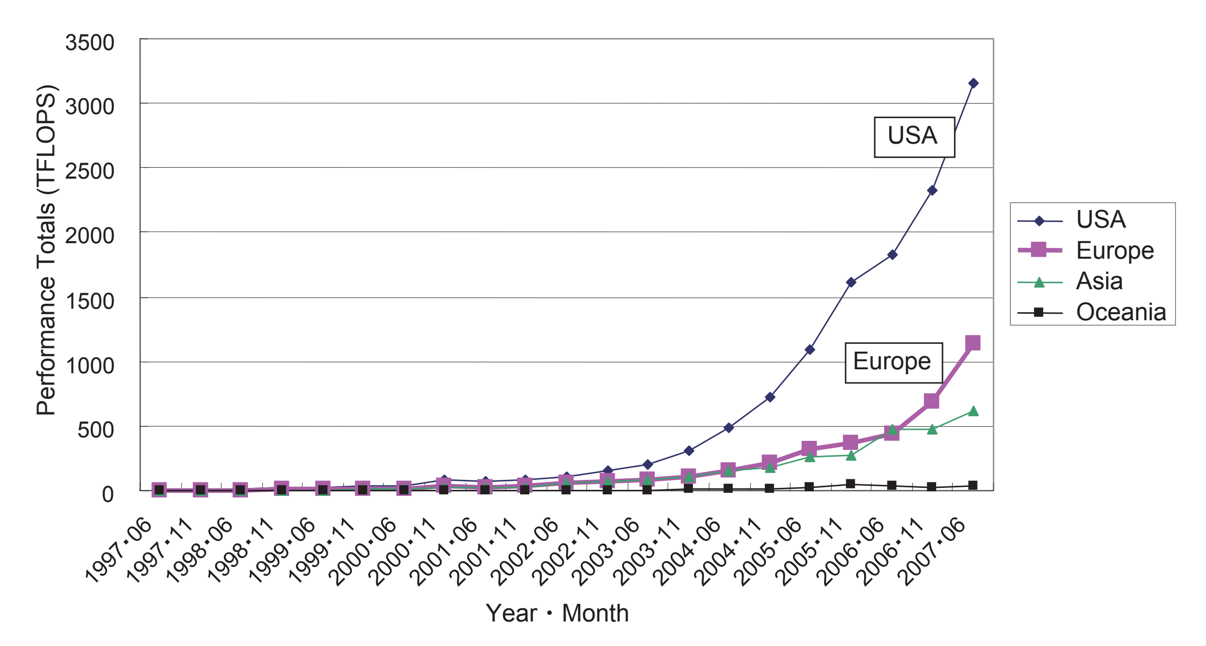

Figure 1 : Transition in performance values for each continent (TOP500 list systems)

Prepared by the STFC based on TOP500 list

a system in its actual operating environment, it has relevance in rating the world's most powerful publicly-known HPC systems. The TOP500 list is published each year in June and November. The situation regarding European HPC systems taken from the TOP500 list published in June 2007 is outlined below.

Figure 1 shows the transition in the LINPACK Benchmark performance values (Rmax) of HPC systems owned by each continent from June 1997 to June 2007. The values are shown as total performance values of all systems ranked in the TOP500 for each continent. From the chart it is clearly evident that Europe is emerging in its strive for ownership of HPC systems following behind the overwhelming predominance of the United States.

Figure 2 shows the performance values of HPC systems owned by each country in Europe with examples for the UK, Germany, France, and Spain where performance growth is particularly noticeable.

Looking at the numbers of systems in the TOP500 list, the UK has 42, Germany 24, France 13, and Spain 6. For reference, the number of systems in Japan is 23, whereas the USA owns 281.

The HPC supercomputer sites listed in each country are UK: the Atomic Weapons Establishment (ranked 24 in the TOP500 list), University of Reading (ranked 36); Germany: Leibniz Rechenzentrum (ranked 10), Forschungszentrum Juelich (FZJ) (ranked 18); France: the Commissariat a I'Energie Atomique (CEA) (ranked 12 and 22); and Spain: the Barcelona Supercomputing Center (BSC) (ranked 9). In addition to these countries, the numbers of HPC systems are increasing in the Netherlands, Switzerland, and Finland.

UK's HECToR (High-End Computing Terascale Resource) is an example of a recently-introduced, large-scale HPC system that is attracting attention. Designed for use by UK's university researchers, it is installed in Edinburgh University's Advanced Computing Facility (ACF). The first-phase system that has top speed of approximately 60TFLOPS (teraflop/s) was opened in October 2007. The second-phase system scheduled for October 2009 will have a top speed of 250TFLOPS. Thereafter, a third-phase with an unspecified top speed is scheduled for 2011.[2]

2-2 European predominance

European HPC systems have their hardware procured almost entirely from overseas. However, software development and HPC system application technologies in Europe are highly sophisticated. Europe's technological developments include contributions to Basic Linear Algebra Subprograms

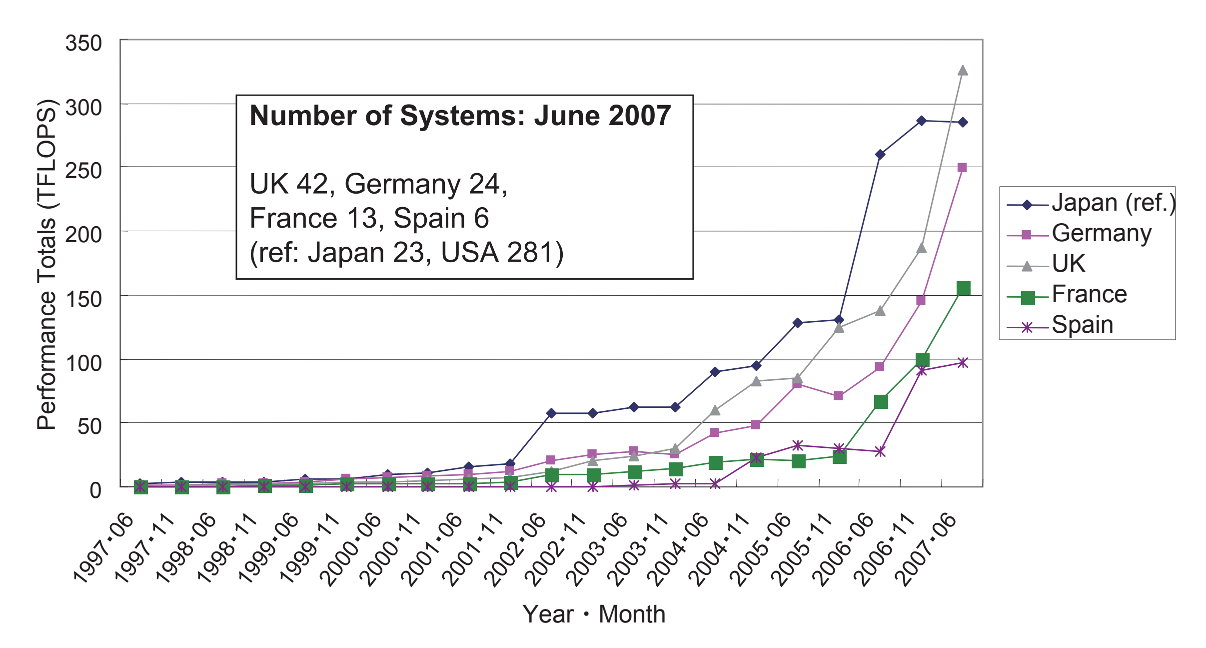

Figure 2 : Transition in performance values for each European country (TOP500 list systems)

Prepared by the STFC based on TOP500 list[*3]

(BLAS),[*4] the development of Numerical Algorithms Group (NAG) library,[*5] Computational Fluid Dynamics (CFD) programs, Finite Element Method (FEM) programs, computer chemical packages and statistical packages.

One aspect of this European application predominance is the vigorous progress made in the efficient application of grid-network system of HPC distributed in each country.[3-6]

2-3 Positioning of HPC within R&D frameworks

The e-Infrastructure programme of the Seventh Framework Programme for European Research and Technological Development (FP7) has added 'Supercomputer System Deployment' as a new category in addition to the grid infrastructure intensified in FP6. Such a move is possibly an attempt to counter government-backed petascale computing research and development in the USA and Japan. In Europe, activities for ownership and use of supercomputer systems capable of petaflop/s performance have also become essential. In the FP7 programme, Geant2[*6] and the grid infrastructure are just to be upgraded. However, new elements such as the Supercomputer, Repository (storage facilities for data, information, software, etc.) and Data Infrastructure have been introduced.[7]

2-4 Transition to petascale computing

Figure 3 shows the progress of the European taskforce's research on transferring to petascale computing. From August 2005 to April 2006, an International Scientific Panel, put together by the cooperation of scientists from Finland, France, Germany, Italy, the Netherlands, Spain, and the UK, investigated the scientific demands of petascale computing. This study on these scientific demands was launched by identifying a strategic role of high-end HPC ('Leadership-class supercomputers') in Europe's scientific and economic development.

HET was established at a meeting sponsored by e-IRG[*7] in June 2006 for the purpose of strengthening cooperation for delivering competitive high-level resources to Europe's computational science community. Consisting of 11 European countries, it is represented by 22 members from Austria: 2 persons, Finland: 2 persons, France: 2 persons, Germany: 3 persons, Ireland: 2 persons, Italy: 2 persons, the Netherlands: 2 persons, Spain: 2 persons, Sweden: 1 person, Switzerland: 1 person, and the UK: 3 persons. In January 2007, HET presented the findings of its investigation.

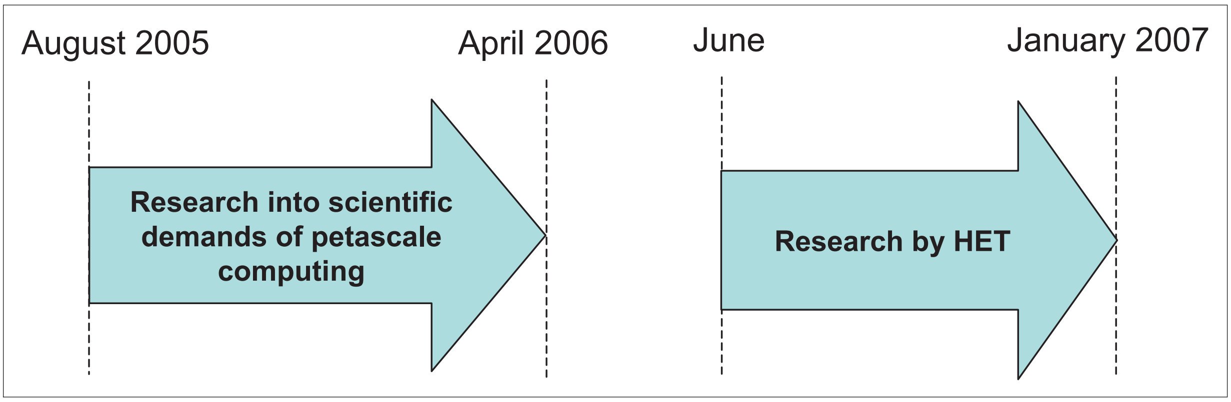

Figure 3 : 'High Performance Computing in Europe Taskforce (HET)' research progress

Prepared by the STFC based on Reference[10]

Table 1 : Estimated Costs of European High-Performance Computing Service

Application		Timescale	Estimated costs
Preparation phase		2006 – 2007	0.16 – 1.6 billion JPY
Medium-level infrastructure	Several medium size installation (5 – 10)	Starting 2007 – 2008	8 – 16 billion JPY every 2 years
High-end (capability) infrastructure	Several installations, where an installation can consist of two different architectures, placed in different locations.	Starting 2008 – 2009	16 – 32 billion JPY every 2 – 3 years
Maintenance and upgrades			8 – 16 billion JPY annually
Support projects such as software development, optimization, and training, etc.			4.8 – 8 billionJPY annually

(Estimated costs: 1 Euro converted to 160 JPY)

Prepared by the STFC based on Reference[8]

2-5 Positioning within the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap[8]

The 'European Strategy Forum on Research Infrastructures (ESFRI)' has prepared a roadmap that will have a great influence on European sciences. The roadmap has reviewed and narrowed down 200 initially proposed projects to 35 projects in seven scientific disciplines (social sciences and humanities; environmental science; energy; biomedical and life sciences; material science; astronomy, astrophysics, nuclear and particle physics; computation and data treatment). Due to the efforts by HET, the 'European High-Performance Computing Service' has been incorporated as one of these projects in the area of computation and data treatment. The estimated costs of this service are presented in Table 1. These cost estimates include all HPC services such as premises for demanding systems and expertise needed for the optimal operation of the HPC systems.

3 "High Performance Computing in Europe Taskforce (HET)" proposals

The proposals presented by HET to the European Commission (EC) in January 2007 are presented in this chapter. Details of these proposals are extracted from references.[9-13]

3-1 Scientific demands for petascale computing

The report[13] created from August 2005 to April 2006 by the International Scientific Panel indicated in section 2-4 is discussed here.

In this report, the scientific demands relative

Table 2 : Scientific fields and applications

Scientific fields	Applications
(1) Weather, climatology, earth sciences	Climate change, oceanography and marine forecasting, meteorology, hydrology and air quality, earth sciences
(2) Astrophysics, high energy physics, plasma physics	Astrophysics, elementary particle physics, and plasma physics
(3) Material science, chemistry, nanoscience	Understanding of complex materials and complex chemistry, and nanoscience
(4) Life sciences	Systems biology, chromatin dynamics, large-scale protein dynamics, protein association and aggregation, supramolecular systems, and medicine
(5) Engineering	Complete helicopter simulation, biomedical flows, gas turbines & internal combustion engines, forest fires, green aircraft, and virtual power plant

Source: Reference[13]

to 'Petascale Computing in Europe' covering the period from 2010 to 2020 are stated. These scientific demands form the basis on which these HET proposals were formulated. The report is put together by five steering committees representing weather, climatology, and earth sciences; astrophysics, high energy physics, and plasma physics; material science, chemistry, and nanoscience; life sciences; and engineering disciplines. Table 2 shows the applications relevant to these five fields. The scientific challenges and potential outcomes of each field are indicated in the Appendices listed at the end of this report.

3-2 Role and scope of HPC in Europe Taskforce (HET)

The HPC in Europe Taskforce (HET) has stated that the lack of powerful facilities within Europe with the capacity to match the computing performance of Japan and the USA represents a significant loss in European computational science competitiveness. HET has attached importance to leadership-class resources that have petaflop/s computing capability and the methods for their effective utilization. HET states that merely having the necessary hardware is not enough to solve the kinds of scientific challenges shown in Table 2; but it will also require software and scalable algorithms adapted to petaflop/s performance computing systems and scientists that have the necessary skills sets. In addition, the integration with national computing centers shall also be required for executing the bulk of processes for which maximum performance computing is not needed. For these reasons, the feasibility of a sustainable, integrated pan-European HPC system (called the HPC ecosystem) was also studied.

3-3 Integration of HPC systems (HPC ecosystem)

(1) Capability and capacity classification

In reference 13, computing by supercomputers is split into the two categories described hereafter. "The requirements for scientific computing can be broadly divided into the categories of capacity and capability. Capacity computing implies high throughput of a large number of program runs of small or medium size on different data sets.

This style of computing can be dealt with in a cost effective manner, by providing adequate computing capacity at the regional or national level, accessed by grid-based computing methods. Capability computing is technologically far more challenging, and is characterized by simulations using a large number of processors in a cooperative mode. Often requiring large amounts of memory and the ability to process extensive data sets, such simulations are dependent on a high-bandwidth, low-latency communication fabric that connects the individual processors. These capabilities imply a single parallel computer that no loosely coupled distributed computing infrastructure can provide. The International Scientific Panel is convinced that the establishment of Europe-wide supercomputer capability is critical for this class of problem."

In reference 9, the difference between capability computing and grid computing is explained by the following example. "Table 3 indicates the broadness of latencies of different components in a grid. Latency is critically dependent on the distance that the signals will have to travel. It explains the very reason why supercomputer (capability computing) performance will never be attainable through grid computing, where by definition systems are included in the grid are spatially (far) apart."

(2) Performance pyramid

The HPC in Europe Taskforce (HET) have indicated the key elements of the HPC ecosystem (HPC integration) by a Performance Pyramid as shown in Figure 4. At the top of the pyramid (Tier 0), they have proposed the construction of a small number of high-end performance HPC systems (referred to here as the 'European Supercomputer Systems') which would be funded through national sources with additional European level funding. HET has ranked systems that perform capability computing as top-of-the-pyramid resources.

The middle layer (Tier 1) represents a number of national and regional level HPC systems, which should have a high enough performance to be capable of running most of the computing load below petaflop and in addition serving as a development platform for the most scalable code directed to the petaflop systems.

The bottom pyramid layer (Tier 2) represents the local level of activity including the development of a strong competence base of scientists in multiple European countries, the renewal and development of new skills through local education and increasing the visibility of scientific computing so to attract new users.

Although different capacity HPC systems exist in different layers, the grid-supported interconnections between layers are included throughout the entire pyramid. This type of service, in addition to the relative computing power, requires efficient storage systems, networks, middleware, and scalable software, etc.

(3) Significance of human factors

In order to support this type of HPC ecosystem, it is necessary to focus on the competence development and other human aspects at various levels. For example, growing investment is required in the following disciplines.

- Code development and optimization skills in all levels of the pyramid
- Research oriented training activities
- Access to expertise and scientific/technical support

Table 3 : Overview of indicative system and network latencies in communication process

Communication system	Latency (nanoseconds)
Supercomputer internal networks HW latency	3 – 5
Supercomputer internal networks SW latency	800 – 2,000
Commercial internal network SW latency	2,000 – 50,000
Speed-of-light in glass fiber(HW) latency per km	10,000
Long distance protocol (SW) latencies	> 1,000,000

(HW:hardware, SW:software) Figures are best estimates, the lower the figure the better.

Source: Reference[9]

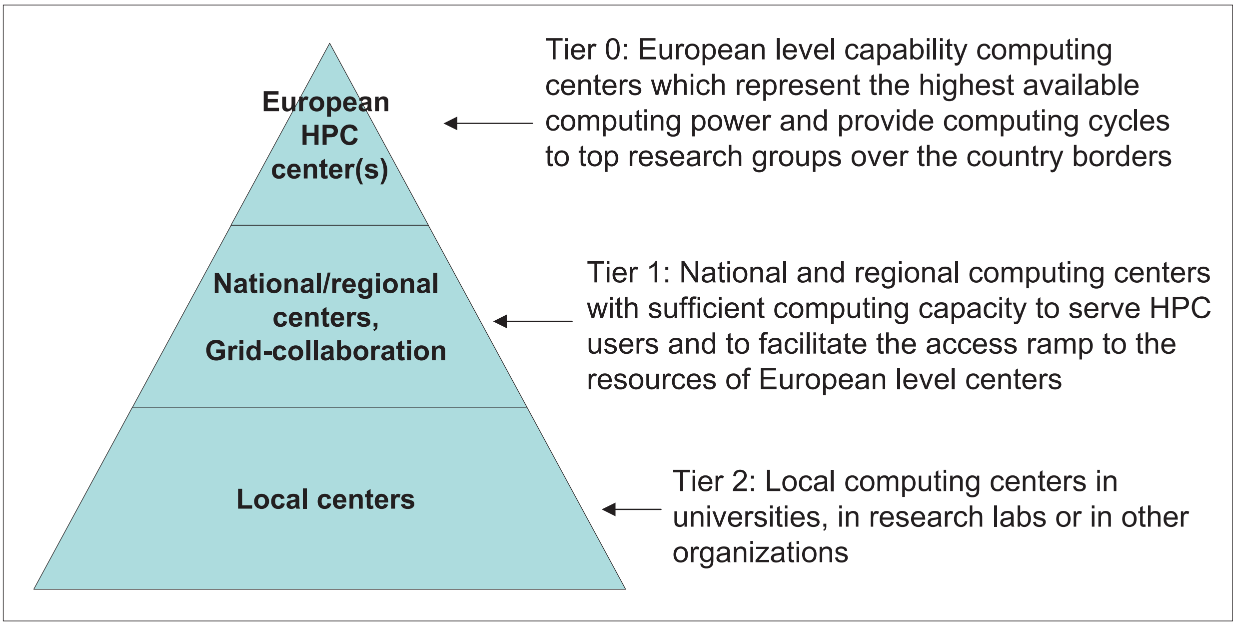

Figure 4 : Performance pyramid

Prepared by the STFC based on Reference[9]

- Access to deliverables such as code libraries
- Collaborative tools promoting sharing of information between different research groups, both within the same discipline and multi-scientific fields

3-4 *Integration with existing infrastructures*

It is essential that all HPC systems in Figure 4 are integrated in the European Research Grid in the same way as other resources regardless of whether they exist in the top or bottom layer of the performance pyramid. The European Research Grid is a highly integrated infrastructure in which every e-resource is integrated at the hardware, software, and communication level. High operational efficiency is achievable through tight integration and optimal utilization of distributed resources and skills sets in each European country. The relationship between HPC systems and the grid is described as follows.

(1) To run all relevant Research Computing to be conducted at the highest competitive level in Europe, supercomputers must be part of any European Research Grid infrastructure.

(2) Grid developments shall support the integration of all e-resources. A scientific research activity is only rarely dependent on just a single IT component, including supercomputing: there may be data pre-processing, a real-time component (with a sensor grid for example), visualization both interactively or as post-processing. This is only achievable by making supercomputing a part of the whole European Research Grid infrastructure. Also, the links between different layers of the computing resources pyramid should be established through grid middleware.

(3) Even at the supercomputing level there is no "one size fits all" for all applications, which means that there should be a flexible environment from which the best resources can be selected. This environment is suitably done within a grid working environment.

Grid integration between HPC systems is currently being achieved by the Distributed European Infrastructure for Supercomputing Applications (DEISA[*8]) project. The grid environment is a means of guaranteeing that all resources within the pyramid can be transparently seen and can be optimally deployed to serve their objective(s) in a single environment. Therefore, grid computing and supercomputing form a complementary relationship.

3-5 *Software development initiatives*

HET have made the following recommendations for addressing the key issues in developing software that allows exploiting the potential of resources having petaflop/s computing performance.

- Top-of-the-pyramid hardware alone will not be sufficient in delivering petascale performance for solving any given scientific problem.
- In order to run such large-scale (and potentially heterogeneous) machines, new operating systems will be required to address the problems related to scheduling, address space management, communication, fault tolerance, scalability, and reconfiguration, etc.
- New program models, compiler techniques, and runtime systems are required in order to process parallel tasks beyond $10.^6$
- Mathematical models of most scientific problems need to be improved in order to scale to the level provided by petaflop machines.
- All these measures are essential for utilizing petascale hardware, and Europe can claim to have a distinct advantage in such software related developments.

3-6 High efficiency, high reliability infrastructure for large-volume data storage

Increasing emphasis on permanent and persistent data repositories as a part of the HPC ecosystem have been recommended for the following reasons.

- The amount of stored scientific data has been doubling every year for the past several decades without indication that this exponential growth will end soon.
- Due to the massive amounts of data involved (many petabytes, approaching the exabyte range), large scale replication is impossible. On the other hand, most of these data cannot be reproduced once they are lost; therefore, systematic measures against failures(including disasters) are necessary.
- To address problems of intellectual property, ownership, and privacy, etc., elaborate security measures must be implemented.

3-7 Development of competent skills sets in computational science

As the computational science may substantially change the way science is performed in basically all fields, HET has proposed that massive educational efforts have to be initiated in order to actively use this new paradigm. In addition, education and training activities which focus on enabling more efficient and higher quality use of the top-end facilities in the long run require enhancement.

In specific terms, activities aimed at computer based modeling, scalable code development, integration work for the existing national infrastructures and training for competence development in computational sciences are cited.

3-8 Funding and utilization models

Building an internationally competitive European HPC infrastructure with a small number of high-end HPC centers requires continuous funding of both hardware procurement and support structures. In describing the design goals for the funding and utilization of Tier 0 European HPC center in Figure 4, HET has proposed the following funding and utilization models for the construction of these.

(1) General goals and design objectives

(a) Regarding utilization, the following conditions are reported to be needed to make the best possible usage of these resources.

- Resources such as computing time, storage, support, etc., should be allocated only to projects that require such capability computing resources and should not be assigned to demands that can be fulfilled by sub-national scale systems.
- Allocation of resources should strictly follow scientific criteria.
- Small-scale partitioning of the Tier 0 resources would compromise capability computing and should therefore be avoided.
- The development of world-class support systems and efficient software for capability computing is a fundamental prerequisite for effective resource utilization.

(b) Regarding funding, in order to accommodate the interests of existing and prospective funding agencies the following matters are proposed.

- Scientists of those EU member states and associated states which provide Tier 0 funding should get access to all European Tier 0 systems according to their countries´ total contribution and that of the EC.
- Scientists of EU member states and associated states not providing Tier 0 funding should get access to all the Tier 0 systems with respect to

the contribution of the EC.

- In accordance with the DEISA project model, the tight integration of top layer (Tier 0) centers with existing national and international middle layer (Tier 1) centers is to be funded.
- While the major part of available EC funding is required for the top-layer (Tier 0) resources, a substantial portion of the EC funding must be reserved for the development of capability computing oriented software and community oriented support structures at the Tier 0 centers and national Tier 1 centers.
- The establishment of pan-European science community should be supported.
- In addition to the core investments by the EC and contributing EU members and associated states, refunds obtained from selling computer time and services to industry as well as science should be considered.

In addition, the funding objectives should in particular include the very strong interest of the EC to include a pre-commercial procurement phase in order to open up European pathways to petaflop prototype systems. Within the pre-commercial procurement phase of about two years, the transfer of part of the R&D activities and production of non-European vendors to Europe and the reflection of Europe's needs in major non-European vendors are to be accelerated.

(2) Mutual utilization model

The introduction of a Mutual Utilisation Model (MUM) has been proposed. The guiding principle of MUM is the establishment of coordinated procurements by two or three EU member states and associated states, following each other within an interval of about 1 to 2 years. In addition to this funding, the EC contributes with a significant share to complement the national funding for every Tier 0 system. Other than by adopting this kind of procurement ‘spiral’, there is no other way of guaranteeing a sustained world-class Leadership HPC infrastructure in Europe.

A major portion of the resources that corresponds to the contribution of the EC to the costs of the infrastructure will be allocated to projects that are open to all EU member states and associated states. The remaining resources are shared among projects of the states that have committed themselves to carry out the successive procurements. Accordingly, on each of the systems, all the latter EU member states and associated states should get a substantial and fair amount of resources following their contribution.

3-9 Peer review process

The requirements for the top-of-the-pyramid (Tier 0) resources have been defined by considering the principles of subsidiarity with existing national and thematic resources to ensure the most relevant contribution to science. Scientists using the top-of-the-pyramid resources are expected to make contributions in advancing science through numerical simulation. This calls for an evaluation process based on peer review to allocate computer resources. However, since the optimal utilization of highly parallel systems such as the petaflop computers is challenging, a two-level review system that evaluates both scientific excellence and efficiency of the application code is required.

HET have indicated the framework, periodic processes, and eligibility of applications. The following requirements have been cited as eligibility of applications.

- Scientific excellence
- Demonstrated need for Tier 0 level resources
- Proven feasibility of computation, data collection and result analysis. Code must have been validated on suitable equipment available to proposer on a national, thematic or local basis.
- In the case of industrial partners, further examination of benefits is warranted, as examination of property of results, confidentiality etc.

4 Points of special interest

(1) Necessity of capability computing

The necessity of capability computing is described throughout the HET report. The report concerning scientific demands created by the International Scientific Panel states that petascale computing would be a great benefit to the multiple world-class research groups that exist in Europe and it is vital to have immediate access to adequate resources that can reduce the time taken to solve problems (Time to Solution) in order to implement approved science and research at a competitive level.

This International Scientific Panel also states that the procurement of Leadership-class supercomputers is essential for European science to maintain a leading position in multiple domains, whereby without access to capability level computers European science and industry would lose its competitive edge. Areas that are under threat include: climate data usable in international negotiations, construction of ITER and adequate utilization of project results, and evolution in biophysics and systems biology for the understanding of complete cells.

(2) Utilizing the 'European Supercomputer System'

HET has ranked the 'European Supercomputer System' as the system which should be used for capability computing. This is explained in detail by referencing specific latencies (delays occurring in communications) in contrast to the capacity computing concept.

However, in terms of computer systems to be deployed, since it is extremely unlikely that a single design or design concept (architecture) of capability computing will be available to satisfy all requirements in capability computing at the highest level in every academic discipline, the demand for multiple systems with different architectures is emphasized.

Regarding utilization, HET proposes that software for the 'European Supercomputer System' should be used for research goals of highest scientific merit and greatest need, whereby the software to be used are selected by a peer review process.

(3) European competitiveness

HET states that it is necessary to conduct activities that focus on the entire HPC ecosystem or more specifically all layers of the performance pyramid, in order to narrow the gap between Europe and the USA or Japan. In doing so, the numerous important factors that give Europe its competitive edge will be enhanced. In specific terms, investments into scientific software development and code optimization, middleware development, data repositories, and efficient networking are cited. The important factors that have hitherto given Europe its competitive edge should be subsequently exploited.

Section 3-5 indicates the important action assignments to be undertaken in software development fields required in petascale computing. However, in the essential measures cited for petascale computing HET states that Europe maintains an advantage.

(4) Necessity of developing human resources

Section 3-7 indicates the necessity of developing computational science skills sets through enhanced education and training activities. In comparison to the acquisition of facilities, obtaining the human resources to manage the facilities is more difficult, therefore strong appeals for necessary investments are made. It mentions that training of human resources with the required skills sets could take several years; therefore, in order to attract such human resources, investments in building supporting environments shall also be needed.

(5) Responding to non-Europe's HPC vendors

In Europe, there are very few vendors that can supply HPC hardware and processors. Because Europe is challenged to accurately convey its HPC requirements to non-European vendors, measures such as promoting a shift of non-European R&D activities into Europe and incorporating Europe's demands into non-European vendors through a pre-commercial procurement phase are being considered.

(6) Science and technology fields chosen by scientific necessity

The American government's high performance computing policy also mentions the benefits of high performance computing to science and engineering.[14,15] By comparing the American proposals to the demands investigated by the European International Scientific Panel, Europe makes few references to 'national security' but raises detailed points about the many applications to life sciences in addition to including matters of deep interest in engineering fields such as helicopter simulation, forest fires, green aircraft, and virtual power plants, etc., which were not raised by the USA.

5 Conclusions

Areas of keen interest regarding petascale computing trends in Europe have been highlighted from the proposals presented by the HPC in Europe Taskforce (HET).

In order to advance science and technology, there is a universal need in Japan, America, and Europe to respond to changes towards large-scale, high-precision, and high-speed simulation. Presently, in America there are four projects (Department of Energy ASC programs, NLCF program, Department of Defense HPCS program, and the American National Science Foundation's Cyber Infrastructure program) and one project in Japan (development and adoption of state-of-the-art general-purpose computers of high performance) that are progressing in the research and development of capability computing systems. In Europe, the issue of constructing 'European Supercomputer System' facilities as capability computing systems is aimed at sharpening Europe's competitive edge to counter the advances made in the US and Japan. Owing to the actions of HET, the 'European High Performance Computing Service' was incorporated as one of 35 projects in the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap which holds a great influence on European sciences. In addition, in April 2007, the memorandom of understanding for 'Partnership for Advanced Computing in Europe' (PRACE, or formerly referred to as 'PACE')[16] initiative was signed by major European countries. One of the key objectives of PRACE is to achieve a pan-European HPC service by 2009/2010. This implies that Europe has taken a significant first step towards the deployment and utilization of petascale computing. It would be considered worthwhile to follow closely the prospects of Europe where excellent achievements in application and software development technologies have been realized.

Acknowledgements

The author of this article would like to express his sincere gratitude to Mr. Hisashi Nakamura of the Research Organization for Information Science & Technology for his valuable opinions.

Glossary

*1 Flops is a unit indication of computer processing speed. A petaflop/s (or PFLOPS) computer performs 10^{15} FLoating point Operations Per Second.

*2 LINPACK (LINear equations software PACKage) Benchmarks are calculated using software libraries for performing simultaneous linear equations used primarily in calculating floating point numbers. The results of the Benchmark tests, indicated as numbers of floating point operations per second (flops), are listed for numerous computing systems from supercomputers and workstations to personal computers.

*3 Charts 1 and 2 show the performance totals of HPC systems listed in the TOP500. For example, the performances of the UK's 42 listed HPC systems are given as a total value. The performance (Rmax) of the individual highest-ranking HPC system listed in the TOP500 is 280TFLOPS (USA's DOA/NNSA/LLNL). Research and development into petascale computing is aiming at exceeding petaflops in this individual HPC performance.

*4 A de facto application programming interface for performing basic numerical calculations such as linear algebra operations.

*5 Wide-range science, engineering, and statistical application numerical software libraries developed by the NAG research and development team formed by world renowned mathematicians and statisticians.

*6 Geant2 is the seventh generation pan-European research and education network. It provides a state-of-the-art network service to 34 countries connected via the National Research and Education Networks (NRENs) covering the world's largest geographically networked area.

*7 e-Infrastructure Reflection Group: e-IRG is supporting the creation of a framework (political, technological and administrative) for the easy and cost-effective shared use of distributed electronic resources across Europe - particularly for grid computing, storage and networking.

*8 DEISA (Distributed European Infrastructure for Supercomputing Applications):

DEISA is a consortium of leading national supercomputing centers that currently deploys and operates a persistent, production quality, distributed supercomputing environment with continental scope.

Abbreviations

FP7: Seventh Framework Programme

DEISA: Distributed European Infrastructure for Supercomputing Applications

EGEE: Enabling Grid for E-sciencE

ESFRI: European Strategy Forum on Research Infrastructures

GEANT: Seventh generation of pan-European research and education network

HET: HPC in Europe Taskforce

HPC: High Performance Computing

The Challenges and Outcomes in Science and Engineering to be Addressed through Petascale HPC Provision

Area	Application	Science Challenges & Potential Outcomes
WEATHER, CLIMATOLOGY AND EARTH SCIENCES	Climate change	Quantify uncertainties on the degree of warming and the likely impacts by increasing the capability and complexity of 'whole earth system' models that represent in ever-increasing realism and detail the scenarios for our future climate.
	Oceanography and Marine Forecasting	Build the most efficient modelling and prediction systems to study, understand and predict ocean properties and variations at all scales, and develop economically relevant applications to inform policy and develop services for government and industry.
	Meteorology, Hydrology and Air Quality	Predict weather and flood events with high socio-economic and environmental impact within a few days. Understand and predict the quality of air at the earth's surface; development of advanced real-time forecasting systems for allowing early enough warning and practical mitigation in the case of pollution crisis.
	Earth Sciences	Challenges span a wide range of disciplines and have significant scientific and social implications, such as the mitigation of seismic hazards, treaty verification for nuclear weapons, and increased discovery of economically recoverable petroleum resources and monitoring of waste disposal. Increased computing capability will make it increasingly possible to address the issues of resolution, complexity, duration, confidence and certainty, and to resolve explicitly phenomena that were previously parameterized, and will lead to operational applications in other European centres, national centres and in industry.
ASTROPHYSICS, HEP* AND PLASMA PHYSICS	Astrophysics	Deal with systems and structures which span a large range of different length and time scales; almost always non-linear coupled systems of ordinary and partial differential equations have to be integrated, in 3 spatial dimensions and explicitly in time, with rather complex material functions as input. Grand challenges range from the formation of stars and planets to questions concerning the origin and the evolution of the Universe as a whole. Evaluate the huge amount of data expected from future space experiments such as the European Planck Surveyor satellite.
	Elementary Particle Physics	Quantum field theories like QCD (quantum chromodynamics) are the topic of intense theoretical and experimental research by a large and truly international community involving large European centers like CERN and DESY. This research not only promise to yield a much deeper understanding of the standard model of elementary particles and the forces between them, as well as nuclear forces, but is also expected to discover hints for a yet unknown physics beyond the standard model.
	Plasma physics	The science and technology challenge raised by the construction of the magnetic confinement thermonuclear fusion reactor ITER calls for a major theory and modelling activity. Both the success of the experiment and its safety rely on such simulators. The quest to realize thermonuclear fusion by magnetically confining a high temperature plasma poses some of the computationally most challenging problems of nonlinear physics.

Area	Application	Science Challenges & Potential Outcomes
MATERIALS SCIENCE, CHEMISTRY AND NANOSCIENCE	Understanding Complex Materials	The determination of electronic and transport properties central to many devices in the electronic industry and hence progress the understanding of technologically relevant materials. Simulations of nucleation, growth, self-assembly and polymerization central to the design and performance of many diverse materials e.g., rubbers, paints, fuels, detergents, functional organic materials, cosmetics and food. Multiscale descriptions of the mechanical properties of materials to determine the relation between process, conditions of use and composition e.g., in nuclear energy production. Such simulations are central to the prediction of the lifetime of high performance materials in energy technology, such as high-efficiency gas-turbines
	Understanding Complex Chemistry	Catalysis is a major challenge in the chemistry of complex materials, with many applications in industrial chemistry. The knowledge of atmospheric chemistry is crucial for environmental prediction and protection (clean air). Improving the knowledge of chemical processing (from soft chemistry including polymers to the atomistic description of combustion) would improve the durability of chemicals. Supra molecular assemblies open new possibilities for the extraction of heavy elements from spent nuclear fuels. In biochemistry, a vast number of reactions taking place in the human body (for example) are not understood in any detail. A key step in the development of the clean fuels of the future requires the realistic treatment of supported catalytic nanoparticles.
	Nanoscience	The advance of faster information processing or the development of new generations of processors requires the shrinking of devices, which leads inevitably towards nanoelectronics. Moreover, many new devices, such as nanomotors can be envisioned, which will require simulation of mechanical properties at the nanolevel. Composite high performance materials in the fields e.g. adhesion and coatings will require an atomistic based description of nanorheology, nanofluidics and nanotribology. As an example the description of the complex magnetic and mechano-optical properties of nanodevices components is only feasible only on systems in the Petaflop/s range.
LIFE SCIENCES	Systems Biology	The use of increasingly sophisticated models to represent the entire behaviour of cells, tissues, and organs, or to evaluate degradation routes predicting the final excretion product of any drug in any organism. To position Europe in the next 4 years to host the first "in silico" cell.
	Chromatine Dynamics	The organization of DNA in nucleosomes largely modifies the accessibility of transcription factors recognition sites playing then a key role in the regulation of gene function. The understanding of nucleosome dynamics, positioning, phasing, formation and disruption or modifications induced by chemical modifications, or by changes in the environment will be crucial to understand the mechanism of gene regulation mediated by chromatine modelling.
	Large Scale Protein Dynamics	The study of large conformational changes in proteins. Major challenges appear in the simulation of protein missfolding, unfolding and refolding (a key element for the understanding of prionoriginated pathologies).
	Protein association and aggregation	One of the greatest challenges is the simulation of crowded "not in the cell" protein environments. To be able to represent "in silico" the formation of the different protein complexes associated with a signalling pathway opens the door to a better understanding of cellular function and to the generation of new drugs able to interfere in protein-protein interactions.
	Supramolecular Systems	The correct representation of protein machines is still out of range of European groups using current simulation protocols and computers. The challenge will be to analyze systematically how several of these machines work e.g., ribosome, topoisomerases, polymerases.
	Medicine	Genome sequencing, massive genotyping studies are providing massive volumes of information e.g. the simulation of the determinants triggering the development of multigenic-based diseases and the prediction of secondary effects related to bad metabolism of drugs in certain segments of population, or to the interaction of drugs with macromolecules others than their original targets.

Area	Application	Science Challenges & Potential Outcomes
ENGINEERING	Complete Helicopter Simulation	The European helicopter industry has a strong tradition of innovation in technology and design. Computational Fluid Dynamics (CFD) based simulations of aerodynamics, aeroacoustics and coupling with dynamics of rotorcraft already play a central role and will have to be improved further in the design loop.
	Biomedical Flows	Biomedical fluid mechanics can improve healthcare in many areas, with intensive research efforts in the field of the human circulatory system, the artificial heart or heart valve prostheses, the respiratory system with nose flow and the upper and lower airways, and the human balance system. Although experiments have significantly improved the understanding in the field, numerous questions, the answers of which need a high resolution of the flow field, of the surrounding tissue, or of their interactions, require a detailed numerical analysis of the biomedical problem.
	Gas Turbines & Internal Combustion Engines	Scientific challenges in gas turbines or piston engines are numerous. First, a large range of physical scales should be considered from fast chemical reaction characteristics (reaction zone thicknesses of about tens of millimetres, 10^{-6} s), pressure wave propagation (sound speed) up to burner scales (tens of centimetres, 10^{-2} s resident times) or system scales (metres for gas turbines).
	Forest Fires	The development of reliable numerical tools able to model and predict fire evolution is critically important in terms of safety and protection ("numerical fire simulator"), fire fighting and could help in real time disaster management. The social impact is very important and is concerned with land, buildings, human and animal life, agriculture, tourism and the economy.
	Green Aircraft	ACARE 2020 provides the politically agreed targets for an acceptable maximum impact of air traffic on people and the environment, while at the same time allowing the constantly increasing amount of air travel. The goals deal with a considerable reduction of exhaust gas and noise. Air traffic will increase by a factor of 3, accidents are expected to go down by 80%. Passenger expense should drop (50%) and flights become largely weather independent. The "Green Aircraft" is the answer of the airframe as well as engine manufacturing industry. However, it is only by a far more productive high quality numerical simulation and optimisation capability that such a challenging development will be possible. It will be indispensable to be able to compute the real aircraft in operation, including all relevant multi-disciplinary interaction.
	Virtual Power Plant	Safe production of high quality and cost effective energy is one of the major concerns of Utilities. Several challenges must be faced, amongst which are extending the lifespan of power plants to 60 years, guaranteeing the optimum fuel use and better managing waste. These challenges demand access to Petascale machines to perform advanced simulations along with a new generation of codes and simulation platforms.

Note: HEP: High-energy physics

Source: Reference[13]

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(Original Japanese version: published in October 2007)

2

Current Situation and Problems of Contiguous Water

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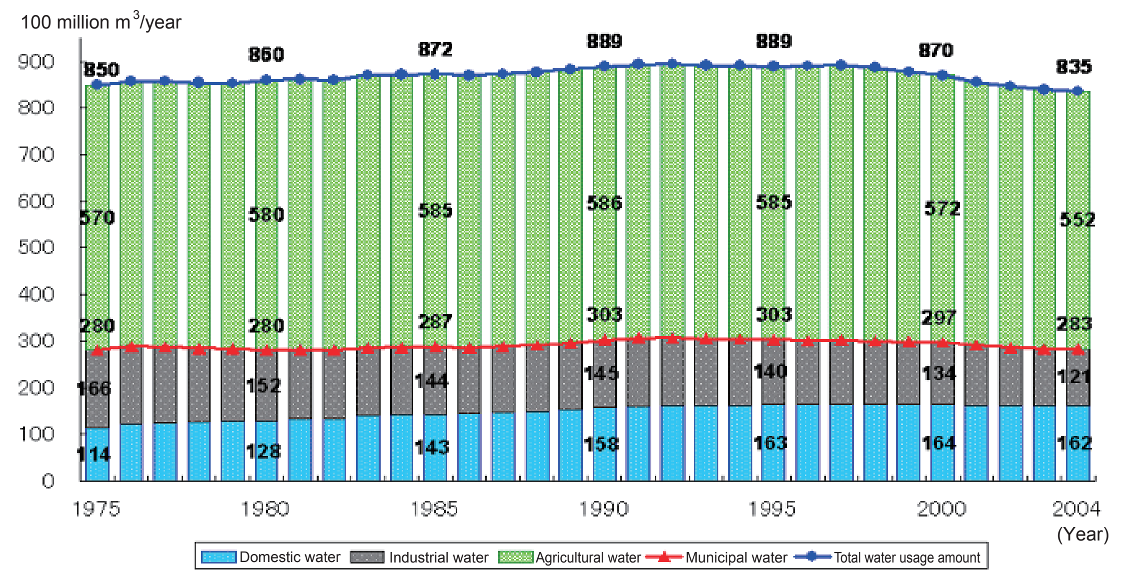
1 Introduction

Water is essential to sustaining life. There are numerous challenges concerning water that include problems such as increasing local water supply associated with lifestyle changes, increasing water usage due to expansion in food production associated with increasing population, the virtual water related food self-sufficiency in Japan, growing demand for bottled water derived due to concerns over safety of tap drinking water, increasing demand in agricultural water utilization associated with increasing biomass production such as corn, etc., and regionally distorted water demands due to population intensification of urban areas. Ninety percent of the natural disasters during the last ten years have been water related, and sixty-three percent of the people who have no access to safe drinking water and seventy-five percent of the people who have no access to sanitary facilities in the world concentrated in Asia and the Pacific region. The situation is very serious.

Figure 1 shows that in 2004 the amount of water used throughout Japan totaled approximately 83.5 billion cubic meters per annum. Usage of municipal water including domestic water and industrial water came to approximately 28.3 billion cubic meters per annum, and water for agricultural use came to 55.2 billion cubic meters per annum.[1] Although the amount of municipal water, which includes water used by industry and domestic household



Notes:
1. These are values based on water withdrawal volumes according to estimates by the Water Resources Department, Ministry of Land, Infrastructure and Transport, which include water volume released to rivers after usage.
2. Industrial water includes the amount of freshwater supply for plants or offices with four or more employees. However, water used in public-utility industries is not included.
3. Regarding agricultural water, the 1980 estimate value is used for 1981 - 1982, the 1983 estimate value is used for 1984 - 1988, and the 1989 estimate value is used for 1990 - 1993.
4. Some totals may differ due to rounding off.

Figure 1 : National water usage volumes in Japan

Source: Reference [1]

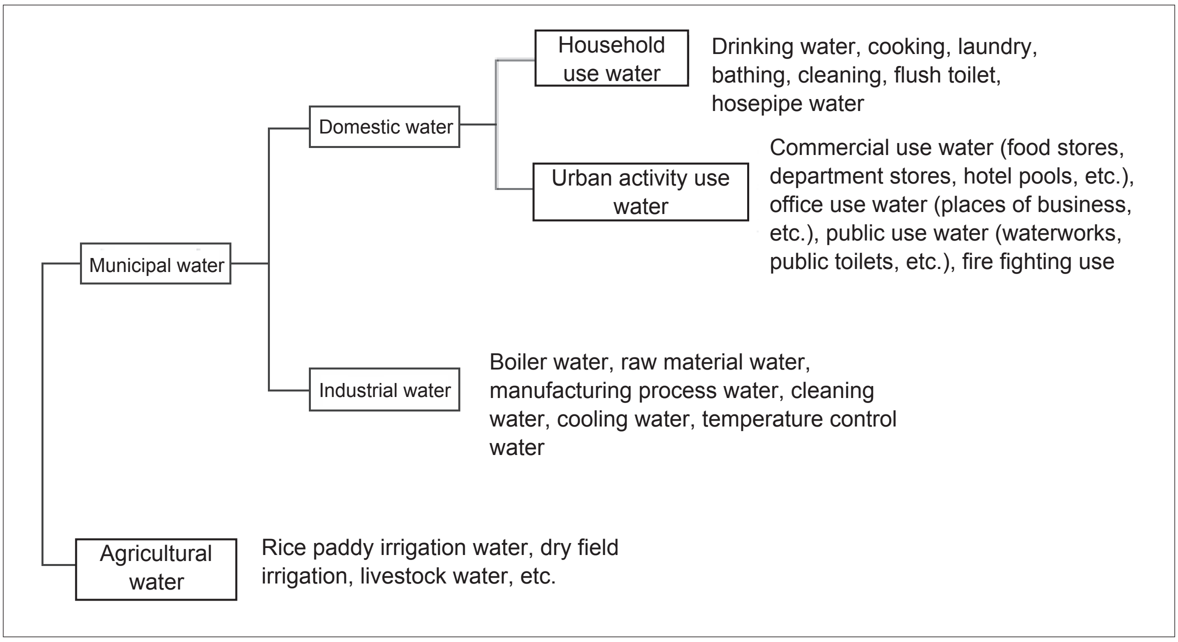


Figure 2 : Grouping of water usage pattern

Source: Reference [2]

use, shows an increasing trend from 1965, over recent years the trend has almost leveled or slightly decreased reflecting the enhancements in water-saving technologies and the economic climate.[2]

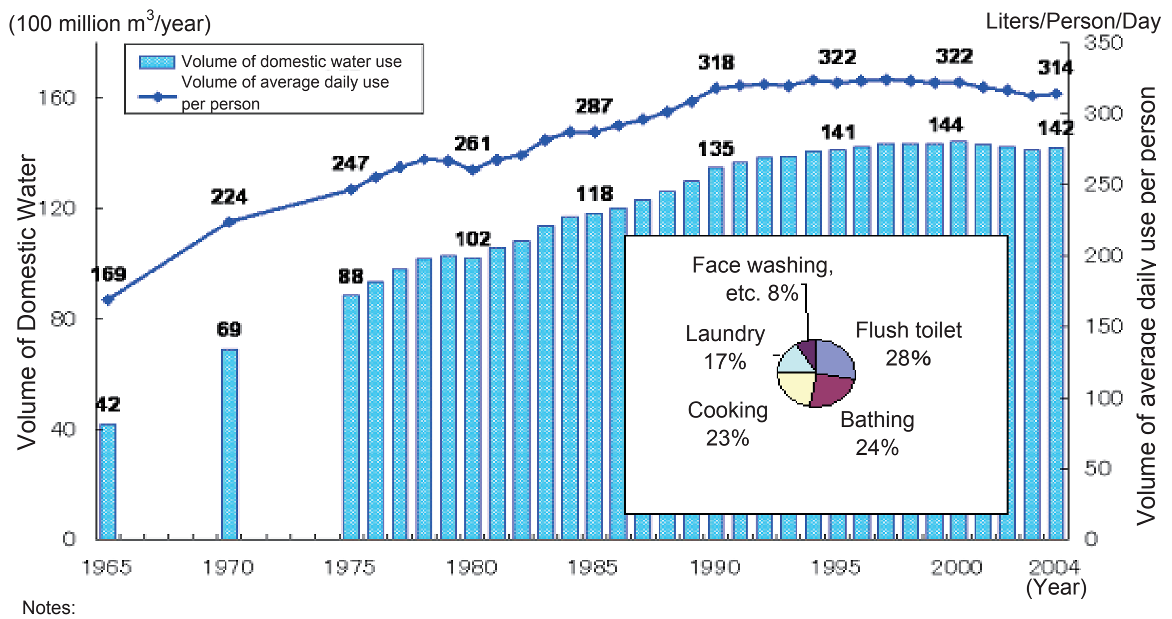
The groupings of the water utilization pattern are shown in Figure 2. This article investigates the problems, centering on local water, concerning water quality and water shortage with current anxieties, the energy increases associated with fresh water generation, and the ways that we should be reducing the impact on the environment associated with the treatment of wastes such as plastic bottle containers, etc.

2 Current situation of water in daily life

2-1 Domestic water

During the course of the last twenty years, droughts have occurred almost everywhere in Japan. The stoppage of water supply due to droughts not only bears a great impact on daily life, it also damages farm produce, raises prices of vegetables, etc., and obstructs the operation of manufacturing plants. For example, in 1995 an estimated 17 million people in 42 prefectures were affected by drought. As Figure 3 shows, the amount of water usage in general daily life has increased throughout the country due to changes of lifestyle.[1] Here, in particular, we will look at the example of the problem occurring in Okinawa prefecture, which has had a history of suffering water shortages, to see how the water problem affects everyday life.

In Okinawa prefecture region where inclouding islands such as Ishigaki, Miyako, Kume etc., the population has increased from approximately 950,000 inhabitants in 1970 to 1.36 million in 2005. In addition, the numbers of tourists has also increased from approximately. 740,000 visitors in 1973 to approximately 2.05 million in 1984, reaching approximately. 5.50 million by 2005. This increase is due to the increase in the numbers of flights and the numbers of direct flights to each of the islands. Along with the increase in tourists, the number of accommodation facilities has also increased. On the main island of Okinawa, the water service criterion of such facilities is 200 to 300 liters per day per staying customer; however, in a survey of 29 accommodations conducted by the Okinawa Bureau of Enterprise, it was revealed that a daily maximum of 2,375 liters, minimum 332 liters, and an average of 778 liters were used per day per staying guest.[3] In the Okinawa countryside, there was no previous custom of taking baths, and taking showers was the established norm. However, in recent years, the water consumption rate has increased together with the growing numbers of tourists. Ensuring a supply of clean water has become a problem. In



Notes:
1. Post 1975, verified by the Water Resources Department, Ministry of Land, Infrastructure and Transport.
2. Values for 1965 and 1970 are according to the Health, Labour and Welfare Ministry's "Tap Water Statistics".
3. Based on the effective volume of water.

Figure 3 : Transitions in domestic water usage volume

Source: Reference [1]

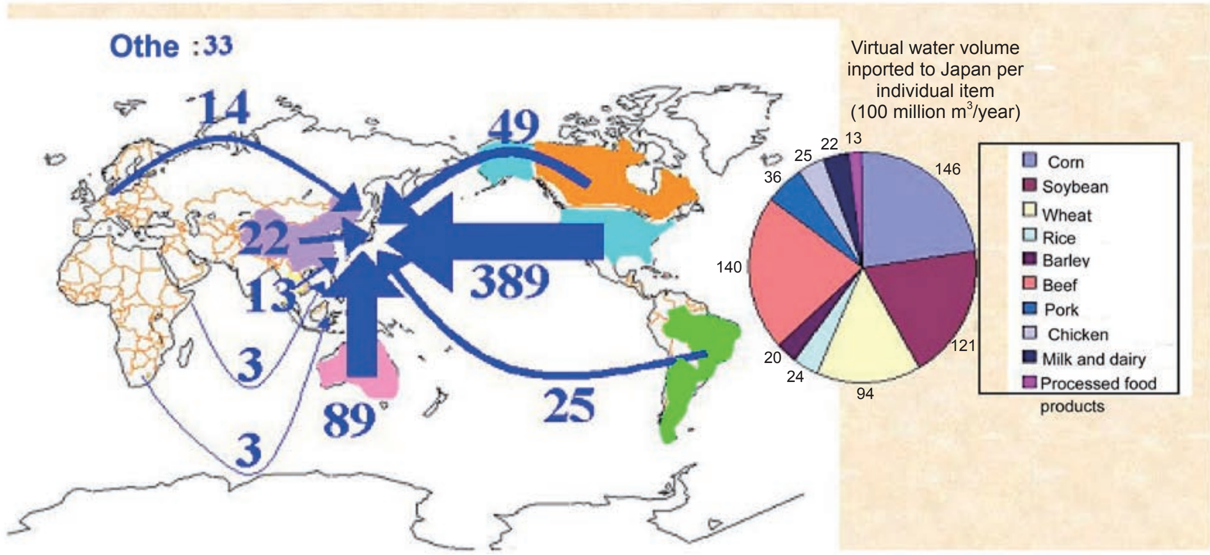
particular, in the more remote islands which are poorer in water resources, in years of low rainfall tap water is in short supply even though there is sufficient water for irrigating the sugarcane crops because ensuring water for agricultural use is the principal objective of the many water resource developments, and residents become dissatisfied regarding water usage rights. Another example, in a village that has two simple waterworks, the water regulated supply time inside the village varies and thereby creating a sense of injustice among its residents. Also, there is regional disparity in water rate charges. For example, in Naha City, the price of tap water is 1,500 JPY per 10m^3, whereas in Minamidaito village where the seawater is desalinated the price is 3,400 JPY, which is two to three times higher than Naha. This charge is also applicable to residents who are not associated with the tourist industry. Consequently, there is a trade-off between reducing the risk of drought and promoting tourism - which has created conflict among the residents.[4] This regional problem that is seen to be a feature of the small municipalities is not only found on Okinawa but is a common problem that occurs throughout the entire country. In particular, on the smaller remote islands there are villages where the only one employee of water supply office is in charge of running the mains water supply from managing the water purification plant to collecting water payments, and therefore the installation of technologically-simplified, easy-to-operate waterworks system is required.

In accordance with these changes in lifestyle and industrial structures, the necessity to produce water by the desalination of seawater is escalating. As the desalination of seawater requires energy, there are concerns about the shortage of energy which is generated only by thermal power plants and related global warming in Okinawa where no nuclear power generation is available.

2-2 Problems associated with food imports

Japan has been importing approximately 60% of food which naturally means that water is also required for its production overseas. This “Virtual Water” as it is called has many problems associated with its quality and quantity. For example, it is estimated that 500 to 600 liters are required to make a loaf of bread, whereas 200 g steak requires approximately 4,000 liters.[4] Since importing food also simultaneously imports the water that is incidental to the food items, there is the issue regarding the quality of such imported waters.

Figure 4 shows the flow of virtual water into Japan from each region of the world. By looking at this diagram, we can see that the majority of



Total imported volume: 64 billion m^3/year

Volume of water used for irrigation in Japan: 59 billion m^3/year (Japan unit yield amount: estimate value from statistics of the food supply and demand tables for the year 2000)

Figure 4 : Virtual water total import volume

Source: Reference [6]

virtual water is imported from North America and Australia, followed by China and South East Asia, and also from Europe. The total imported volume of virtual water comes to approximately 64 billion m^3 per annum. Whereas the total volume of water resources used inside Japan is approximately 90 billion m^3, and the virtual water which is effectively the volume used by Japan overseas, corresponds to approximately two-thirds of the actual volume that is used in Japan. If Japan aimed to reach an annual food self-sufficiency of 30 million tons, it would be necessary to generate irrigation water that is needed for food production.[6]

2-3 Problems associated with bottled water

In Japan, the use of mineral water and natural water when drinking whisky, etc., became generally widespread some time ago. However, recently, the amount of safe and good-tasting bottled water that is purchased daily at almost every opportunity is increasing. Besides domestically produced bottled water, imported products are also increasing. In 2000, the imported amount of bottled water was 195,000 m^3. Approximately one-third of bottled water sold in Japan is imported from North America and Europe. Since transporting bottled water is directly associated with CO_2 generation through the use of fueled transportation, it is seen as a part of the problem concerning further usage energy resources and generation of global greenhouse gases. It also creates the problem of dealing with the waste treatment of plastic bottles.

In June 2007, the mayor of San Francisco issued a permanent ban on the purchasing of bottled water in the city for the purpose of saving taxes and protecting the environment. In America, trial calculations show that 40 million gallons of oil are consumed per annum in the production of container materials of bottled water purchased by its citizens. Furthermore, because this also generates the problem of disposing of the containers, there are many controversies concerning this matter.[8,9]

3 Present water situation

3-1 Attitudes to water

Presently, the national average of the popularization of water purifiers has exceeded 30%, and that of large metropolitan areas in which the water is considered to be "unpleasant" is comparatively higher than in other areas. Figure 5 shows the results of a survey on water purifiers conducted in Japan.[10] Among the reasons for installing water purifiers, "To improve the taste" accounted for 54.1%, or just over half, whereas the health and safety concerns regarding tap water

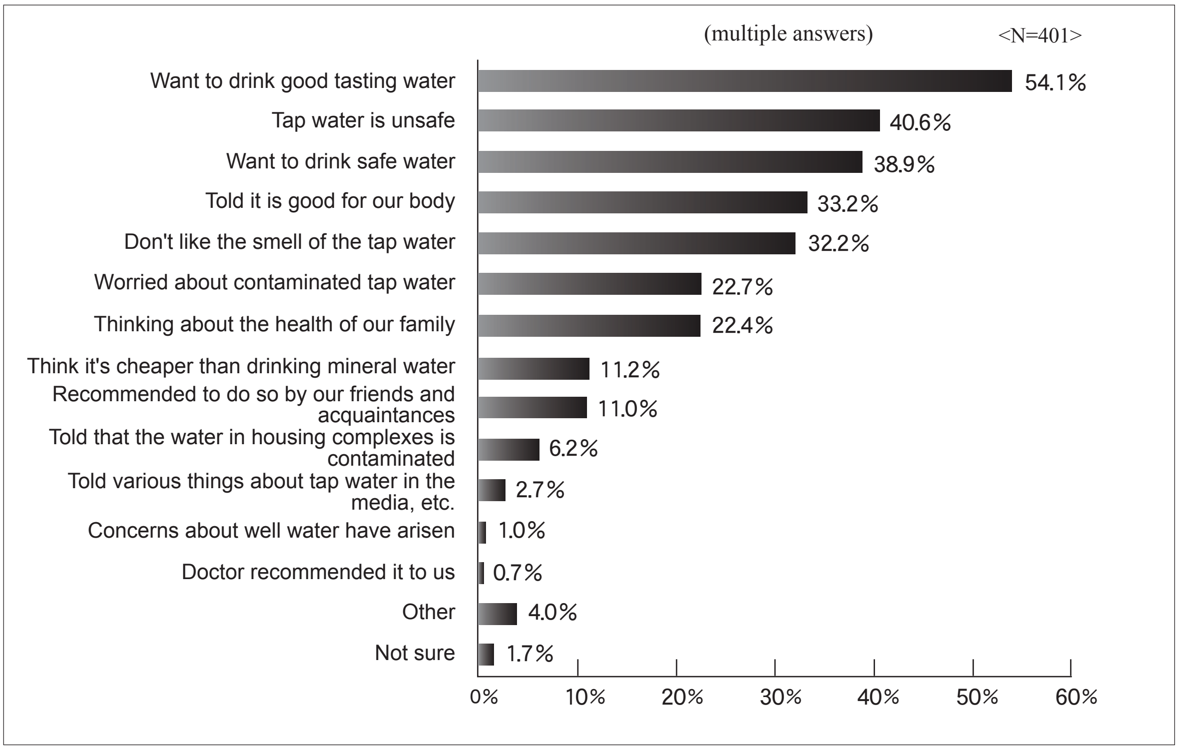


Figure 5 : Reasons for installing water purifiers

Source: Reference [10]

was also considered to be of importance. A large number of households installed water purifiers because they were more concerned about corroded pipes and contaminated storage tanks through which the water passes than about the actual quality of water supplied as tap water. Figure 6 shows the result of an opinion poll of the tap water supplied by the Bureau of Waterworks, Tokyo Metropolitan Government.[11] These results suggest that there is a considerable sense of distrust regarding the quality of tap water.

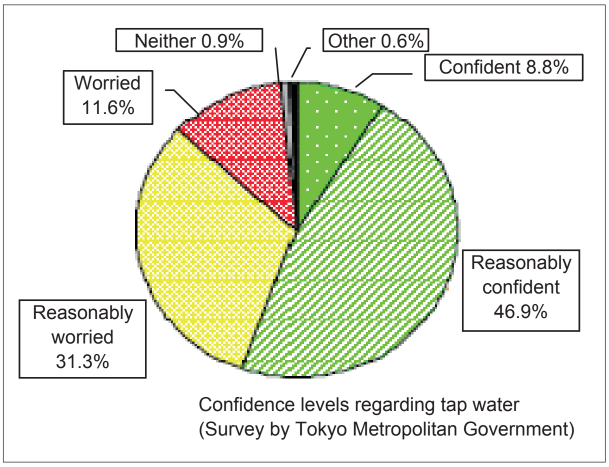


Figure 6 : Confidence levels regarding tap water

Source: Reference [11]

3-2 Current situation of tap water

As Figure 7 shows, Japan's water supply system covers 97.2% of the country. Since the number of patients suffering waterborne diseases is nil, almost all residents are supplied with safe drinking water. Furthermore, the water quality standard conformance over the last few years has been 99.9% or higher.[12,13] However, the water management infrastructure includes a large number of vulnerable small and medium-scale water service operators.

The water quality of tap water is regulated by the "Ministerial Ordinance Concerning the Standard for Water Quality" (Ministerial Ordinance of Ministry of Health, Labour and Welfare, No. 101,

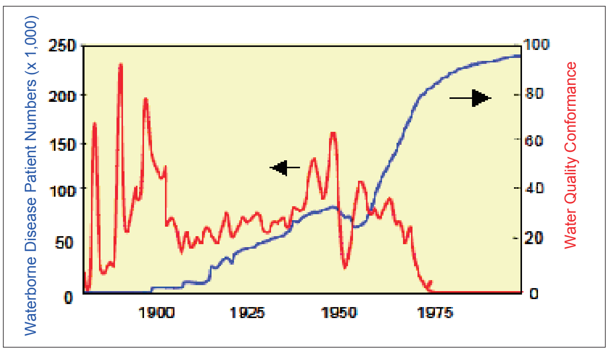
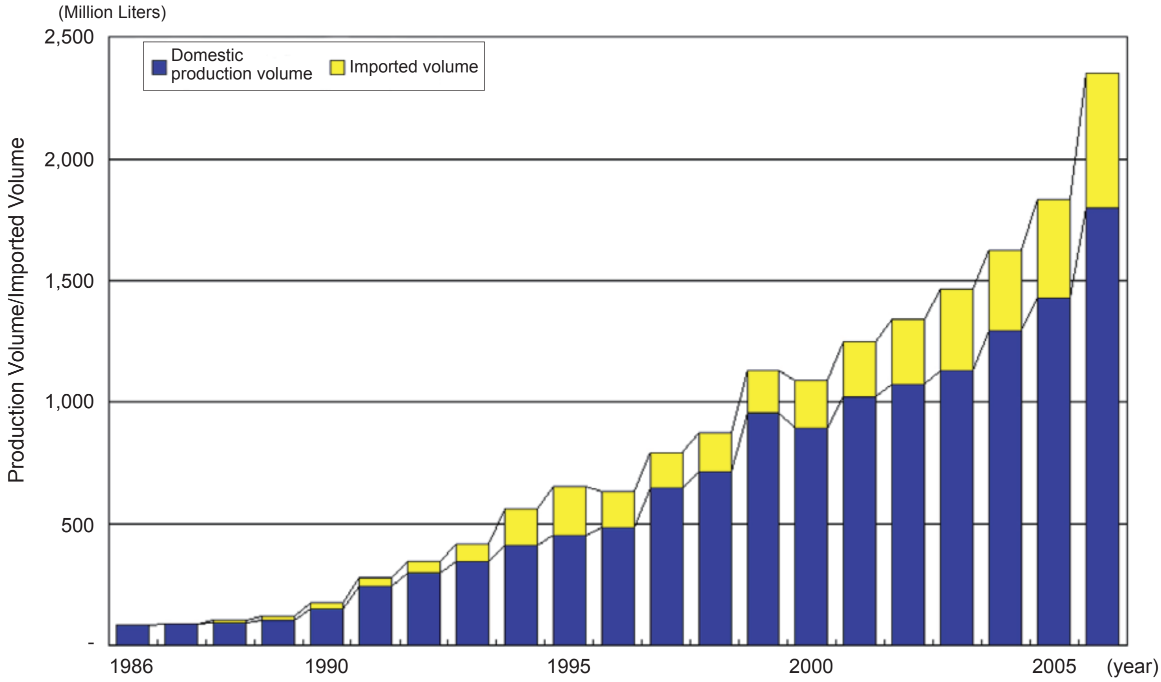


Figure 7 : Transitions of water supply system coverage (right axis) and waterborne disease patient numbers (left axis) in Japan

Source: Reference [12]



Note: Orepared by the Water Resources Department, Ministry of Land, Infrastructure and Transport based on data from The Mineral Water Association of Japan

Figure 8 : Transition in mineral water production and imported amounts

Source: Reference [18]

May 30, 2003) based on the Waterworks Law. The inspection data (maximum value, minimum value, average value, and inspection frequency) for the water purification plants of the water service operators and water providers are tabulated separately for raw water and purified water and the quality of water is controlled by each operator.[14] There are currently 50 inspection items [15] such as common bacteria, coliform bacteria, heavy metals, and organic materials such as benzene, etc., and also pH, color, and turbidity. However, in light of recent knowledge, these are considered to need revising, and therefore the gathering of necessary information and successive investigations are already underway.[16] While the cost of tap water varies from region to region, the national average cost per cubic meter is approximately 170 JPY. Although water contained in a 1.5 liter bottle costs approximately 200 JPY, costing 500 to 1000 times more than tap water, the consumption of bottled water is on the increase as Figure 8 shows.[18]

3-3 Current situation of bottled water

The water (raw water) used as the raw material of mineral waters must be suitable for drinking and also conform to the criteria regulated by the Waterworks Law or the Food Sanitation Law. Since bottled water is in a form that is subject to the Food Sanitation Law and not the Waterworks Law, it comes under the soft drinks category and, therefore, the manufacturing criteria and component standards are set by the Ministry of Health, Labour and Welfare. In Food Sanitation Law, mineral waters are described as a “soft drink of which the raw material is water only”, and include plain mineral water and waters into which carbon dioxide is injected and/or calcium added. The quality of mineral waters is controlled by the “Standard for Food and Additives” based on Article 11 of the Food Sanitation Law. The number of controlled inspection items for raw water used in the manufacturing of bottled water is 18 items, which include common bacteria, lead, cadmium, and arsenic, etc. In addition, the bottled water manufactured using raw water other than tap water must satisfy the component standards criteria such as turbidity, sediments, arsenic, lead, cadmium, tin, coliform group bacteria, gram-positive micrococcus, and pseudomonas aeruginosa, etc.[19, 20] But, there is still a significant difference by comparison to the 50 items that are applicable to tap water regulated by the Waterworks Law. Table 1 shows a comparison of each item. It is plainly evident that quality of tap water is far more strictly controlled.

Table 1 : Comparison of the quality inspection items for tap water and bottled water

Item	Tap Water	Bottled Water
Common bacteria	Number of colonies formed in 1ml of test water: 100 or less	Number of colonies formed in 1ml of test water: 100 or less
Coliform bacteria	Shall not be detected	Shall not be detected
Cadmium or its compounds	Amount of cadmium: 0.01mg/l or less	<=0.01mg/l
Mercury or its compounds	Amount of mercury: 0.0005mg/l or less	<=0.0005mg/l
Selenium or its compounds	Amount of selenium: 0.01mg/l or less	<=0.01mg/l
Lead or its compounds	Amount of lead: 0.01mg/l or less	<=0.05mg/l
Arsenic or its compounds	Amount of arsenic: 0.01mg/l or less	<=0.05mg/l
Hexavalent chromium compounds	Amount of hexavalent chromium: 0.05mg/l or	<=0.05mg/l
Cyanide ions and cyanogen chloride	Amount of cyanide: 0.01mg/l or less	<=0.01mg/l
Nitrate nitrite nitrogen	10mg/l or less	<=10mg/l
Fluorine or its compounds	Amount of fluorine: 0.8mg/l or less	<=2mg/l
Boron or its compounds	Amount of boron: 1.0mg/l or less	Boron: 30mg or less
Carbon tetrachloride	0.002mg/l or less	-
1, 4-Dioxin	0.05mg/l or less	-
1, 1-Dichloroethylene	0.02mg/l or less	-
Cis-1, 2-Dichloroethylene	0.04mg/l or less	-
Dichloromethane	0.02mg/l or less	-
Tetrachloroethylene	0.01mg/l or less	-
Trichloroethylene	0.03mg/l or less	-
Benzene	0.01mg/l or less	-
Monochloroacetic acid	0.02mg/l or less	-
Chloroform	0.06mg/l or less	-
Dichloroacetic acid	0.04mg/l or less	-
Dibromochloromethane	0.1mg/l or less	-
Bromic acid	0.01mg/l or less	-
Total trichloromethane (sum aggregate of chloroform, dibromochloromethane,	0.1mg/l or less	-
Trichloroacetic acid	0.2mg/l or less	-
Bromodichloromethane	0.03mg/l or less	-
Bromoform	0.09mg/l or less	-
Formaldehyde	0.08mg/l or less	-
Zinc and its compounds	Amount of zinc: 1.0mg/l or less	<=5mg/l
Aluminum and its compounds	Amount of aluminum: 0.2mg/l or less	-
Iron and its compounds	Amount of iron: 0.3mg/l or less	-
Copper or its compounds	Amount of copper: 1.0mg/l or less	<=1.0mg/l
Sodium or its compounds	Amount of sodium: 200mg/l or less	-
Manganese or its compounds	Amount of manganese: 0.05mg/l or less	<=2mg/l
Chloride ions	200mg/l or less	-
Hardness (calcium, magnesium, etc.)	300mg/l or less	-
Total dissolved solids	500mg/l or less	-
Anionic surfactants	0.2mg/l or less	-
(4S,4aS,8aR) octahydro-4,8a-dimethylnapthalene-4a(2H)-ol (or	0.00001mg/l or less	-
1.2.7.7-tetramethylbicyclo [2.2.1] hepthane-2-ol (or 2-methylisoborneol)	0.00001mg/l or less	-
Cationic surfactants	0.02mg/l or less	-
Phenols	Converted amount of phenol: 0.005mg/l or less	-
Organics (amount of Total Organic Carbon (TOC))	5mg/l or less	<=12mg/l
pH	5.8 - 8.6 or less	-
Taste	There shall be no abnormality.	-
Odor	There shall be no abnormality.	-
Chromacity	5 degrees or less	-
Turbidity	2 degrees or less	-
Barium	-	1mg or less
Sulfide	-	0.05mg

Prepared by the STFC based on References [19, 20]

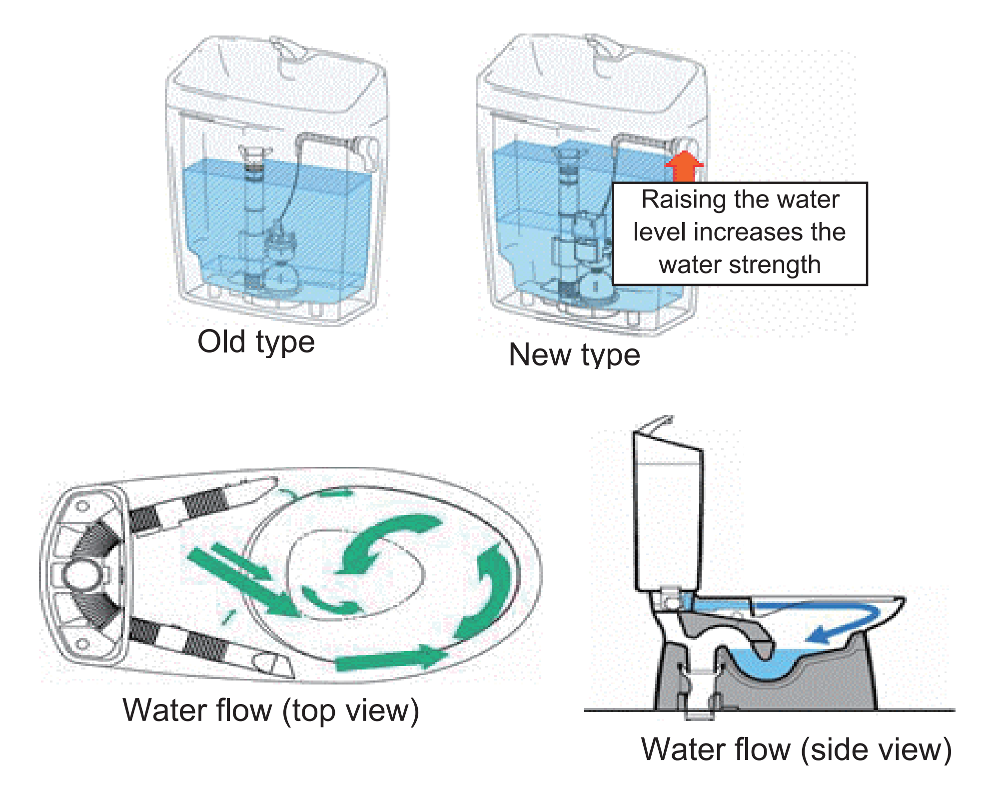


Figure 9 : Toilet flushing systems (old and new designs)

Source: Reference [21]

4 Water technologies

4-1 Water-saving technologies

Amid the global heightening of environmental awareness, while presently every conceivable industry and every conceivable product is compelled to be environmentally friendly, the water-saving technologies available for general households are also progressing.

For example, ordinary toilet cleaning is achieved by flushing water that enters either directly from the water mains or from a storage tank. Due to recent technological developments, by effectively combining these two water flow systems, it is now possible to flush the toilet by using a much smaller volume of water. Many overseas toilets require approximately 13 liters, whereas products by Japanese manufactures require only 5.5 liters of water per large flush and 4.5 liters per small flush. This can be achieved by the results of research into water flows or, in other words, basic fluid dynamics as shown in Figure 9. Compared to earlier toilets, the amount of cleaning water is more than halved to approximately 40%. This indicates a water saving efficiency equivalent to one bathtub of water (calculated to be 180 liters when full) over two days, which amounts to an annual saving of approximately 12,000 JPY. In addition, this also enables a CO_2 reduction of approximately 27 kg per year,[*1] which also contributes to preventing global warming. On the other hand, technology is also being developed that makes it possible to reduce the amount of water used in heated bidet toilet seats to approximately half the amount formerly used by pulse-jetting the water at 70 cycles per second.[21]

4-2 Water circulation by reclaimed wastewater system

Reclaimed wastewater system refers to system that processes rain water and drain water and then reuses it as reclaimed wastewater. There are standalone circulatory systems, regional circulatory systems, and wide area circulatory systems. Biodegradation, membrane filtration, and

*1
This value is calculated based on the fact that 0.59 kg of CO_2 is released per cubic meter in processing sewage water or purifying river water.

Table 2 : Examples of utilizing heat from water by using heat pumps

Description	Water Source	Utilizing Facility and Application	Volume of Water Used (m^3/day)
Tokyo Nakano treatment plant	Treated sewage water	Air conditioning of administration building (5,600m^2)	Approx. 3,000
Tokyo Yushima pumping station	Untreated water	Air conditioning of office building (490m^2)	Approx. 2,000
Tokyo Ariake treatment plant	Treated sewage water	Air conditioning of administration building (4,419m^2)	Approx. 1,500
Yamagata prefecture, Mogami-machi town office	Groundwater	Heating, supplying hot water to 5 town office facilities (10,604m^2)	Approx. 2,300
Tokyo Hakozaki district	River water	Regional air conditioning, supplying hot water to business premises, other (22.7ha)	Approx. 34,700
Tokyo Koraku, 1-chome district	Untreated water	Regional air conditioning of business premises, other (21.6ha)	Approx. 130,000

Source: Reference [23]

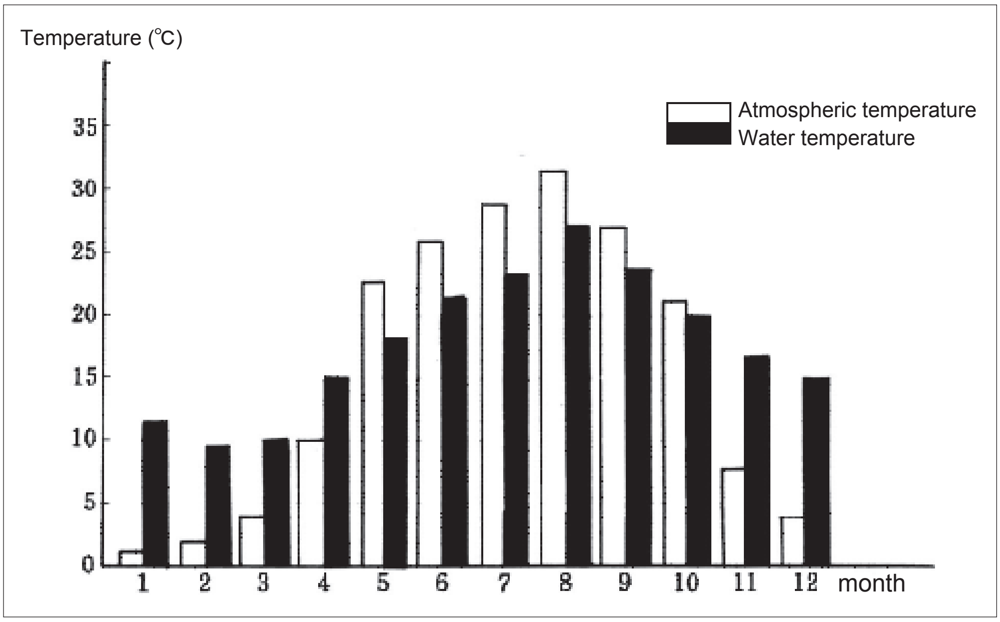


Figure 10 : Comparison of water temperature and atmospheric temperature

Source: Reference [23]

a combination of these are used for the treatment methods. Applications of reclaimed wastewater include, depending on the water quality, toilet flushing, watering, cooling tower supply, fire extinguishing, and vehicle washing, etc. Introduction of these reclaimed wastewater systems is an effective way to save water, alleviate water shortages, reduce the load on sewage systems, and save money.[22]

4-3 Water thermal energy utilization technologies

During recent years, due to the popularization of heat utilization instruments such as heat pumps, etc., it is possible to utilize the thermal energy of water that exists in large volumes in low-temperature heat sources such as river water, etc. Table 2 shows examples utilizing water thermal energy similar to ground thermals. For example, heated or cold water from effluents, or water from hot springs is used either directly or by heat pipes for cooling and heating and melting snow, etc. In addition, groundwater and treated sewage water is also utilized for cooling and heating and for supplying areas with hot water, etc. by using heat pumps which transfer heat from low temperature heat source to high temperature medium. Compared to the atmospheric temperature, the temperature of a large volume of water is higher in winter and cooler in summer, and during the course of the year, the temperature is comparatively stable. So it can be utilized as an effective heat source. For example, as shown in Figure 10, by using the waters as a heat source, an energy saving of approximately 20% is foreseeable compared to using the air in the center of Tokyo. There are also other examples of injecting surfactants into circulatory water used in heaters to reduce the energy consumed by the pump's power source by 65%.

By introducing this technology in buildings, hotels, and hospitals, etc., throughout Japan, assuming that overall energy consumption is 2.6 million kWh per year, a reduction of 4.55 million tons of CO_2 per year is possible. By applying these kinds of technologies in the majority of buildings, there is potential for a further effective energy savings.[23]

The use of water thermal energy makes practical use of a clean unused source of energy, which is also effective in preventing global warming. However, in order to use this type of thermal energy source, it must be utilized appropriately by considering the impact on the environment by returning low temperature water back into effluents or underground and potential obstructions such as land subsidence associated with using groundwater. In addition, the amount of thermal energy stored in each water source and the economic efficiencies are also to be investigated. In fact, because ground subsidence in metropolitan areas used to be a serious issue, measures such as the groundwater extraction regulations were adopted to prevent the dropping of groundwater levels. Presently, the groundwater levels have recovered and the water levels are rising. However, certain cases where new detrimental and adverse impacts on subterranean structures and groundwater environment taking place are becoming apparent.[24]

5 Areas of future advancement

5-1 Global distribution of Japanese technology

Throughout the world, the amount of water resources per person differs greatly from country to country, as shown in Figure 11. By comparison to Canada, which has the most amount of water per person, Japan has a meager 4% of that amount.[25] As the world's population is increasing, it is vital to secure food resources and the amount of water used for daily living is expected to increase. In China, in particular, where not only there is an increase in industrial water usage, but with the approaching Beijing Olympic Games, there is also a huge problem concerning the quality of water. In order to deal with these types of problems, it would be desirable to popularize Japan's sophisticated water treatment technologies, general household water-saving technologies, and reclaimed wastewater utilization systems around the world.

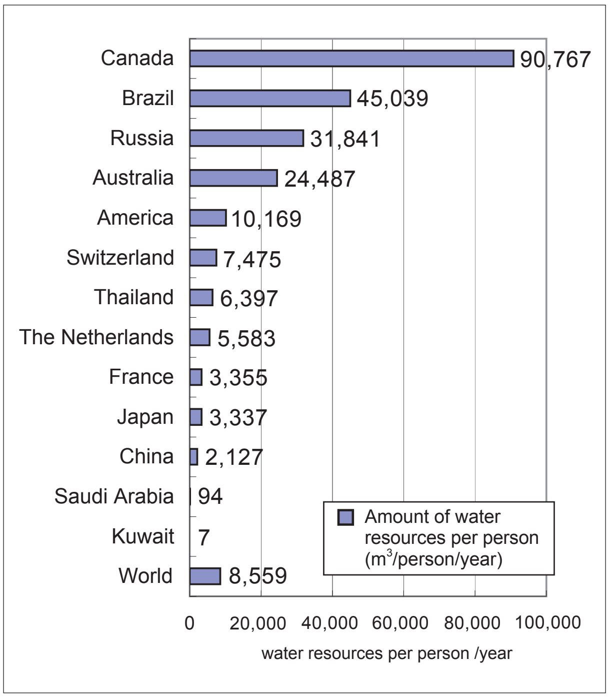


Figure 11 : Amount of Water Resources per Person/Year for each country

Prepared by STFC based on Reference[25]

In Okinawa, the island is not blessed with water resources from the natural environment, and water shortages have led to enforced supply restrictions each year. Therefore a number of water resource developments are underway centering on multipurpose dam developments. Since 1996, the resultant effect of these ongoing water resource developments and the completion of seawater desalination plants have stabilized the situation, thereby mitigating the need to impose supply restrictions. Also, the effective utilization of waste reverse osmosis membranes in seawater desalination plants, byproducts of hardness reduction processes, and granular activated carbon used in high purification processes, in addition to actions such as the introduction of small-scale hydroelectric power plants, etc., serve as a reference for regions that have limited water natural resources.[26]

5-2 Improving water recycling efficiency

It is possible to enhance the recycling ratio of water from current level by, for example, the reuse of rainwater in everyday life and recycling bathtub water, etc.. Presently, many older buildings are being rebuilt, and reclaimed wastewater utilization systems are being introduced in high-rise buildings. As indicated in Chapter 4, this system can be applied to many kinds of buildings, and improving the efficiency of water recycling is achievable by further popularizing this system in general households.

5-3 Raising public awareness

It is vital to raise the public awareness regarding tap water. In Tokyo, highly purified bottled tap water is sold under the brand of “Tokyo Water”.[27] For sometime now, the waterworks department has been manufacturing bottled water as stockpile provisions to be used in times of emergency; however, the bottled water manufactured by the waterworks department has been put on sale as a public relations exercise to raise awareness of its higher purity water. These sorts of activities are expected to contribute to change the perception of people who buy bottled water simply for peace of mind and to help popularize the notion that tap water is safe and reliable.

Due to climate change brought about by global warming, the fluctuation in the amount of rainfall increases and the impact on the balance of supply and demand is becoming more apparent. According to the No. 4 evaluation report released by the Intergovernmental Panel on Climate Change (IPCC) in 2007, the average global surface air temperature is anticipated to rise by a maximum of 6.4℃ at the end of the 21st century. In the first half of this century, it is anticipated that the annual average river flow rates and usable water volume will decrease by 10 to 30% in the mid-latitude areas.[25] In order to tackle these kinds of problems, it is important to recognize that this water issue is not merely a question of supply and demand, but it is also linked to numerous other environmental problems. In particular it is necessary to improve the image of tap water.

Acknowledgments

The author would like to take this opportunity to thank Mr. Sombou Yamamura, Manager of the Water Supply Division, Health Service Bureau, Ministry of Health, Labour and Welfare; Mr. Akira Nitta, Deputy Director, Acid Rain Research Center, Japan Environmental Sanitation Center; Professor Keisuke Taira, Department of Engineering, and Dr. Daisuke Kamiya, Department of Civil Engineering and Architecture of the University of the Ryukyus; Professor Taikan Oki, Institute of Industrial Science, University of Tokyo; Mr. Kazunari Yoshimura of Global Water Japan; and Dr. Norifumi Isu, Creative Technology laboratory, Technical Research Center, INAX Corporation for providing valuable discussion and information in the writing of this article.

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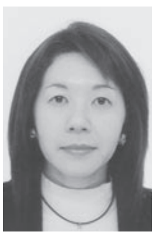

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(Original Japanese version: published in November 2007)

3

Waste Recycling Technologies Required by a Sound Material-Cycle Society

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1 Introduction

Realization of a recycling based society in harmony with the environment is stated as one key policy issue in Japan's Third Science and Technology Basic Plan. There is a close and inseparable relationship between the waste problem, which has attracted considerable interest in recent years, and a sound material-cycle society.

Accompanying the flow of material in diverse social activities and everyday life, large quantities of waste are generated. Efficient removal and treatment/disposal of this waste is an essential urban service in the modern age. With changing times, the main purpose of these activities has also changed to securing public sanitation, protecting the environment, and forming a recycling based society. From Japan's annual material balance (fiscal year 2004), it is estimated that approximately half of the country's material input, which exceed 1.9 billion tons, is accumulated as buildings and infrastructure facilities.[1] Buildings, urban structures, and the like, which form this type of stock, all eventually become waste.

Reducing the generation of waste, which is the first priority in the concept of the 3Rs (Reduce, Reuse, Recycle), is a response at the so-called upstream side of the material flow, and is the basis of waste countermeasures. On the other hand, on the downstream side, a response that satisfies both treatment of the wastes discharged each day in the course of everyday life and production activities and, simultaneously, recycling of materials and energy, is also important for the formation of a recycling society. Thus, an approach which involves both reducing the generation of wastes and, in parallel, reuse and recycling would appear to be realistic.

Furthermore, today, as global warming countermeasures are being accelerated in all fields, reduction of carbon dioxide (CO_2) emissions by actively utilizing biomass, etc. is an urgent matter. Because much of the biomass in Japan is waste-type biomass, efforts related to waste treatment are demanded. In addition, circulating use of resources also plays a major role in reducing consumption of virgin natural resources.

Based on the conditions outlined above, this paper describes directions for the development of waste treatment when given the mission of forming/realizing a sound material-cycle society, and considers waste recycling technologies for the near future and related problems by examining actual examples.

2 Trends in waste and waste treatment technologies

2-1 Quantitative and qualitative changes

(1) What is waste?

Waste can be defined as unnecessary substances or impurities. Concretely, however, it is a byproduct of industrial and agricultural products, and as such, is a material. The quantity and quality of waste change in response to the economic conditions of the times, human lifestyles, the introduction of new products, and similar factors. Figure 1 shows the changes in the amount of discharges of general waste (municipal solid waste: MSW) and industrial waste resulting from the totality of these factors. Quantitatively, MSW has shown little change since 1995, but has increased approximately 20% since 1975. The amount of waste discharged per person (unit discharge) was around 1,000g/person-day before 1985, then increased to around 1,100g/person-day after 1990, and has declined since 2001. (Between 1985 and 2000, the increase in waste discharged was greater than the increase in population.) Here, it should be noted that unit discharge includes commercial and general household waste; the unit waste discharged purely by households is roughly 700-800g/person-day. On the other hand, industrial waste increased substantially between 1985 and 1990, but showed no large changes thereafter. Currently, approximately a half of annual discharge amount of 400 million tons is utilized after recycling.

As one index expressing the qualitative features of waste, Figure 2 shows the trend in the heating value of waste (MSW). Although the heating value of waste shows different values depending on the local government treating the waste, it increases consistently over time. This seems to be attributable to increased use of paper, plastic materials in packaging, and similar factors.

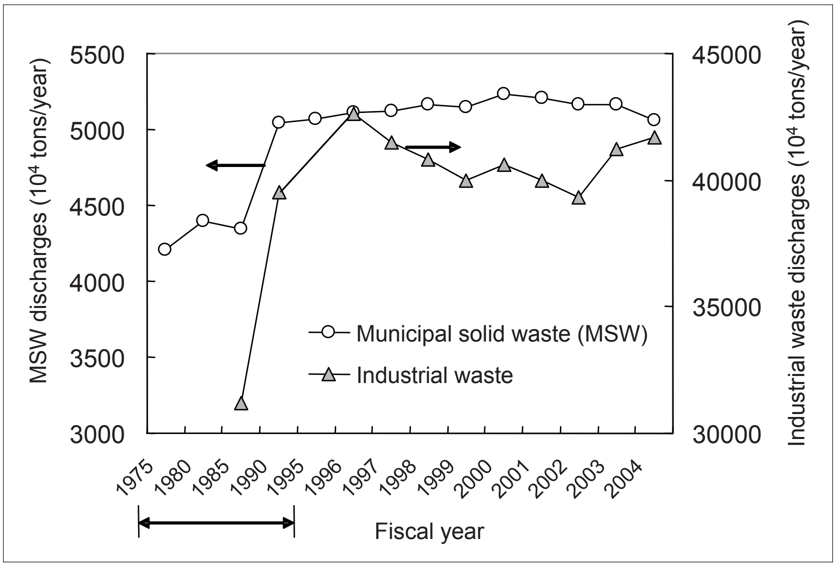


Figure 1 : Change over time in amounts of municipal solid waste (MSW) and industrial waste (Data for 1975-1995 are for 5 year intervals).

Prepared by the STFC based on Reference [1]

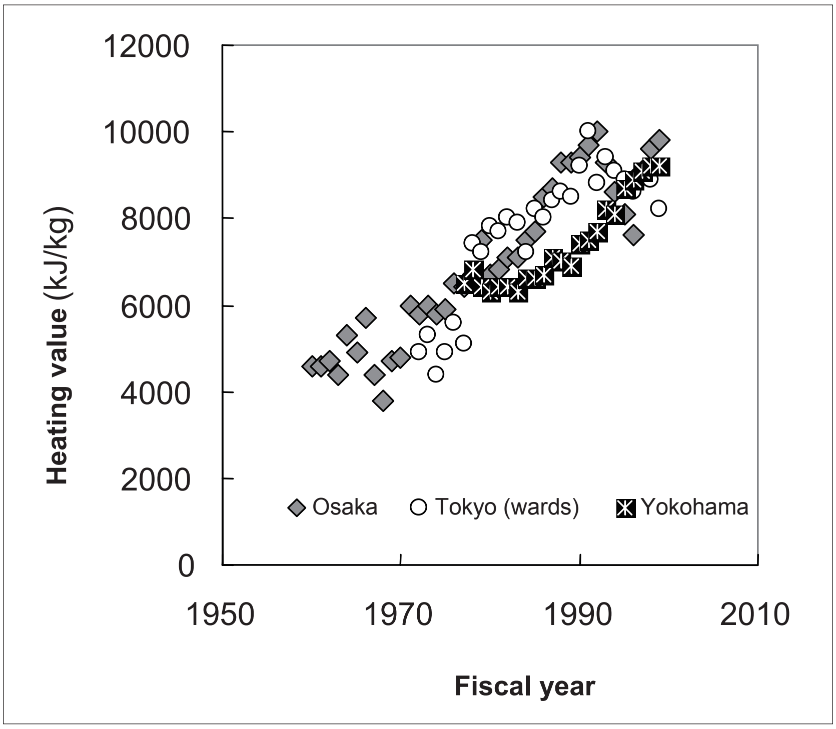


Figure 2 : Change over time in heating value of waste (lower heating value)

Prepared by the STFC based on Reference [2]

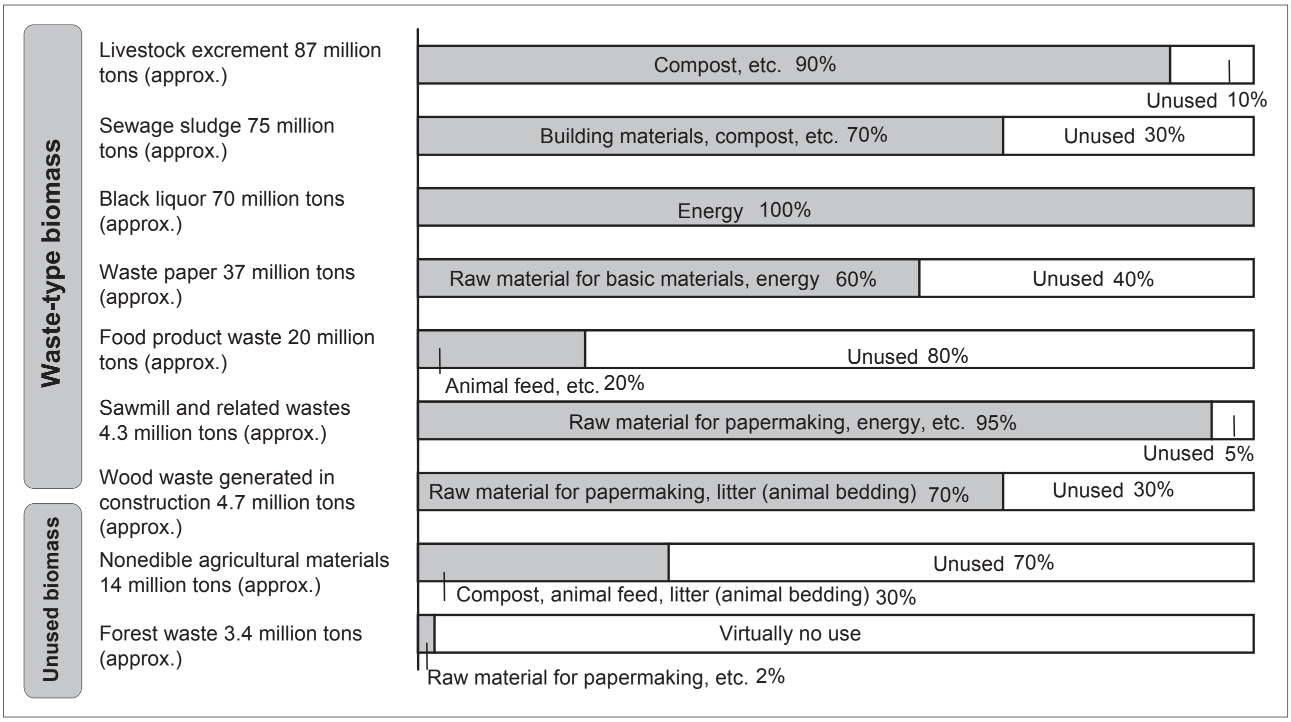


Figure 3 : Occurrence of biomass in Japan and breakdown of uses

Source: Reference [3]

(2) Biomass

Biomass is classified into three types: ① Waste-type biomass, ② unused biomass, and ③ dedicated biomass crops (crops grown specifically for use as biomass). At present, biomass occurrence quantity and its utilization (carbon equivalent) are put at 298 million tons of waste-type biomass, which has a utilization rate of 72%, and 17.4 million tons of unused biomass with 22% utilization.[3]

Figure 3 shows rough values of the occurrence and utilization of various types of biomass. Depending on the item, waste-type biomass may be either biomass in the form of industrial waste or biomass including both MSW and industrial waste. Of these, the items with direct potential for circulating use include food product waste, waste paper, and construction-generated waste wood, all of which have comparatively high unused ratios, and sawmill waste and other scrap wood, although the latter have relatively low unused ratios. Excluding livestock excrement, which has a high moisture content and tends to be produced in limited geographical areas, and sewage sludge, which also has a high moisture content (unused amount: 22.5 million tons), the amount of unused biomass for the four above-mentioned items exceeds 32.4 million tons. However, even though some kinds of waste-type biomass are currently used, effective and useful applications have not necessarily been developed. The annual occurrence of waste-type biomass is estimated at approximately 327 million tons on a wet-weight base and 76 million tons on a dry base. By energy conversion, this corresponds to approximately 1,270PJ (petajoule: 10^{15} Joule).[4] By crude oil conversion, this is equivalent to approximately 32.8 million kiloliters, or about 5.6% of Japan's total primary energy supply of 22,751PJ (FY 2005).

2-2 Transition of waste treatment technologies

(1) Transition of incineration treatment technologies

The direct purposes of incineration treatment are prevention of decay and stabilization by combustion treatment of waste at high temperature, and in combination with this, reduction of the weight and volume of the waste. Historically, however, the functions and roles widely required in incineration treatment have changed in response to the needs of the times, beginning with appropriate treatment for sanitation, followed by weight/volume reduction and reduction of environment impacts, and later by recycling. In recent years, the dioxin problem brought about a particularly large change. In line with the movement toward a sound

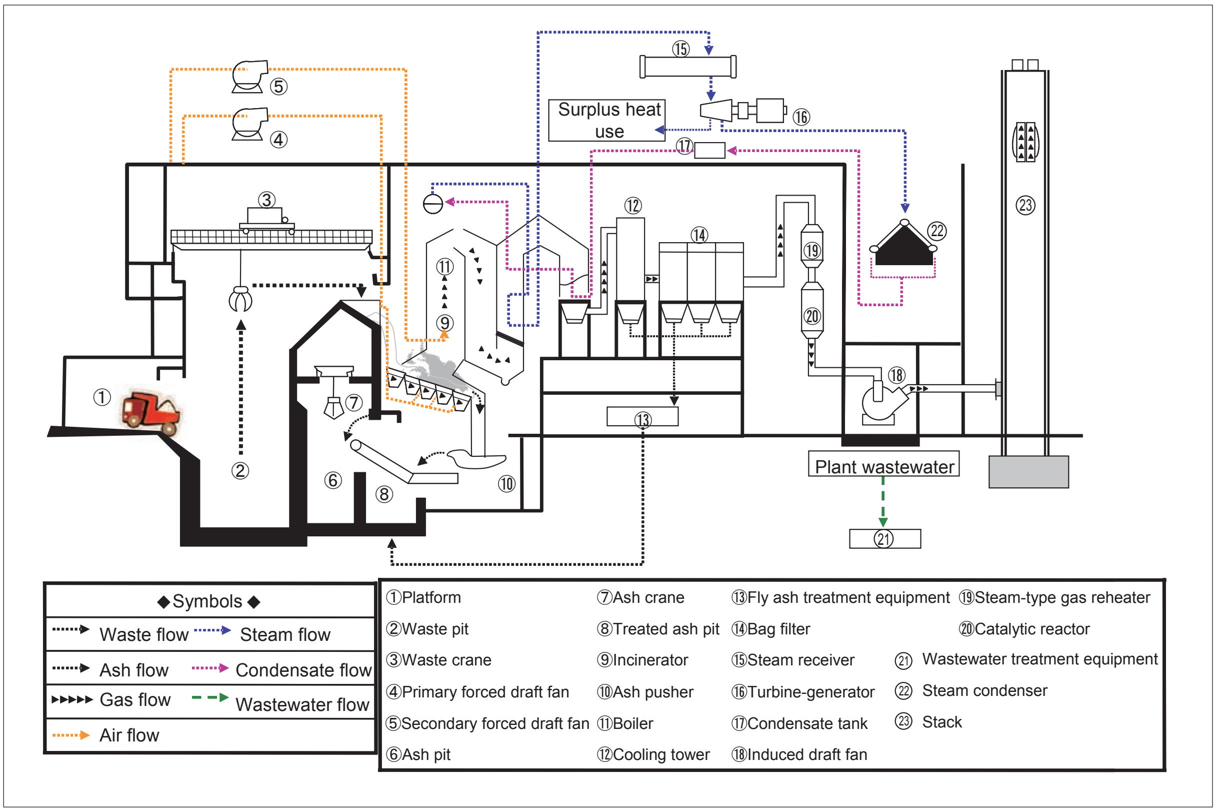


Figure 4 : Example of configuration of typical fully-continuous stoker-type incinerator

Source: Reference [5]

material-cycle society, heightened expectations were placed on resource recycling through the introduction of new methods such as the gasification and melting furnace and other technologies. The number of waste incineration facilities has gradually decreased, and was 1,320 as of the end of FY 2005 (March 31, 2006). This represented a decrease of 25% from FY 1998. However, this number is extremely large in comparison with other countries. In Japan, large-scale fully-continuous facilities like that in the example in Figure 4 account for 40% of the total number of incineration facilities and more than 80% of treatment capacity. This type of large-scale facility includes a diverse range of equipment in addition to the actual incineration furnace, such as flue gas and wastewater treatment equipment, residue (ash) handling equipment, and power generating equipment, and the number of units of equipment is larger in these facilities. Technically, complete implementation of the 3Ts of Temperature, Time (residence time), and Turbulence (adequate mixing and stirring) is promoted by a variety of technical innovations, including improvement of the secondary combustion air injection method, advanced control using artificial intelligence, etc.

Incineration is extremely effective for the purpose of treating waste. However, it is also necessary to treat the incineration ash and fly ash generated in the incineration process. These substances are equivalent to approximately 10% and 3% of the incinerated waste, respectively. In case of landfill disposal of these substances, securing landfills and chemical treatment to prevent leaching of harmful substances contained in fly ash become problems. Other issues include improving the recovery efficiency of metals, improving power generating efficiency, which is generally low at present, etc.

(2) Influence of the dioxin problem

The dioxins include the 4-8 chlorides of the polychlorinated dibenzoparadioxins (PCDDs), the 4-8 chlorides of the polychlorinated dibenzofurans (PCDFs), and among the polychlorinated biphenyl (PCBs), dioxin-like PCB, which has properties similar to the PCDDs and PCDFs. These substances are environmental pollutants having the following features: In general, these substances are characterized by long-term persistence, high accumulation, and various types of toxicity. While they have diverse environmental effects in extremely low concentrations, reliable

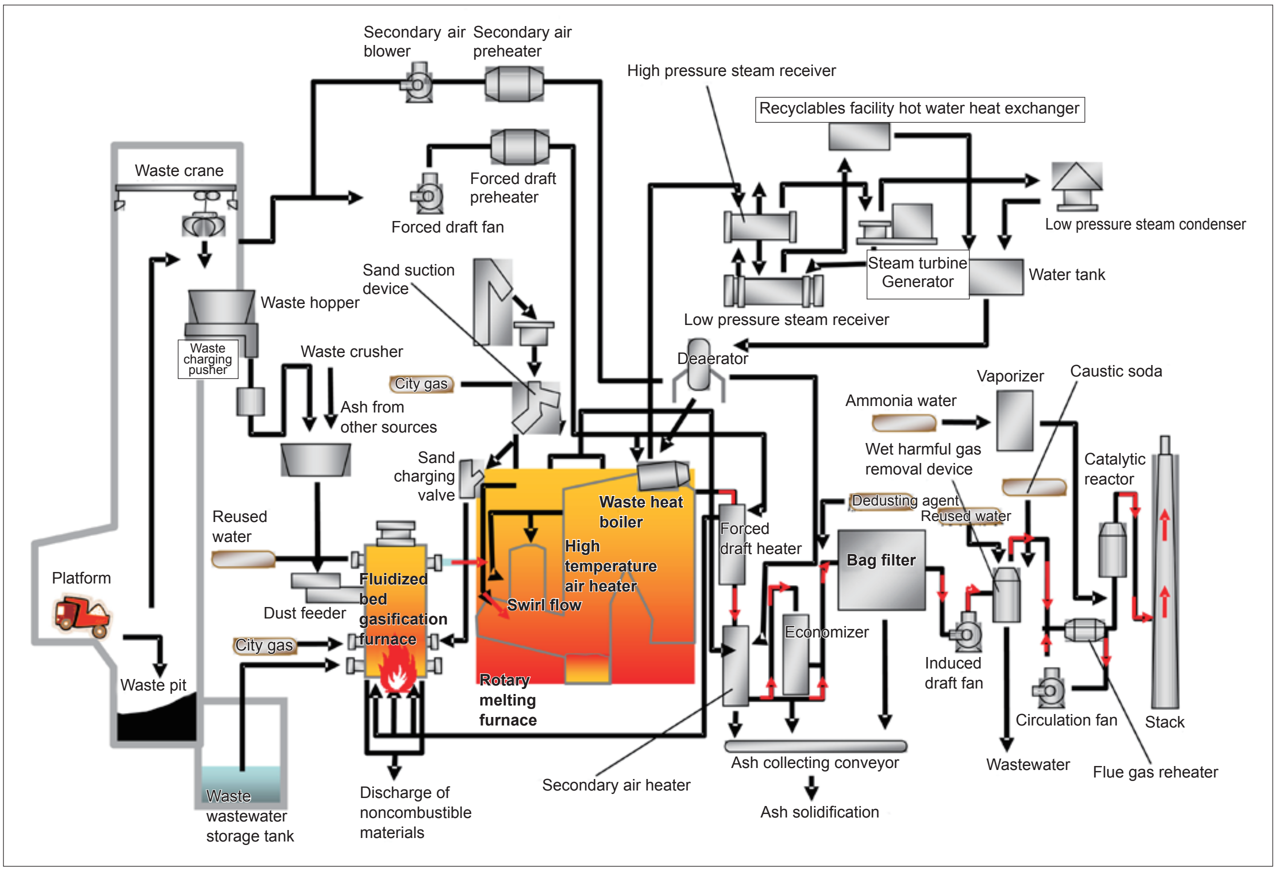


Figure 5 : Example of typical gasification and melting plant (In case of fluidized bed gasification type)

Source: Reference [5]

prediction is difficult. Because dioxins were discharged unintentionally from routine waste treatment processes, including also discharges accompanying the use of agricultural chemicals in the past, the pattern of penetration into the environment was different from that of conventional industrial pollution. The dioxins became an extremely large problem in Japan from around the mid-1990s. Subsequently, this had a direct effect on improvement of the element technologies of incineration treatment processes, including improvements in technologies, such as improvement of combustibility and higher efficiency in power generation, improvement in flue gas treatment technologies, such as changing dust collecting equipment to the bag filter, and others. This problem gave impetus to the implementation of regional waste treatment in an effort to reduce dioxins and recycle resources by regional collection and treatment of general waste in areas spanning several municipal units (cities, towns, and villages), and also led to a review of the conventional easy dependence on incineration and encouraged efforts to create a recycling society. The following section will describe gasification and melting technology, which had a large influence.

(3) Melting treatment and the gasification and melting furnace

The aforementioned dioxin problem encouraged the development and introduction of gasification and melting furnaces (Figure 5) advanced. The features of this technology are as follows:

① Dioxins can be reduced by high temperature combustion at 1,300-1,400°C in the melting process, and as a result, discharges can be minimized.

② Because a reducing atmosphere is used in the gasification process, recovery and effective utilization of the metal content in the waste is possible.

③ Because the excess air ratio is low, the amount of flue gas is reduced. (The “excess air ratio” is the ratio of the actual amount of air to that theoretically necessary for combustion). As a result, compact flue gas treatment equipment and other auxiliary equipment can be used, and power generating efficiency is improved.

④ If the heat contained in the waste is adequate, melting can be performed using the heat of the material being treated alone, thereby eliminating the need for supplementary energy inputs from external sources. In addition, the costs of construction and maintenance control are lower than with a combination of a general stoker furnace and ash melting furnace.

The process referred to as melting in gasification and melting is one that causes perfect combustion at high temperature. Gasification and reforming is a more advanced process, in which the composition of the gas is reformed by controlling the atmosphere, etc. under high temperature in a similar manner, producing a gas, such as carbon monoxide or hydrogen, which has use value as an energy source or feedstock for chemical synthesis processes. Gasification and reforming is a stage of technology that has been applied to waste incineration facilities in a small number of cases.

2-3 Transition to a sound material-cycle society and the flow of technology

(1) Formation of a sound material-cycle society

Conventional waste treatment was performed so as to avoid environmental impacts, but was limited to a one-way type of treatment and disposal. However, in recent years, there has been a common recognition in society that reducing CO_2 emissions as a global warming countermeasure and recycling use of materials and energy are important issues. This thinking has revolutionized the conventional concept of waste treatment. As a result, improvements have been made to actively promote recycling and recovery of energy and resources in incineration treatment itself, as described in section 2-2.

On the other hand, in countermeasures for harmful substances contained in waste, technical progress has been achieved from the viewpoint of reducing the spread and the risks of chemical substance extending to the global scale, for example, in countermeasures based on the Stockholm Convention on Persistent Organic Pollutants (POPs), which took effect in May 2004. The treatment of PCB is a typical example of this. Similarly, the development and introduction of treatment/disposal technologies is also progressing. Examples include technologies for the mercury contained in batteries, fluorescent tubes, and other products, asbestos contained in many products, beginning with building materials, and infectious waste, among others.

From the viewpoint of contributing to the 3Rs, there are technologies which aim at reducing waste by improving efficiency in the use of raw materials, etc. and extending the life of products, and technologies which aim at reuse, as seen in parts for copying machines. Where recycling is concerned, the development of design techniques which improve ease of disassembly during recycling and improve the potential for recycling of resources may be mentioned.

As a technology for recycling, in other words, recovery and use, various technologies have been developed for waste PET bottles and waste plastics, which are classified as container and packaging waste. The technologies that have been developed include material recycling, in which the waste plastic is processed again into molded products, "bottle-to-bottle" recycling, in which waste PET bottles are reused as raw material for new PET bottles, a method in which waste plastic is used as a reducing agent in the blast furnace, and a method in which waste plastic is thermally decomposed in the coke oven, producing oil and coke oven gas for use as industrial raw materials.[1] Technologies related to these items are described in detail in the following Chapter 3. However, in recent years, the amount of waste exported to China and other countries has increased, as represented by PET bottles. Under these circumstances, there is concern not only that this trend will make it impossible to make full use of the excellent recycling technologies which Japan possesses, but also that the sound material-cycle society as a whole will suffer.

Three general indexes may be mentioned in connection with the aims in constructing sound material-cycle society systems. These are resource productivity (= GDP/Inputs of natural resources, etc.), the circulating use ratio (= Circulating use / (Circulating use + Inputs of natural resources, etc.)), and final disposal (amount of final disposal in landfills). The targets up to the FY 2010 are to increase resource productivity to approximately ¥390,000/ton, improve the circulating use ratio to approximately 14%, and reduced landfill disposal to approximately 28 million tons.[1] The following may be mentioned as conditions required in waste recycling technologies for the formation of a sound material-cycle society: The technology in question must ① reliably accomplish appropriate treatment of waste (effectiveness and practicality of treatment), ② be capable of efficiently producing an energy source or material as a recycled product (effectiveness and practicality of recycling process), ③ have appropriate cost and energy consumption for recycling (economy), ④ be capable of minimizing environmental loads (low environmental load), and ⑤ produce a recycled product that can be effectively utilized (utility of the recycled product). Although concrete indexing should be carried out prudently, it can be thought that an easily understood evaluation of technologies will be required.

(2) Technologies using biomass

In Japan, the Biomass Japan Comprehensive Strategy was adopted by a resolution of the Cabinet in December 2002. Internationally, the Kyoto Protocol has come into effect, making implementation of effective global warming countermeasures extremely urgent, while the rapidly rising price of crude oil has led to a deeper recognition of the necessity of reducing dependence on fossil resources. These various factors have heightened interest in biomass energy. In March 2006, the Biomass Japan Strategy was revised.[6]

In the revised Strategy, concrete targets for the realization of “Biomass Japan” are arranged from the technical, regional, and national viewpoints. From the technical viewpoint, the revised strategy sets targets in connection with conversion efficiency or raw material price for direct combustion and gasification plants as technologies for converting low-moisture biomass to energy, for methane fermentation and other technologies as technologies for converting high-moisture biomass to energy, and for the production of biomass-derived plastics as technologies for converting biomass to products.

Based on this, the Ministry of the Environment has made technologies in connection with bioethanol and biodiesel an object of priority technical development. The Strategic Technology Roadmap 2007 (STR) published by the Ministry of Economy, Trade and Industry (METI) includes a roadmap for the 3Rs field. Biomass-related technologies are shown under “Other main 3R technologies” other than metal resource 3Rs, as shown in Figure 6.

According to Figure 6, the main development targets for biomass utilization are fermentation technology applying the function of microorganisms, fuel conversion technology based on thermochemical principles, and higher efficiency in existing power generation. In biomass recycling technologies, the key issues are considered to be improvement of methane and ethanol fermentation technologies, development of hydrogen fermentation technology, high efficiency gasification, conversion to liquid fuels, and the like. In the following chapter, these items will be examined concretely.

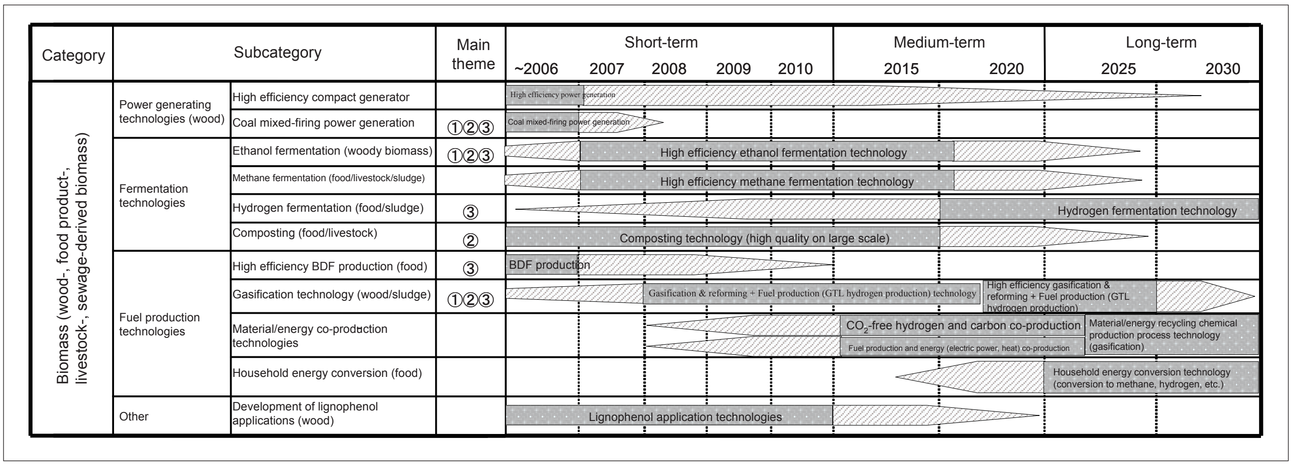


Figure 6 : Strategic Roadmap of individual biogas technologies prepared by METI

Source: Reference [7]

Table 1 : Comparison of waste recycling technologies

Evaluation item	Technologies using microorganisms	Gasification technologies	High temperature/high pressure fluid technologies
Main object substance	· Wet biomass, mainly foods: 20 million tons/year (approx.)	· Dry biomass, mainly wood, paper, etc.: 16 million tons/year (approx.) (general waste: 50 million tons)	· Food, animal residue, and other wet-type wastes. Application to wood-derived biomass is also studied. Applicability to toxic wastes is a feature.
Recycled product	· Biogas, mainly methane · Hydrogen · Biomass plastics	· Hydrogen, CO · Methanol · Liquid fuels	· Intermediates such as raw material for methane fermentation, etc., chemicals.
Technical principle and evaluation of system	· Hydrogen fermentation, methane fermentation, ethanol fermentation, lactic acid fermentation by biological systems · Systemization of gasification and incineration	· Pyrolysis, gas reforming (from high temperature to low temperature) · Systemization using gas engine generator, fuel cell, etc. ·Systemization with ethanol production and liquid fuel production	· High speed, high efficiency reaction with special fluid. · Systemization with methane fermentation, gas reforming, etc.
Cost	· Same as conventional technology; however, advantageous if effective utilization of recovered energy is possible.	· Low temperature processes are advantageous because energy requirements are reduced. · Possible to reduce total cost by using pyrolysis char as heat source.	· Use of subcritical water is more advantageous than supercritical because required heat and energy for pressurization are lower.
Outlook for practical application and problems	· Some facilities. Because sorting is not easy, expansion to MSW treatment facilities is a problem. · Reduction of price of plastic products	· High temperature facilities exist. However, low temperature processes and systemization with liquid fuel are future developments.	· Some facilities. Problems include resistance of materials to high pressure, corrosive environment.

Prepared by the STFC.

3 Waste recycling technologies required by a sound material-cycle society

3-1 Outline and comparison of technologies

Table 1 presents an outline and comparison of the waste recycling technologies which provide the conditions desired in a recycling based society and are considering promising for the future. The respective technologies will be described in the following sections.

3-2 Technologies utilizing biofunctions

(1) Biogasification

Food waste (garbage) and food product waste have become one focus as resources with comparatively low circulating use ratios. From the viewpoint of biomass-type circulating resources, food waste, wood chips, sludge, livestock excrement, etc. account for approximately half of the amount of waste generated. Because these substances have high contents of moisture and organic matter, their circulating use ratio is 16%, and the reduction ratio of weight by incineration and dewatering is limited to 53%. At present, many examples of circulating use are in the field of agriculture, where these substances are used as fertilizers and animal feed. However, there are questions about these methods of use whether they are optimal.

Given these circumstances, methods of biogasification of food waste and waste paper by methane fermentation and recovery of methane gas are under study. Methane fermentation of thick organic waste, sewage sludge slurry, and similar wastes is a technology with a long history of use and does not involve any technical novelty. However, in application to solid wastes with relatively low moisture contents, various improvements will be necessary in the future.

In methane fermentation processes, liquid and solid residues are produced after the gas is recovered. For this reason, appropriate treatment/disposal of these substance considering the environment is desirable. The liquid residue is a highly concentrated waste liquid after fermentation, which is called digestion sludge. Because the reduction ratio of sewage sludge and similar wastes has an upper limit of 40-50% with the current technology, it is necessary to increase the decomposition ratio of the organic component and improve energy efficiency.[8] On the other hand, where the solid residue is concerned, reduction by incineration with other combustible wastes is one direction for improving efficiency. Figure 7 shows an example of an analysis of the energy recovery effect when biogasification and incineration

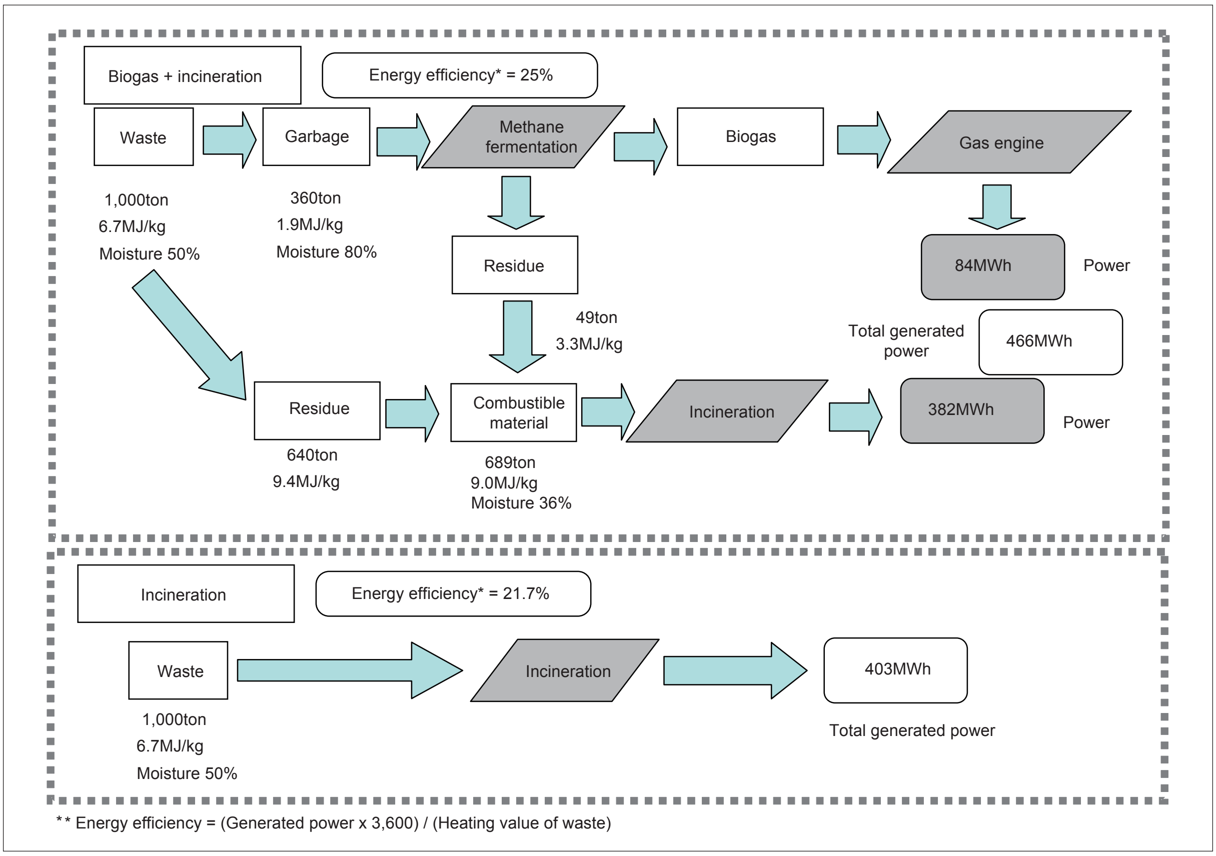


Figure 7 : Example of trial calculation of energy recovery effect by methane fermentation process

Source: Reference [9]

are combined. Because power generation using the heat of both the biogas and incineration can be performed using advanced, high efficiency equipment in this method, energy recovery can be performed effectively by a system simply combining power generation with incineration. Examples of introduction can already been seen in private-sector waste treatment facilities. In an example in which the energy balance was calculated for the case of incineration of 100% of waste and a case in which part of the food waste was sorted and used in methane fermentation under certain conditions (assuming that the biogas is used for power generation with a gas engine), it was estimated that the amount of generated power increases by approximately 16% in the case with partial gasification.

However, where incineration is concerned, it goes without saying that adequate countermeasures for air pollutants, beginning with dioxins, must be adopted.

(2) Hydrogen fermentation and ethanol fermentation

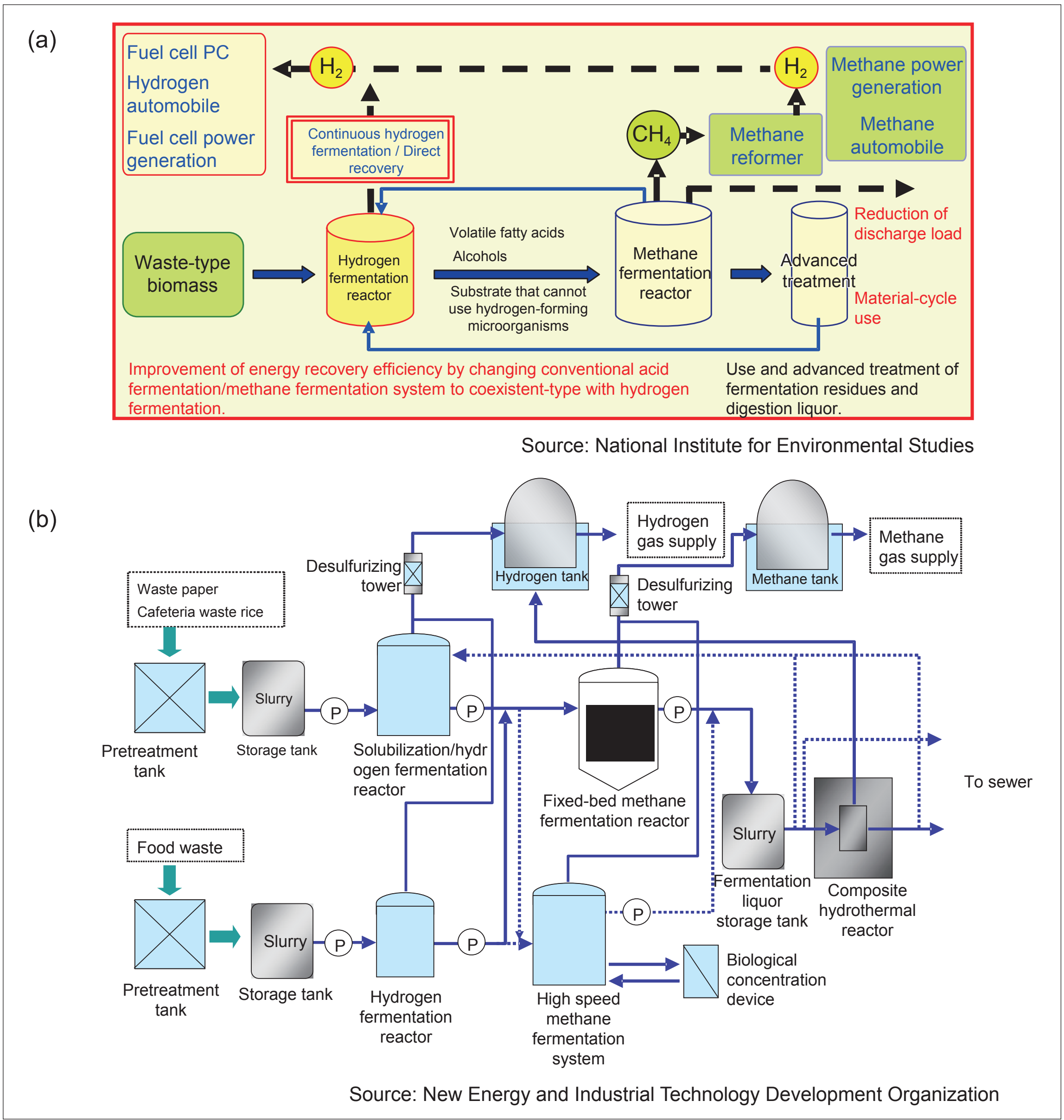
In the Strategic Technology Roadmap in Figure 6, development of hydrogen fermentation in fermentation technologies is predicted as a mid- to long-term technology. This appears to be based on the assumption of an emerging hydrogen society.

In processes in which organic compounds are subjected to methane fermentation under anaerobic conditions, hydrogen is generated in the acid fermentation stage. For example, in case glucose is used as the fermentation substrate, $C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 4H_2 + 2CO_2$. Representative bacteria which form hydrogen under anaerobic conditions include the Clostridium species, Enterrobacter species, and others.

Because hydrogen fermentation is normally a transition process, it is unstable. To obtain a stable recovery rate, it is necessary to provide environmental conditions for culture within the optimum range. Thus, the key to development aiming at improvement and practical application of hydrogen fermentation technologies is considered to be one of the following:

① Achievement of long-term sustained hydrogen recovery using mixed microorganisms by optimizing its environmental conditions.

② Isolation of a microorganism with a high



Source: National Institute for Environmental Studies

Source: New Energy and Industrial Technology Development Organization

Figure 8 : Examples of the development concept of hydrogen/methane 2-stage fermentation process

(a) Development concept proposed by NIES (b) System configuration proposed by NEDO

hydrogen fermentation capacity and effective utilization of its capacity.

Accordingly, research and development are being carried out in connection with fermentation technologies which promote hydrogen formation from mixed microorganisms with high efficiency and the related recovery processes, or the search for microorganisms with a high hydrogen-forming capacity. Examples of main large-scale research projects[10] include "Technical development of 2-stage fermentation technology for organic wastes centering on high efficiency hydrogen/methane fermentation" (FY 2001-2005), which was carried out by private-sector companies and the National Institute of Advanced Industrial Science and Technology (AIST), under the leadership of Japan's New Energy and Industrial Technology Development Organization (NEDO), the "Development of Kuzumaki Town advanced use cogeneration system," carried out under the leadership of Tohoku University, and the technical development project "Development of hydrogen production technology using bioresources/waste, etc." (FY 2003-2007) of the National Institute for Environmental Studies (NIES). In addition to these, there are also numerous examples of research on hydrogen-forming bacteria by other research institutes and private companies.[11,12] Figure 8 (a) and (b) show the development concept of the hydrogen/methane 2-stage fermentation process developed by NIES and the configuration of a system of 1/10-1/100 scale of actual size by

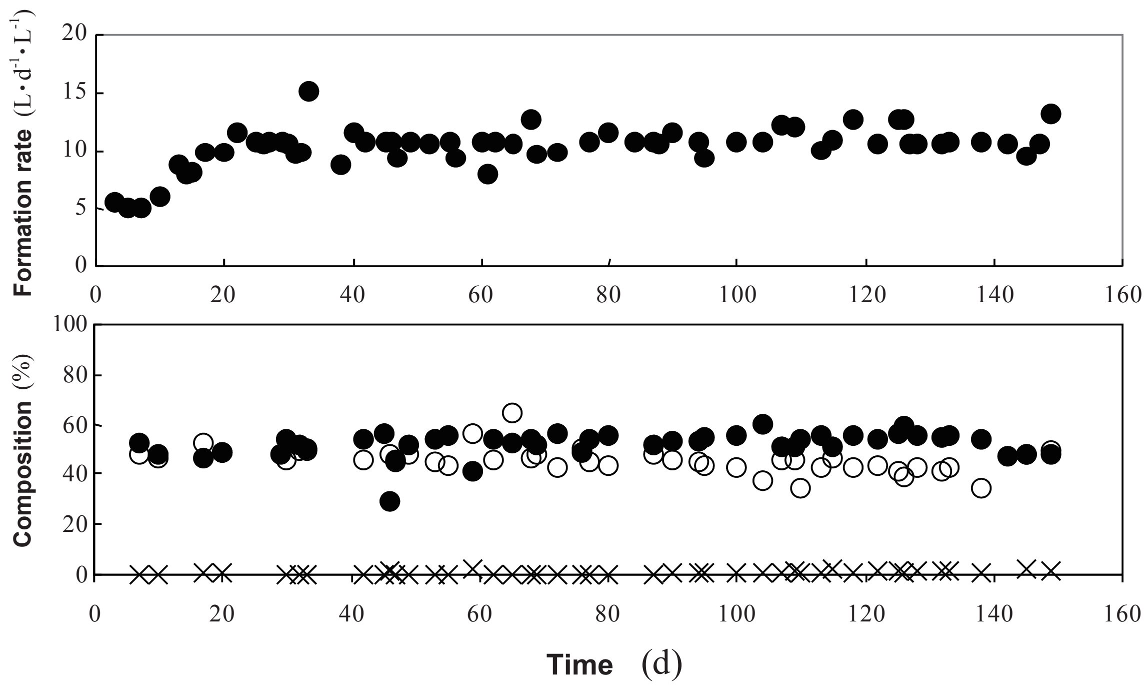


Figure 9 : Generated gas composition and hydrogen formation rate (velocity) in long-term test of hydrogen fermentation reactor (●: H_2, ×: CH_4, ○: CO_2) 13)

Source: Reference [13]

NEDO. As features of the technology developed by NIES, the aims include recovery of hydrogen and methane, and simultaneously, removal of the eutrophication salts such as nitrogen and phosphorus. Figure 9 shows the results of a continuous hydrogen recovery test conducted over a 150-day period using food waste from a cafeteria as the raw material. Hydrogen gas with a concentration of approximately 50vol% was obtained continuously. This test also clarified the fact that maintaining a substantially constant pH in the system by returning the digestion sludge after methane fermentation to the hydrogen fermentation reactor is an important condition.

Where ethanol production from biogas is concerned, because the target for introduction of so-called eco-fuels has been set at 500,000kl by crude oil conversion (equivalent to approximately 0.6% of all fuels used in transportation in Japan), active technical study of bioethanol, biodiesel fuel (BDF), liquefied biomass fuel (biomass-to-liquid: BTL), and other fuels is underway. Japan is also targeting production from waste-type biomass. An ethanol production plant using waste wood from the building industry as the raw material began operation at a scale of 1,400kl/year in Osaka Prefecture in January 2007. In this process, waste wood which has been collected from the neighboring area is crushed, followed by hydrolytic degradation by dilute sulfuric acid under pressure. As a particular feature, the process utilizes a bacterium which enables use of hemicellulose together with cellulose, which is a sugar (hemicellulose is a type of short-chain sugar).[14] In Okayama Prefecture, a pilot test is being conducted on ethanol fermentation using a special yeast with unused waste wood from sawmills, etc. as the raw material, production of anhydrous ethanol using a separation membrane, and E3, which is a mixed fuel containing 3vol% of ethanol. Ethanol production is 250kg/day.[10]

(3) Biomass plastic

The material that has attracted the highest expectations as a biomass plastic is poly-L-lactic acid (PLLA), which is produced by fermenting multiple vegetable-derived sugars. Because PLLA is more easily decomposed by processes such as hydrolytic degradation than petroleum-derived plastics, conversion to L-lactic acid and similar raw material substances is comparatively easy. PLLA is not simply only a plastic which is easily biodegradable in the environment, but can also be considered a recyclable plastic material,[15] and is

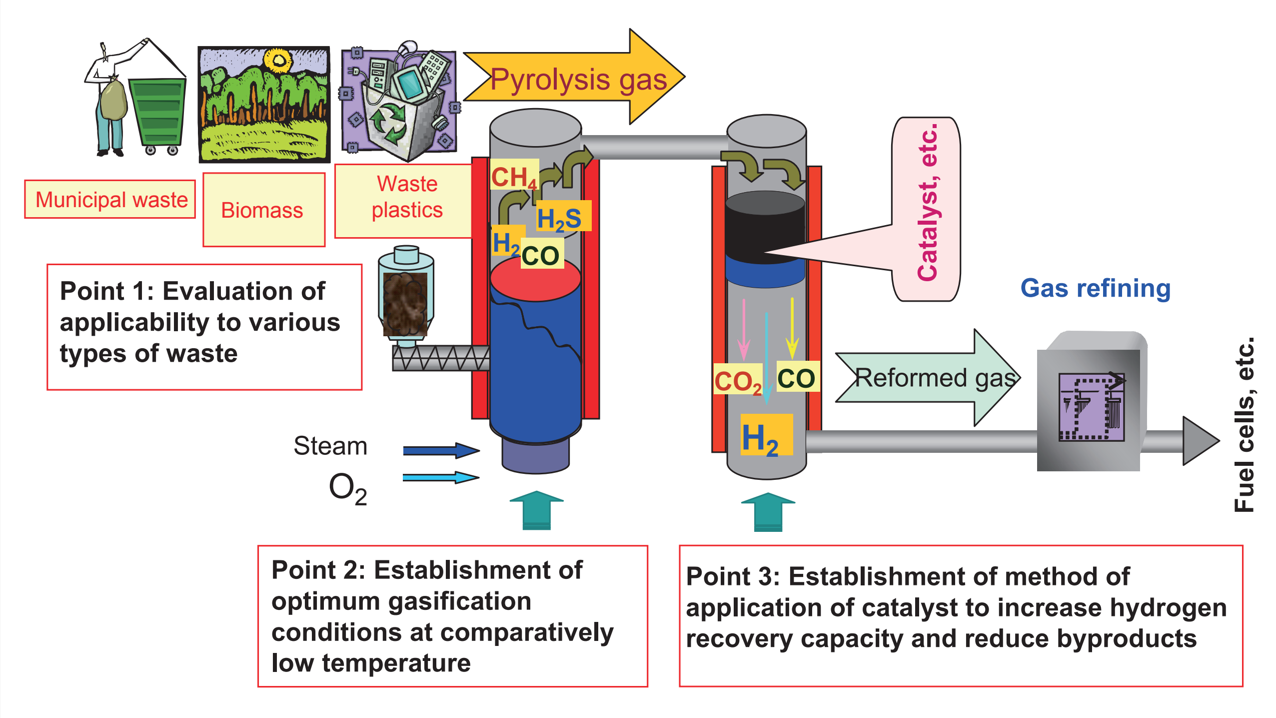


Figure 10 : Development concept of gasification and reforming system

Source: Reference [10]

therefore an attractive object for material recycling.

One important issue for producing PLLA from biomass is reduction of the cost of the refining process, for example, by a distillation process which produces high purity lactic acid from the lactic acid fermentation broth.[16] In order to obtain products which are competitive with low-cost petroleum-derived plastic products, the above-mentioned recycling from PLLA is one useful method for development of a low-cost production process.

3-3 Improvement of gasification technology

Effective utilization of waste was already a priority in Japan in the 1970s. The former Agency of Industrial Science and Technology, Ministry of International Trade and Industry (MITI; the corresponding organizations are the new AIST, which was mentioned previously, and the Ministry of Economy, Trade and Industry, METI) carried out a comprehensive research and development project called "Stardust 80" in connection with "Resource recycling and use technology systems" from FY 1973 to FY 1982. As part of this project, a pilot plant with a municipal waste treatment capacity of 100 tons/day was constructed in Yokohama. The plant comprised a total of six subsystems, including pretreatment for sorting and crushing municipal waste, high speed composting for garbage, pulp recycling from waste paper, pyrolysis and gasification for conversion of waste paper and waste plastic to oil and gas, and others. The targets were to recycle municipal solid wastes with a miscellaneous composition as material resources or energy resources, and to achieve high compatibility with social systems by minimizing secondary pollution, etc. Nevertheless, a number of problems remained to be solved with the gasification technology, including the fact that both the equipment cost and running cost were extremely high, treatment of acidic tarry substances was not possible, etc.[17] As a result, it would be difficult to call the project a success.

However, with progressive introduction of gasification and melting technologies following this project, as described previously, substantial improvements were made in the gasification technology, melting technology, and other elements. Moreover, because expectations were also placed on resource recycling and hydrogen energy, gasification technology became the focus of renewed interest. For example, there was an case in which a system for synthesizing hydrogen using waste plastics as the raw material (Ebara Ube Process: EUP) was applied commercially to the production of hydrogen for use in ammonia

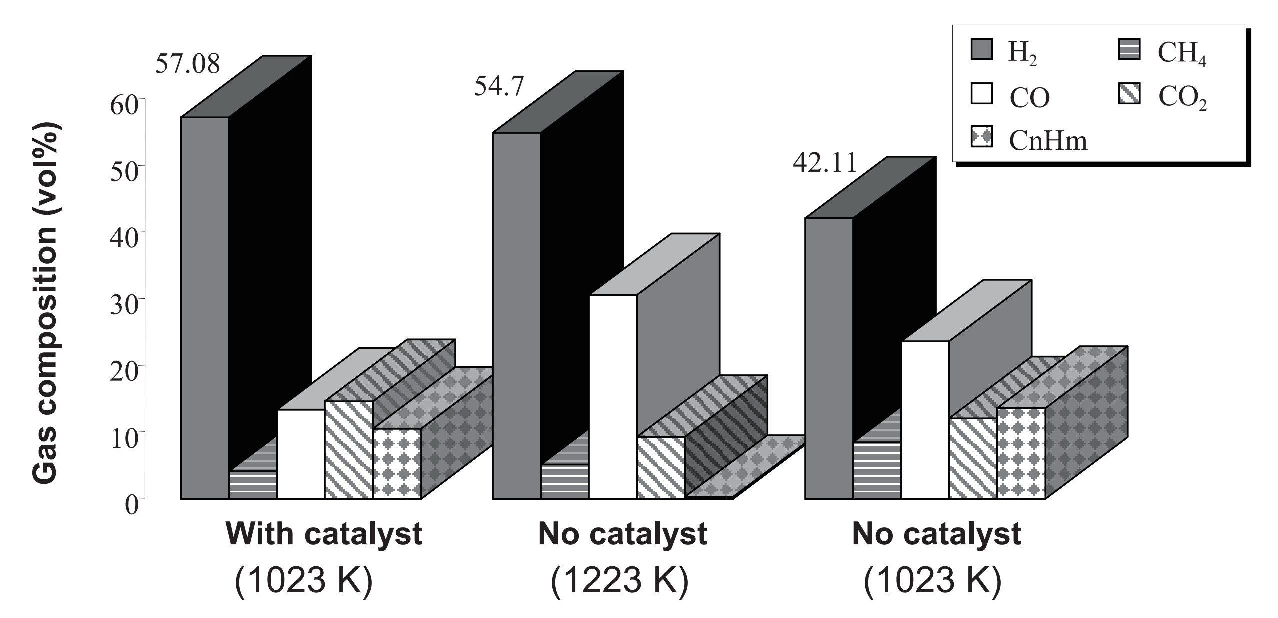


Figure 11 : Difference in formed gas composition depending on application of catalyst
(Numbers in parentheses on the x-axis show temperature. CnHm means hydrocarbon species.)

Source: Reference [10]

synthesis.[18] The technology in this example is a pressurized 2-stage process, comprising a low temperature fluidized bed-type gasification furnace (600-800°C) directly connected to a high temperature (1300-1500°C) swirl flow combustion chamber-type gasification and melting furnace. In addition, there are also a small number of examples of application to gasification and reforming-type MSW treatment.[19]

Although these technologies have attracted attention, it is difficult to say that application to biomass and MSW has made wide progress. As the reason for this, because a high temperature melting process is necessary, the process is subject to various restrictions, including the quantity of heat in the raw materials, cost performance, plant operability, and so on. Therefore, in order to promote utilization of biomass and expand the supply sources of hydrogen gas, technical development is underway with the aim of realizing a lower temperature process than with the developed technology, centering on the reforming process. As illustrated in Figure 10, technical development is being carried out based on the concept of compensating for the problem of reduced efficiency due to low temperature operation by applying a catalyst. A variety of issues are being studied in this development project, including the temperature when hydrogen is the main substance recovered, the steam and oxygen injection volume, the composition of the catalyst and amount used, the method of catalyst regeneration, and the gas refining effect, among others, with the objective of discovering the optimum applicability to waste or biomass.

For example, Figure 11 shows the results when a catalyst containing 20wt% of nickel as the active ingredient and somewhat over 10wt% of calcium oxide is applied, in comparison with the results with no catalyst in operation at different temperatures. In an experiment with waste wood, when using this catalyst, a gas with the same or higher concentration of hydrogen gas as in a process at 950°C with no catalyst could be obtained at 750°C.[10]

Similarly, as a project in connection with a biomass utilization technology in which gasification is an element technology, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) Leading Project "Composite treatment and recycling project for municipal solid waste, industrial waste, and biomass" was carried out during the period FY 2003-2007.[20] Here, development of a high efficiency process technology for recovery of energy and resources from waste was carried out as one sub-theme, and included the development of a high efficiency gasification conversion technology, development of a high efficiency gasification system technology, development of a high efficiency power generating

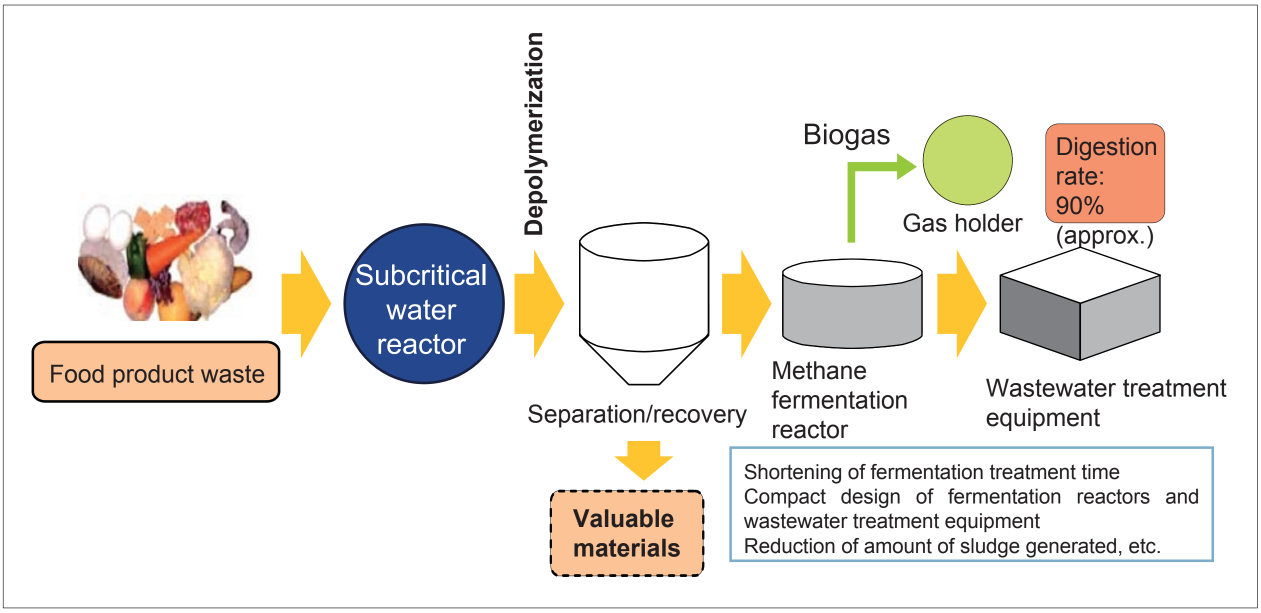


Figure 12 : Example of recycling applying subcritical process

Source: Reference [23]

technology, and development of a hydrogenation and liquid fuel synthesis technology.

In treatment technologies that use heat, environmental consideration in connection with the flue gas discharged out of the system is particularly important. Pyrolysis gasification technologies do not release flue gas directly into the open environment. However, in fuel cells, gas engine generators, and other technologies which are the use stage of the product gas, it is necessary to avoid environmental impacts related to operation, for example, due to tar and the like. Accordingly, the objects that must be considered is different from the case of incineration and other technologies which are premised on direct release into the general environment. The problems which arise here include sulfur compounds (hydrogen sulfide, etc.) which can easily damage the catalysts, polycyclic aromatic compounds, which form tar, hydrocarbons, which may cause carbon deposition, etc. Basically, it is possible to cope with refining of this kind of flue gas using conventional technologies, but from the viewpoint of optimization of the temperature conditions and the economy of the system as a whole, the optimum values will differ in each case.

3-4 Technologies applying high temperature/ high pressure fluids

As high temperature, high pressure fluids, supercritical water, subcritical water, and supercritical CO_2 are extremely distinctive fluids which make it possible to change properties from high polarity to nonpolarity, depending on the temperature and pressure conditions. A fluid in a state in which the temperature is approximately 370°C and pressure is 22MPa or higher is generally called a supercritical water. Because water in this condition is in a mixed state consisting of a liquid (reaction solvent) and gas, its strong oxidizing power can be utilized effectively, enabling application to the decomposition of hard-to-decompose substance such as organic chlorides, etc. and the detoxification of harmful chemical substances. On the other hand, subcritical water is a more moderate state than supercritical water, as its temperature/pressure are not as high as supercritical conditions. Because its ion product is larger than that of ordinary water and its reactivity is high, it can be used in reaction fields where the hydrolytic degradation reaction proceeds rapidly. Conventionally, supercritical fluids with high reactivity were the main type used in decomposition treatment of substances. However, technical studies are examining the possibility of recovering various substance by using subcritical water in this reaction field. Possible applications include reducing plastics to monomers and recovering amino acids from protein-type waste.

For example, a recycling process in which stepwise subcritical water treatment is applied to waste fish flesh has been proposed. It is possible

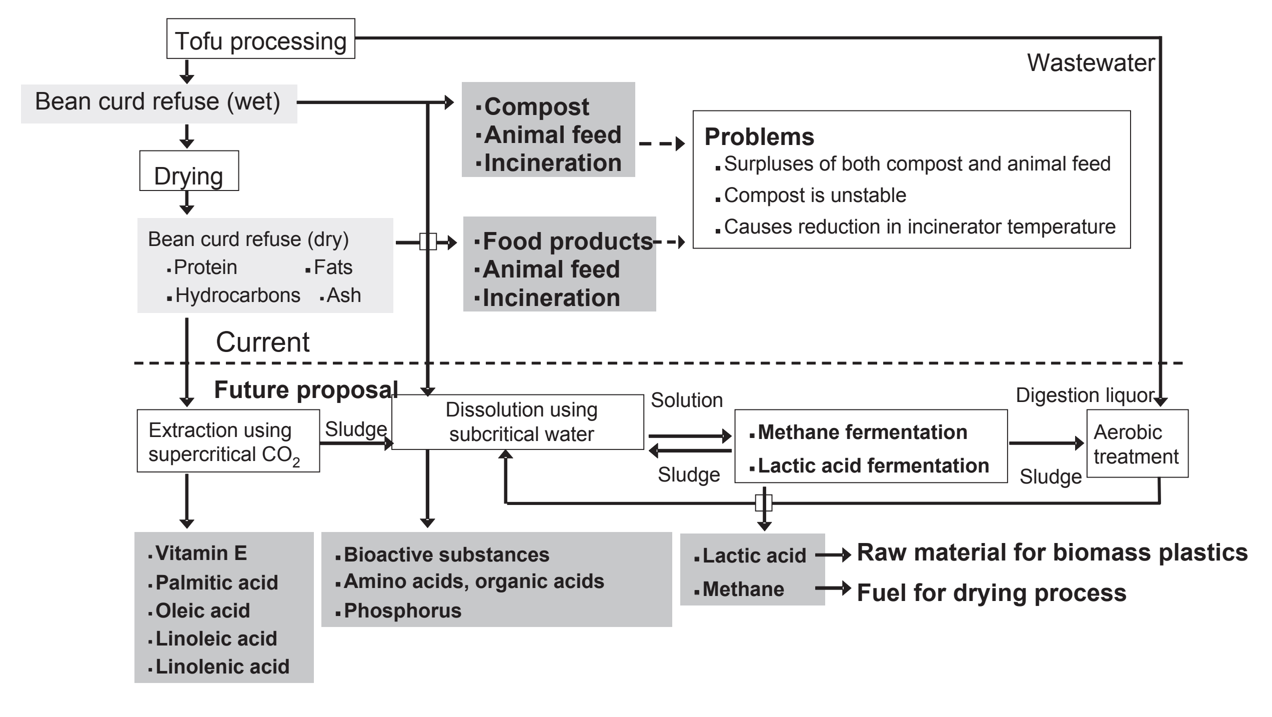


Figure 13 : Current status of treatment of bean curd lees and proposal for recycling system

Prepared by the STFC based on Reference [21]

to separate and recover pyroglutamic acid, cystine, alanine, glycine, and leucine by first refining, separating, and recovering lactic acid, phosphoric acid, and histidine in a reaction for approximately 5min under conditions of 200°C and 1.6MPa, followed by a reaction for approximately 30min at 270°C under 5.5MPa.[21] Subcritical water can be used in the recovery of tolylene diisocyanate (TDI), which is a raw material for polyurethane, in a process in which TDI is produced based on toluenediamine recovered from the residue. Subcritical water can also be applied to a process in which sugars are obtained from cellulose with high efficiency by applying subcritical water to woody biomass and adjusting the decomposition rate, and then proceeding to ethanol fermentation.[22] Possible applications include depolymerization as a pretreatment process, extraction of useful components, and gasification/oilification, etc.

Figure 12 shows the concept of a combined system which depolymerizes high molecular weight organic compounds in food product waste utilizing subcritical water and then supplies the product to a methane fermentation process. In this example, a subcritical water process is applied, enabling rapid hydrolytic degradation, which requires time in methane fermentation, while also producing a composition which is suitable qualitatively for methane fermentation.

The fact that these are high temperature/high pressure fluids also gives rise to various technical issues, including the durability of the reaction equipment, separation and refinement of the recovered substances, increased costs, and others. However, when the waste is in a dried condition, it is possible to recover bioactive components by supercritical CO_2 extraction. With wastes with a high moisture content, recovery of water soluble bioactive components and the like is possible by solubilizing the waste using subcritical water, and development to methane fermentation is possible after depolymerization. Thus, if the proper treatment is selected based on the moisture content of the waste, properties of the contents, etc., recycling of wastes can be maximized. Figure 13 shows the flow of recycling and use when this concept is applied to bean curd waste discharged from the tofu manufacturing process.

4 Issues and Recommendations

4-1 Issues for waste recycling technology as a total technology

The author would like to point out the following as technical issues for the recycling of wastes. First, some technologies which are applied to waste are in fact based on unit operations which were developed or are used in conventional production technology, and a modification of this technology is used. This is not limited to wastes, but is also applied with various other environmental technologies, such as waste water and flue gas treatment. The most important point to note is that wastes are rarely homogeneous in terms of raw material composition, and there is a large possibility that the object waste will vary in both quality and quantity. There are also cases in which the composition of the waste that can be collected when actual operation begins differs substantially from that assumed in the design stage, and it is difficult to assess this accurately in advance.

Accordingly, the pretreatment process plays a crucial role in the treatment of wastes. From this viewpoint, appropriate and effective functioning of all operations is necessary. This is not limited to the fermentation reactor, gasification furnace, and other processes which are central to recycling, but also includes crushing and classification of waste in the pretreatment process, removal of mixed foreign matter, refining in the downstream stage, and similar operations.

Furthermore, as described in connection with the fermentation process, this technology is not complete in the true sense as an environmental technology if it is not a total technology which includes treatment/disposal of the various types of liquid and solid residues generated after treatment. At present, these functions are implemented as necessary treatment/disposal auxiliary to recycling. In the future, it is hoped that the research institutes, private corporations, and others conducting technical development will carry out studies and make improvement from the viewpoint of cascade use methods and effective recycling methods for residues. Moreover, the administrative agencies which evaluate technologies should also give priority to the degree of completeness as a total technology, as outlined above, as an evaluation index.

4-2 Notes on technical development

(1) System design from a comprehensive viewpoint including safety

From the viewpoint of labor accidents, for example, the average of deaths and injuries (frequency rate) per million working hours was approximately 2 for all industries, but in contrast, this number was around 12 for facilities handling waste.[24] In the case of biomass, it would seem that there is almost no possibility that the waste will contain hazardous materials. However, because combustible substances are recovered for use as energy sources and fuels, it is necessary to take adequate work-related safety measures against accidents due to explosion, fire, or the like, which can occur in equipment used to transport and store these substances. Those concerned must make use of examples of accidents in facilities storing refuse derived fuel (RDF)[25] and facilities treating PCB[26] when responding to safety needs in the future.[27]

Accordingly, the design of systems from a total viewpoint, which heightens consideration of safety, together with excellent core technologies, are demanded as a key point in technical development. Governmental and business people who are in a position to decide the introduction of technologies must not simply focus on energy or material recovery, but must have a wide vision of the response to residue discharges, securing safety, and other matters.

(2) Consideration of efficiency of treatment and recycling

In waste recycling, there is an unfortunate tendency to make recycling an end in itself. In the Japanese government's Basic Plan for Establishing the Sound Material-Cycle Society, the circulating use ratio (Amount of circulating use / (Amount of circulating use + Inputs of natural resources, etc.; %) is used as an index, and a target value is set (approximately 14% by FY 2010). It is important to exceed this rate. Individual laws such as the Food Recycling Law (Law Concerning the Promotion of Recycling Food Cyclical Resources) set targets for the amount of recycling and related matters. However, simply comparing these numerical values does not seem appropriate. Mass consumption and mass recycling is not necessarily a desirable choice.

In other words, if the energy and new resources which are input to the recycling process are disproportionately large in comparison with the object of recycling, this is a problem which must be considered. By nature, some amount of energy and resources must be input in artificial production and consumption. For example, where energy input into the recycling process is concerned, the following was pointed out recently in an example of recycling of PET bottles.[28] In FY 2004, PET bottle consumption was approximately 510,000 tons. Of this, 240,000 tons were sorted and recovered, and the amount reused (estimated as the amount recycled as basic material) was 30,000 tons. Because 510,000 tons were manufactured and 240,000 tons were recycled, the remaining 270,000 tons were discarded as waste. According to a trial calculation, both the amount of petroleum for reuse of this very small 30,000 tons and the amount of waste as part of the total (including PET bottles which were discarded as waste as-is) were approximately 7 times larger than in the period (FY 1993) when there was still no recycling of PET bottles. Among the above-mentioned 270,000 tons, the amount that was sold to China and other countries was thought to be quite large. The details will be omitted, but there are points in the claims mentioned above which are partially correct. On the other hand, the assessment of the content of recycling is inadequate, and there is no comparison with the case of production from natural resources at the present point in time. In view of these and other shortcomings, it is possible to view this an argument which, as a whole, lacks accuracy.

The importance of reducing the energy, resources, and cost requirements in recycling and reducing the load of unnecessary materials discharged is self-evident. Proper guidance is necessary in the development of recycling technologies for which the determination of inputs and costs is inadequate, which tends to occur when the focus is limited to technical development.

(3) Expanded use of recycled products

In the recycling of wastes, effective utilization of the recycled products, in other words, users, is equally important as the technology for recycling. A resource circulation cycle is realized for the first time when this condition is met. For example, in energy recovery, operation in combination with a fuel cell system or power plant must be possible so as to effectively utilize the combustible gases such as hydrogen and methane produced in the recycling process. The social infrastructure for the siting of these facilities must also be prepared in a realistic manner. This point will be particularly important in the formation of the coming fuel cell society. Because pilot tests and other related activities are already underway, a realistic study with a view to actual social introduction is necessary.

With regard to power generation from waste, the Law Concerning Promotion of the Use of New Energy (New Energy Law) opened the way to promotion of recycling-type energy by utilization of waste power generation/heat use and biomass power generation/heat use. However, in the case of waste power generation, generating efficiency is no more than an average of about 10%, and at most reaches only something more than 20%. There is still considerable room for technical development, for example, improvement of boiler efficiency. Moreover, the upper limit (2,000kW) on general high voltage power generation, which is a condition of the Electric Power Grid Inter-Connection Technical Guideline, is a restriction, and in some cases, full use of generating capacity is not possible. Accordingly, together with technical development, improvement of operational restrictions is also important.

On the other hand, as problems confronting material recycling, little progress is being made in expanding the use of recycled products, and in particular, construction-related recycled products. This applies to products such as aggregate, road base course material, and others which use slag formed in the melting furnace or gasification and melting furnace. Because use of construction-type recycled products in public places is assumed, there is a possibility of numerous, undesignated environmental safety effects. Therefore, due care with regard to safety is required, and appropriate evaluation and control are also necessary. For some recycled products, such as molten slag from general waste and sewage sludge, preparation of test methods for quality assurance and quality control in the environmental safety aspect is progressing under JIS standards and others, and the creation of a comprehensive system of testing standards is also underway.[29] It is hoped that this kind of standardization will convey realizable quality assurance widely to users, and that this will encourage expanded use by improving the image of recycled products.

This would also seem to apply to recycled products produced by carbonizing carbon-rich materials formed in the gasification process and the use of valuable materials formed in reactions by subcritical water as products or chemical intermediates, etc. Quantitatively, these types of products are still small, and regular markets have not yet developed. However, in the future, it will be necessary to establish social systems for further promotion of the distribution and use of diverse recycled products, while continuing to give due consideration to the environmental safety aspect and other related conditions. Therefore, as a first requirement, businesses which are engaged in recycling of wastes and administrative agencies on the so-called venous side (return side) of the material cycle, and manufacturing industries that use recycled products, governmental agencies, and others on the arterial side, must share information and come to a mutual understanding on cooperation.

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Doctor of Engineering. Dr. Kawamoto's career includes work in a private corporation and as a professor, etc. His work includes environmental fate assessment of chemical substances, measurement and evaluation of the treatability of harmful substances discharged accompanying waste incineration, etc. He is currently involved in the development of recycling technologies, mainly for energy recovery from waste by gasification and reforming.

(Original Japanese version: published in December 2007)

4

Japan's Policies to be adopted on Rare Metal Resources

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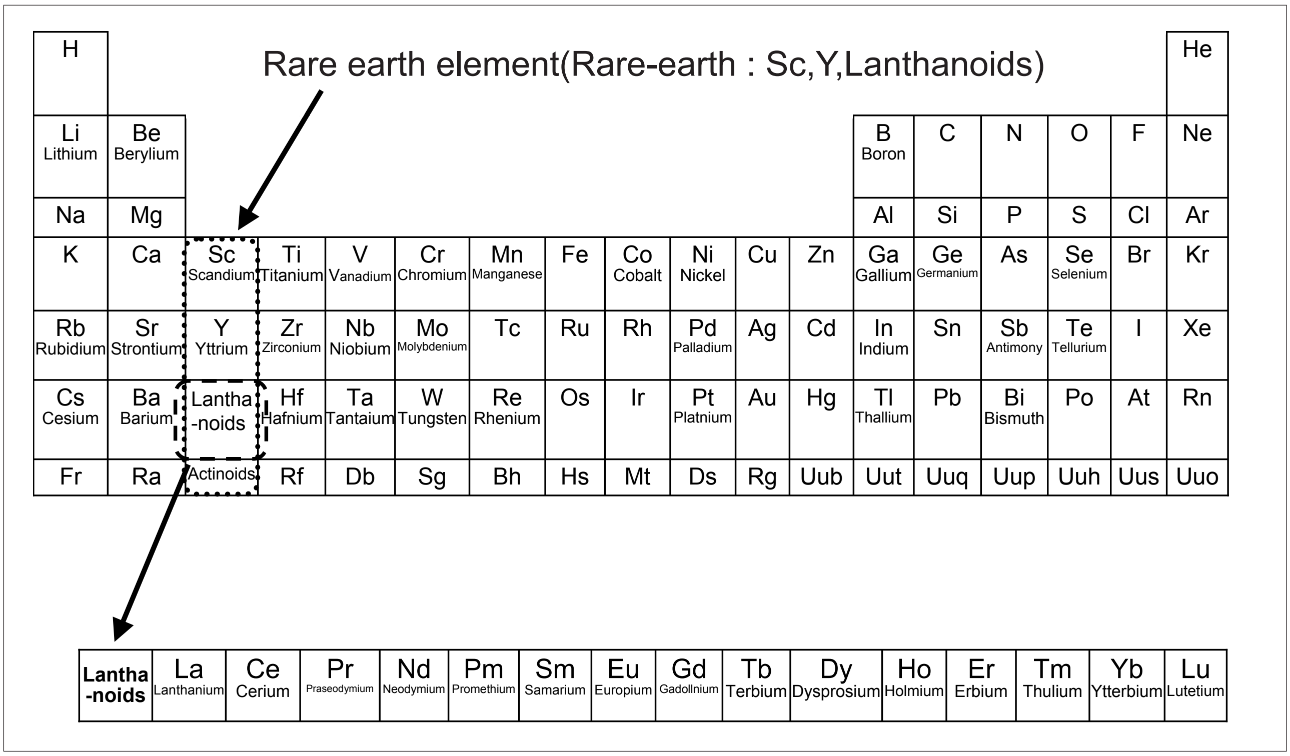
1 Introduction

The term rare metal is often used to indicate non-ferrous metals that are found only in rare amount and used in various industrial applications even in small quantities. The term rare amount, rather than indicating deposits that are scarce, more strongly implies that the production volume or supply volume is very small, and therefore, it is difficult to economically or technologically acquire these materials in the quantities that are required. Although not strictly defined, generally rare metals mean 31 types of metal elements as shown in Figure 1.[1]

Rare metals are utilized in a broad range of manufacturing areas that include materials machineries and electronics production. These are the raw materials for high value added products that sustain sectors of Japan’s manufacturing industries. In recent years, the demand for rare metals has exploded. Due to the significant growth in demand in the emerging countries and scarce amount of existence in comparison to other metals, as well as Japan’s characteristic high dependency on specific producing countries in unevenly distributed production areas, there is a growing anxiety for securing a mid-to-long-term stable supply.[2, 3] The balance of rare metal supply and demand is linked to various problems of product



Notes: The non-ferrous metal elements (30 types), Scandium, Yttrium and the Lanthanoids (15 types) that are indicated in bold type (with their chemical names written underneath) are all rare metals.

Figure 1 : List of rare metals in the periodic table

Modified by the STFC based on Reference[1] recycling and substitute material development that are unlikely to be solved quickly. While these are not problems that can only be solved by people involved in research and development of material resources, other research fields such as material science are also starting to feel the impact.

On the other hand, on the subject of securing rare metals, it has been pointed out for a long time that there is a possibility of various mineral resources to be found in the sea areas within Japan's interests such as Japan's Exclusive Economic Zone (EEZ) and at the small-scale mines that have been developed hitherto. However, during times when demand was low, mines were forced to close as they became economically unviable or new developments were overlooked. With recent increase in demand, the necessity to reexamine such matters has become increasingly apparent.

The development of seabed resources, from here on in particular, is also considered to be an important issue from the viewpoint of ensuring a stable supply of rare metal resources. The 'Basic Ocean Law' enforced on July 20, 2007, cites the development of socioeconomic health in Japan by comprehensive and systematic promotion of ocean-based strategies as the objective, and the positive utilization of oceans for satisfying marine related scientific knowledge and the development of ocean resources, etc., are also included.[4]

This article hopes to point out the future considerations that Japan in particular should take from both a short-term and long-term perspective by reviewing the present situation of rare metals with respect to the current background.

2 Rare metals and Japan's industrial technology

As Japan's external trade balance depends largely on manufacturing fields such as materials production, machineries and electronics manufacturing industries, Japan has become a world leading consumer of non-ferrous metals. Base metals such as copper, lead, and zinc, etc., in addition to rare metals such as tungsten and cobalt, etc., are mineral resources that are indispensable to Japan's socioeconomic and industrial activities. Any obstruction to the supply of these rare metals would have a great impact on a part of Japan's staple industries.

Indium, which is used in LCD televisions, mobile phones, and transparent electrodes of solar batteries, etc., is one such rare metal for which the supply and demand has become an issue. The applications and supply and demand status of indium are indicated in Figure 2.[5-7] Since France, a former principal source of indium ingots, ceased production, China has virtually become the only supplier of new ingots. In addition, due to the increasing demand for plasma screen televisions, the price of indium is expected to continue to go up. On the other hand, as will be discussed later, indium is an associated ore of lead and zinc (a byproduct of lead and zinc ores). Therefore, due to China's heavy demand for lead and zinc, the amount of lead and zinc mined globally will increase in response to China's growing demand. This situation will lead to increased production of

[Glossary]

Rare metals: metals that exist in limited amounts in the earth's crust, or 31 types elements of non-ferrous metals (30 ore varieties and 1 rare earth ore type) that are economically or technologically difficult to extract in pure form despite being found in ample quantities and utilized in industry. However, these do not include non-ferrous base metals used in large amounts and high-value precious metals.

Rare earth: These are elements referred to as rare earth elements of which there are two group-III elements in the periodic table (scandium, yttrium) and 15 types of lanthanoids (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium). There are 17 rare earth elements that are summarized as one ore type.

Base metals: Non-ferrous metals such as copper, zinc, and aluminum, etc., that are used in large quantities following iron.

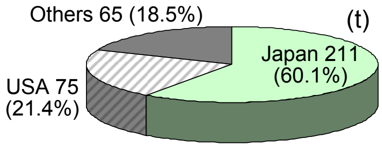
Key applications	○Transparent electrodes (LCD TV's, plasma TV's, solar batteries) ・Metals required in LCD displays (indium oxide is an efficient, high-transparency electrical conductor) ・Used extensively in large LCD TV's for which Japan is technologically renowned ・90% of total consumption is used in transparent electrodes for large LCD TV's ○Bonding (sputtering target bonding adhesives) ○Low melting point alloys(solder containing indium)

World indium ingots production volumes (t)

Country \ Year	2001	2002	2003	2004	2005
China	100	85	100	200	250
Japan	55	55	70	70	70
Canada	45	45	50	50	50
Belgium	40	40	40	30	30
Russia	15	15	15	15	15
France	65	65	65	10	10
Other	29	30	30	29	30
Total	349	335	370	404	455

Source: Mineral Commodities Summaries

World consumption amount (2002)



Sourced: "Rosskil Indium 2003"

Japan's demand and raw material supply (t)

	Year	2001	2002	2003	2004	2005
	Transparent electrodes	260	300	360	470	—
	Bonding agents	19	21	25	35	—
	Low melting point alloys	6	6	6	8	—
	Battery, contact materials	5	5	5	5	—
	Fluorescent materials	8	8	8	8	—
	Compound semiconductor	17	4	7	7	—
	Other	8	11	8	8	—
	Total	323	355	419	541	634 (Estimated)
Raw material supply	Production	70	70	70	70	70
	Imported amount	171	141	264	421	422
	Recycled scrap	127	158	159	249	329
	Total	368	369	494	721	821
Features	• China accounts for approx. 70% of total imports • Approx. 30 – 40% of total supply obtained from recycled scrap, etc. • Due to the closure of the Toyoha mine (March, 2006), domestic production is predicted to decrease to 1/3					

Source: Industrial Rare Metals

Figure 2 : Applications and supply and demand status of indium

Modified by the STFC based on References[5-7]

indium as byproduct that will have a calming effect on the price. Due to this complex arrangement, the future price trend is uncertain, and the impending balance of supply and demand is something that must be looked at more carefully.

Among rare metals, rare earth elements tend to be used in specific applications only. The applications and current supply and demand situation of rare earth are shown in Figure 3.[5-7] Rare earth magnets (in particular neodymium-iron-boron (Nd-Fe-B) magnets) are, for example, used in hard disks and hybrid car motors and due to the growth in demand for rare earth magnets, the importance of not only the main component neodymium but also dysprosium and terbium, elements that are added to increase the coercive force and magnetic flux density in the high-temperature region, has also increased. Dysprosium is a particular element that has become essential for enhancing these characteristics. Presently, no ground-breaking substitute magnets that can rival its high performance is found even in research stage.

Rare earth raw materials are 100% imported, and imports from China account for approximately 90%. Conversely, Japanese industries and component manufacturers that utilize rare earth products, such as manufacturers of household electric appliances, electrical tools, mobile phone devices, and automobiles, are increasingly transferring production to China. While its high economic growth continues, the market in China for products that utilize rare earth elements is considered to expand accordingly. In contrast, Japanese industries linked to products utilizing rare earth elements that are not moving into China will need to obtain a stable supply of raw materials from China while developing products that are different from those currently swelling the markets inside China.

3 Rare metal resource consumption, present and future

3-1 Uneven distribution of rare metal resources

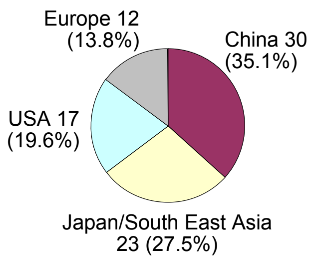
The rare metal resource producing territories

Key applications	○Rare earth magnets (neodymium, samarium, praseodymium, dysprosium, terbium) ・Used in hybrid cars ・Used in technical fields in which Japan is technologically advanced ○Abrasives (cerium) ○Optical glass (lanthanum) ○Nickel hydrogen batteries (mischmetal, lanthanum) ○Fluorescent materials (yttrium, europium, terbium, gadolinium) ・Color TV Braun tubes

Japan's demand and raw material supply (t)

Year		2000	2001	2002	2003	2004
Demand	Abrasives (CeO_2)	3,738	2,544	3,721	4,061	4,228
	FCC catalysts (crude rare earth metal chlorides)	702	776	814	682	710
	Braun tubes (CeO_2)	1,500	1,098	1,020	907	944
	UV glass (CeO_2)	1,332	1,283	1,346	1,350	1,406
	Optical glass (La_2O_3)	526	409	384	437	455
	Exhaust gas catalysts (CeO_2 + La_2O_3)	670	646	677	680	708
	Desulfurization catalysts (CeO_2)	533	533	555	603	628
	Condensers (Nd_2O_3 + Sm_2O_3)	1,139	633	762	942	981
	Fluorescent materials (Y, Eu, Gd, Tb)	-	-	850	1,200	1,249
	Sintered rare earth permanent magnets (Nd_2O_3 + Sm_2O_3)	3,753	3,065	3,365	4,058	4,225
	Bonded magnets (Nd_2O_3 + Sm_2O_3)	165	139	118	127	132
	Mischmetal (MM + La)	2,360	1,490	3,920	3,560	3,707
Raw material supply (metal amount)		27,671	19,737	22,570	25,704	26,762

World consumption amount (2003) (t)



Sourced: "Rosskil Rare Earth 2004"

Figure 3 : Key rare earth applications and supply and demand status

Modified by the STFC based on References[5-7]

of the world appear to be unevenly distributed throughout the earth. However, the information concerning the supply of rare metals that are used in comparatively large amounts is noticeably clear (Figures 2, 3, and Table 1). Nickel, for example, in the past was extracted from deposits in Russia and Canada. As newly developed extraction methods have recently made it possible to extract and recover such rare metals from low-grade ores in tropical Indonesia, the Philippines, and New Caledonia, there is little concern regarding the future supply of these resources. South Africa produces approximately half of the world's chromium output and, since Japanese industries are also producing chromium in South Africa, there is relatively little concern in Japan regarding the supply of this element. Cobalt, which is recently supplied by countries such as the Congo, Zambia, and South Africa, is also available on the market, so for the time being, there are no supply concerns regarding this resource. On the other hand, due to acute geographical mal-distribution, there is a great concern regarding the supply of tungsten and dysprosium, for examples, in Japan. China produces and exports 90% of the world's tungsten. In addition, 93% of the rare earth elements including dysprosium are also produced by China.

Indium, for example, is an element for which reserves are not so small and there are many producing countries (Figures 2, 4) of which Japan was formerly a world leader. Rare metal elements like indium are vulnerable to supply factors such as the closing of a single mine, etc., and are consequently prone to large swings in their supply and demand status. Therefore, the recycling of scrap materials has become an important source for stabilizing supplies.

When viewed geographically, presently, China is the world's overwhelming producing nation of not only rare metals, but metal resources in general. China is regarded as the number one ore deposit for antimony, bismuth, cadmium, lead, magnesium, molybdenum, rare earth elements, tin, tungsten, vanadium, yttrium, zinc, and titanium. China is also the world's second largest source of silver and indium, and the third largest source of copper, gold, and lithium.

Table 1 : Rare metal key producing countries and the Japan's import origins

Mineral type (Reserves: Yes/No)	Producing country (2005)	Key import origins (2005)	China's trend	Comments	Japan's world share (Ranking)
Nickel (Reserves: Yes)	Russia 22% Canada 15% Australia 14%	Indonesia 44% Philippines 14% New Caledonia 13%	Imports increasing rapidly due to stainless steel production expansion	• LME listed metals • Mining development by Japanese industries	No. 2 No. 1: China No. 3: USA
Chromium (Reserves: Yes)	South Africa 43% India 19% Kazakhstan 19%	South Africa 49% Kazakhstan 26% India 9%	Import amount increasing annually	Examples of Japan's ferrochrome producers making inroads into South African market	-
Tungsten (Reserves: Yes)	China 90%	China 79%	Domestic demand is a priority	Sudden reduction of ore imports due to China's value-added policy	No. 4 No. 1: China No. 2: USA
Cobalt (Reserves: Yes)	Congo 31% Zambia 17% Australia 13%	(Post-fabrication products procured from Finland, Australia, Canada)	Demand for rechargeable batteries is growing rapidly, sharp rise in imports from Congo	• Byproduct of copper, nickel • Mining development by Japanese industries	No. 1 No. 2: Europe
Molybdenum (Reserves: Yes)	USA 34% Chile 27% China 17%	Chile 45% China 15%	China is one of the exporting countries	•Mainly byproduct of copper •Mining development by Japanese industries	No. 3 No. 1: Europe No. 2: USA
Manganese (Reserve: Yes)	South Africa 22% Australia 14% Gabon 13%	South Africa 47% Australia 23% China 19%	Imports increasing rapidly	• Cooperation with South African industries in securing ores • Examples of China's industries advancing silicon manganese production	No. 5 No. 1: China
Vanadium (Reserves: Yes)	South Africa 42% China 34% Russia 21%	South Africa 49% China 25%	90% production by domestic major companies	Examples of Japan's ferrovanadium producers making inroads into South African market	No. 4 No.1: Europe No. 2: USA
Indium (Reserves: No)	China 55% Japan 15% Canada 11%	China 70% (Extracted in China from foreign zinc ores)	(Details unclear)	Byproduct of zinc	No. 1 (60%) No. 2: USA
Rare earth metals (Reserves: No)	China 93%	China 90%	Produced in Inner Mongolia, China	-	No. 2 No. 1: China

Modified by the STFC based on References[2,7]

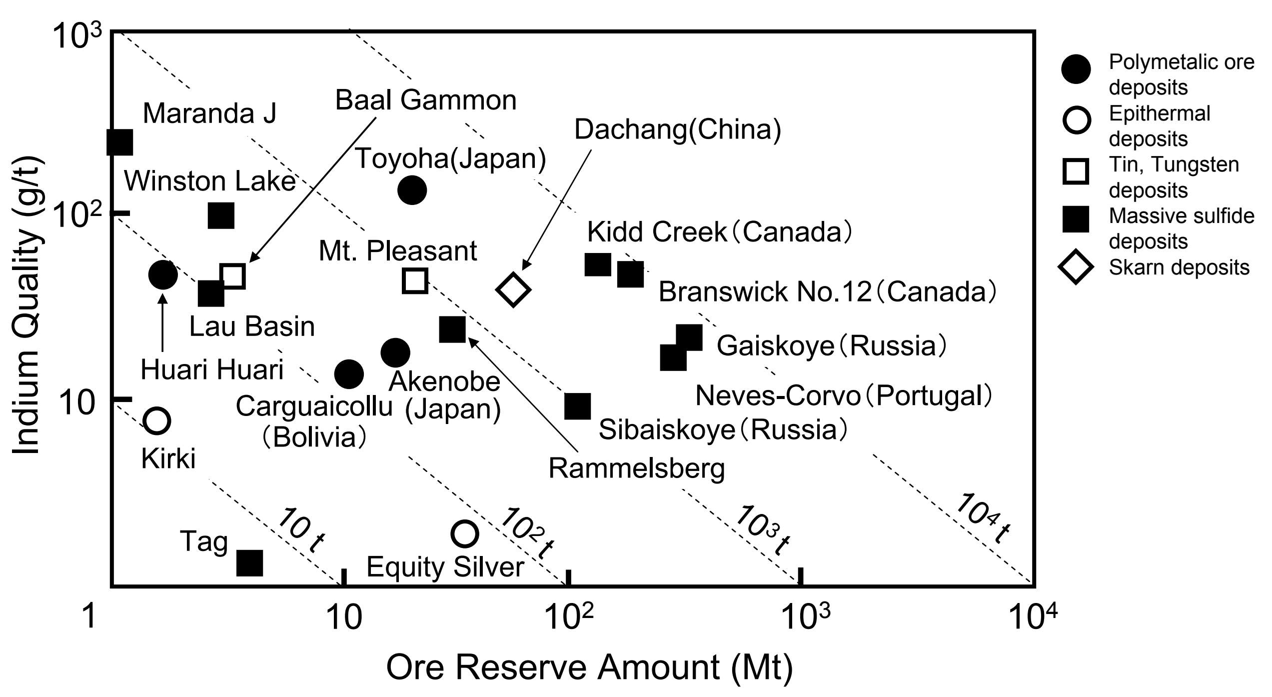


Figure 4 : Location and scale of the key indium deposits (2002)

Modified by the STFC based on References[2,8,9]

3-2 Rare metal consumption status and supply disruption issues

The only mineral resource that Japan is self-sufficient in is sulfur and is therefore reliant on imports for all other metal mineral resources. More recently, amid the sudden increases in consumption of the world's non-ferrous metals among the emerging nations, many supply problems have been highlighted. For consumer countries like Japan, circumstances are becoming increasingly

Table 2 : Price escalation of important metals and resources

Metal type (bullion)	Unit price	July 2003		July 2005		July 2007		Key applications
		Price	Percent (%)	Price	Percent (%)	Price	Percent (%)	
Copper	US$/t	1710	100	3614	210	7540	440	Electrical wires, electronic devices, machineries
Zinc	US$/t	827		1194	140	3384	410	Galvanized steel, alloys
Platinum	US$/oz	690		879	130	1280	190	Vehicle exhaust catalytic converters, electronic instruments
Nickel	US$/kg	8.8		14.6	170	52	590	Stainless steel, rechargeable batteries
Tungsten	US$/MTU	46		145	320	165	360	Carbide tools, high speed steels
Cobalt	US$/kg	23.5		30	130	70	230	Heat resistant alloys, rechargeable batteries
Molybdenum	US$/kg	11.5		66.6	580	65	570	Construction alloys, pipes
Indium	US$/kg	183		899	490	700	380	Transparent electrodes (LCD, solar batteries)
Neodymium	US$/kg	6.8		11.7	170	24	350	Rare earth magnets
Dysprosium	US$/kg	25		65	260	90	360	Rare earth magnets

Note: Created from Japan Oil, Gas and Metals National Corporation (JOGMEC) website.
MTU: Metric Ton Unit also referred to as Kilo Ton. The market quotation price of tungsten (W) ore is indicated by 1% (1kg) pure WO_3 in 1 ton of ore.

Modified by the STFC based on Reference[2]

difficult for ensuring a stable supply of resources.

Historically, during the past 50 years or so, while the international price of non-ferrous metals has fluctuated greatly, in relative terms the monetary value has come down. Over the course of this period, as mines in western countries have been closed due to falling prices and there has been a downturn in mine exploration activities, a sudden recovery in production seems highly unlikely. On the other hand, in recent years, the rate of consumption in the BRICs countries beginning with China has rapidly grown to the extent where an inversed supply and demand trend is evident. Even for base metals, Japan's ranking as a world consumer is falling, and its controlling influence is weakening. For example, by looking at the consumption of copper, which runs parallel to the scale of Japan's economy, for a long time Japan has been consistently second behind that of the USA. However, China has overtaken Japan, followed by the USA to become the current world's largest consumer country.

With this current background, monopolization of supply resources has started due to the buying up and merging of the major overseas non-ferrous metal resource refining companies and, in recent years, resource nationalism has become noticeable in some countries. China, for example, has been quick to adopt the resource protection policies particularly for rare earth elements by imposing export restrictions. The resource nationalism and the major non-ferrous corporations have started to control this supply and demand. These are the factors why consumer-only countries such as Japan have lost their controlling influence, and the impact that this will have on universally scarce rare metals is likely to escalate.

In terms of consumption – especially in rare metals – Japan accounts for more than half of the global consumption for some kinds of these elements. For example, Japan consumes 60% of the world's supply of indium. Besides Japan, and with the exception of the United States, the only several other key consumer countries of indium are entirely in Asia. Since indium is the main constituent in the transparent electrode material applications, utilized in display devices, etc., it follows that the key indium consumer countries are also the key producing countries of these types of electronic devices. Therefore, from a global viewpoint, the consuming regions are also geographically acutely mal-distributed. A similar situation also applies to dysprosium. Because dysprosium is used extensively as an additive in rare earth magnets found in information communication tools, mobile phones, computers, and drive motors in hybrid cars

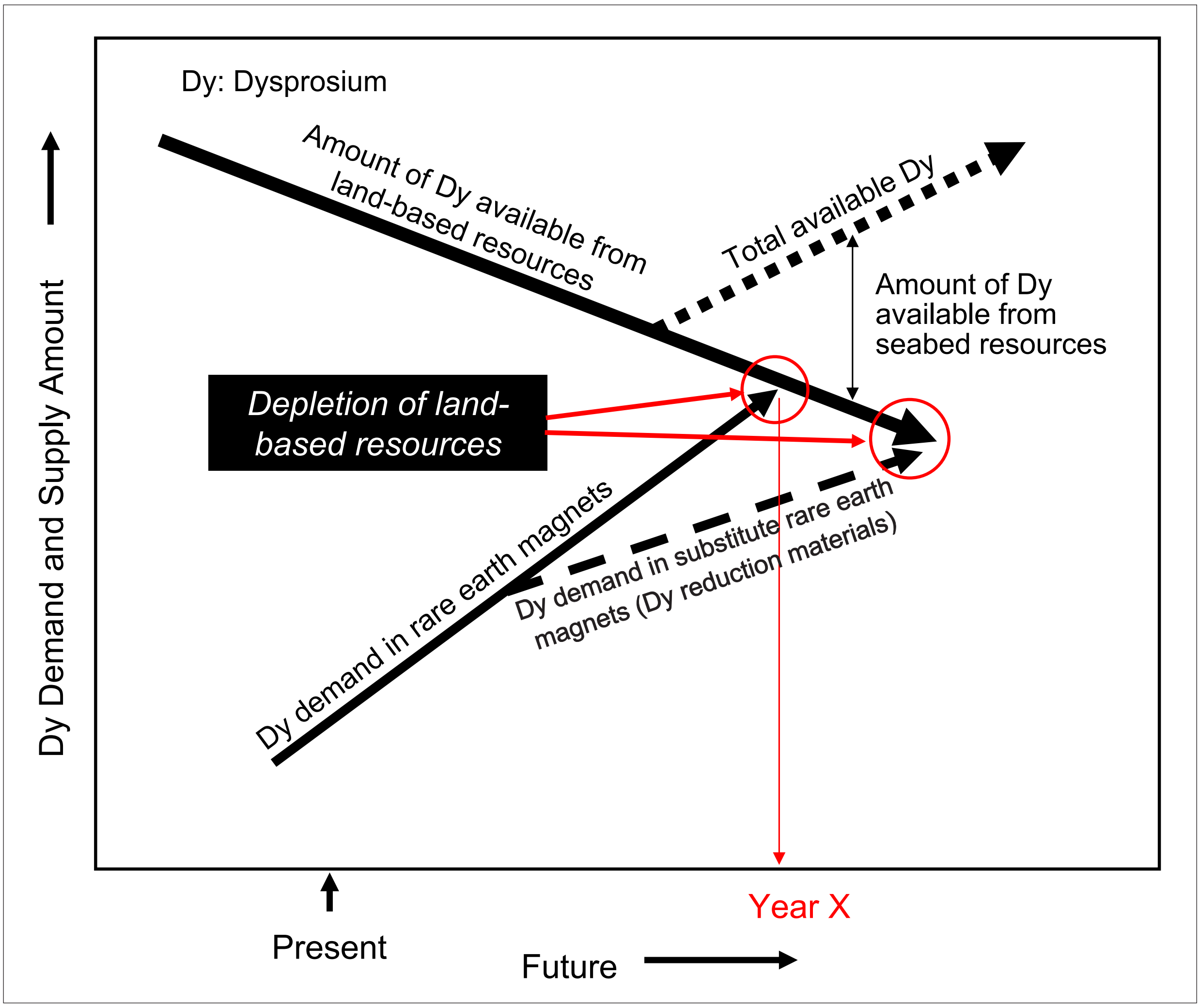


Figure 5 : Anticipated view of the supply and demand relationship of dysprosium in rare earth magnets

Prepared by the STFC

(vehicles that are powered by a combined gasoline engine and electric motor power source),[1] it stands to reason that the world's biggest consumer is Japan; whereas consumption in other countries is comparatively low. The soaring situation regarding the key metals and resources is indicated in Table 2.[2, 10] The prices of dysprosium and nickel have gone up by four to six times during the past four years. In the past there have been instances where the supply of rare metals was actually disrupted in Japan. In 1997, vanadium became difficult to obtain for a period lasting twelve months, and reserves from the national resource stockpile were released for the first time. Also, in 2000, due to a shortage of tantalum, domestic manufacturers of condensers issued a formal plea for shipments to be suspended.[3]

Figure 5 shows an anticipated view of the supply and demand relationship for dysprosium as a rare earth magnet. As the recoverable reserves of dysprosium are limited, the chart diagrammatically indicates the risk of resources depletion should the future demand for dysprosium suddenly increase. Presently, rare earth magnets are used in hard disks, industrial motors, and hybrid cars, etc., and the application for hybrid cars is expected to expand particularly rapidly from here onwards. The domestic demand for dysprosium in 2004 was approximately 260t.[11] On average 2kg of rare earth magnets are used per vehicle. Since the annual production of hybrid cars is expected to reach 1.2 million units by the year 2010,[12] the annual demand for dysprosium will be 240t assuming the amount of dysprosium in magnetic is 10%.[1] In specific terms, the amount of dysprosium that will be required for use in hybrid cars alone in the year 2010 will be close to the total amount utilized in 2004. By considering the use of rare earth magnets in factory products other than hybrid cars, the supply and demand of dysprosium will

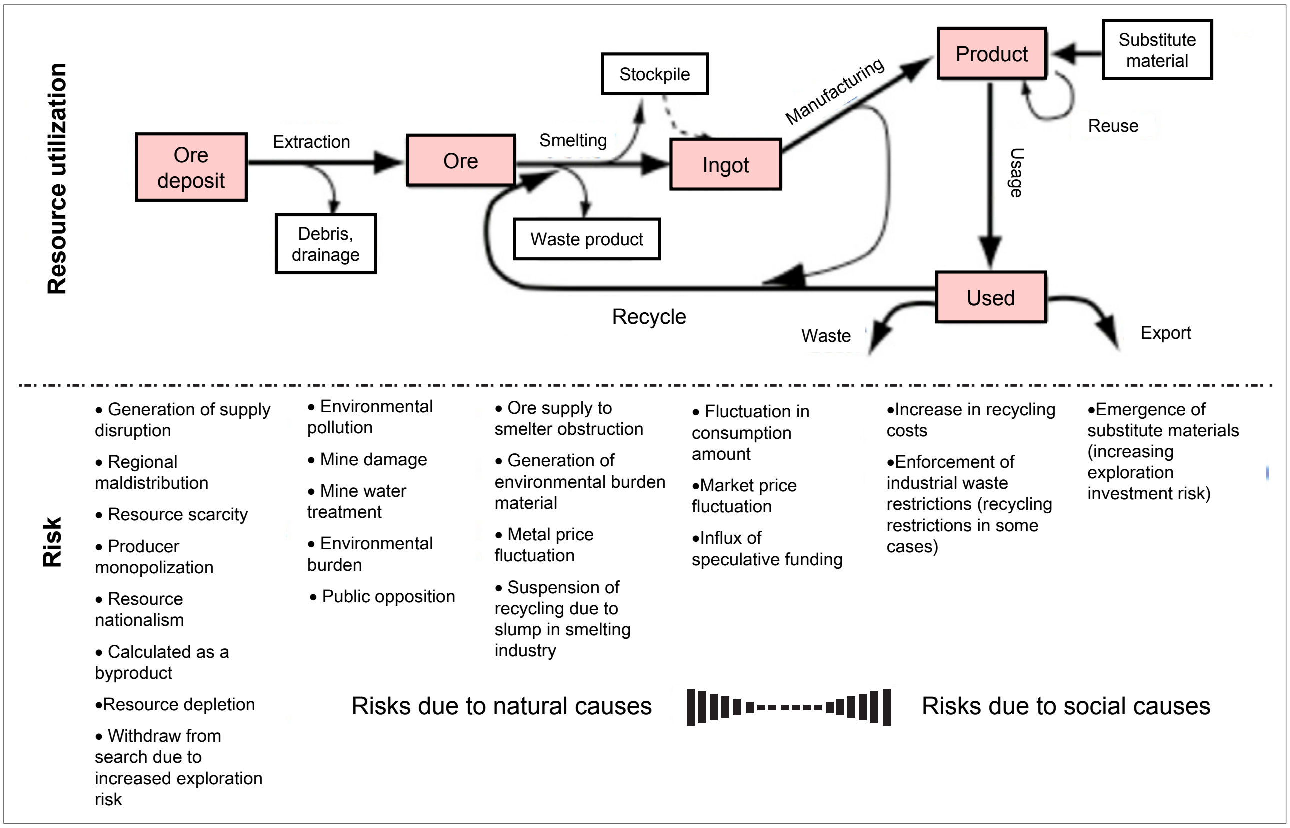


Figure 6 : Supply, recycling, and risks of mineral resources

Soruce: References[2,3]

become inevitably tight. By simply calculating the recoverable amount and the assay amount of dysprosium contained in ore obtainable from rare earth deposits[13] as well as the yield when refined, a problem of supply should not be encountered for several decades. However, by considering the growth in demand for industrial products other than hybrid cars, future efforts will be essential to speed up the development of magnets in which the amount of dysprosium used is reduced and to increase recoverable reserves. Since it is highly unlikely that technology for substituting dysprosium, which is necessary for enhancing the coercive force of permanent magnets, will become available in the short-to-mid term future, the development of magnets in which the amount of dysprosium used is reduced is perhaps the only viable solution.

3-3 Status of rare metal recycling and reducing the consumption

Unlike energy resources, there are reuse and recycling processes for mineral resources which are beneficial for increasing the utilization efficiency of these resources. In addition, although only applicable to certain rare metals, Japan has its own private sector and national reserves. However, there are certain rare metals for which recycling is not economically viable. Also, if primary substitute materials emerge, there may be an immediate, sharp decrease in the economies of scale, which will result in an increase risk in exploration investment. The only workable solution for securing a stable supply of resources is by combining the multiple risk reductions at each stage.

The risks associated with the supply and recycling of mineral resources are indicated in Figure 6.[2,3] The residues from ingot manufacturing processes including ore deposit exploration, ore production by mining, and ore dressing as well as spent products are all recycled. In addition to this, there are various processes such as stockpiling and limiting supplying of reserves and searching for substitute materials, etc. These activities are accompanied by certain inherent risks such as risks due to uncontrollable natural forces, risks due to social factors, and exploration risks, etc. For example, on upstream risks such as skyrocketing prices, the supply disruption, etc., are not generated.

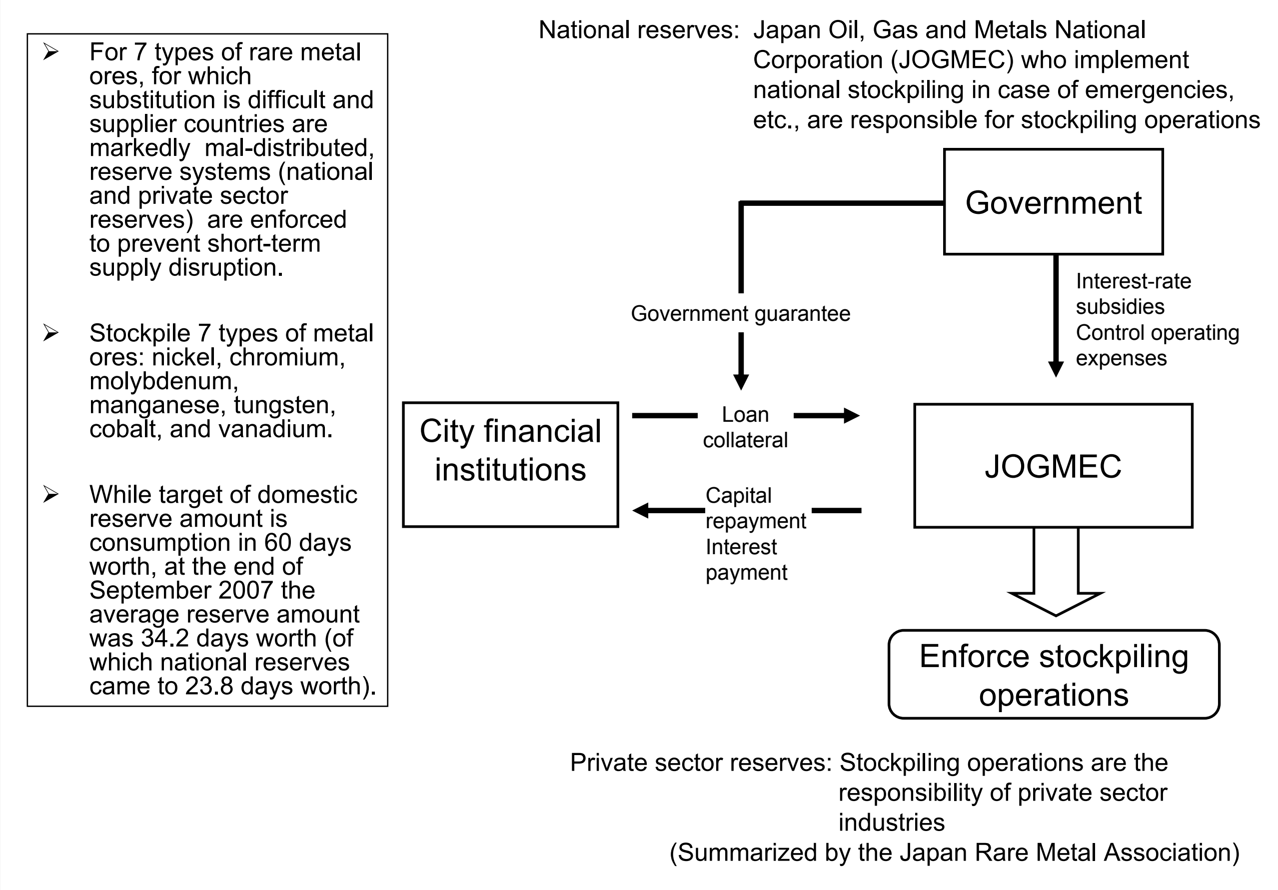


Figure 7 : Overview of rare metal stockpiling system

Source: Reference[23]

4 Securing a future stable supply of rare metal resources

4-1 Present day mineral reserve policies

In December 2005, the Agency for Natural Resources and Energy set up the 'Resources Strategy Committee' which examined the medium term measures considering the characteristics of ore production, the types of anticipated risks, and ways of implementing actions for rare metals such as tungsten, rare earth elements, and indium, etc., from upstream to downstream shown in Figure 6. These discussions are ongoing in the discussions in 'Mining Subcommitteee for the Advisory Committee on Energy and Natural Resources'. In June 2006, in the report on 'Strategies for Securing a Stable Supply of Non-Ferrous Metal Resources' from the Agency for Natural Resources and Energy, specific current measures arranged and based on (1) Promoting exploration development, (2) Promoting recycling, (3) Development of substitute materials, and (4) Stockpiling are already underway.[14] A summary of the rare metal stockpiling system is outlined in Figure 7.[23] The mineral resources policy budget for the year 2006 was 6.46 billion JPY, and for 2007 it becomes 7.07 billion JPY.

The keyword that represents Japan's resource policy is "Securing a Stable Supply". Various policies have been implemented by Japan Oil, Gas and Metals National Corporation (JOGMEC), which include aid and finance loans for mine exploration at home and abroad, tectonic surveillance, dispatching of specialists and technological cooperation to developing countries, development of technologies relative to domestic recycling, exploration funding reserve system, and the compiling of mining information from overseas for the purpose of "Securing a Stable Supply". As non-ferrous metal prices are thought to remain high, from 2007 a new budget was allocated for the development of recycling technology and substitute materials. A further new budget has also been allocated for the development of resources in the 2008 budget request.

In order to secure a stable supply of rare metals to Japan, the implementation of the following mid-to-long-term policies centering on the Ministry of Economy, Trade and Industry have been activated. Firstly, in order to bolster the securing of overseas resource development interests, direct relations with resource producing nations should be strengthened by adopting a diplomatic approach of resources, while at the same time taking measures to support exploration development. Next, to ensure internal availability, promotion of material recycling with backflow of resources from downstream to upstream together with developing recycling technologies related to waste materials that have hitherto made recycling problematic are underway. The development of substitute materials for those that are anticipated to be supply restriction has also been promoted.

4-2 Problems to be tackled in the short term: Recycling, information, and market issues

(1) In the case of rare metals in particular, a confluent resource system that will share the risks with three groups in the upstream position of resources (provision of geological and resource information, etc.), downstream position (consumption, etc.), and backflow position (recycling, etc.) is required. In addition to establish this kind of system, Japan must quickly and precisely grasp the present state of affairs of the world's mining industries through gathering and analyzing resource data for those industries concerned. In more specific terms, by engaging the government agencies to advance the preparation of geological and resource information, the detailed and exact survey analysis of the production amount and material flow would be continuous thereby enabling clarification of the price setting mechanism. For example, a detailed examination of the indium recycling system has recently begun.[15] Although the recycling of display panels, etc., is too inefficient and therefore not viable, the examination shows the estimation result that recycling during manufacturing is promising. Figure 8 shows a case example of a recycling study for indium

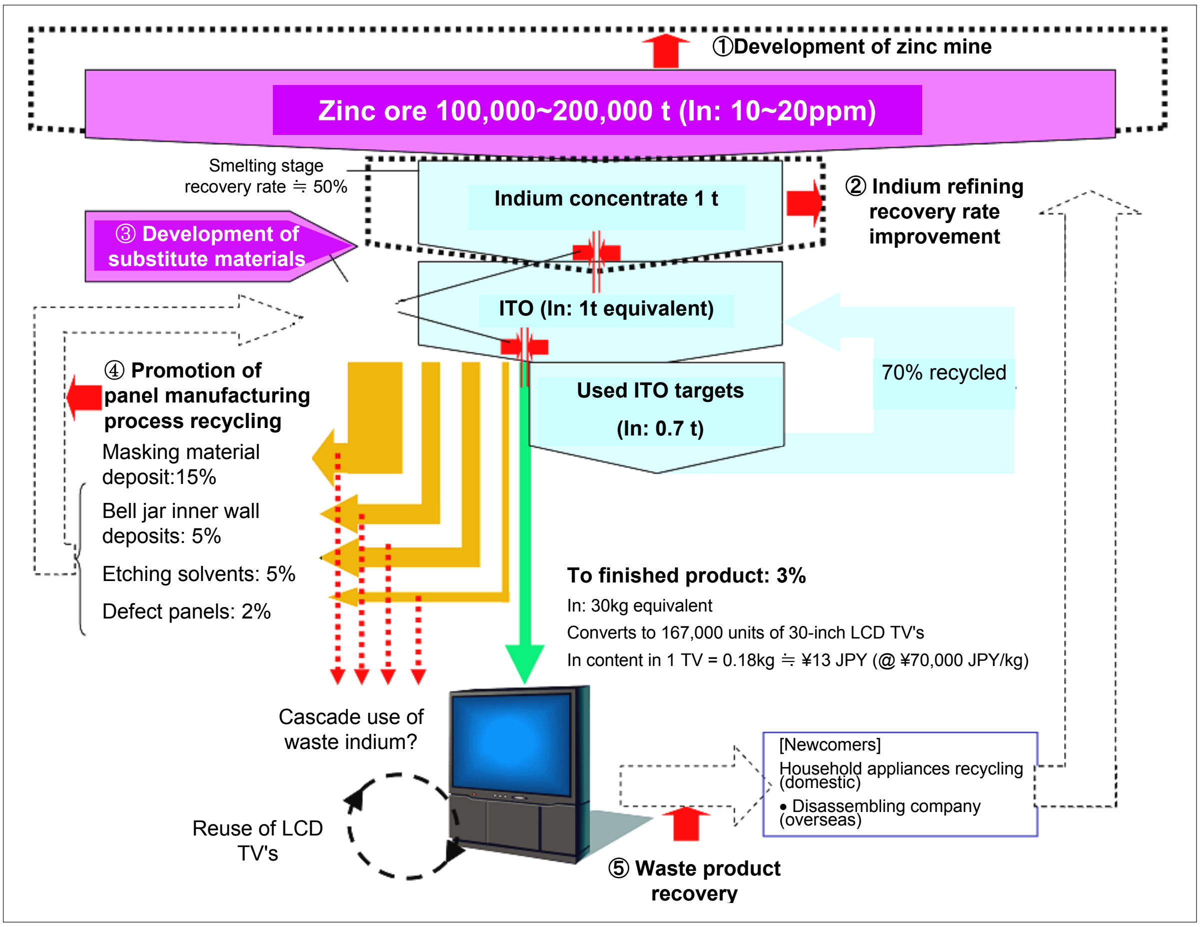


Figure 8 : Recycling study for indium in the lifecycle of a display panel

Source: Reference[15]

in the lifecycle of a display panel.[15] Here, the recovery of ITO (Indium Tin Oxide) from scrap LCD televisions, LCD computers, and mobile phone display screens, etc. and the recovery of ITO deposited on machines in the panel manufacturing processes, etc., are being studied. Since the amount of indium incorporated in LCD panels is small, recycling from panels is not profitable. Therefore, together with technological difficulties, recovery of indium has not progressed. Consequently, targets that are consumed in the LCD panel production processes are the main source of material recovery. However, the indium recovery rate from spent panels is expected to increase further due to the recent rise in indium prices.

(2) Heavy consumer nations like Japan should prepare accurate information about certain rare metals that cannot always be supplied from overseas. While requirement of stable supply of rare metals changes from large amounts at traditionally low prices to small amounts of high-quality metals, radical technological developments have generated an unforeseen sudden change in supply and demand. Information about supply and demand, including recycling, has not been adequately prepared. In the case of rare metals in particular, experience and instinct about base metals alone cannot control the markets. An abundance of available information is the only way to prevent an inflow of speculative money, and holds the key of independent circulation. In addition, if Japan's domestic reserves can be maintained based on this type of data, it will potentially counteract any unforeseen disruption of supply. In the case of rare metals, unlike base metals, their supply sources are limited, and there is a possibility of creating ambiguity without sufficient data. Furthermore, since it normally takes about 10 years to develop a mine, recovering a supply is not that straightforward. Since the majority of rare metal producing nations are extremely unevenly distributed, supply companies are becoming increasingly monopolistic. In addition to this, another factor affecting supply is that the majority of metals are not available as byproducts. In particular, in response to resource nationalism, the customary, "Even though the price is a bit high, if we hand over the money we'll be able to buy." will no longer hold true from here onwards and we shall have to assume the worst case scenario: "Despite it exists, we can't get it…!" For reasons of economic incompatibilities, a need has also occurred to reexamine resource developments that are consigned to domestic resources. In order to advance this kind of argument, first of all the accurate information must be prepared.

(3) Related to (2) above, no stabilized market has been established for rare metals at the lower end of the economic scale, therefore the mechanism for setting prices is unclear. In addition, there is also no global stable market for rare metals that are consumed in small amount and in unevenly distributed areas. In this regard, the issue of rare metals such as indium and dysprosium is fundamentally different from that of base metals. For example, world leading consumers of indium such as Japan will become increasingly dependent on China in which consumption increases from here onwards. Indium is one such element that carries an extremely high mechanism of risk for Japan. In fact, at the present moment Japan is probably the only country that is troubled by a sense of growing crisis regarding the obstruction of rare metal supplies owing to these imbalances of supply and demand, and this is not a globally common problem. The problems peculiar to Japan must be addressed by the Japanese people. We must derive some sort of mechanism that can sidestep soaring prices that will at least prevent a disruption of supply even if a small fluctuation in prices occurs. For these reasons, setting up a metal exchange for rare metals in Japan is very attractive idea.

4-3 Problems to be tackled in the long term: Effective use of rare metal resources and development of substitute technologies

The above-written short-term actions are means to evade supply disruption for the time being.

However, for elements which the mid-to-long-term absolute amount is anticipated to be undersupplied, a radical rethink of materials research and development is required. From 2007, the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Economy, Trade and Industry respectively launched the 'Elements Strategy Project' and the 'Development Project on Rare Metals Substitution'. Both projects are ranked as the research on 'Innovative Technologies on Rare Resource and Scare Resource Substitute Material for Determining Solutions to Resource Issues' in the 'Strategic Emphasis on Science and Technology' which is cited in the field of 'Nanotechnology and Materials' - one of the four key fields promoting the '3rd Science and Technology Basic Plan'.[16] Relative to this research domain, the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Economy, Trade and Industry have undertaken both projects by obtaining cooperation from the public subscription stage, mentioned blow, in order to implement effective research and development through establishing a support system that can be developed over a broad range from laying the groundwork to practical utilization. It is also hoped that they will be able to cooperate in advancing the follow-up to these findings.

Ministry of Education, Culture, Sports, Science and Technology: 'Elements Strategy Project'

The purpose of this project is to develop high-functionality substances and materials, without using rare or hazardous elements, by clarifying the formation mechanism of the functions and characteristics of substances and materials. It is anticipated that the research will look into the development of substitute materials from the abundantly available harmless elements, high practical utilization of the effective function of strategic elements, and practical material design technology for the effective element utilization. These projects are to run for a five-year fundamental research period after which they are expected to advance to practical applications. In principle, they will aim for the development of complete substitution technologies and to greatly reduce the amount of rare metal element usage.

As a result of reviewing the publicly subscribed research and development project themes, seven projects shown in Table 3 have been chosen from an initial 54 candidate projects themes.[18]

Ministry of Economy, Trade and Industry: 'Development Project on Rare Metals Substitution'

This project is a part of general measure to substitute and reduce the usage amount of rare metals aiming to achieve 'Innovative Technologies on Rare Resource and Scare Resource Substitute Material for Determining Solutions to Resource Issues' together with establishing a seamless support system from the basics to full practical application. The research and development objectives, until 2011, are to establish production technologies that will enable reductions in the unit consumption of the following three types of ores to the target percentage level, and to establish technologies to an extent to be able to provide laboratory samples for the purpose of functional evaluation by external organizations such as user industries and universities, etc. In addition, it is a prerequisite that product functionality and manufacturing costs do not deteriorate from current levels. The R&D project themes include technologies for reducing the usage amounts of indium for transparent electrodes (50% reduction from present levels), dysprosium used in rare earth metal magnets (30% reduction from present levels), and tungsten used in carbide tools (30% reduction from present levels). After the public subscription of the R&D project themes, five themes were selected from the initial 11 candidates.[18]

The research and development projects mentioned above are not expected to deliver immediate results, but are essential in Japan's science and technology policies for probing intrinsic solutions to the inevitable main issues.

These undertakings need to deliver mid-to-long-term groundbreaking transformations. Because the development of substitution technologies that will enable the substitution of specific rare earth elements with other rare earth elements is not linked to the fundamental solution to solving the problems, it has not been made an objective priority. Even though there are significant difficulties to be overcome, innovative results must be aspired to.

However, due to the resistance and stability of

Table 3 : 'Strategic Elements Project' adopted assignment list

Theme	Representative organization	Participating organizations	Summary of assignment
Development of steel plate surface treatment by molten Al alloy plating in place of zinc	Tokyo Institute of Technology	Tohoku University , National Institute for Material Science, JFE Steel Corporation, Nippon Steel Corporation, Nippon Light Metal Co. Ltd.	To develop surface treatment technologies by substituting zinc with aluminum alloy. To establish surface treatment technologies by abundant harmless elements Al-Mg-(Zn, Si) alloys by active use of current technology, manufacturing facilities.
Development of next-generation non-volatile memory using aluminum anodized film	National Institute for Material Science	GIT Japan	To substitute harmful rare elements such as praseodymium, cerium, ruthenium, and bismuth, etc., to produce promising candidates for next-generation variable resistance type memory (ReRAM) by aluminum anodizing.
New hydrogen induced function in subnano-lattice materials	Tohoku University	Fukuyama University, Iwate University, Kyushu University, Research Institute for Electric and Magnetic Materials, Toyota Motor Corporation, Nippon Mining & Metals Co., Ltd., Honda R&D Co., Ltd., Asahi Engineering Corporation, Future Products Co., Ltd., Shoei Chemical Inc., Toshiba Corporation	To understand the many facets of the effects of hydrogen and to drastically improve the characteristics of Al, Cu, and Ti alloys by grain refinement using hydrogen absorption and desorption heat treatment. Also, to study new functions induced by dissolved hydrogen in subnano lattices and to pursue the possibility of applying to materials.
New excavation of nanoparticle self-generating catalysts aimed at eliminating precious metals from catalysts	Japan Atomic Energy Agency (JAEA)	Daihatsu Motor Co., Ltd., Hokko Chemical Industry Co., Ltd., Osaka University	To greatly reduce the amount of precious metals (palladium, rhodium, and platinum) used in vehicle exhaust catalytic converters and organometallic compound catalysts, and furthermore achieving elimination of precious metals from catalysts. To develop the high-catalytic function peculiar to nanoparticles for the purpose of greatly reducing the usage amount of precious metals and for final elimination of precious metals from catalysts while at the same time establishing optimum nanoparticle synthesizing technology to serve the usage environment.
Creation of barium based new giant piezoelectric effect materials for developing piezoelectric frontirers.	Yamanashi University	Tokyo Institute of Technology, Kyoto University, Tokyo University of Science, National Institute of Advanced Industrial Science and Technology (AIST), Canon Inc.	To surpass lead-based piezoelectric materials, create new barium-based giant piezoelectric effect materials that do not include not only harmful lead and bismuth but also potassium, sodium, and lithium which are unsuited to silicon processing. To pioneer new applicable fields that straddle materials, electronics, and machinery for new device development based on the technology seeds of composition phase boundary design and domain structure control.
Development of TiO_2 based transparent electrode materials as a substitute for ITO	Kanagawa Academy of Science and Technology	Tokyo University, Asahi Glass Co., Ltd., Toyoda Gosei Co., Ltd.	To establish processes for depositing films of TiO_2 based transparent conductors (TNO) on glass using established practical methods (sputtering and CVD) for the purpose of substituting ITO needed in transparent electrodes with TNO. Also, to pursue the possibilities of using TNO as transparent electrodes for blue light emitting diodes.
Development of low rare element composition high-performance, anisotropic nancomposite magnets	Hitachi Metals Ltd.	Nagoya Institute of Technology, Kyushu Institute of Technology, National Institute for Material Science	To aim at developing completely new magnetic materials with low rare earth element inclusion compositions that do not use heavy rare earth elements such as dysprosium and reduce the usage amount of rare earth elements such as neodymium. To develop high performance anisotropic nanocomposite magnets by coupling high saturation magnetic flux density soft magnetic phase with high coercivity hard magnetic phase.

Modified by the STFC based on Reference[18]

indium thin film electrodes, no substitute of indium has yet been found. In addition, since there have been no recent discoveries of magnetic materials that can surpass present permanent magnet materials such as neodymium iron boron (Nd-Fe-B) developed more than 20 years ago, even if the additive elements that improve the thermal characteristics could be effectively substituted with only other rare metals, not other than rare metals, in the future, there is still a possibility that this will not fundamentally solve the problems facing these resources. These materials may have to be reverted back to having their basic physical properties researched again from scratch. Permanent magnet materials research in particular may need to be taken back again to look at characteristics such as the coercive force and squareness ratio of permanent magnets in the research of the fundamental physical properties of these materials. In order to do this, merely taking the traditional metallurgical approach may not be enough, and it will be necessary for researchers who have a completely new way of thinking, such as using computer simulation, to radically rethink the way in which elements are perceived. These types of research are issues concerning researchers of materials, physics, and chemistry fields that are outside of the scope of the projects mentioned above.

4-4 Reviewing resource development: Land-based resources –

Global efforts are underway in reviewing resource development in order to avoid the dangers of resource nationalism by reexamining the overconcentration of resource production. While it normally takes about 10 years to develop a mine, it is vital to rethink the situation particularly for indium and dysprosium for which their applications look set to expand and the expectation of finding substitute materials is for the interim more or less hopeless.

As discussed in section 3-2, since metal mines in western countries are, mainly for business reasons, closing one after another and exploration and development activities as a whole have been on the decline for a long while. Nevertheless, until very recently, Japan was a producer of some kind of rare metals. Furthermore, the Toyoha mine (Sapporo city, Hokkaido prefecture) in Japan was one of the few world indium mines. However, the mine was closed in March 2006 because it was technologically difficult to mine above the scale at that time. The Toyoha mine produced silver, zinc, lead, and indium, and after the mine closed Japan became almost entirely reliant on overseas supplies of base metals and rare metals. In addition, apart from the closing of the Toyoha mine, other mines such as Kunitomi(Hokkaido prefecture); No. 2 Ryuo (Nagano prefecture); Ashio (Tochigi prefecture); Tohgane, Kurokawa, Umakichi (Gifu prefecture); Akenobe and Ikuno (Hyogo prefecture); and Hoei, Obira (Oita prefecture) are known to have rich deposits of indium.[19]

Resource engineering has hitherto not been able to assess the total amount (ultimately, the total amount of mineral resources that will be available for future use) of non-ferrous metal mineral resources. There are some deposits in which a lowering of the grade increases the amount of ore available and others that do not, and there are some mines such as zinc, lead, and indium mines where lowering the grade does increase the amount of ore available. Although not necessarily highly efficient, in South East Asia and South America the use of low-grade ore is progressing due to new technological developments in refining techniques.

In the example of tungsten also, in 1993 all tungsten mines in Japan were closed and by 1994 nearly all tungsten mines in western countries were also closed. However, recently, due to fears of soaring tungsten prices and overconcentration in China, mines that were once closed in North America are being reopened and new exploration developments are taking place.

By looking at the rare metal producing centers overseas, the individual operations are comparatively small-scale and are often form the mainstay of local developments. In this regard, it might be time to reconsider rare metal production as local small-scale enterprises in Japan also.

4-5 Resource development; Expectation to the development of seabed rare metal resources

An additional long-term issue facing Japan is the development of seabed resources. Although the existence of seabed mineral resources is something which has been known about since the 19th century, surveys only began in the 1950's becoming fully-fledged by the early 1970's. With the exception of oil and natural gas, the development of seabed resources – despite commercial mining having once been considered to be too cost ineffective here in Japan – has very recently been attracting a lot of interest owing to the existence of precious metals and rare elements. Compared to the size of its land, Japan has an extremely large exclusive economic zone (EEZ). These territorial waters and adjacent seamounts are understood to be endowed with an expansive cobalt-rich crust containing some of the world's highest grade platinum, cobalt, copper, and manganese. In addition, it also been proven that in the Okinawa Trough and territorial waters of Izu and Ogasawara, there are hydrothermal deposits containing gold, silver, copper, lead, zinc, and rare metals that, in terms of grade and scale, match any similar land-based mineral deposits. Japan's land-based ore deposits were originally created from hydrothermal deposits, and many of these land-based deposits were formed due to uplifts in the earth's crust. As Japan is a volcanic country, this means that it has the advantage of being surrounded by many hydrothermal ore deposits. From here on also, detailed surveys of the seabed may indicate that there is also a possibility of the continental shelf expanding further out from the economic exclusion zone.[20] Therefore, the resources of this area are also attracting attention.

Regarding the use of ocean resource, on July 20, 2007 the 'Basic Ocean Law' was implemented.[4] A basic ocean plan is currently being drawn up for January 2008. Article 4 of this 'Basic Ocean Law' sets out the enrichment of marine related scientific knowledge as: "While scientific knowledge regarding oceans is essential in order to properly conduct ocean development, utilization, and conservation of the ocean environment, scientific understanding must also be enriched given the many ocean related fields that have not been revealed." In addition, Article 17 concerning the advancement of development and utilization of ocean resources states: "The development and utilization of mineral resources such as oil, combustible natural gas, manganese ore, and cobalt ore, etc. that exist on or below the ocean floor are to be promoted and the systems and other measures necessary for advancing the developments are to be provided." The promotion of the development in the exclusive economic zone and oceanographic surveys are also cited. The development of these related technologies is reported in detail in March's edition of 'Science and Technology Trends' (2007).[20]

5 Potential of seabed minerals as rare metal resources (in particular hydrothermal deposits)

Here, the potential of Japan's seabed minerals indicated in section 4-5 are mentioned in a little more detail. The seabed resources are largely divided into three categories, as shown in Table 4.[2]

These are manganese crust (also referred to as the cobalt-rich manganese crust or the iron manganese crust), manganese nodules, and seabed hydrothermal deposits. Figure 9 shows the main categories and deposit sites of the seabed mineral resources.[2] More noteworthy are the considerable differences in the locations and water depths due

Table 4 : Important seabed mineral resources components, deposit scales and locations

Type of mineral resource		Manganese nodules	Manganese crust	Seabed hydrothermal deposits
Mineral resources details	Shape	Spherical: 1 ~ 10 cm dia.	Thickness: 1 ~ 10 cm encapsulated	Chimneys, mounds
	Main component	Iron and manganese oxide	Iron and manganese oxide	Iron, copper, zinc oxide
	Target metals	Copper, nickel	Cobalt, platinum, rare earth	Gold, silver, copper, zinc, lead
	Origin	Chemical deposition from seawater	Chemical deposition from seawater	Precipitation from high-temperature thermal waters
	Scale of deposit	~ 100 km	~ 10 km	~ 1 km
	Amount of primitive resource	500 billion t (estimated)	50 billion t (estimated)	1 million t (per site)
	Formation period	< 80 million years	< 120 million years	< 1 million years
Mineral resource existence status	Water depth range	3500 ~ 6000 m	1000 ~ 3000 m	1200 ~ 3000 m
	Ocean areas	Pacific Ocean, Indian Ocean	Western Pacific Ocean	Mid-oceanic ridge 284, island arc 58
	Geological environment	Slow sedimentation rate, deep seabed	Exposed rock area of seamounts and plateaus	Mid-ocean ridge and island arc volcanoes
	Relationship to EEZ	Outer international waters	Japan's EEZ and international waters	Japan's EEZ and international waters
Development status of exploration methods		On-site testing completed	Undeveloped	Venture companies investigating

Modified by the STFC based on Reference[2]

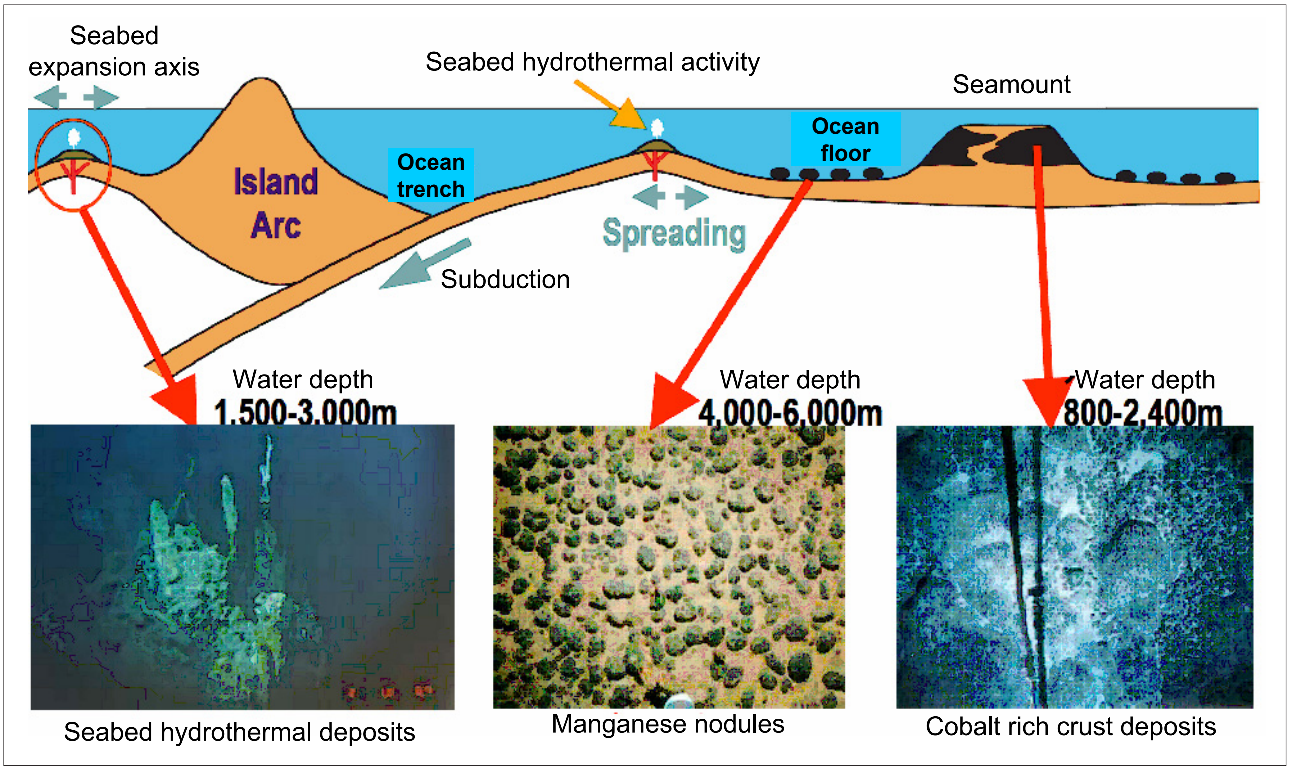


Figure 9 : Main types of seabed mineral resources and deposit sites

Source: Reference[2] (JOGMEC data modified by the STFC)

to various causes of formation. Figure 10 shows the distribution of seabed mineral resources in the Pacific Ocean.[21]

The existence of manganese crust and manganese nodules has been known about from a comparatively long time ago, and these have been vigorously surveyed and mining has been investigated. However as they are in deep seas, they will cost an enormous sum of money that is concluded to be incalculable to develop as a resource. Also, the high-grade manganese nodules are in international waters.

On the other hand, the seabed hydrothermal deposits, referred to as 'chimneys' and 'mounds', are a comparatively recent discovery, and as of yet, they have not been well surveyed. These exist on moderately shallow seabeds and are high-grade mineral resources. In addition, since these are regenerative deposits that can be repeatedly mined and, as the resource developments are anticipated to be profitable, foreign venture companies have already started developmental work.

Because hydrothermal deposits are formed over a comparatively short time period lasting only several decades, even after they have been mined there is a possibility of being able to re-excavate them after several decades. While seabed mineral resources are naturally more difficult to mine than land-based deposits, the possibility of repeatable mining is an incentive for development. The hydrothermal deposits are made up from iron, copper, and zinc sulfides whose composites are quite different from manganese crusts and manganese nodules. The important factor is that they contain precious metals such as gold and silver, etc. In addition, since these also contain copper, lead, and zinc, it is anticipated that they may also contain rare metals such as indium, etc. Japan's land-based mines are also considered to originate from hydrothermal deposits on the ocean floor. By looking at their existing locations, up to now there are approximately 300 seabed hydrothermal deposits that are known around the world, and many also exist within Japan's exclusive economic zone. Japan's outlying seamounts are said to contain particular large quantities of gold and silver and have the advantage of being located in comparatively shallow sites. In addition, due to the extension of the continental shelf,[20] the range of speculative exploration is expected to increase.

The seabed hydrothermal deposits that have up until now been discovered in the seas around Japan

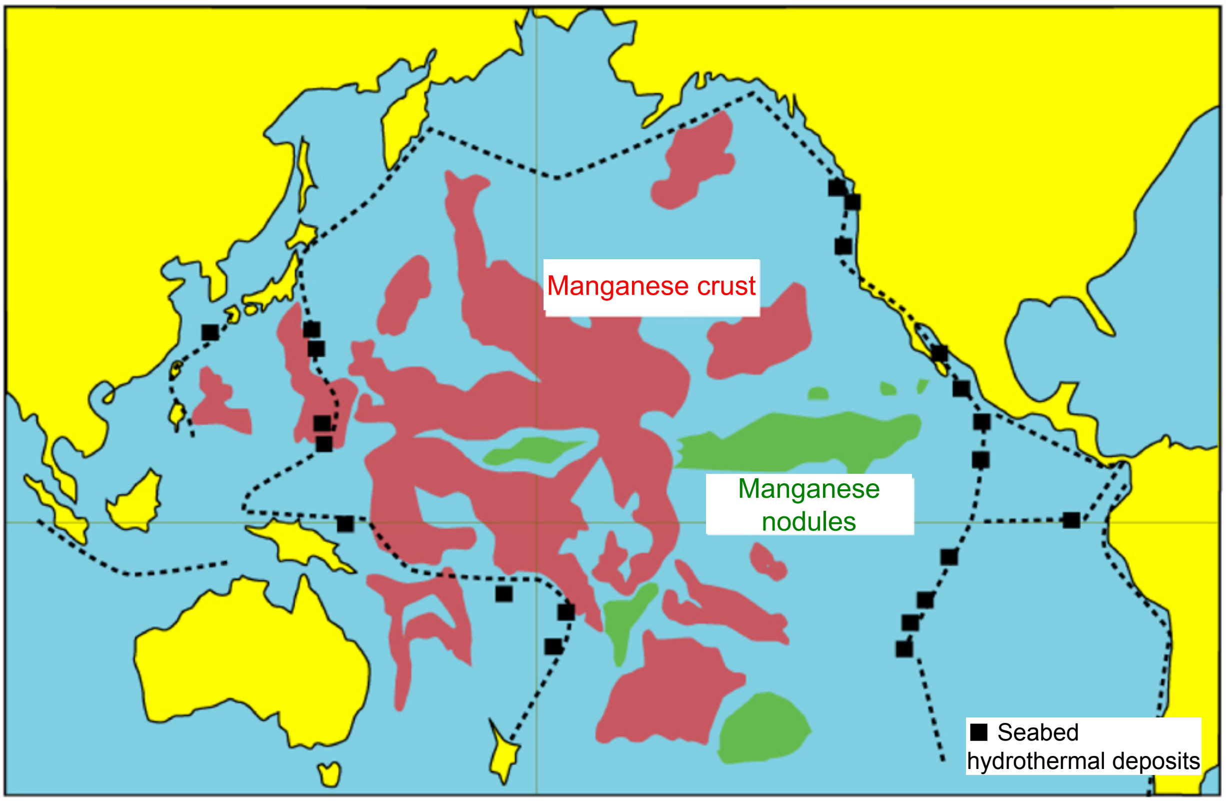


Figure 10 : Distribution of seabed mineral resources in the Pacific Ocean

Source: Reference[21]

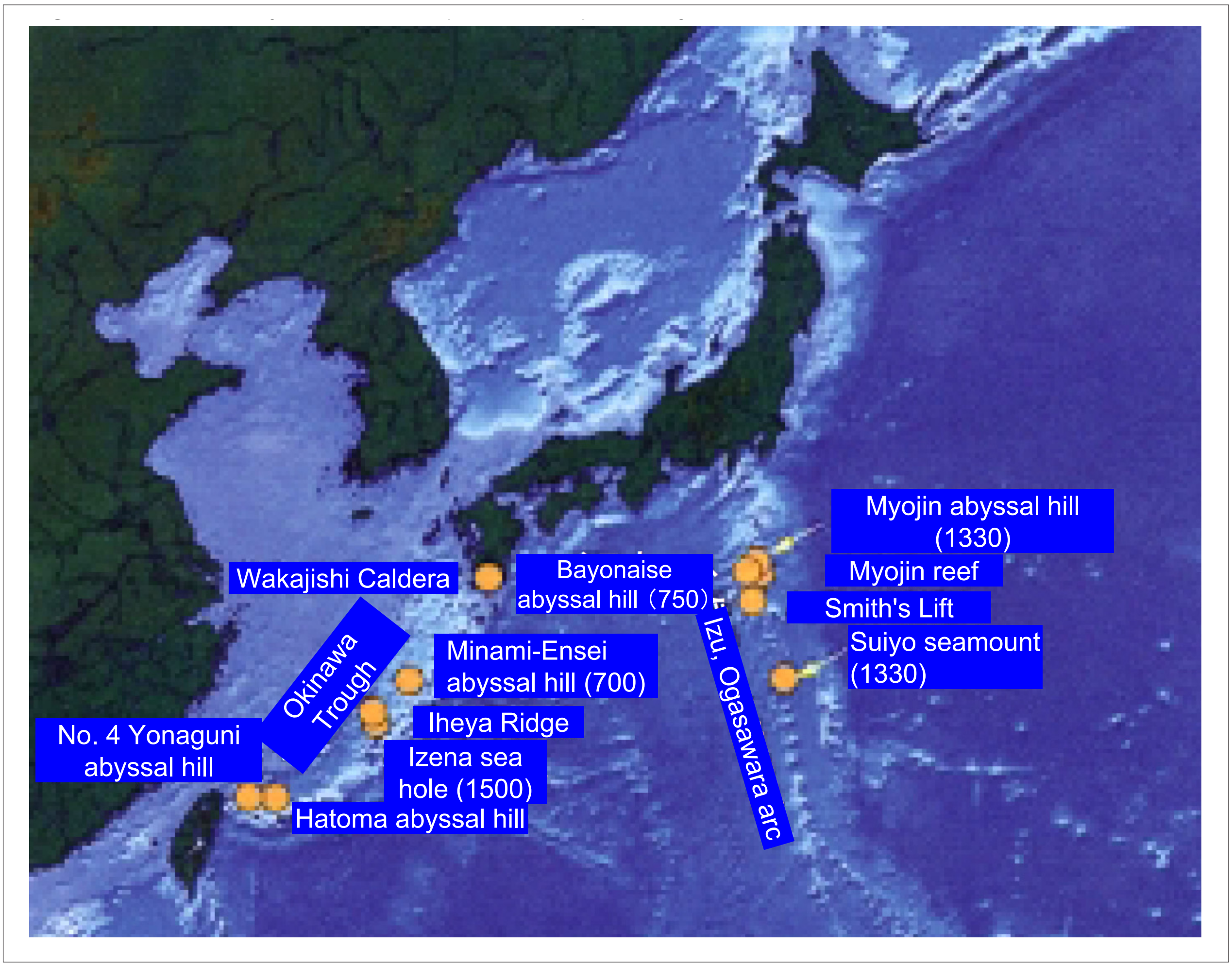
are shown in Figure 11.[21, 22] The Pacific Ocean hydrothermal deposits are found almost entirely in the mid-ocean ridge in relatively deep locations in comparison to Japan's exclusive economic zone. On the other hand, since Japan's outlying seabed hydrothermal deposits contain high quantities of gold and silver, as mentioned previously, and they are located in shallow places, that attracted a remarkable amount of interest of foreign venture companies and they have recently started applying for mining lots. The places that are attracting most interest in Japan's outlying waters are the hydrothermal areas of the Sunrise deposit, Hakurei deposit, and Okinawa's Izena hydrothermal holes. Presently, acting under the direction of the Agency for Natural Resources and Energy, resource surveys by JOGMEC are underway by commissioning the No.2 Hakurei-maru fitted with seabed excavation equipment. To ascertain the amount of reserves from the amount of deposits will require continuous surveying by concentrated boring in order to ascertain the depth and horizontal spread. If these surveys progress, it is likely that private sector companies will be able to decide whether or not to commit. The methods of lifting ore from the seabed will become developed as a mining technology. Although there are many other technological issues such as pollution control and metallurgical techniques, together with larger economic issues, the systematic excavation of a number of hydrothermal ore deposits once the system has been established will be possible. However, because many rare species of living organisms have also been discovered in the hydrothermal deposit fields, there is also interest in researching the origins of life on the earth. From the survey stage of investigating exploration methods, adjustments may have to be made in relation to accommodating research into these living organisms.

6 Conclusions

The matters that this article wishes to emphasize are as follows.

Securing functioning market

As the international market function operates for base metals, even though there may be temporary price hikes, there is a high possibility that given time a balance of supply and demand



Note: The numerical data in parentheses ( ) indicates the depth (m) of mineral endowment of the hydrothermal deposits

Figure 11 : Seabed hydrothermal deposits of Japan's adjacent seas

Modified by the STFC based on the images published in Reference[21,22]

can be achieved. However, there are no healthy functioning international markets for quantitatively or regionally scarce rare earth elements. For example, because indium and dysprosium, etc., are elements which hold interest only in Asian countries, there is no scheme to achieve a naturally stabilized international market. For these several types of rare metals, even though the suppliers and consumers are relatively limited, Japan should consider taking the lead in securing a small-scale functional market capability.

Rethink towards Japan's land-based resource development

The overall scale of the world's rare earth market is primarily small. Taking a global perspective of mining developments, because reserves in each region are small, large-scale development is unnecessary. While diversification of risk is important for the resource supply origins, under these sorts of conditions there is enormous scope for rethinking rare metal resource developments as small-scale local industries for Japan's land-based and coastal rare earth resources.

Exploration of seabed mineral resources and creating a business scheme

The exploration of seabed mineral resources is a field in which Japan should become a world leader through its geological advantage of being a volcanic archipelago nation. By investigating business models such as private sector venture capital funding and NPO contributions, etc., once this type of scheme has been established, an entirely new research mechanism needs to be considered in order to simultaneously facilitate a scientific exploration of seabed resources. For those that will be able to establish such mechanisms, it is worth for states considering offering support in the form of priority free-of-charge equipment loans, etc.

Material science research based on extensive findings

If innovative materials such as thin-film electrode materials that are not indium based or permanent magnet materials that are not Nd-Fe-B based are found to exist, then it is hoped that Japan will be the first country to discover these materials. For material technology fields which have guaranteed future large markets, such as displays and hybrid cars, we would like see Japan become a world leader in making free use of material scientific techniques that have reverted back to fundamental condensed matter physics.

Researchers who are engaged in material science can no longer be disinterested in the supply and demand of resources concerning the components from which certain materials are constructed. Materials researchers will not be able to merely focus on individual substances and materials,but they will need to consider a wider range of substances and materials that will incorporate the demands of research findings and a stable supply of resources. At the very least, there will be very little possibility of developing research in target applications utilizing large quantities of substances or materials that are not estimated to exist in quantitatively adequate resources or to be available through a guaranteed stable supply. Research utilizing substances or materials for which the supply is uncertain will have to search for potential substitute materials that are more readily available. It is inevitable that the later will supersede the former. Researchers who are engaged in material science will have to become involved in reforming the disruptive innovations of past findings without becoming fixated on temporal research results perse.

Acknowledgments

This article is written based on the subject of the lecture: "Development of Seabed Rare Mineral Resources and Japan's Strategy" by Professor Tetsuro Urabe, School of Science, The University of Tokyo that took place at the meeting of National Institute of Science and Technology Policy on July 3rd 2007. Further studies relating to mineral resources policies, the effective utilization of resources and development of substitution technologies as activities concerning the future stable supply of rare metal resources has been added and summarized at the Science & Technology Foresight Center. I would like to thank Professor Tetsuro Urabe for providing information.

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(Original Japanese version: published in October 2007)

5

New Problems in the Study of Disaster Prevention Based on Disaster Risk Governance

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1 Introduction

Recently in Japan, earthquakes causing heavy damage occur frequently in areas with low probabilities of occurrence. There is also an imminent danger of the occurrence of large-scale earthquakes in Tokai, Tonankai, Nankai, and Minamikanto regions, and those with an epicenter in metropolitan Tokyo. The Intergovernmental Panel on Climate Change (IPCC) predicts that flood and storm damage caused by global climate changes like earth warming will increase. It also forecasts that the risks of tsunamis, storm surges, volcanic eruptions, snows and ice, tornadoes, etc. will be unavoidable, indicating that some regions may need to take measures to control multi-hazard risks. Combined with increasing uncertainty about disaster risks as mentioned above, changes in social structures, such as a rapidly aging population, a declining birthrate, and weakening communities, are pressing us to revolutionize existing disaster prevention policies and strategies.

Learning a lesson from the repeated occurrence of unpredicted disasters, Japan has been changing the concept of its disaster prevention policy from preventing (avoiding) damage to mitigating (reducing) it by taking pre-/post-measures against disasters on the premise that disasters inevitably happen. Disaster measures are also shifting from conventional measures focusing on structures (hardware approaches) to the development of evacuation systems and emergency response measures (software approaches). Changes in social structures including a rapidly aging population, a declining birthrate, and urbanization have been forcing us to recognize the importance of integrated pre-/post-disaster prevention policies with the objectives of recovering local economies and communities in damaged areas and increasing the possibility of restoring the normal lives of individuals and families.

A disaster resilient society is the one where society members understand, without assuming "zero risk," disaster risks characterized by uncertainty and determine acceptable risk levels, based on which various major concerned bodies constituting the society take appropriate measures and cooperate with each other to perform disaster reduction activities.

The restructuring of disaster prevention policies thus requires to take full account of the uncertainty of disaster risks, individual and social vulnerability to them, mid- and long-term resilience to reconstruct communities and restore lives, social and individual diversity, and interdependence between society, economy, culture and tradition.

This paper hence analyzes the current problems of disaster prevention policies from the viewpoint of constructing a disaster-resilient society, premised on changes in social structures and various factors to be considered in disaster prevention policies. It also outlines the context and the basic concept of "disaster risk governance" we are proposing as a new framework for innovative disaster prevention policies. It then describes our proposed direction of research and development on the disaster reduction technology integrated with the social science, focusing on disaster risk information in particular. This paper proposes disaster risk governance as the "cooperative administration of disaster risks through social interactions between various major concerned bodies (risk communication based on disaster risk information) and the formation of social networks."

2 Current situation and problems of Japanese disaster prevention policies—seen from the viewpoint of disaster risk governance

2-1 Systems for disaster prevention planning and their current situation

Based on the "Basic Law on Disaster Management" and relevant laws, Japanese disaster measures are taken at each of the following stages: disaster prevention, emergency disaster response, and disaster recovery. The Central Disaster Prevention Council developed the highest-level plan, the "Basic Plan for Disaster Prevention," according to the Basic Law (Figure 1). The Basic Plan indicates basic policies for priority issues in establishing disaster prevention systems, facilitating and optimizing disaster recovery, encouraging sciences and technologies as well as research on disaster prevention, disaster prevention services, and local disaster prevention plans.

As to imminent large-scale disasters in particular, the plan assumed damage, developed disaster prevention strategies, and set a disaster reduction target for each case (Figure 2). The disaster prevention strategy for Tokyo metropolitan epicentral earthquakes,[1] for example, assumes that the worst case (wind velocity 15 m/s) causes a human damage of about 11,000 persons and an economic loss of about 112 trillion yen, setting a disaster reduction target of 50% and 40% in 10 years, respectively. The strategy lists actual problems to be solved to achieve the targets. Those for reducing human damage are the seismic retrofitting of housing and buildings, fire measures, and the maintenance of dense urban. Those for reducing economic loss are the measures to reduce disaster recovery costs, the continuation of business operations, and the measures to quickly recover traffic networks.

At prefectural and municipal levels, disaster prevention councils consisting of the heads or their designated staff members of local public bodies, designated local administrative agencies, police and fire departments, and designated public institutions have been formed in prefectures and municipalities. Various disaster measures are taken based on the community disaster prevention plans developed by these councils.

Disaster prevention plans prepared by the Government and local public bodies include, however, no actual measures taking account of individual lifestyles, family relations, and the diversity of communities. Some of local public bodies have set up action programs for disaster prevention in addition to community disaster prevention plans based on the Basic Law on Disaster Management, expecting to add concreteness, flexibility, and effectiveness to the plans. The actual examples of these programs include pre-disaster measures such as making a list of human resources with skills in disaster prevention and making a system for collecting disaster damage information with the help of bike-riding residents. Community disaster prevention plans based on the Basic Law thus tend to give a formal description and lack concreteness and effectiveness. The development of new planning techniques including the creation of action programs for disaster prevention is needed to compensate the shortcomings of such plans.

2-2 Necessity of multiple networks

(1) Encouragement of voluntary disaster prevention activities

The Basic Law on Disaster Management encourages community members to voluntarily participate in disaster prevention activities. It also calls on the Government and local public bodies to foster voluntary disaster prevention organizations (voluntary organizations based on the spirit of mutual aid among neighbors), to improve the environment for the voluntary activities of disaster prevention, and to promote voluntary disaster prevention activities by community members. The Law defines Japanese disaster management on the premise of the comprehensive and integrated efforts of various major concerned bodies as well as administrative agencies. According to the White Paper on Disaster Management 2007, the disaster prevention agencies of central and local governments have been working in close cooperation with each other to establish systems for information collection, communication, and wide area response operations.

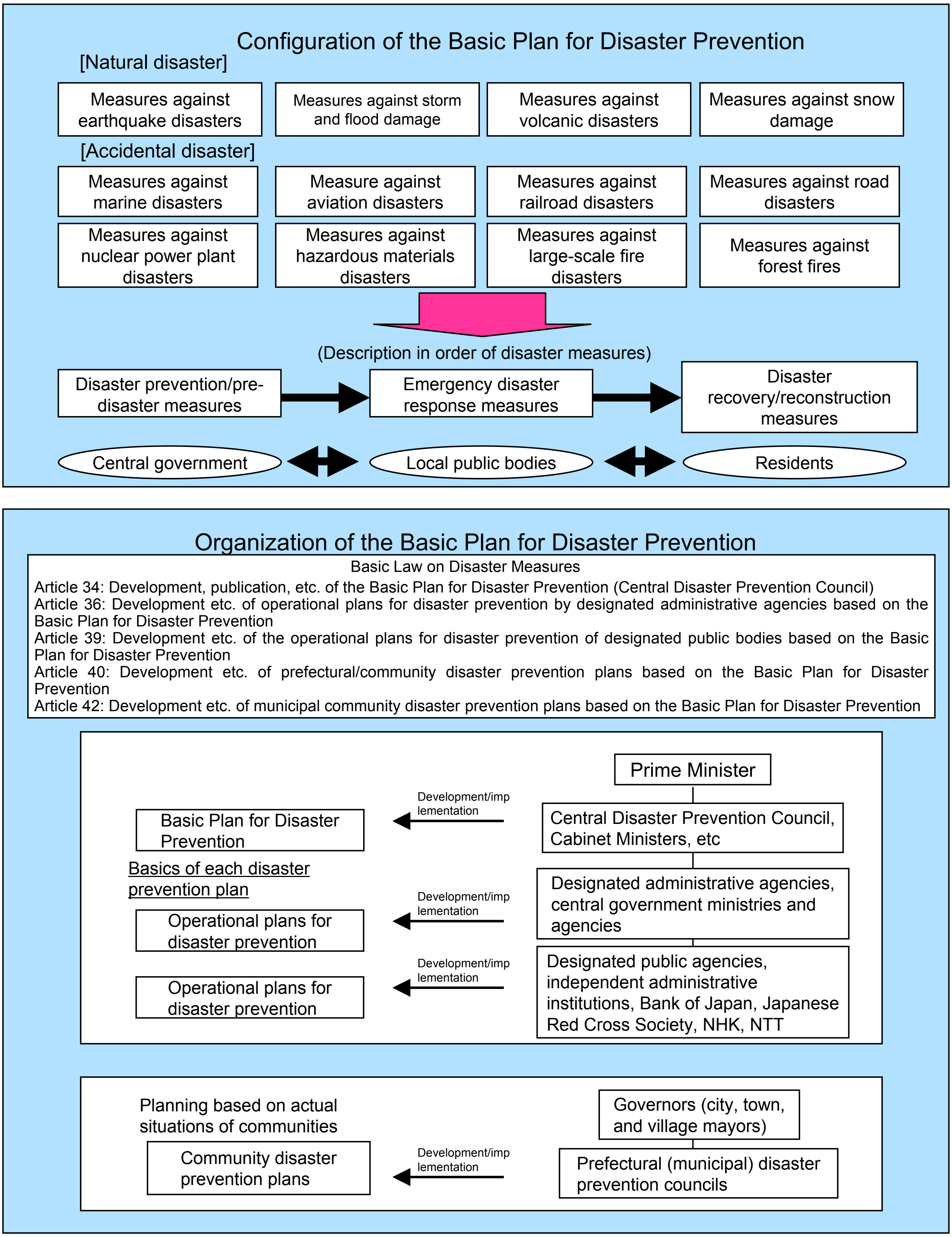

Figure 1 : Configuration and organization of Japanese disaster prevention plan

Source: White Paper on Disaster Management 2007

In the current situation, however, individuals, communities, administrative agencies, NPOs, and other related organizations have fixed roles in society and are acting independently with insufficient results. For example, local public bodies have started developing a system for confirming the safety and supporting the evacuation of people who need care at the time

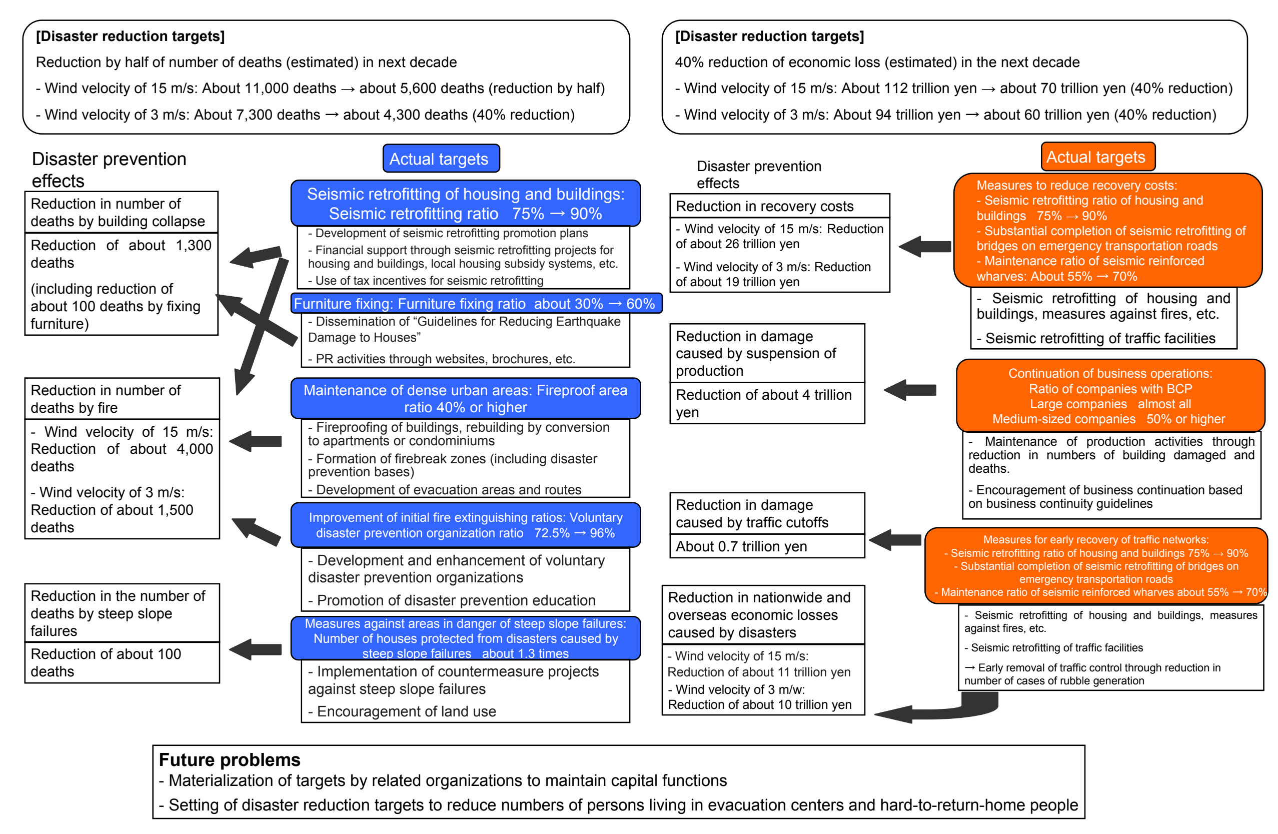

Figure 2 : Disaster prevention strategy for Tokyo metropolitan epicentral earthquakes

Source: White Paper on Disaster Management 2007

of disaster time, using a guideline[2] prepared by the Government. And nationwide municipalities have started making a list of them. Some of them, however, have not yet built a system for the safety confirmation and evacuation support. Even in the areas trying to establish their support systems, there is hardly any community that has set up a system consisting of multiple social networks including daytime working people in the communities concerned and conducted drills for emergencies. As described above, current disaster management systems are not designed well to cope with multiple social structures.

(2) Current situation and problems of voluntary disaster prevention organizations

According to the "Current Situation of Community Disaster Prevention Administration,"[3] the national average of the organization rates of voluntary disaster prevention organizations consisting of neighborhood associations or residents associations as a unit (as of April 1, 2005) was 64.5%. Even in Shizuoka Prefecture with the highest organization rate (98.5%), there are some districts where voluntary disaster prevention activities like evacuation drills are uniform and routine. Voluntary disaster prevention activities based on relations within a community tend to become a mere name all over the country as the aging of society progresses. On the other hand, expectation for the roles of voluntary disaster prevention organizations is increasing. Such organizations are expected to confirm safety, perform rescue activities, and operate evacuation centers at the time of disaster. They are also expected to play various roles at ordinary times, such as to create disaster prevention maps, cooperate with public institutions to develop disaster prevention action programs based on assumed damage specific to the communities concerned, and pass on the experiences of disasters and the knowledge of disaster management (disaster cultures) to the next generation. Networking to support the various roles of voluntary disaster prevention organizations and the establishment of information sharing environment to enhance the knowledge management capabilities of communities will be essential in the future.

(3) Establishment of the environment for disaster prevention activities through multiple networks

In recent years, disaster relief volunteers aiding victims have been significantly contributing to disaster recovery. The Basic Law on Disaster Management (revised in December 1995) and the Basic Plan for Disaster Prevention (revised in July 1995) incorporated disaster relief activities by volunteers in disaster management policies. As a result, local public bodies have been positioning disaster relief volunteers in their community disaster prevention plans, cooperating with Councils of Social Welfare, NPOs, and other organizations to develop the contact points for volunteers (volunteer centers). The "Basic Policy on the Promotion of National Campaign to Reduce Disaster Damage"[4] indicates the importance of the establishment of local networks participated by various organizations such as Government agencies, local governments, schools, community centers, PTAs, enterprises, and volunteer organizations. Some communities set up an NPO participated by administrative agencies, medical institutions, a Council of Social Welfare, private businesses, voluntary disaster prevention organizations, residents associations, local media (community FM stations and CATVs) to establish disaster relief networks, operating volunteer centers at the time of disaster, as well as supporting the voluntary disaster prevention activities at ordinary times. At a disaster area (Hojo District) in Kashiwazaki City struck by the recently occurred Niigataken Chuetsu-oki Earthquake, a community organization for lifelong education took the initiative in forming a private-public joint disaster prevention network with voluntary disaster prevention organizations, community action groups, the local government, the Self-Defense Forces, and the fire department. Some districts are performing wide-area voluntary disaster prevention activities setting elementary or middle school district as a unit. While such pioneering activities have been gradually spreading nationwide, the establishment of the environment to support these social networks in performing disaster reduction activities has emerged as a new challenge for disaster prevention policies.

To reinforce emergency response and recovery activities at the time of large-scale disaster, local governments have an emergency assistance agreement on medical care, food, materials, information, and recovery activities with private businesses and industrial associations. Some Contractors Associations, for example, have an agreement (onerous) to send heavy machines and operators for emergency recovery operations. Various agreements, such as to supply the distribution stock of fresh food to supermarkets and cooperative societies in place of emergency food stock, are concluded. An example of information-related agreement is to produce educational programs for increasing disaster awareness at ordinary times as well as to broadcast disaster information at the time of disaster. There are cases where local governments have mutual assistance agreements with each other to prepare for massive emergency response and recovery operations and continue administrative services. To ensure the effectiveness of these wide-ranging disaster prevention agreements, however, a common understanding of circumstances among related parties including voluntary disaster prevention organizations and disaster volunteers in general, as well as information sharing among the parties concerned with the agreements, is essential. Building cooperative mechanism between various major concerned bodies based on information sharing is hence important as part of disaster prevention policies.

(4) Comprehensive restructuring of residents associations

Comprehensive restructuring of residents associations beyond limited relations within a community will become important to increase the disaster prevention capabilities of communities through multiple social networks and administrative agencies for disaster prevention.

The "Basic Proposals on Disaster Prevention Strategies Taking Advantage of the Power of the Private Sector and the Market"[5] prepared by the "Expert Study Group on Improving Disaster Prevention Capabilities Taking Advantage of the Power of the Private Sector and the Market," a subsidiary organization of the Central Disaster Prevention Council, suggested that, in addition to efforts aiming primarily at preventing disasters, activities like community renovation would

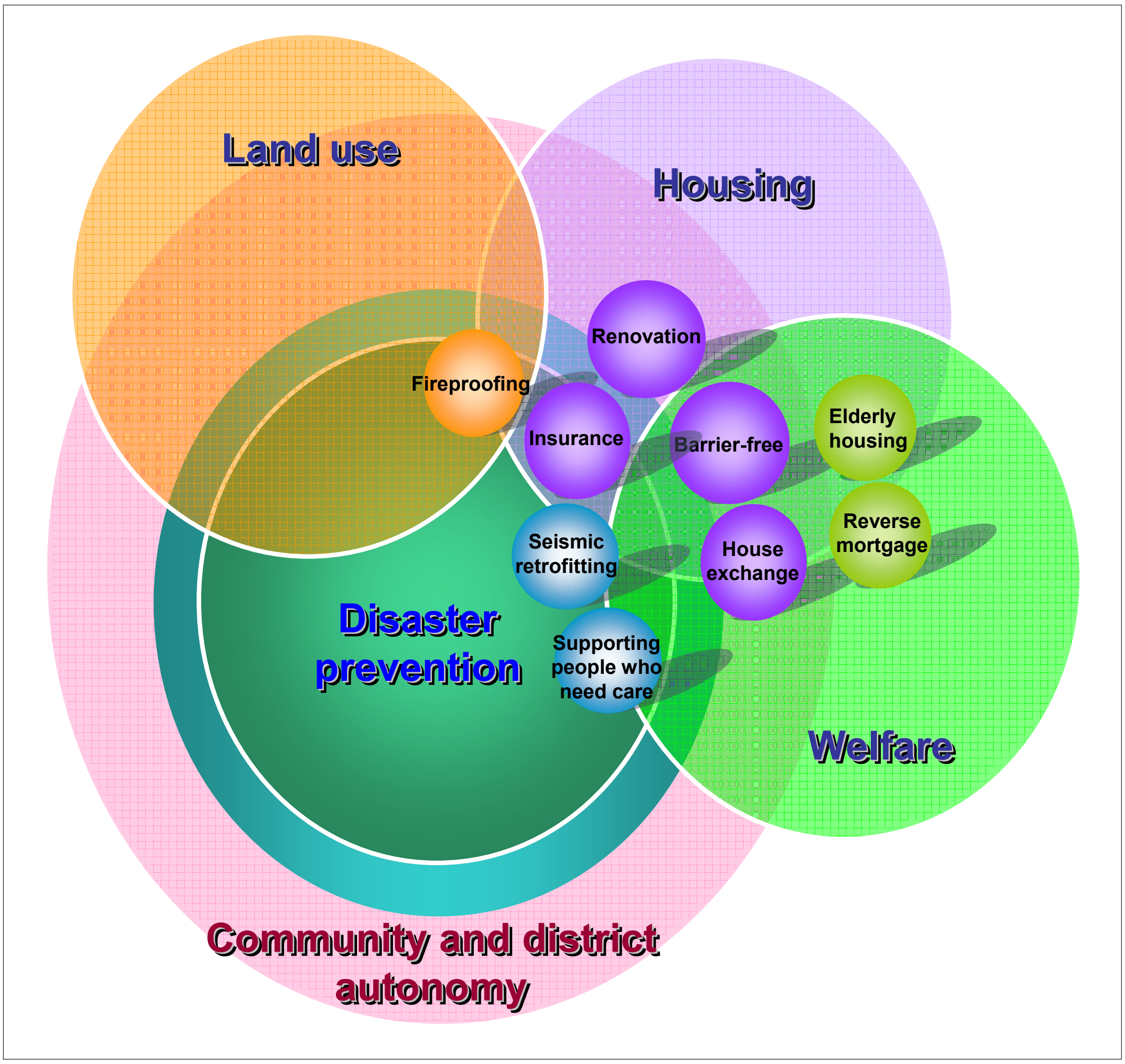

Figure 3 : Linkages between disaster prevention policies and other related policies (case of seismic retrofitting of housing)

Source: National Research Institute for Earth Science and Disaster Prevention

increase the capabilities of individuals and communities, change communities, and improve their disaster prevention capabilities. The disaster prevention strategies should hence be modified to increase community disaster prevention capabilities, which are primarily of voluntary disaster prevention organizations, to encourage the comprehensive activities of regional organizations to find and solve community problems, and to use multiple social networks covering various life areas.

2-3 Comprehensiveness and integrity of disaster prevention policies

(1) Current situation on the comprehensiveness and integrity of disaster prevention policies

Disaster prevention policies must cover not only a framework of so-called disaster prevention administration but also multiple policy areas related to all life areas of residents (Figure 3). The current disaster prevention administration deals with pre-disaster measures such as to accelerate the seismic retrofitting of housing, expand voluntary disaster prevention organizations, establish activity environment for disaster prevention volunteers, and develop business continuation plans. To reduce social vulnerability and help disaster victims restore normal life, however, the future administration will need to link disaster prevention policies with wide policy areas for normal times including housing policies, urban planning, community policies, welfare policies, policies to promote civil activities, commercial policies, and industrial policies.

As for post-disaster measures, the Government and local governments have abandoned the idea of simply restoring things to their original state. They are instead taking various measures including legal, tax, and budgetary incentives to systematically implement regional development programs, reconstruct disaster areas in a planned way, restore the lives of victims, secure housing, and recover regional economies. These measures are carried out in coordination with policies in areas other than disaster prevention.

Systematic and comprehensive assessment on Japanese disaster prevention policies should be performed separately. As far as the framework of the Basic Law, the planning system, and the trends of the policies are concerned, they are comprehensive and integrated to some extent. Looking at them from the viewpoints of disaster-affected people and response to uncertainty, however, each of disaster measures of administrative agencies, communities, and individuals is insufficient. In the case of individuals, for example, they do not always use distributed hazard maps for evacuation, sometimes throwing them away. Many local governments have neither publicized information on evacuation routes nor performed evacuation drills. Creating better hazard maps and indicating evacuation routes in an easy-to-understand way are the problems that administrative agencies and experts are facing. They are also related to personal risk literacy, disaster psychology, and the tradition of disaster experiences. People often want to find economic, traditional, or cultural reasons for moving house and choosing a site. The Government and local public bodies therefore should not one-sidedly offer hazard maps and information on their use, but should attach importance to risk communication (mutual learning process by various stakeholders through discussions and deliberations on risk information) and comprehensively take account of social and economic vulnerability and cultural value, before taking comprehensive and integrated measures to ensure the effectiveness of disaster prevention policies.

(2) Examples of the seismic retrofitting of housing

Using the policies for the seismic retrofitting of housing as case examples, the below describes actual problems on the comprehensiveness and integrity of the disaster prevention policies mentioned above. The Central Disaster Prevention Council estimates that about 11.5 million houses, 25% of a total number of about 47 million houses in the country, have insufficient earthquake resistance. In September 2005, the Council decided the Government's "Policy on Emergency Measures for the Seismic Retrofitting of Buildings."[6] The Governments set the national target of achieving a seismic retrofitting ratio of 90% by the end of the next decade, expanded the subsidy systems for seismic assessment and seismic retrofitting, and introduced tax benefits including housing loan tax credits and the reduction of income taxes and fixed property taxes for households performing seismic retrofitting. Low-interest financing by Japan Housing Finance Agency and other financial institutions and the premium discounts (a maximum of 30%) of earthquake insurance based on the ratings specified by the "Housing Performance Indication System" (introduced in 2000) became available. The Revised Implementing Regulations of the Building Lots and Buildings Transaction Business Law (2006) obligate real estate dealers to disclose the results of seismic assessment and housing performance assessment as important information to the purchaser or the tenant of the building concerned when such assessments are made. The primary subjects of these policies are house owners and housing suppliers in general.

From the viewpoints of various residents, a policy to accelerate seismic retrofitting in conjunction with the rebuilding of old houses or barrier-free renovation may be effective to ensure the safety of housing and to improve the quality of life. To implement the policy, the construction of systems to provide information on financing methods for seismic retrofitting (e.g. reverse mortgage, financing systems for the reconstruction of old apartments, etc.) will be essential. According to the "Special Opinion Survey on Earthquake Disaster Measures" (2007) conducted by the Cabinet Office, many respondents gave reasons like financial difficulties, being a tenant, etc. for not performing seismic retrofitting. Although local governments subsidize for seismic retrofitting costs, they have no measures for tenants (Figure 4).

Policies to encourage the tenants who have been living in rental houses built on the old earthquake resistance standards to move house are also effective. In addition to seismic retrofitting polices premised on continuing to live in the same house, providing comprehensive housing information on

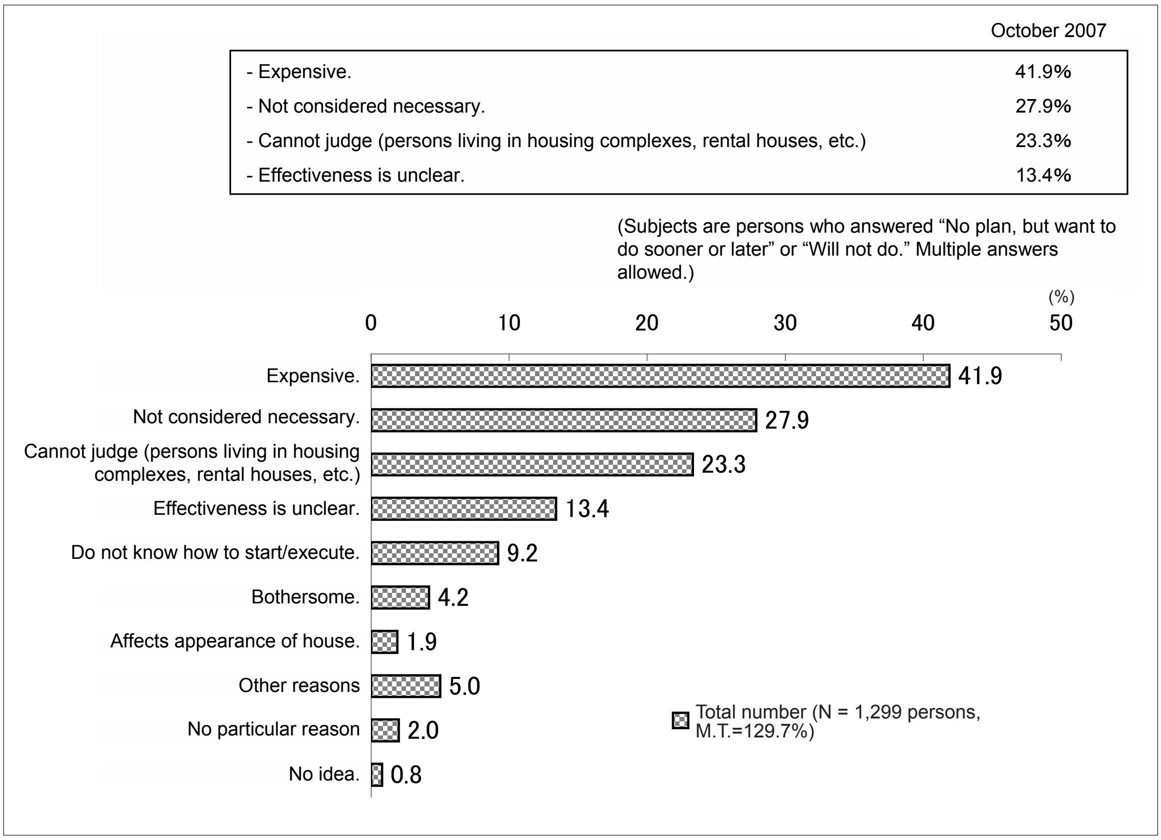

Figure 4 : Reasons for resistance to seismic retrofitting work

Source: Summary of "Special Opinion Survey on Earthquake Disaster Prevention Measures" (Cabinet Office, November 2007)

various ways of living according to life styles and stages, such as moving house by using public rental housing systems and a move to an apartment with care or a group home for seniors, will be effective from the viewpoint of disaster prevention. The current websites operated by local public bodies, however, hardly provide such information. These comprehensive information services and consulting systems will become available only through the networking of local governments, central governments, and private-sector organizations.

Solving the problems requires taking advantage of various measures in policy areas other than disaster prevention from the viewpoints of various residents, in combination with the services of private businesses and those of the nonprofit sectors of NPOs. It is desirable, for example, that the Cabinet Office, the National Research Institute for Earth Science and Disaster Prevention, and local governments cooperate in developing guidelines for house builders, building contractors, and real estate agents to follow when providing to their customers the disaster risk information, such as hazard maps and historical disaster maps, created and provided by administrative agencies. It is also desirable to develop an incentive system that the market assesses the provision of appropriate disaster risk information by private businesses as their contribution of society. The asymmetry of information between private businesses and consumers should be considered when providing the disaster risk information.

(3) Examples of systems to help disaster victims restore normal life

The comprehensiveness and integrity of disaster policies are also required for policies on systems to help disaster victims restore normal life following disasters. The current Japanese system is based on the Law to Help Disaster Victims Restore Normal Life enacted in 1998 as legislation introduced by Diet members. The law aims to help natural disaster victims start an independent life by providing them with aid money. The intended victims are those who have difficulty restoring normal life by themselves due to damaged infrastructures and economic reasons. In July 2007, the Cabinet Office published "An Interim Report of Review Meeting on Systems to Help Disaster Victims Restore Normal Life,"[7] a summary of discussions toward the revision of the law. After going through these discussions, the Revised Law to Help Disaster Victims Restore Normal Life was enacted in the 168th extraordinary Diet session convened in 2007. The Revised Law enables the Government to provide disaster victims with cash as a token of sympathy on a fixed amount basis according to housing reconstruction methods (a maximum of 3 million yen), without limiting the use of money. The disaster victims are allowed to use aid money for the construction of a new house or the purchase of a house. Annual income and age limits to receive money were removed (before the revision, annual income limit was not more than 5 million yen in principle).

Before the interim report was published, the discussion point was whether to support housing construction (use of taxpayers' money to restore private property). Another discussion point was whether to fix the amount taking account of self-help efforts such as pre-disaster measures like seismic retrofitting and buying earthquake insurance, self-financing ability to restore normal life, and so on. The law is, however, only partly useful in helping disaster victims restore normal life. The Government should hence design a comprehensive support system that includes an incentive to encourage self-support efforts and acts as a safety network after assessing the social and economic vulnerability and the mid- and long-term difficulties in restoring normal life of disaster victims and affected areas.

3 Aim of disaster risk governance

3-1 Necessity of disaster risk governance

As described in Section 2-2, the current Basic Law on Disaster Management as a basis for forming a framework of disaster prevention policies stipulates the role and responsibility of the measures taken by disaster prevention agencies (public support, government support), of those based on the self-responsibility of individuals, households, and enterprises (self support), and of those taken by communities and volunteer networks (mutual support). Although the Basic Law assumes the diversity of major concerned bodies, actual disaster prevention policies are centered on public support. Concerns about excessive dependence on public support are hence expressed. As for measures against infrequent large-scale disaster risks in particular, disaster prevention plans and measures centered on disaster prevention policies based on the hierarchy system are insufficient, and therefore, research and development on social technologies to integrate the measures with mutual support efforts in communities is essential.

An international mainstream approach in disaster prevention policies is to systematize disaster measures as an integrated risk management system.[8] The South Hyogo Prefecture Earthquake in 1995 was a good opportunity for Japanese people to recognize the necessity of a standard framework for continuous risk reduction based on the PDCA cycle. The framework was standardized as JISQ2001 "Guidelines for Building Risk Management Systems." The standard was at first developed as the one for crisis management focusing on emergency responses immediately after the outbreak of crisis, but was later expanded to include pre-disaster and recovery measures. It covers the risk reduction of not only concerned parties like enterprises and local governments but also others including consumers, residents, stakeholders, and business connections. The risk management systems are, however, extremely weak in creating multiple networks because they rely on top-down internal control.

The concept of "disaster risk governance" is hence needed as a new framework to complement the weakness of risk management systems and build horizontal social networks and disaster measures based on the networks.

3-2 Trends of governance arguments in various policy areas

In Japan and other countries, major concerned bodies in the production and supply of public services have recently diversified. It is pointed out that administrative agencies have been changing their way of policy implementation to form and maintain networks with enterprises and NPOs.[9] Traditional governance performed by the Government and local public bodies are changing to cooperative governance and coordination involving various major concerned bodies. This trend is called "from governance to governance" in the filed of public administration. In the USA and UK, empirical discussions and analyses on the effectiveness of governance through the multiple networks led by administrative agencies are being made.[10, 11]

With a growing trend toward decentralization in Japan, the subsidiarity principle (principle that policy decision and implementation should be made at levels closer to the residents and communities affected by it) on the sharing of roles of the Government and local governments has been extended to arguments about governance inside local governments. Subcontracting and designated management have become popular between local governments and various major concerned bodies in communities. Many parts of the country have started to adopt cooperation systems between residents associations and NPOs, as the intention of autonomous ordinances.[12]

3-3 General definition of risk governance

Expanding the concept of risk management, the field of general risk study uses a terminology of "risk governance" to address new technologies and environmental risks. Chapter 9 "Risk Governance as a New Trend of Addressing Risks" of "Handbook of Risk Research, Revised and Enlarged Edition" defines it as "the concept indicating the direction of new management to address social risk problems that, in place of regularly institutionalized governance, diversified and decentralized parties make coordination and decision called "joint governance or cooperative governance" through various networks and organizations (international, national, local governments, communities, NPOs, etc.) while keeping their autonomy and emergence."[13]

International Risk Governance Council, a Switzerland-based private-sector network for international risk governance, proposed an integrated analysis framework for risk governance with the objective of providing a guideline for developing a comprehensive risk analysis and management strategy to deal with risks including natural disasters.[14] The framework emphasizes the importance of the way of effective involvement of stakeholders, risk-benefit relations, and trade-off between risks, as well as the scientific, social, and cultural aspects of risks. Such approaches are appreciated as the efforts to clarify the elements contained in risk management and risk communication through the framework of risk governance, and to improve the quality of decision making on acceptable risk levels and measures in the social context.[15]

3-4 Concept of the National Research Institute for Earth Science and Disaster Prevention on "disaster risk governance"

The National Research Institute for Earth Science and Disaster Prevention launched the second phase of "Study on Disaster Risk Governance" project from the year 2006, aiming to change its research strategy from extending disaster risk management to innovating the governance structure itself constructing the framework of comprehensive risk governance.[16] The project defines disaster risk governance as the "cooperative governance of disaster risks through cooperation by forming social interactions (risk communication based on disaster risk information) and social networks between various major concerned bodies, presenting the following three requirements shown below in Items (1) - (3) for implementing the "disaster risk governance" in communities:

(1) Multiplicity (professional knowledge, experiential knowledge, and local knowledge) of disaster risk information and its community-wide sharing

The first requirement is that a community shares the scientific knowledge of local hazards and disasters, the knowledge of local disaster culture, as well as risk reduction technologies and methods. "Disaster risk information" can be classified as follows from the viewpoints of the producers and scopes of information:

- Professional knowledge

Knowledge, information (hazard maps, estimated damage maps, etc.), engineering measures, disaster prevention systems, social technologies, etc., held by professionals or administrative agencies.

- Experiential Knowledge

Experiences and lessons of disasters (disaster ethnography etc.)

- Local knowledge

Disaster characteristics of community, wisdom peculiar to a community, etc. (incidents, signs of disasters passed down for generations, disaster culture, etc.)

Integrated disaster measures are taken based on the risk communication between these three information areas. In a broad sense, disaster risk information also includes the socially acceptable levels of disaster risks and personal and social preferences on disaster measures.

(2) Social decision-making (risk preference) based on deliberate communication and discussions (risk communication) between various stakeholders

The second requirement is that various stakeholders make comprehensive decisions based on deliberate communication and discussions (risk communication) about the selection of measures for reducing disaster risks, taking account of risk-benefit relations, trade-off between risks, and social acceptability.

Risk communication is carried out in various contexts based on the shared disaster risk information described in Item (1) according to changes in social situations. It is neither merely positioned in a system of institutional procedures for disaster prevention administration, nor directly related to decision making within an institutional framework. The effects of learning and training on disaster risks (literacy acquisition) and of knowledge management are expected during risk communication process for decision making. The rapid expansion of Internet enables web communication as a complementary tool for face-to-face risk communication. The development of the means and technologies to support risk communication in such information environment is required.

(3) Establishment of horizontal and non-institutional cooperative frameworks consisting of various organizations and individuals in society through the use of social relations and personal incentives

The third requirement is that various organizations and individuals in society cooperate to take measures to reduce disaster risks, using social relations such as mutual confidence and the norms, networks, and personal incentives cultivated on a daily basis, creating new mechanisms when needed, and taking advantage of individual abilities and technologies.

Disaster risk governance should not be implemented on the premise that confidence between individuals and between stakeholders or social relations like the norms are built up. Disaster measures are likely to be taken by trial and error through the formation of social networks and communities. If the comprehensive autonomy of a community is vulnerable, disaster risk governance can be realized only when a novel community strategy of simultaneously forming and networking new public-supporting entities is implemented.

Disaster risk governance creates dynamism in communities in such a way that non-institutional and horizontal cooperation emerged from multiple networks is incorporated into institutional disaster measures.

4 New directions of disaster prevention studies based on disaster risk governance

4-1 Positioning of research and development on the disaster reduction technology integrated with the social science

The research and development of the disaster reduction technology integrated with the social science corresponds to “the disaster reduction technology integrated with the social science,” one of the strategically important technologies mentioned in the “promotion strategies in the social infrastructure area” developed by the Council for Science and Technology Policy based on the Third Science and Technology Basic Plan[17] (Table 1). The Committee on Research and Development in the Disaster Prevention Area prepared “On the Policy for Promoting the Research and Development of Disaster Prevention”[18] in March 2003, positioning this technology as one of priority issues to be further promoted, requiring the promotion of “an understanding of social vulnerability and its causes, an assessment of the economic impacts of disasters, and the establishment of coordination with the social science area.” The above committee belongs to the Subdivision on R&D Planning and Evaluation attached to the Council for Science and Technology, Ministry of Education, Culture, Sports, Science and Technology. A long-term strategic guideline, “Innovation 25”[19] mentioned

Table 1 : Key research and development issues on disasters and their objectives mentioned in the Third Science and Technology Basic Plan

(1) Survey study on observation, monitoring, and prediction of earthquakes	Subject	Observation and survey research and disaster prevention technologies to reduce damage on massive earthquakes such as Tokyo metropolitan epicentral earthquakes, Tonankai/Nankai earthquakes, off-Miyagi Prefecture earthquakes; intensive development and extension of information infrastructures for disaster prevention and reduction; research on assessment and prediction of crust activity; survey research on earthquakes; construction of earthquake hazard stations; observation for earthquake prediction.
	Objective	To improve earthquake prediction and disaster assessment immediately after occurrence of earthquakes and reduce damage by 2010 by carrying out intensive survey, observation, simulation on massive earthquakes such as Tokyo metropolitan epicentral earthquakes, Tonankai/Nankai earthquakes, off-Miyagi Prefecture earthquakes, and large-scale active fault earthquakes.
(2) Geological survey study	Subject	Systematic arrangement, database construction, and integration of geological information
	Objective	To reduce earthquake and volcanic disasters by 2010 by systematically arranging geological information essential for prediction of ground motion and volcanic eruption. To use information as a basis for industrial siting.
(3) Damage reduction technologies such as seismic retrofitting, improved disaster response, and advanced recovery and restoration planning	Subject	Disaster reduction technologies such as seismic retrofitting of structures to prepare for large-scale earthquakes,* simulation of behaviors of structures and ground during earthquakes; prediction of effects of long-period ground motion and measures against it; development of earthquake-resistant construction methods; improvement of construction systems using robots and other means; safety verification of buildings; research on derailment during earthquakes.
	Objective	To elucidate the overall earthquake-resistant performance of structures, develop simple and inexpensive technologies for seismic diagnosis, reinforcement, and retrofitting of existing structures, and significantly reduce damage caused by earthquakes and tsunamis by 2010 by conducting destructive vibration tests of full-scale models and analyzing the mechanism and strength of collapse of structures due to earthquakes.
(4) Technologies for predicting volcanic eruption	Subject	Prediction of volcanic eruption, prevention of volcanic disasters
	Objective	To reduce eruption disasters by 2010 by establishing a method for quickly and reliably determining strength of volcanic activity and developing physicochemical models of eruption.
(5) Technologies for observation, prediction, and disaster reduction of storm and flood damage, sediment disasters, and snow damage	Subject	Water management technologies using rainfall prediction and other means; prediction technologies of sediment disasters and storm and flood damage through radar and lidar observation; elucidation of mechanism of phenomena in natural disasters such as storm and flood damage and snow damage, and establishment of simulation technologies,* improvement of rainfall prediction technologies; prediction of typhoons and locally intense phenomena through simulation; processing and analytical technologies of observed offshore wave information; hazard prediction of sediment disasters and related disaster reduction technologies,* qualitative reinforcement of river banks for flood control safety.
	Objective	To improve simulation technologies for storm and flood damage and snow damage caused by heavy rains and strong winds and reduce damage by 2015. To elucidate the mechanism of locally intense phenomena such as urban heavy rains, establish technologies for predicting occurrence of locally intense phenomena, and significantly reduce damage associated with such phenomena by 2012. To increase the ratio of flood protected areas to about 62% (about 58% in 2000) and increase number of sediment protected houses to about 1.4 million (about 1.2 million in 2002) in 2007.
(6) Technologies for observation and monitoring of natural disasters using satellites and other means	Subject	Satellite technologies for disaster monitoring; unmanned aircraft systems for disaster monitoring.
	Objective	To contribute to ensuring public safety and security by 2015 by developing a satellite observation and monitoring system and continuously providing observation data useful for disaster prevention and reduction. To begin operation of an unmanned aircraft system and enable collection and provision of timely and detailed on-site information at the time of disasters by 2012.
(7) Technologies for monitoring, warning, information transmission, and disaster prediction at the time of disaster	Subject	Immediate transmission of earthquake information; disaster information sharing systems; methods for collecting and transmitting disaster information; real-time observation of submarine earthquakes; ensuring fire safety in various buildings and facilities; technologies for assessing and publicizing the hazard and spread of damage in various disasters using interdependence analysis and other means;* damage reduction for dangerous facilities in large-scale earthquakes; technologies for early assessment of damage situations.
	Objective	To enable protection of human life by 2010 by using digital bidirectional communication technologies and providing the public with information clearly indicating dangerous areas by a maximum of about one hour earlier than in the past in order to ensure time for evacuation. To establish social science-based analytical methods for identifying social vulnerabilities to disaster and predicting damage, including secondary and tertiary damage, by 2015. To improve disaster information transmission during disasters, speed up proper judgment of initial response, and establish technologies for evacuation behavior through independent, quick, appropriate self-help and mutual-help evacuation behavior by 2010. To strengthen overall disaster prevention capabilities by communities and establish methods for planning optimum measures and recovery strategies.
(8) Technologies for initial response and emergency response such as rescue activities	Subject	Significant improvement of on-site fire-extinguishing and rescue activities and modernization of fire equipment; information systems to support firefighting and disaster prevention activities during large-scale disasters; firefighting methods and ensuring safety against specific disasters; fire and explosion prevention and control of chemicals; technologies to support quick transport of emergency assistance materials and victims; technologies to support early economic recovery.
	Objective	To materialize the following in response to the type of disasters by 2015 by surveying and reviewing strategies for improving firefighting and disaster prevention science and technology through use of advanced sciences and technologies in response to current social conditions and public needs: (1) ensuring safety in overcrowded urban spaces in fires, (2) firefighting and disaster prevention activities during large-scale natural disaster, (3) ensuring safety against specific disasters, (4) fire and explosion prevention and control of chemicals, (5) improvement of safety of dangerous facilities (earthquake resistance and measures against aging degradation). To develop support systems for emergency and alternative transport, draw up pre-disaster emergency and alternative transport plans, and contribute to implementation of quick emergency and alternative transport during disasters by 2008. To develop risk management methods for international transport infrastructures enabling maintenance and early recovery of international transport and economic activities after disasters and improve reliability of Japanese international transport functions by 2010.
(9) Research useful for forming a disaster-resilient society	Subject	Research on improving business continuity management capabilities at the time of disaster;* research on disaster risk management to improve community disaster prevention capabilities; safety measures for man-machine systems at the time of earthquake; use of deep subterranean spaces.
	Objective	To predict in an integrated way damage caused by various disasters by 2011 by developing methods for assessing overall risk in communities and constructing standard emergency response systems for organizational operation at the time of disasters. To run a model business and apply results of research on disaster prevention to disaster prevention activities in communities.
(10) Technologies for ensuring safety and reducing accidents in facilities	Subject	Research on safety of dangerous facilities; technologies for planning of equipment safety
	Objective	To standardize technological criteria for dangerous facilities, promote quick and smooth introduction of new technologies and materials, diversify safety measures for dangerous facilities, and reduce accidents frequently occurring in dangerous facilities by 2010. To develop basic technologies for safety measurement and assessment of facilities in steel works and ensure safety by 2010.

* Partly included in strategically important sciences and technologies

Source: Promotion Strategy for Priority Areas (March 28, 2006, Council for Science and Technology Policy)

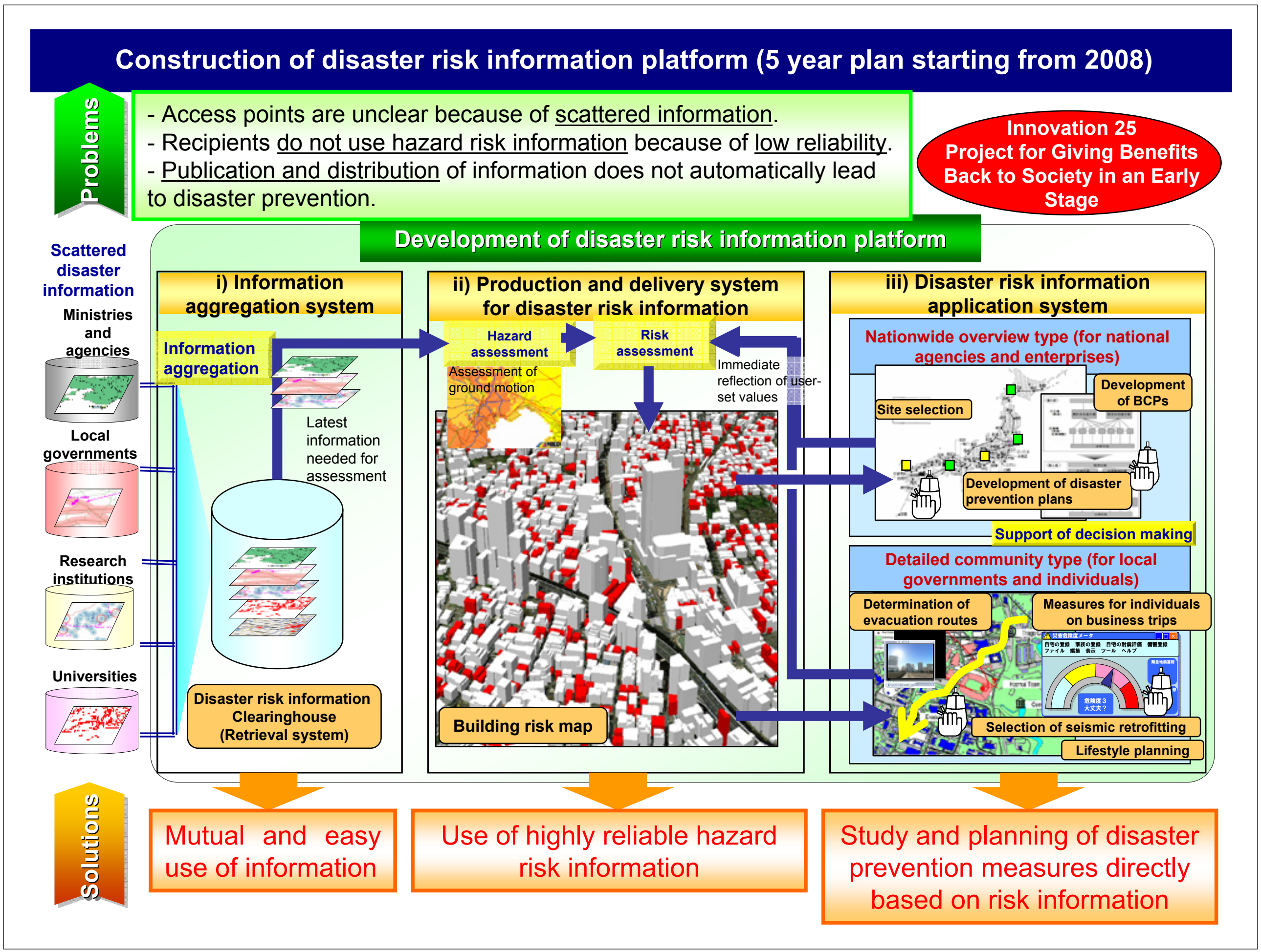

Figure 5 : Research and development on a disaster risk information platform at National Research Institute for Earth Science and Disaster Prevention

Source: National Research Institute for Earth Science and Disaster Prevention

the construction of "disaster information communication systems" as one of the subjects of "Project for Giving Benefits Back to Society in an Early Stage" to materialize the roadmap for the technological innovation strategy. In response, the National Research Institute for Earth Science and Disaster Prevention will launch the research and development of "a disaster risk information platform (tentatively called)" (Figure 5) to support disaster risk governance as one of the subjects of the "Project for Giving Benefits Back to Society in an Early Stage." This research and development should be carried out in close coordination with that of the disaster reduction technology integrated with the social science made by other research institutions, universities, etc.

4-2 Research areas and potential subjects on the disaster reduction technology integrated with the social science

The Promotion Strategy for Priority Areas mentioned in the Third Science and Technology Basic Plan (social infrastructure area) defines the disaster reduction technology integrated with the social science as "the technology to assess social vulnerability to disasters and their effects on society and economy, taking account of interdependence, to make the degree of risk known to the public for improving overall disaster prevention capabilities including the self-help and mutual help efforts in communities, and to ensure the continuity of administration, business, and transportation at the time of disaster." The National Research Institute for Earth Science and Disaster Prevention interprets it as the social technology integrated with knowledge and technologies in the science and technology areas as well as a variety of knowledge in the social science area.

The disciplines required for the disaster reduction technology integrated with the social science are risk management, risk analysis, disaster psychology, disaster information, urban

Table 2 : Examples of particularly important integrated research areas and potential research subjects

(1) Integrated risk assessment methods ・Integrated community risk assessment methods considering multiple hazards and risks ・assessment methods for social and economic vulnerabilities of individuals, communities, and enterprises to natural disasters considering interdependence ・Mid- and long-term disaster risk simulation methods for individuals considering lifestyles and life stages
(2) Participatory disaster risk communication methods ・methods in which individuals and communities share disaster risk information (professional knowledge, experiential knowledge, local knowledge) and increase risk awareness ・Consensus building methods to study disaster prevention methods considering risk acceptability, risk trade-off, and costs and benefits of individuals and communities ・methods in which multiple networks make decisions on disaster measures through communication
(3) Comprehensive and integrated disaster measures and disaster response measures ・disaster prevention plans to increase comprehensiveness and integration of disaster prevention policies, and participatory and cooperative development methods for action plans ・Autonomous and decentralized disaster response measures in which multiple networks aggregate information, unify situation awareness, and cooperate at the time of disaster ・Comprehensive risk life planning methods considering disaster risks
(4) Technologies and methods of social operation for decentralized and interoperable disaster risk information platforms ・Shared application technologies for disaster risk information, and cooperative models in which multiple networks provide Comprehensive and Integrated disaster information based on those technologies ・participatory Integrated risk assessment and simulation technologies using decentralized interoperable environment ・knowledge management methods that store information such as residents disaster experiences, potential incidents, and risk awareness and transform such information into local knowledge on local information platforms in order to support Comprehensive community autonomy and community formation in ordinary times

Source: National Research Institute for Earth Science and Disaster Prevention

planning, land use planning, insurance system, fund system, voluntary disaster prevention, disaster volunteering, and restoration. In addition to the above, research areas such as local administration, district administration, resident activities, resident participation and cooperation, community, housing policy, welfare, finance, local development, local economy, industry, community information, communication, and consensus building will become important from the view points of the three requirements of disaster risk governance.

Of these research areas to be integrated with the disaster reduction technology, the following four areas are particularly important. Potential research subjects in these areas are exemplified as follows (Table 2):

(1) Integrated risk assessment methods

Research on risk assessment methods to comprehensively assess the interdependence and social and economic vulnerability of individuals and communities by integrating a variety of hazard information and disaster risk information (professional knowledge, experiential knowledge, local knowledge) on earthquakes, tsunamis, volcanic eruptions, sediment disasters, storm and flood damage, etc.

(2) Participatory disaster risk communication methods

Research on risk communication methods, based on the results of the risk assessment described in the above Item (1), to help local governments, individuals, communities, and businesses mutually understand social and economic vulnerability to disasters in the process of participatory risk assessment, and to create various disaster measures and disaster response measures comprehensively integrated with various policy areas.

(3) Comprehensive and integrated disaster measures and disaster response measures

Research on social measures to use social relations (multiple networks) formed in communities at ordinary times and a variety of local resources stored in communities, and to implement various disaster measures and disaster response measures created by the methods described in the above Item (2).

(4) Technologies and methods of social operation for decentralized and interoperable disaster risk information platforms

Research on the construction of decentralized and interoperable disaster risk information platforms to facilitate the materialization of disaster risk governance and on their social operation.

5 Conclusion

Taking account of the uncertainty of disaster risks and changes in social structures, this paper has described the necessity of changing the subjects of present disaster prevention policies and the methods of disaster risk management from the viewpoints of multiple networks and the comprehensiveness and integrity of disaster prevention policies. The concept of disaster risk governance should be established as a new framework to create innovative disaster prevention policies. "The disaster reduction technology integrated with the social science" is important as a new research subject based on the concept. What are required are research on comprehensive risk assessment methods taking account of the interdependence and social and economic vulnerability of the multiple networks of individuals, communities, local governments, and enterprises, and that on disaster risk information based on these methods.

Individual research and development on the materialization of the concept of "disaster risk governance" should not be performed independently, but should be promoted in an integrated way under unified research and development management. Research and development should also be conducted in close cooperation with related administrative agencies, local public bodies, enterprise, NPOs, resident organizations, etc. To consistently and effectively carry out a series of research and development, researchers and businessmen in various disciplines need to work in close cooperation with each other. Setting social missions, integrating a variety of knowledge in various areas, and coordinating problem-solving research and development require to build a research environment including the training of qualified project managers and the formation of networks. These efforts should be carried out under the cooperation of research and development oriented independent administrative institutions and universities.

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(Original Japanese version: published in December 2007)

6

Disaster Management Satellite System Development and International Cooperation Promotion in Asia

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1 Introduction

Japan is a country that is frequently damaged by natural disasters due to earthquakes. Possible large-scale disasters due to an epicentral or inland earthquake in the Tokyo metropolitan area and due to ocean trench-type earthquakes such as Tokai, Tonankai/Nankai, and near Japan Trench/ Kuril Trench earthquakes are one of Japan's most serious concerns. The White Paper on Disaster Management 2007[1] prepared by the Cabinet Office and approved by the Cabinet on June 1, 2007 reports that earthquakes have occurred even in areas where earthquakes had not been considered an imminent threat. Several earthquakes have occurred in Japanese areas following the January 1995 Great Hyogo-Awaji Earthquake: the Chuetsu area of Niigata Prefecture in October 2004, the western offshore area of Fukuoka Prefecture in March 2005, Noto Peninsula of Ishikawa Prefecture in March 2007, and subsequently the Chuetsu offshore area of Niigata Prefecture on July 16, 2007. The last earthquake is presumed to be caused by a submarine active fault. It is said that even though there exist a lot of such active faults in the seas near Japan, these faults have not been studied in detail because of their undersea locations.[2]

Japan also suffers from heavy rains and storms caused by typhoons, and, in recent years, from frequent heavy rainfalls probably due to the global warming. Heavy rain and storm disasters caused by a Baiu seasonal rain front and typhoon No. 4 from June 11 to July 17, 2007 caused severe damages to the Kumamoto, Miyazaki, Kagoshima and other prefectures, and on August 7, 2007, the Japanese government ranked the heavy rain and storm disasters caused by typhoon No. 4 and the disasters caused by the July 2007 Niigata Chuetsu offshore earthquake as severe. [3] Japan is becoming more and more vulnerable to disasters due to its aging population, low birthrate, and depopulation of rural areas, and efforts for disaster management and mitigation are becoming more important than ever.

With regard to Asian areas other than Japan, the large-scale earthquake off Sumatra in Indonesia and the resulting Indian Ocean Tsunami[4] are still fresh in our memory. On December 26, 2004, a magnitude 9.0 earthquake whose seismic focus was off Sumatra Island occurred, triggering huge tsunamis and causing catastrophic disasters in Indonesia, India, Thailand, and other countries. In addition to tsunamis, much of Asia also suffers heavy damages caused by earthquakes, typhoons, floods, and other natural disasters.

Japan is conducting research and development activities on earth observation satellite application to disaster management. Japan's efforts to promote international cooperation in this field with Asian countries that suffer heavy damages caused by natural disasters, and to maintain and strengthen friendly relationships with these countries should serve Japan's national interest.

In Asia, countries that can develop large rockets and satellites, and launch them from their own territories are currently only Japan, India, and China. South Korea, after having acquired the capability to develop satellites, currently endeavors to obtain such a launch capability, and other Asian countries are currently cooperating with the United States, Europe and other nations to develop small earth observation satellites. Japan also could utilize its space technologies as a diplomatic tool, and should actively do so.

2 Priority in the Science and Technology Basic Plan and government study group report

2-1 Priority in the Science and Technology Basic Plan

The Sectoral Promotion Strategy,[5] formulated by the Council for Science and Technology Policy based on the Third Science and Technology Basic Plan, has selected a Technology to Monitor and Manage National Land to Mitigate Disaster, within the social infrastructure field's disaster management part, as one of the strategically prioritizes S&T areas, to which the Japanese government should invest intensively, and one of its elements is a Disaster Monitoring Satellite Application Technology.

The Disaster Monitoring Satellite Application Technology develops satellite disaster monitoring and information utilization technologies as well as promotes quasi-zenith satellite high accuracy positioning experiments, and the reason for this selection is explained as following: since the characteristics of satellites with regard to large-scale natural disasters are wide area coverage, simultaneity, and resilience, autonomous disaster monitoring and risk management information utilization using satellites must be one of the most effective means for disaster mitigation. The technology's cited goal is to establish a satellite observation and monitoring system by JFY2015, and to continuously provide observation data useful for disaster management and mitigation, thereby ensuring the safety and security of the Japanese people.

The "Economic and Fiscal Reform 2007" [6] approved by the Cabinet on June 19, 2007 also establishes a policy to promote research, development, and practical application of such science and technology areas as satellite positioning and monitoring, intelligence capability enhancement, and a disaster information sharing system that contribute to Japan's public security and disaster management .

Since the quasi-zenith satellite, which will complement and augment the Global Positioning System (GPS) of the United States, will provide accurate position and time information, it is expected that the satellite will become an effective tool for emergency disaster response activities in the future. Since earth observation satellites, without being affected by disasters, can quickly observe disaster areas over a wide range, it is expected that their observation data combined with information obtained by such means as aircraft and helicopters will be useful for disaster condition assessment that would make rescue operations more effective. Moreover, since they can visit and observe the same area regularly, they are expected to help us extract topographical information reflecting latest land use changes, and identify disaster risks.

2-2 Government study group report

In February 2006, the Cabinet Office and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) set up a study group on the application of earth observation satellites to disaster management, to which Japanese government ministry, agency and organization officials, and external experts involved in disaster management gathered for deliberation, and in September 2006, published a report entitled "On an Approach to Constructing and Operating an Earth Observation Satellite System for Disaster Management.[7]" After user needs in such fields as earthquakes, volcanoes, windstorm and flood damages, and maritime and coastal disasters having been consolidated, top-level requirements for the next-generation earth observation satellite system were established as shown in Table 1.

Representative observation equipment onboard earth observation satellites are optical sensors and microwave sensors including synthetic aperture radars. Optical sensors receive visible, infrared (IR) and other lights with specific spectral bands to observe the ground surface and other features. Although some optical sensors can conduct meter-order or higher resolution observations, their observations are limited during daytime and are also affected by clouds because they receive sun lights reflected from the Earth's surface. Those with only one single spectral band are called panchromatic optical sensors, while those with more than one band are called multispectral optical sensors. Microwave sensors can conduct

Table 1 : Top-level requirements for the next-generation earth observation satellite system

Sensor	• High-resolution panchromatic optical sensor with target resolution of approximately 1m • Multispectral optical sensor to detect flooded areas, oil spills, vegetation, land coverage, etc. • Synthetic aperture radar for observation at night and in bad weather
Swath width	• Target swath width: 50km or more (approximately 40 to 70km required for earthquakes, approximately 30 to 50km for windstorm and flood damages: the goal is to realize wide-area observation with the high-resolution panchromatic optical sensor.)
Observation frequency	• Within approximately 3 hours after event (the optical sensor and the synthetic aperture radar are carried by different satellites. A four-satellite system consisting of two optical and two radar satellites is under study.)

Source: MEXT, Reference [7]

observations irrespective of day and night, and weather conditions. While synthetic aperture radars emit electromagnetic waves, and receive signals reflected from the Earth's surface, some other sensors passively receive microwaves emitted from the surface.

The report notes as follows: although Japanese national government ministries and agencies involved in disaster management and local governments currently use information such as observation data from aircraft and ground-based equipment to respond to large-scale natural disasters, earth observation satellites, making it possible to assess disaster conditions over a wide range of several tens of kilometers, and to conduct observations at night and under bad weather conditions, are expected to make rescue and relief operations more effective, and to play an active role in the field of disaster monitoring.

3 Natural disasters in Asia

Figure 1 shows the worldwide numbers of natural disasters and their victims from 1990 to 2006. The figure was prepared using the Emergency Events Database (EM-DAT)[8] operated by the Center for Research on Epidemiology of Disasters (CRED) at the Catholic University of Louvain, Belgium. In the figure, earthquakes, floods, slides, volcanoes, windstorms, and tsunamis/surges are considered as natural disasters.

While the number of natural disasters in East Asia, Southeast Asia, and South Asia accounts for approximately 38% of the world total, the number of deaths in these areas about 84%, the number of injured there about 92%, and the number of affected there about 96%. These statistics show that these Asian regions suffer heavily from natural disasters.

Figure 2 shows damage statistics by disaster type such as earthquake, flood, and typhoon/windstorm from 1990 to 2006. The percentages of damages caused by earthquakes, floods, and windstorms are relatively large. The number of deaths caused by the other category is large, but the majority was caused by the Indian Ocean Tsunami in 2004. It may be said that although tsunamis occur not so frequently, they can bring devastating damages once they occur.

Since it is impossible to prevent natural disasters from occurring, quick rescue operations when a natural disaster occurs, and damage mitigation measures are important. Earth observation data can be used to assess the damages caused by earthquakes, floods, typhoons/windstorms and other disasters, and to identify disaster risks. There may be cases in Asia when it is difficult to assess damage conditions, for example, because of being an island country, or because of conditions of infrastructures such as road or communication networks. For such cases, earth observation satellites provide an effective means to assess damage conditions. Also, for areas where map information is not developed adequately, earth observation data may be applied to the creation and dissemination of flood hazard maps.

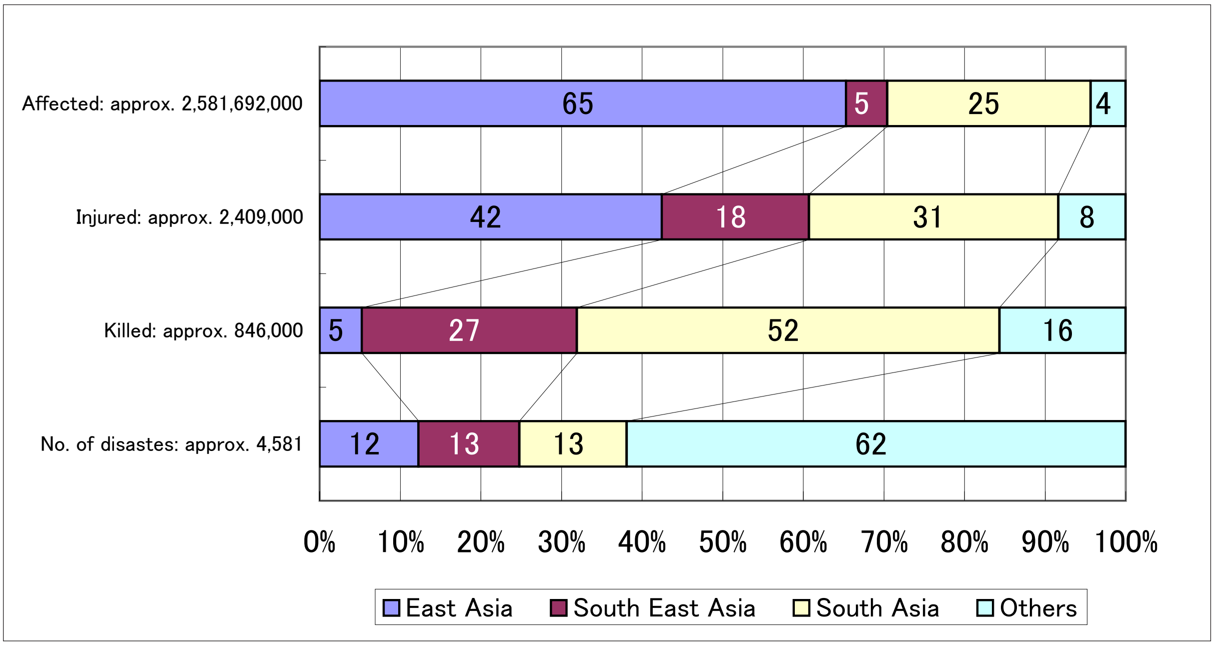

Figure 1 : Natural disasters in the world (1990-2006, by region)

Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net-Université Catholique de Louvain -Brussels- Belgium"

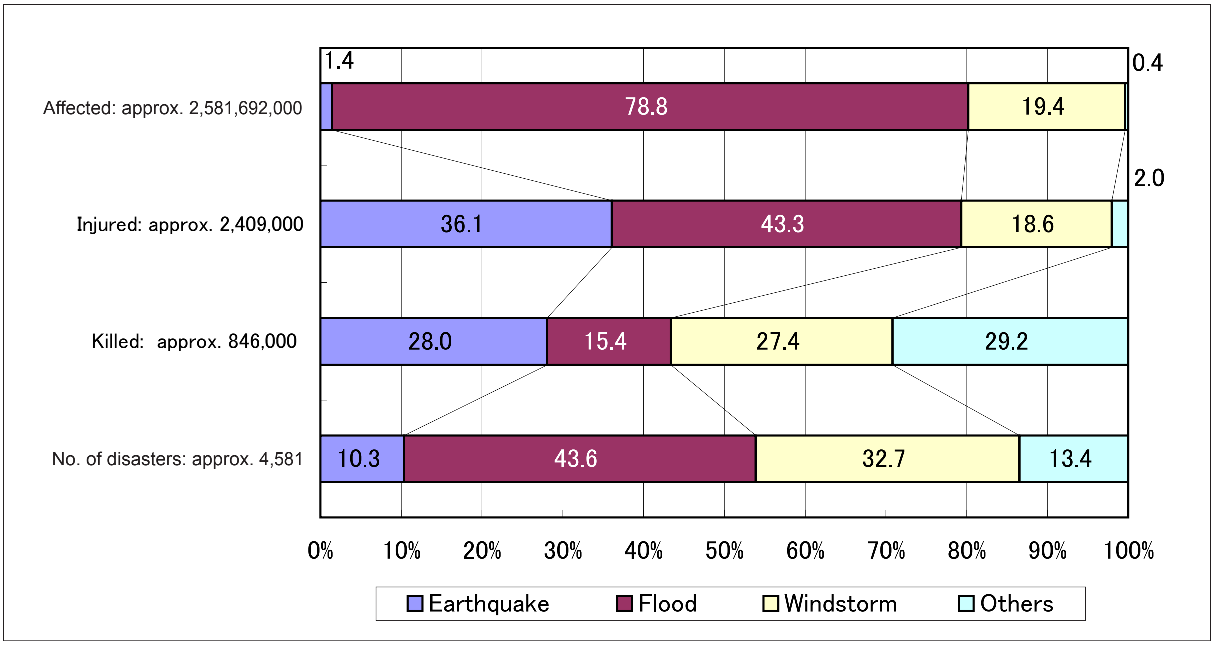

Figure 2 : Natural disasters in the world (1990-2006, by disaster type)

Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net-Université Catholique de Louvain -Brussels- Belgium"

4 Activities in Japan and abroad to develop disaster management satellite systems

Japan has been conducting disaster management application demonstration activities using the "DAICHI" Advanced Land Observing Satellite (ALOS), and is also studying to utilize the "KIZUNA" Wideband InterNetworking engineering test and Demonstration Satellite (WINDS), a super high-speed internet satellite, for disaster management. The European Union also plans to utilize earth observation satellites for emergency response. Not only Japan but also the European Union is promoting the practical use of earth observation satellites for disaster management.

4-1 Activities in Japan

(1) Disaster management application demonstration activities using "DAICHI"

The "DAICHI" Advanced Land Observing Satellite (ALOS), which was launched on January 24, 2006 by the Japan Aerospace Exploration Agency (JAXA) for disaster damage condition assessment as well as for 1: 25,000 mapping and natural resource surveying, entered into an operational phase on October 24, 2006 after the completion of the satellite's initial functional verification and initial calibration. The satellite's onboard sensors are the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) and the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2), which are optical sensors, and the Phased Array type L-band Synthetic Aperture Radar (PALSAR), which is a microwave sensor. Characteristics of these sensors are shown in Figures 3 to 5, respectively.

The study group described in Section 2-2, to proceed toward the development and operation of a next-generation earth observation satellite system for disaster management, prepared a plan for disaster management application demonstration activities using "DAICHI" to verify improvements in disaster management operations to be realized by using earth observation satellites, and proposed

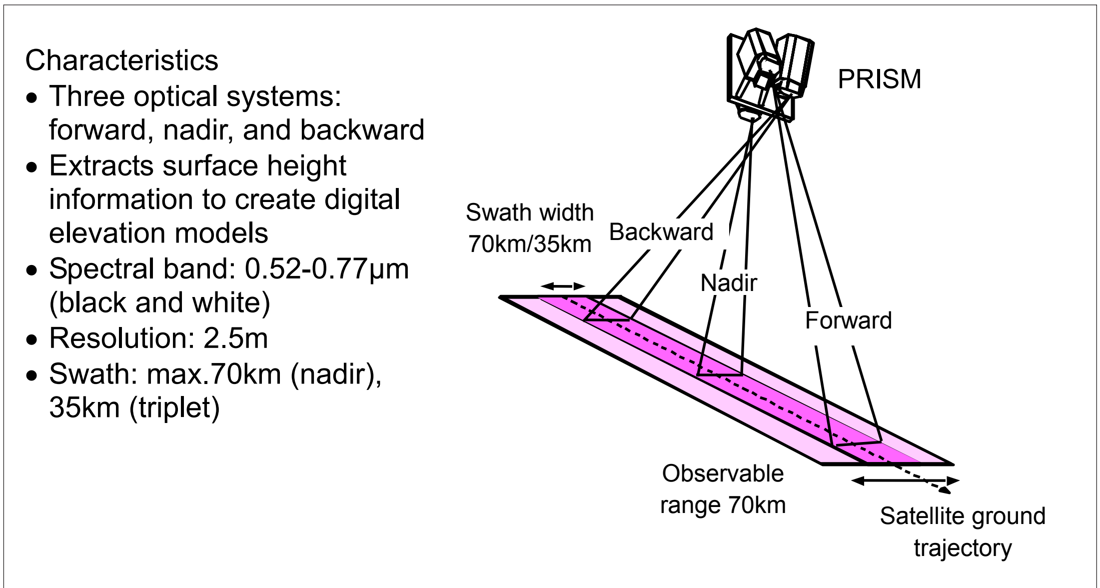

Figure 3 : Panchromatic Remote sensing Instrument for Stereo Mapping (PRISM)

Source: JAXA

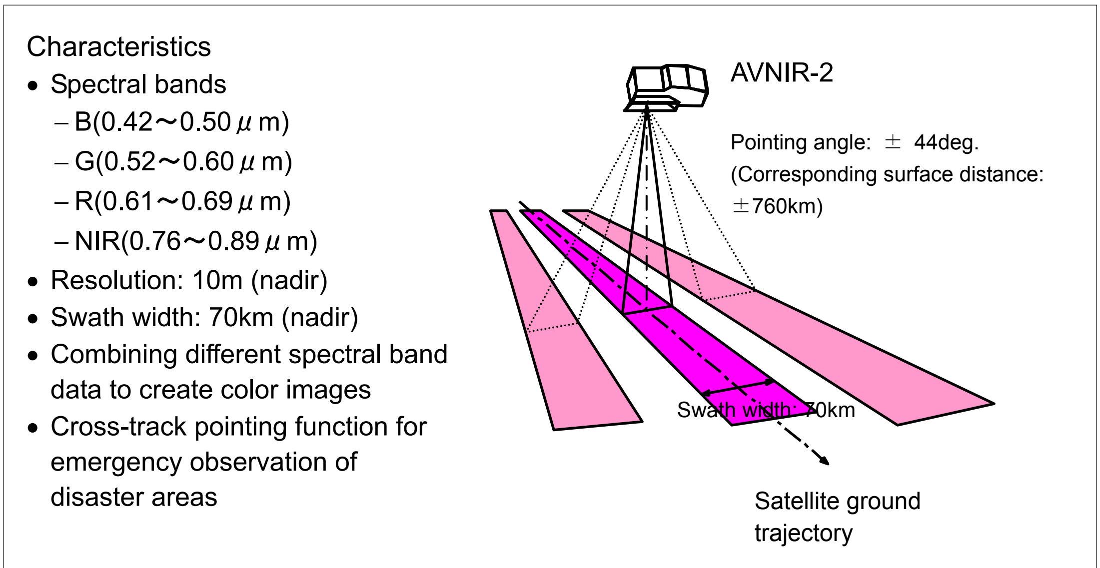

Figure 4 : Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2)

Source: JAXA

to set up working groups by subject[7] (Table 2).

The plan also includes studies on demonstration activities to assess windstorm and flood damages and to utilize satellite image maps for various disaster management activities of local governments, and Gifu Prefecture and the Construction Research Center of Gifu Prefecture as well as Shimanto City in Kochi Prefecture, and Sanjo City and Mitsuke City in Niigata Prefecture concluded memoranda with JAXA to conduct

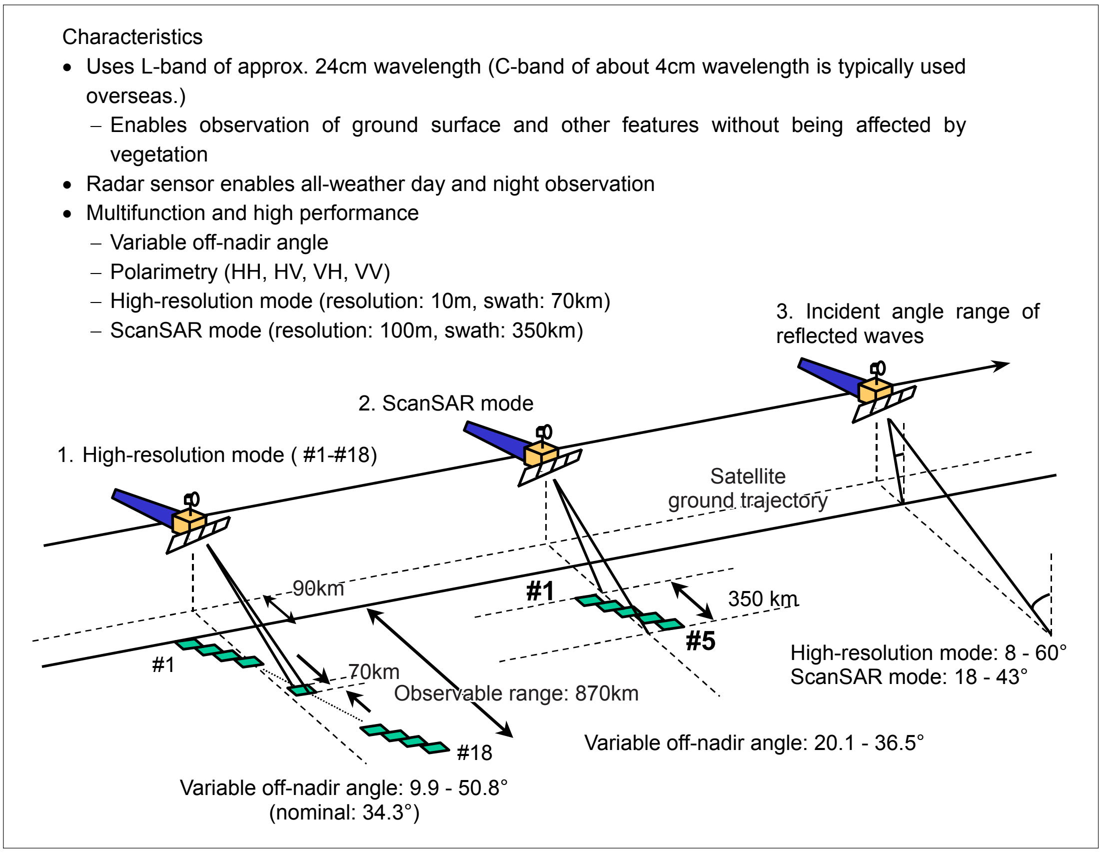

Figure 5 : Phased Array type L-band Synthetic Aperture Radar (PALSAR)

Source: JAXA

Table 2 : Disaster management application demonstration activities using "DAICHI"

No.	Theme	Activities
1	Satellite image map development and its application to disaster management	To integrate "DAICHI" observation data with standard maps to create satellite image maps, and to apply created satellite image maps to disaster mitigation, damage condition assessment after event, and other disaster management activities
2	Volcano activity assessment and eruption monitoring	To study methods to monitor volcanoes and detect their anomalous events using "DAICHI" observation data, and to utilize the data to assess volcano activities
3	Crust/ground movement and damage assessment	To utilize "DAICHI" observation data to detect crust/ground movements
4	"DAICHI" data application to RAS	To apply "DAICHI" observation data to the "Real Damage Information Analysis System (RAS)" developed to assess disaster damage conditions caused by large-scale earthquakes and other natural disasters
5	Maritime/coastal disaster condition assessment	To utilize "DAICHI" observation data to assess oil spill and other disaster damage conditionss
6	Slide disaster sign monitoring and damage condition assessment	To study technical feasibility of detecting slide (mudflow, landslide, etc.) signs and assessing slide disaster damage conditions in areas designated as prone to slide disaster damage

Source: MEXT, Reference [7]

disaster management application demonstration activities using "DAICHI".

The 1: 25,000 scale topographic maps provided by the Geographical Survey Institute (GSI) are the most comprehensive national base maps covering whole Japan, and are prepared and updated using aerial photographs. However, due to cost, time and other constraints, the maps are currently updated approximately every three years for urban areas and approximately every ten years for mountainous areas.[9]

On the other hand, combining observation data from PRISM and AVNIR-2 onboard "DAICHI" with Digital Map 25000 compiled by GSI produces topographic map information called "satellite image maps.[10]" Since "DAICHI" can visit and observe the same area regularly, and this satellite image map can provide topographic map information reflecting latest land use changes, application of the satellite image map to disaster management is being studied as described in the "preparation of satellite image map and its application to disaster management" theme in Table 2. To use Digital Japan, or Denshi Kokudo in Japanese, developed by GSI to create satellite image maps is also under study, and satellite image maps with various scales may become available through the internet.[11]

In case of large-scale disasters that exceed the response capabilities of affected local governments, which local fire and police departments alone cannot deal with, emergency response teams are dispatched from the National Police Agency, the Fire and Disaster Management Agency, and furthermore the Self-Defense Forces, and region-wide support operations are carried out.[12] Since these external support operators are unfamiliar with local areas, the satellite image maps that reflect latest land use changes there can play a significant role in quickly implementing rescue and relief operations, relief supply transportation, and other emergency response activities. It would contribute to realizing effective emergency response operations if satellite image maps were integrated with the on-site observation data obtained by aircraft, helicopters, on-site operators, and other means to provide the latest topographic map information.

Stereographic or three-dimensional topographic map information called "digital elevation models" can be created using the data obtained by PRISM or PALSAR onboard "DAICHI", which may be used for forecasting flooding caused by floods, tsunamis, and typhoons, and can be useful when making hazard maps.[13] Since Asia suffers from heavy damages caused by floods, tsunamis, and typhoons, it would contribute to disaster management activities in this region if such hazard maps were developed and used there.

(2) Super high-speed internet satellite

The geographical information systems of local governments contain their own specific information on roads, railroads, evacuation areas, medical facilities, the addresses of aged and other people requiring assistance during disaster, and lifelines such as power, gas, water supply, and telephone lines. If emergency responders dispatched by the Japanese national government can access and use the geographical information systems of disaster-affected local governments, they can obtain information when needed as required, and this will make emergency response activities more efficient. Although currently such information becomes inaccessible and unavailable if ground information networks in a disaster area are damaged, the "KIZUNA" super high-speed internet satellite, to be launched in the winter season of JFY2007,[NOTE1] will help construct an internet network, and solve this problem in the future. "KIZUNA" will realize super high-speed data communications: approximately 1.5-6Mbps transmission and approximately 155Mbps reception when using a ground terminal with an antenna of about 45cm in diameter, and approximately 1.2Gbps transmission and reception when using a ground terminal with an antenna of about 5m in diameter.[14]

"KIZUNA" will cover almost whole Japan with its nine beams (eastern Hokkaido, western Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku/Shikoku, Kyushu, and Okinawa), enabling two-way internet communication within the same beam, for example, two-way internet communication between the geographic information systems of local

[NOTE1]
"KIZUNA" was successfully launched on February 23, 2008 (JST).

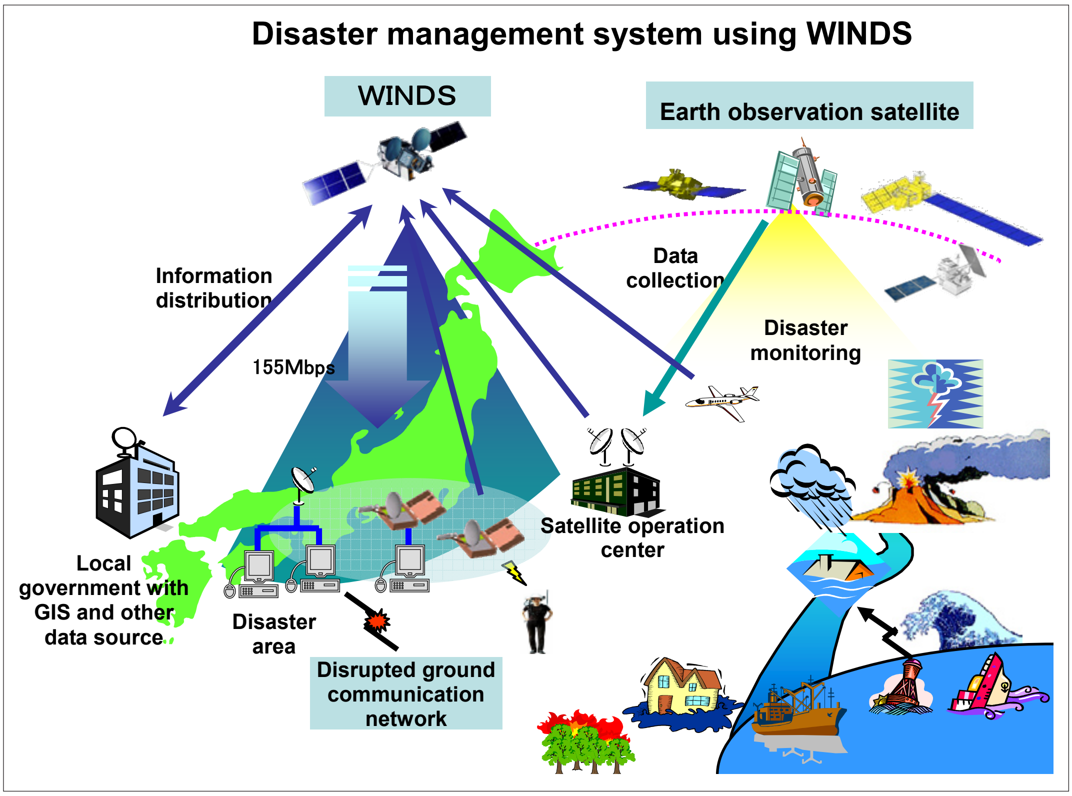

Figure 6 : Application of "KIZUNA" (WINDS) to disaster emergency response activities

Source: JAXA

governments and terminals in disaster areas, and two-way internet communication between different beams, for example, two-way communication between terminals in disaster areas and the national government's disaster management headquarters. Digital information such as e-mail messages and digital camera images will also be exchanged quickly (Figure 6).

4-2 Activities in Europe

In cooperation with the European Space Agency (ESA), the European Union (EU) is developing a system for collecting and distributing earth observation data to help national and local governments of EU member states perform disaster management and other services. The system, which is called the Global Monitoring for Environment and Security (GMES), is currently planned to start three core services of land monitoring, marine monitoring, and emergency response by about 2008.[15] GMES is deemed as a European contribution to the Global Earth Observation System of Systems (GEOSS), and also aims to assist humanitarian aids to developing countries in regions such as Asia and Africa.

The European Commission is responsible for GMES user requirement studies and for setting up its governance structure, whereas ESA develops a series of satellites called Sentinel and their ground operations facilities. The data obtained by European national government and private-sector earth observation satellites will also be used to meet diverse data requirements. In the EU's 7th Framework Programme (EP7: 2007-2013), approximately 1.43 billion euros are to be funded to the space field, about 1.2 billion euros, or about 85%, of which are appropriated for GMES. Of this amount, about 780 million euros are provided to ESA for the Sentinel satellite development.[16] On the other hand, within the framework of ESA, transition to the next-phase of the Sentinel satellite development was approved in September 2007, resulting in the contribution of about 500 million euros from its member states to ESA.[17]

The Sentinel 1 series satellite will carry a C-band synthetic aperture radar, and be used for the land monitoring, marine monitoring, and emergency response services.[18,19] The Sentinel 2 series satellite will carry a multispectral optical sensor, and be used for the land monitoring and emergency response services. The first satellites of the Sentinel 1 and 2 series will be launched around 2011 and

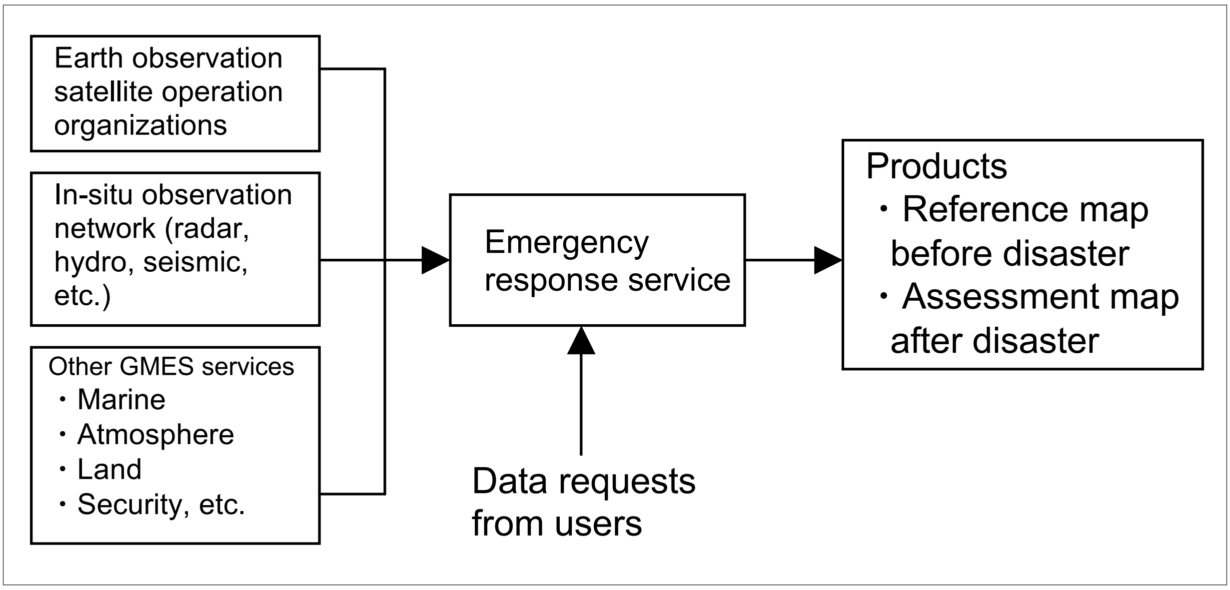

Figure 7 : GMES emergency response service

Source: Reference [15]

2012, respectively.

The emergency response service, when disasters such as earthquakes and floods occur, will integrate earth observation data with in-situ observation data to provide map information for damage condition assessment, rescue operations support, and other activities. Map information, before disasters occur, will be used to identify disaster risks, and updated when earth observation data are obtained or at other appropriate times. When disasters occur, post-disaster earth observation data will be integrated with in-situ observation data to provide map information daily for damage condition assessment, rescue operations, and other activities (Figure 7).

5 International cooperation activities in Asia

Through the framework called Sentinel Asia, earth observation data of "DAICHI" are provided to Asian countries for damage condition assessment. Through the framework called the International Charter "Space and Major Disasters" initiated by the European Space Agency (ESA) and other space agencies, such observation data are also provided. Furthermore, a United Nations project has been launched to provide UN member states with opportunities to use space technologies for disaster management and capacity building, and thus, through various frameworks, the application of space technologies to disaster management is being promoted.

5-1 International Charter "Space and Major Disasters"

As was introduced in the Topics section of the July 2006 issue of Science and Technology Trends,[21] the European Space Agency (ESA), the French space agency (CNES: Centre National d'Études Spatiales), and the Canadian Space Agency (CSA) established the International Charter "Space and Major Disasters" in October 2000 to utilize earth observation satellites to assess disaster damage conditions.[22] Space agencies operating earth observation satellites are eligible to join the International Charter, and JAXA that operates "DAICHI" became an International Charter member from Japan.

Charter member agencies provide observation data on a voluntary basis, and no funds are exchanged between them. The Indian Space Research Organization (ISRO), the National Oceanic and Atmospheric Administration (NOAA) of the United States, the Argentine space agency (CONAE: Comisión Nacional de Actividades Espaciales), the United States Geological Survey (USGS), and the China National Space Administration (CNSA) are also Charter members, and the total number of current Charter member agencies is 10.

Disaster management offices or other public

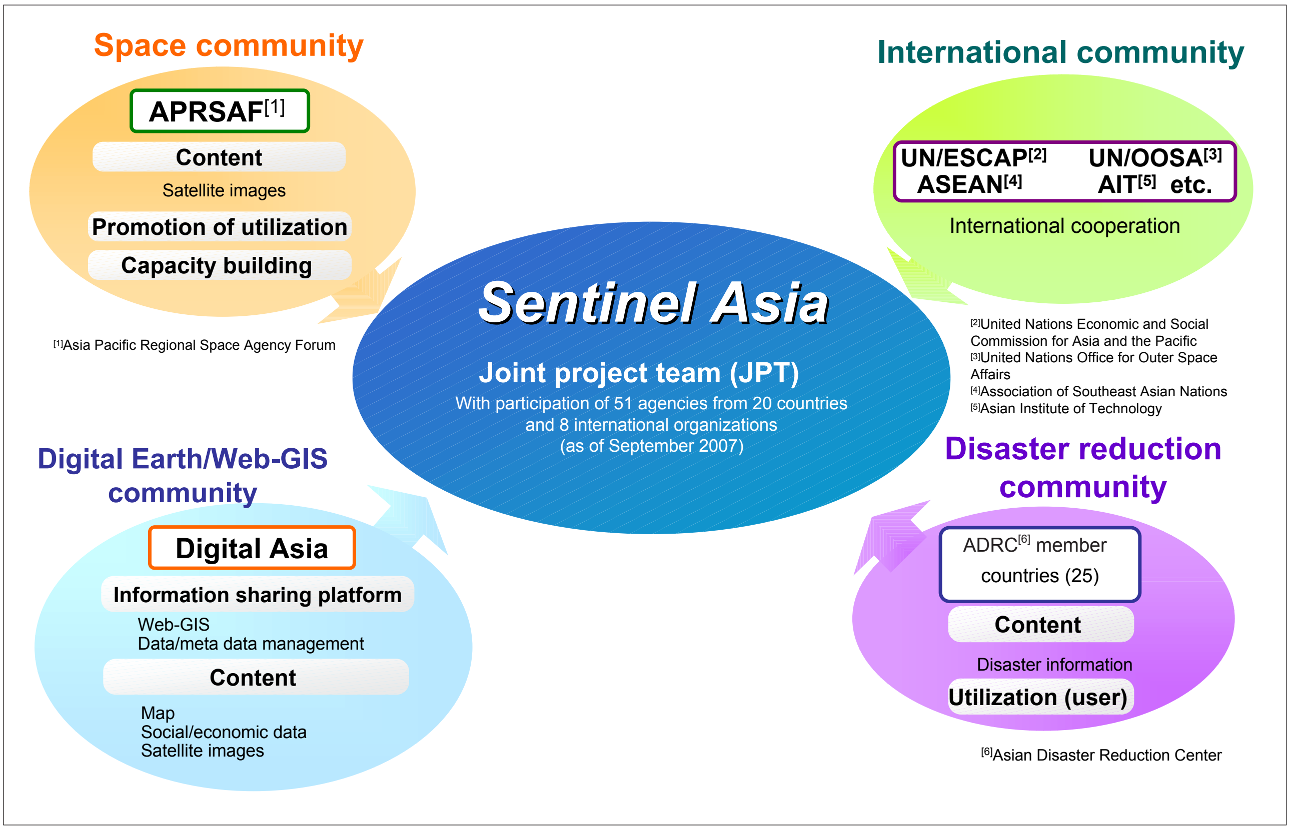

Figure 8 : Framework of Sentinel Asia

Source: JAXA

authorities of national governments of countries to which Charter member agencies belong are eligible to become Authorized Users who can request data acquisition to the Charter. Japan's Authorized User is the Cabinet Office.[23] There are cases where the United Nations or other international organizations request data acquisition to the Charter when disasters occur in countries other than those to which Charter member agencies belong, and indeed the Charter was activated to respond to such natural disasters occurred in Asia.

In addition to directly providing earth observation data, the Charter, using earth observation data, also provides damage map information that shows damage conditions of affected areas. Although creating such map information requires additional processing time compared with directly providing earth observation data, such map information is very useful for assessing damage conditions.

5-2 Sentinel Asia

At the Asia-Pacific Regional Space Agency Forum (APRSAF)[Note2] meeting held in October 2005, when JAXA proposed an initiative to establish an Asian disaster management satellite system and proposed, as a first step, to develop a Sentinel Asia system that would distribute via the internet images obtained by earth observation satellites operated by participating members,[24] many agencies attending the meeting endorsed the proposal, and a joint project to develop Sentinel Asia was launched. For readers' information, Japan has contributed to the training of remote sensing engineers in Asia, and is now assisting disaster management capacity building there through Sentinel Asia.

Sentinel Asia has been operational since October 2006, providing images obtained by "DAICHI" and related geographic information via the internet. The fact that 51 agencies from 20 countries and 8 international organizations in Asia and Oceania are participating in the Sentinel Asia joint project as of September 2007[25] suggests that Asian and Oceania countries are very much interested in this joint project (Figure 8). A website has been set up to provide information on Sentinel Asia (http://dmss.tksc.jaxa.jp/sentinel/).

The Asian Disaster Reduction Center (ADRC) serves as the contact point to receive and accept emergency observation requests from the ADRC

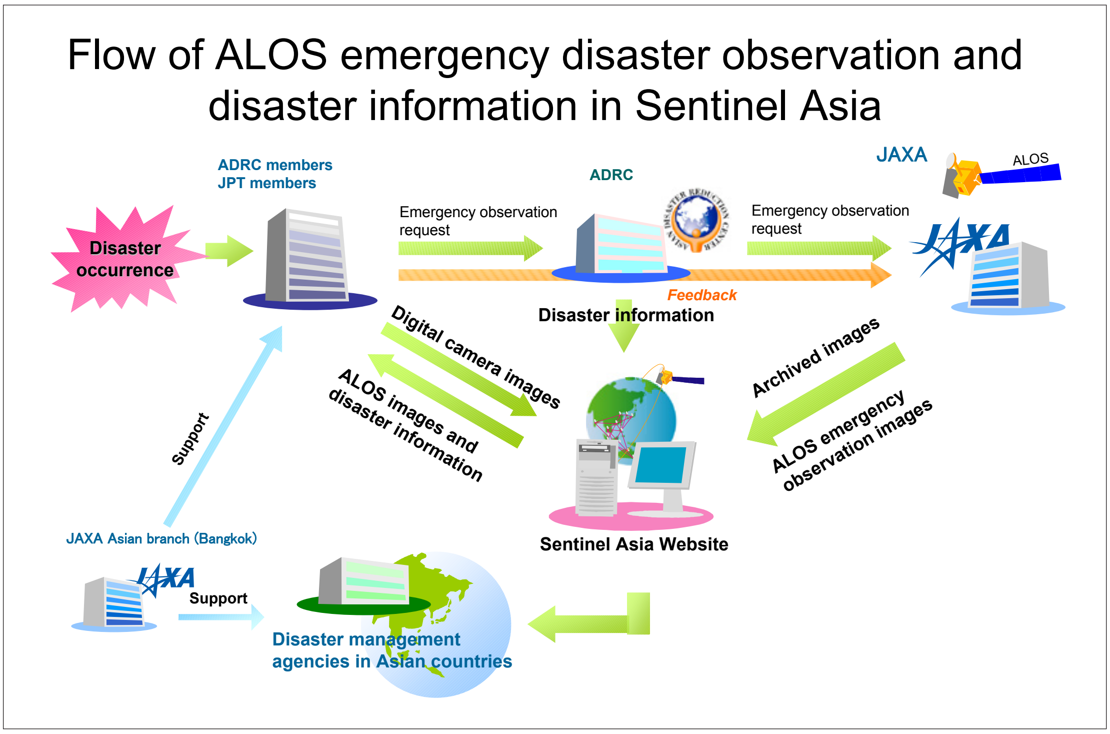

Figure 9 : Flow of emergency observation and disaster information when using "DAICHI"

Source: JAXA

member countries and the joint project member agencies, and requests JAXA to implement accepted emergency observations. JAXA conducts requested emergency disaster observations, and enters the observation data in a dedicated Sentinel Asia server (http://arrs.adrc.or.jp/adrc/MyMap/adrc/index.jsp). The ADRC member countries and the joint project member agencies retrieve image data and other disaster information from this server via the internet (Figure 9). If "DAICHI" alone were available for emergency observations of disaster areas, such observations could be done within three days with AVNIR-2 if the effects of clouds are ignored, and within five days with PALSAR that can conduct observations without being affected by clouds. A single satellite system has limited observation capabilities, and a multiple satellite observation system is required to realize seamless and immediate observations of areas affected by disasters soon after they occur.

Since it is difficult, in Asian regions where broadband services are not available, to download large volumes of image data quickly, low-resolution image data are also provided through Sentinel Asia

[NOTE2]

Asia Pacific Regional Space Agency Forum (APRSAF): An international forum for exchanges of information on the space activities and future plans of the participating counties, and discussion of the construction of actual cooperative activities under the participation of space agencies in the region, concerned administrative bodies, and international organizations having space use needs, which was established with the objective of promoting the use of space in the Asia-Pacific region. Based on a proposal from Japan in the closing declaration of the Asia-Pacific International Space Year Conference (APIC) in 1992, it has been held almost every year since 1993. The 13th forum was held in Jakarta, Indonesia, in December 2006 under the joint sponsorship of Japan's Ministry of Education, Culture, Sports, Science and Technology and the Japan Aerospace Exploration Agency (JAXA), and the Ministry of Research and Technology (RISTEK) and National Institute of Aeronautics and Space (LAPAN), both of Indonesia. The 14th forum was held in India in November 2007 cosponsored by the Indian Space Research Organization (ISRO), MEXT and JAXA.

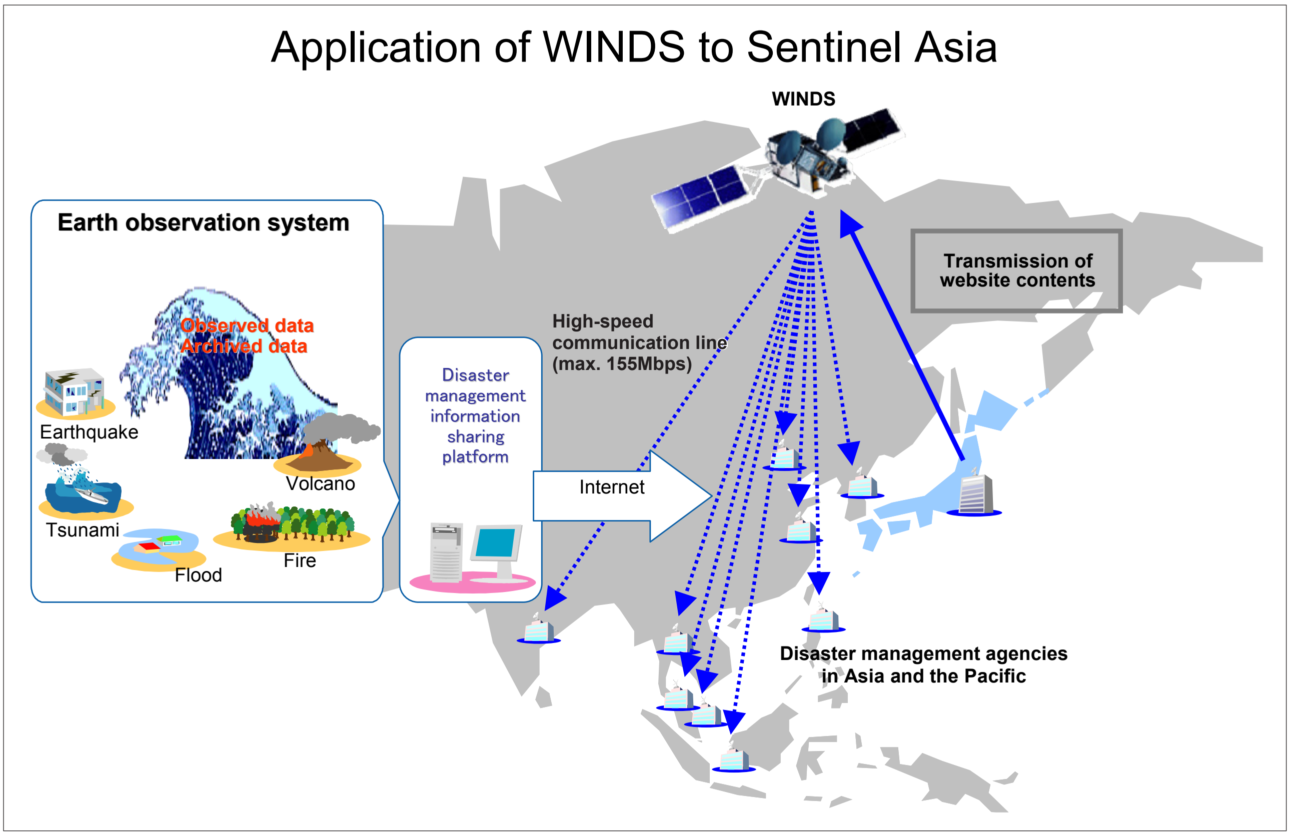

Figure 10 : Application of "KIZUNA (WINDS)" to Sentinel Asia

Source: JAXA

for such regions. The "KIZUNA" super high-speed internet satellite will be able to provide super high-speed internet services to Asian regions as well as to Japan.[14] In the second step of Sentinel Asia, when "KIZUNA" will be available, the problem of such large-volume data transmission in these areas will be overcome.

"KIZUNA" will cover major Asian cities of Seoul, Beijing, Shanghai, Hong Kong, Manila, Bangkok, Bangalore, Kuala Lumpur, Singapore, and Jakarta with 10 beams, enabling high-speed internet communication with Japan. If, taking into account the effect of rain, a ground terminal with an antenna of about 1.2m in diameter is installed and used in these cities, disaster information can be provided with a maximum transmission rate of approximately 155Mbps (Figure 10).

At present, image data on disaster areas are distributed to furnish disaster information quickly. The damage map information provided by the International Charter seems to be an effective means to assess disaster damage conditions. It would further contribute to disaster management activities in Asia if such information were provided through Sentinel Asia.

Asia is also frequently damaged by forest fires and floods. MODIS data from the National Aeronautics and Space Administration (NASA) of the United States are distributed to provide information on hotspots that might indicate forest fire locations. Observation data from the NASA Tropical Rainfall Measuring Mission satellite that carries the precipitation radar developed by Japan are also distributed, assisting the prediction of heavy rains and floods. Since Asia is also frequently damaged by typhoons, data from the Japanese Meteorological Agency's "HIMAWARI" satellite are also provided.

Data from satellites owned and operated by India, Thailand, and other countries will also be provided. India has been making great progress in the field of space development. In January 2007, it launched an earth observation satellite equipped with a panchromatic optical sensor with a resolution of 1m. Thailand is receiving technical support from Europe to develop a small earth observation satellite. It is of great significance if participating countries other than Japan provide their own earth observation satellites' data to enhance and strengthen Sentinel Asia.

Applying small satellites to earth observation is thought to be promising because one of their advantages is their relatively low development costs, and some Asian countries are highly interested in such application.[26] Though not directly related to Sentinel Asia, as an example of such small satellite application other than that of Thailand, the Surrey Satellite Technology Ltd. (SSTL), a UK company, manufactured small satellites weighing about 70-130kg for disaster damage monitoring, and delivered them to countries such as Algeria, Turkey, China, and Nigeria.[27]

5-3 Activities of China and the United Nations

China, being frequently damaged by natural disasters such as earthquakes, floods, and typhoons, in its White Paper "China's Space Activities in 2006" [28,29] released in October 2006, officially announced its plan to use earth observation satellites for disaster management. China joined the International Charter in 2007, and furthermore, together with Austria, Germany, and India, China expressed to the United Nations (UN) its commitment of support to establish a UN space technology application project for disaster management. The United Nations General Assembly approved in December 2006 to establish the UN project, whose official name is the United Nations Platform for Disaster Management and Emergency Response (UN SPIDER), to apply space technologies such as earth observation satellites, meteorological satellites, and navigation and positioning satellites to disaster management.[30] Algeria, Argentina, Italy, Morocco, Nigeria, Romania, Russia, Switzerland, and Turkey expressed their support for the project.

The project has started its activities in 2007 with the objectives to cooperate with existing programs such as the International Charter to provide UN member states, especially developing countries, with opportunities to apply space technologies to disaster management as well as to help those countries build human capacities for such application. UN SPIDER is to have an office in Vienna, Austria, one in Beijing, China, and one in Bonn, Germany. As part of its outreach activities, a workshop is scheduled to be held in China in December 2007[NOTE3], following one held in Germany in October 2007.

> [NOTE3]
> The workshop was held on December 3 to 5, 2007 in Shenzhen, China.

6 Conclusion—Space technology for Japan's diplomacy in Asia

Japan's efforts to promote international cooperation with Asian countries to apply earth observation satellites to disaster management, and to maintain and strengthen friendly relationships with these countries should serve its national interest. Following are recommendations to further utilize Japan's space technologies for Sentinel Asia, which is really becoming Asia's disaster management satellite system, and to carry out Japan's space diplomacy in Asia.

(1) Planning and implementing a strategy for science and technology diplomacy in the field of space activities

Space technology applications to disaster management are carried out through various frameworks such as the Europe-led International Charter, United Nations-led UN SPIDER, and APRSAF-led Sentinel Asia.

In Japan, the Council for Science and Technology Policy at the meeting held on June 7, 2007 established a working group for S&T diplomacy, which is now discussing issues in the field of environment.[31]

Likewise, it is desirable that Japan plan and implement a comprehensive national strategy for S&T diplomacy in the field of space activities.

(2) Establishing a cooperative relationship between the International Charter and Sentinel Asia

The International Charter is a framework where member states that own and operate earth observation satellites exchange observation data among them for disaster damage assessment. Asian countries that do not own such satellites cannot be members of, and request observation data to, the International Charter . At present, such observation data can be acquired only when international organizations such as United Nations agencies activate the Charter.

Although observation data from Indian, Thai and other Asian nations' satellites in addition to those from Japan's "DAICHI" and "HIMAWARI" satellites are to be provided through Sentinel Asia, as in the case of the EU's GMES, to ensure diverse observation data sources is desirable to quickly respond to disasters.

Establishing a new cooperative relationship between the International Charter and Sentinel Asia is desirable to enable mutual data exchange between them.

(3) Continuation of research and development on successor earth observation and super high-speed internet satellites

Sentinel Asia does not require owning an earth observation satellite as a condition to be its member, and can be said to be a friendly framework for Asian counties, which are frequently damaged by natural disasters, to participate. Its members include the National Disaster Reduction Center of China (NDRCC) and Beijing Normal University (BNU), as well as international organizations such as the Secretariat of the Association of Southeast Asian Nations (ASEAN), the United Nations Economic and Social Commission for Asia and the Pacific (UN ESCAP), and the United Nations Office for Outer Space Affairs (UN OOSA). Although limited to the area of disaster management, Sentinel Asia is an international project where Japan is demonstrating its leadership and is making a visible contribution.

Japan should continue research and development on successors to the "DAICHI" earth observation satellite and the "KIZUNA" super high-speed internet satellite, through which Japan is contributing to Asia, to expand and enhance Sentinel Asia under the leadership of Japan, and to maintain and strengthen friendly relationships with Asian countries.

(4) Promotion of cooperation in small satellite development activities in Asia

As part of its industry-academia-government cooperation activities, JAXA provides Japanese research institutes and private sector with opportunities to launch small satellites weighing 5-50kg onboard the H-IIA launch vehicle.

Japan has succeeded in the development of a very small science satellite called "REIMEI" and in the observation of auroras using the satellite. A common bus for 500kg-class small science satellites is under study. While there are numerous examples of small satellite development in Asian countries in cooperation with European and other countries, Japan has just begun cooperation with Vietnam and other countries for such development. Thus, it can be said that Japan has a low presence in Asia as a partner in the small satellite development.

To enhance Sentinel Asia with diverse satellite data sources, as well as to improve Japan's presence in Asia, Japan should not only provide Asian countries with opportunities to launch small satellites, but also promote cooperation with them in the small satellite development, provided that they cooperate for Sentinel Asia.

Acknowledgment

The author would like to express his deep gratitude to Mr. Hideshi Kozawa, Associate Executive Director,[NOTE4] and other officials of the Japan Aerospace Exploration Agency for their invaluable comments and information when preparing this paper.

[NOTE4]
JAXA Executive Director as of April 2008.

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(Original Japanese version: published in November 2007)

About SCIENCE AND TECHNOLOGY FORESIGHT CENTER

It is essential to enhance survey functions that underpin policy formulation in order for the science and technology administrative organiztions, with MEXT and other ministries under the general supervision of the Council for Science and Technology Policy, Cabinet office (CSTP), to develop strategic science and technology policy.

NISTEP has established the Science and Technology Foresight Center (STFC) with the aim to strengthen survey functions about trends of important science and technology field. The mission is to provied timely and detailed information about the latest science and technology trends both in Japan and overseas, comprehensive analysis of these trends, and reliable predictions of future science and technology directions to policy makers.

Beneath the Director are six units, each of which conducts surveys of trends in their respective science and technology fields. STFC conducts surveys and analyses from a broad range of perspectives, including the future outlook for society.

The research results will form a basic reference database for MEXT, CSTP, and other ministries. STFC makes them widely available to private companies, organizations outside the administrative departments, mass media, etc. on NISTEP website.

The following are major activities:

1. Collection and analysis of information on science and technology trends through expert network

— STFC builds an information network linking about 2000 experts of various science and technology fields in the industrial, academic and government sectors. They are in the front line or have advanced knowledge in their fields.

— Through the networks, STFC collects information in various science and technology fields via the Internet, analyzes trends both in Japan and overseas, identifies important R&D activities, and prospects the future directions. STFC also collects information on its own terms from vast resources.

— Collected information is regularly reported to MEXT and CSTP. Furthermore, STFC compiles the chief points of this information as topics for “Science and Technology Trends” (monthly report).

2. Reserch into trends in major science and technology fields

— Targeting the vital subjects for science and technology progress, STFC analyzes its trends deeply, and helps administrative departments formulate science and technology policies.

— The research results are published as articles for "Science Technology Trends" (monthly report).

3. S&T foresight and benchmarking

— S&T foresight is conducted every five years to grasp the direction of technological development in coming 30 years with the cooperation of experts in various fields.

— International Benchmarking of Japan's science and engineering research also implemented periodically.

— The research results are published as NISTEP report.

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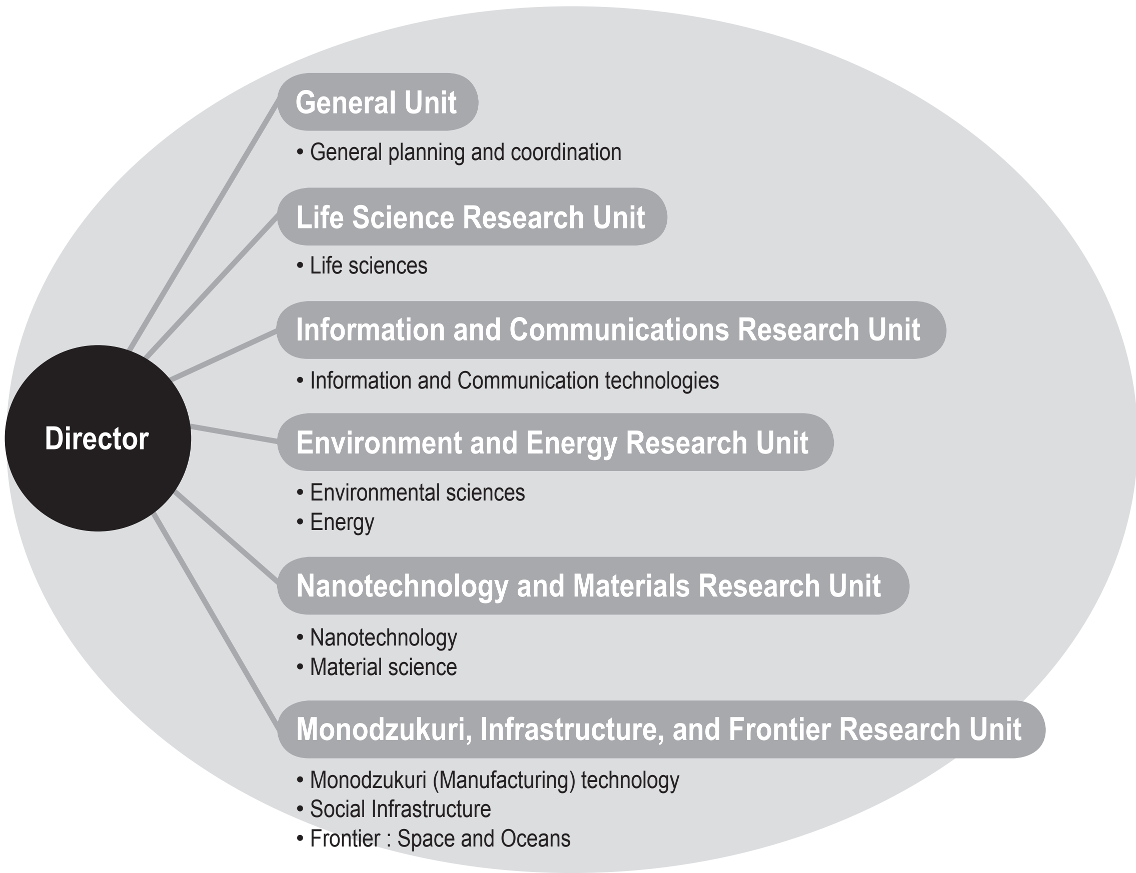

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