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Executive Summary

1 Trends in Research and Development of High-quality Domestically Produced Wheat

p. 9

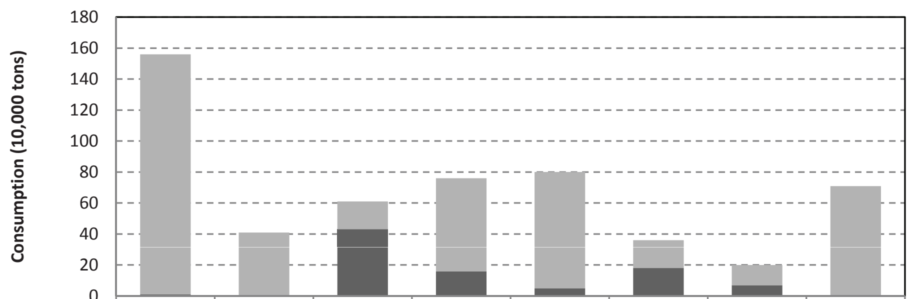
A Japanese household with two or more people consumes 86kg of rice, 45kg of bread, and 36kg of noodles annually (these are three major staple foods for the Japanese). The food self-sufficiency rate for rice is almost 100%, but the rate for wheat, a main ingredient for bread and noodles, is low at about 13%. In particular, the rate for bread wheat is only 1%.

Due to its environmental adequacy, the world's wheat output is concentrated in certain regions where the weather is relatively cold and precipitation is low at the time of harvesting. Due to frequent abnormal weather conditions, the world's wheat production has been destabilized, and, in 2010, more than ten countries limited their wheat exports. At the same time, wheat consumption is expected to substantially increase as the population of wealthy people grows in emerging countries. Due to the recent trend, the global trading prices of wheat are expected to roughly triple in 2020 compared to 2000.

In Japan, the demand for domestically produced wheat is growing due to concerns over food security (the idea that Japan should aim to secure a stable food supply) as well as a rise in the food-safety awareness. Since the late 1990s, the Ministry of Agriculture, Forestry and Fisheries and other organizations have been trying to improve technologies for high-yielding varieties and cultivation. However, the scale of such research and development is small and scattered, and human resources are scarce.

It is necessary to substantially enhance research and development for domestically produced wheat at public research institutes and universities and develop good-quality domestic wheat varieties comparable to imported wheat. It is also essential to improve product development technologies such as cultivation of new varieties, processing, milling, and bread- and noodle-making. In addition, it is desirable to use such developed technologies in order to establish a brand name for domestically produced wheat and, from an international strategy perspective, to focus on regional development and vitalize the food industry.

(Original Japanese version: published in July, August 2011)



	Bread	Ramen noodles	Udon noodles	Confectionery	Other noodles /pasta	Miso/soy sauce	Household use	Animal feed, etc.
Import	155	40.5	18	60	75	18	13	71
Domestic production	1	0.5	43	16	5	18	7	0

Figure : Self-sufficiency Rates for Wheat by Use

Prepared by the STFC based on reference[4]

2 New Type of Nucleic Acid Drugs: Recent trends in micro RNA research

p.22

Now small RNAs transcribed from genomic DNA are commanding considerable attention. In the post-genomic era, it has been revealed that the non-coding RNAs, formerly believed to have no biological functions, play important roles such as a transcriptional control. In particular, the short length (18-25 nucleotides) non-coding RNA, micro RNAs (miRNAs), have been found to bind to the target messenger RNAs and interfere with the translation. In recent years, the involvement of miRNA has been revealed in various diseases, including cancer, leading to a big expectation for a new development of nucleic acid drugs molecularly targeting miRNA.

Research and development of miRNA drugs are advancing rapidly in Europe and the United States, and there is a candidate drug for Hepatitis C already in Phase II. The development of drugs to treat lung cancer and prostate cancer are also underway. Since one miRNA has the property to regulate multiple gene expressions, regulating one target miRNA is able to adjust multiple disease-related gene expressions. Unlike antibody drugs, mass production of miRNA drugs is easy and requires no special know-hows for the development. Therefore, further advancement of miRNA drugs development is expected.

(Original Japanese version: published in July, August 2011)

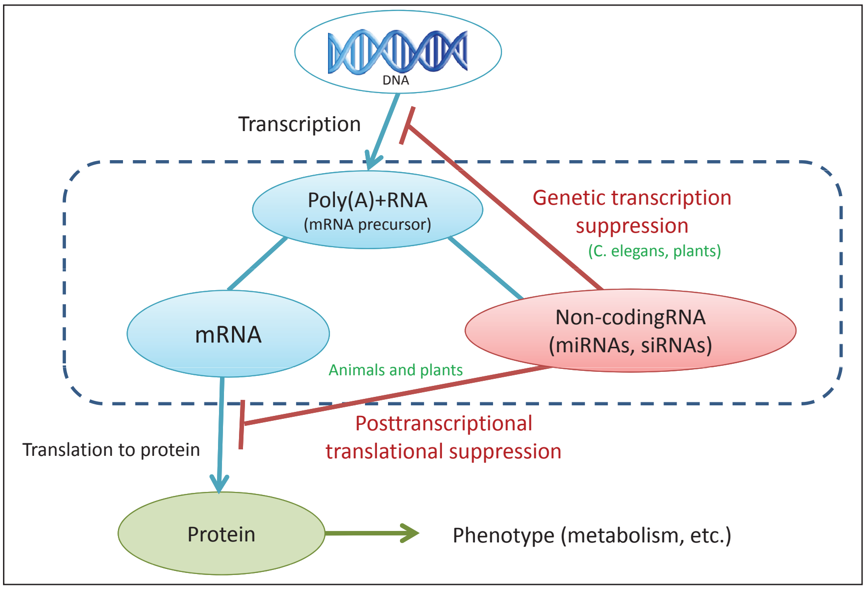


Figure : Active Sites of miRNAs

Prepared by the STFC

3 Report on the Annual AAAS Forum on Science and Technology Policy (2011)

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The American Association for the Advancement of Science (AAAS) held its annual Forum on Science and Technology Policy in Washington D.C. on May 5 and 6, 2011. The topics for the Forum include trends in the federal budgets for science and technology and key public policy issues that the science community is facing. The Forum brings together scientists, policy-related professionals, and others to understand such trends and issues and provides an important opportunity for discussions.

The topics for this year's 36th Forum included the following: the outlines of President Obama's science and technology policies; R&D budget proposed for fiscal 2012 and its financial, economic, and social backgrounds; engineering issues to strengthen American competitiveness; national innovation strategies; emerging issues in scientific integrity; communicating science issues for policymakers; and the future of American research universities.

Underlying fiscal conditions in the United States have been deteriorating and the implementation of fiscal 2011 federal budget has been long-delayed. To strengthen the future economic growth and international competitiveness of the United States, an updated "Strategy for American Innovation: Securing Our Economic Growth and Prosperity" was released on February 4, 2011. This Forum also contained presentations and discussions on how to simultaneously pursue fiscal reconstruction, economic growth, and competitiveness.

In the United States, the role of science and technology has been emphasized to resolve different kinds of national issues surrounding, for example, public finance, the economy, and education. This recent trend is exemplified by the increase of the total R&D budget proposed (research, development, equipment, and facilities) for fiscal 2012 by 3.3% over the previous year to 149.1 billion dollars (according to AAAS's estimate based on the President's Budget Message). The budget allocation shows that basic and applied research is prioritized. Education is also emphasized and $100 million have been requested in order to educate teachers for K–12 STEM (Science, Technology, Engineering, and Math) education. Among the agencies, the growth rate of the budget request is the largest for the Department of Energy (DOE), and much attention is drawn to the direction of R&D investments in energy policies.

To strengthen American competitiveness, one of the lecturers suggested that the United States should produce more engineers and pointed out that the percentage of those who acquire engineering degrees in the United States is lower than in Asian and European countries separately. It was also reported that the financial situation was deteriorating at state research universities. In contrast to increased investment by the federal government in K–12 STEM education, financial support by state governments for state research universities has been decreasing, and it is necessary to pay attention to these opposing trends affecting science and technology.

(Original Japanese version: published in July, August 2011)

4 The Direction of Embedded Software Development: Focusing on Japan's Social Characteristics —Reinforcing the basis for software development in electronics-driven durable goods—

p.36

From the viewpoint of strengthening a common foundation to gain higher industrial competitiveness, the 4th Japan's Science and Technology Basic Plan discussed issues surrounding the measures to cope with the ever-diversifying market needs. The discussion indicated the need for advanced development technology for embedded systems to constitute a pillar toward this movement. The importance of non-physical assets, typically software, has been gaining importance in the global knowledge-based economy. Software is also one of the prominent components in embedded systems.

In Japan, secondary industry has traditionally shouldered the major burden of trade balance. Japan's manufacturing sector, however, has already been exposed to fierce competition with the developing countries in East Asia. We must note that the improved technical capability in developing countries is the engine for their upgraded competitiveness, supported by lower production costs and their distinctive market capturing strategy. Typical industrial sectors that find themselves in such situation include those producing home electric appliances and automobiles (hereinafter simply referred to as "durable goods"). Ever increasing use of advanced electronics in these products in recent years – typically reflected in abundant use of embedded computers – has effected a change in the constitution of development costs for these products – costs for developing software to control the embedded devices have become increasingly prominent. East Asian countries have also gained increasing capabilities in this area of development efforts, threatening the superiority of Japan.

Embedded software runs on specialized and application-specific embedded computers used, for example, to control automobile engines and implement mobile communications, which must embrace stricter constraints in many aspects of its operations as compared with its counterpart that runs on general-purpose computers. The trend toward higher performance prompts more complex and bloated software to cope with the requirements for upgraded products with a much higher level of sophistication. On the other hand, the need for quicker delivery of improved performance at a lower cost is increasing. For long-term maintenance and improvement of competitiveness in the arena of embedded software development, correct recognition and leveraging of the social characteristics in Japan is of importance in addition to the promotion of innovation in science and technology. Japanese society is characterized by such unique aspects as its high-context nature in communication, its highly sensitive quality awareness shared by the manufacturers and consumers, its consumption-oriented public adopted to diversified needs, as well as its rich experience in customized software development. This viewpoint also helps alleviate wasteful price rivalry with developing countries.

The development of embedded software provides an area where "suriawase" – a Japanese term meaning fine coordination and sync-up among parties – can work effectively: It requires delicate mutual adjustment among integral components for producing a high performance product, where a high-context nature of thinking and past experience in customized software development may be exploited. Need-driven rapid prototyping is conceived effective in this area - reflecting and taking up diversified needs quickly. This requires involvement of the consumer, who provides first-hand information that is generally out of reach of the developers: here again, the high quality awareness and diversified consumer-orientation of the society have a beneficial effect. Leveraging the social characteristics of Japan is one thing, but, on the other side of the coin, there is a lack of logical coherence in communication lying in the background of the high context nature of Japanese society. To help resolve this problem, we should review our school education; close linkage between the subjects starting from elementary and secondary education should be achieved, and logical thinking in high school information education should be strengthened.

(Original Japanese version: published in September, October 2011)

5 Trends in Globalization around Supercomputers

p.50

The latest TOP500 list of high-performance supercomputers in the world has been released in June 2011. At number one is the Japanese next-generation supercomputer “Kei,” the K Computer, which is currently undergoing development and enhancement by the Institute of Physical and Chemical Research and Fujitsu Ltd. Countries around the world are now accelerating installation and application of supercomputers, while actively competing in their development.

When looking at the world’s supercomputers, there seems to be three types of globalization happening. The first is a globalization in installation. More countries than ever have installed supercomputers and a growing number of countries have installed Petascale performance supercomputers. The second type of globalization has more countries developing their own supercomputers. The days when only the United States and Japan manufactured supercomputers are no more. China, France, Russia, and India are now developing supercomputers by themselves. China has even developed core components for supercomputers —microprocessors. The third is a globalization in research and development. Countries are collaborating internationally to develop supercomputers. A lot of technical issues have arisen not only in hardware, but also in software, for example, how to run hardware at its maximum-speed or how to use or apply supercomputers. Some leading-edge research and development activities are now the center of international collaborations, where knowledge and power are gathered from many countries. For example, in an international project called International Exascale Software Project, researchers from Europe, Japan, and China are collaborating with U.S. researchers. The research group has made and shared a unified technical roadmap for tackling the issues of software running on Exa-FLOPS supercomputers.

Quite naturally, those three waves of globalization have occurred one after the other. In the days ahead, international collaborations will be indispensable for the realization of high-performance supercomputers. So, in order to hold a superior position in such international collaborations, the primary step is to have advantages that the world acknowledges. Japan has already created the best supercomputer in the world, “Kei.” The next step will be to show the world superior achievements in “Kei” applications and gain acknowledgement from around the world. In other words, there are opportunities around Japan. Japan should proactively promote international collaborations around “Kei,” absorb the wisdom of researchers from around the world, and bring Japanese technologies to a higher level.

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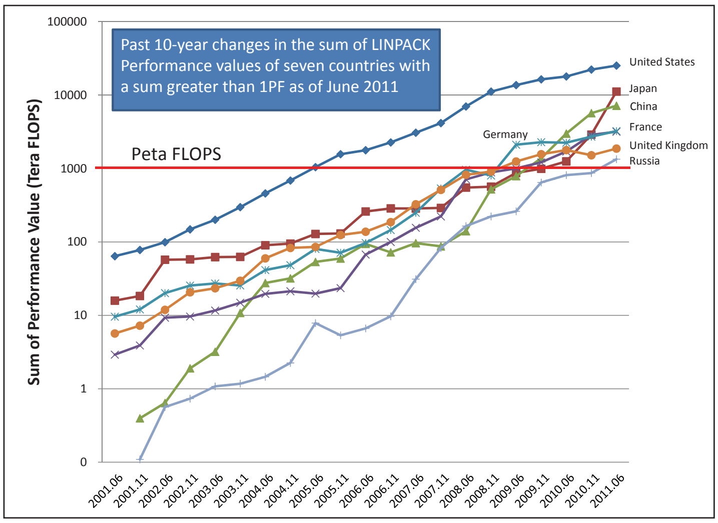

Figure : Line Plot of the Sum of LINPACK Performance Values of Countries with a Sum Greater than 1 PF (as of June 2011)

Prepared by the STFC based on the 37th TOP500

6 Discussion on Emission Reduction Targets for Individual Countries in Tackling Climate Change

p.63

Extreme weather patterns have been observed more frequently around the world, and it is widely acknowledged that climate change is the cause. To minimize climate change, which is expected to create various adverse effects, it is necessary to substantially reduce greenhouse gas emissions. Measnwhile, we have not seen much progress in international cooperation, and especially within a negotiating process under the United Nations Framework Convention on Climate Change (UNFCCC) since 2007, countries have not reached a consensus concerning mandatory limits on greenhouse gas emissions for individual countries.

Scientific studies have made global emission pathways increasingly clear as well as the permissible levels of greenhouse gases concentration in the atmosphere if temperature stabilization goals are to be met. How to allocate emission reductions among countries is an issue. The allocation is based on equity (fairness), which in turn is based on two principles: 1) the extent of responsibility and 2) the ability-to-pay principle that determines emission reductions. However, there are many different measures of these concepts, and countries have proposed measures that are to their own advantage and are not likely to reach a consensus. In addition, many countries, including the United States, do not accept the approach where a multilateral treaty requires each country to shoulder its "fair share." Japan has a target to reduce emissions by 25% compared to 1990 levels by 2020, and this is Japan's "fair share" from the point of view of equity. If Japan cannot achieve a target of this size, it will lose the legitimacy that it has been emphasizing to other countries, which is a call for all countries to accept their respective "fair share". As long as countries see emission reductions as a burden and continue to negotiate over the allocation of the burden, they will not be able to reach a consensus to tackle climate change. What is needed is a structural shift away from negotiations concerning burden allocation and toward competition for gain.

In recent years, Japan has been more interested in a bilateral credit system, which is basically the same as the clean development mechanism (CDM) under the Kyoto Protocol but has the advantage of being able to avoid the complicated procedures of the CDM. Developing countries can shift toward low carbon societies by adopting developed countries' technology, and Japanese companies can establish markets overseas. Competition for the production of solar panels as well as in new businesses for the reduction of carbon dioxide emissions (such as hybrid cars, electric cars, and bio fuels) are becoming intense, and it is critical for governments to form policies so that companies can become internationally competitive.

If we are to aim for a long-term temperature rise target below 2°C from pre-industrialized period as has been proposed as the ultimate target through international negotiations under the UNFCCC for stabilizing temperature, there will almost be no room to increase the world's CO_2 emissions again. As such, it is necessary reducing emissions contiunuously even after 2020. Countries and companies should be able to accrue economic gains when they swiftly develop technology to reduce emissions.

To solve climate change, we cannot avoid the international consensus-building process. Specialists in international negotiations or in natural sciences alone cannot achieve this. The establishment of a domestic system where specialists from various fields, including natural sciences, humanities, and social sciences gether, is the precondition for successful international negotiations.

(Original Japanese version: published in September, October 2011)

1

Trends in Research and Development of High-quality Domestically Produced Wheat

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1 Introduction: Current State Wheat Production and Consumption in Japan

According to the Family Income and Expenditure Survey conducted by the Statistics Bureau of the Ministry of Internal Affairs and Communications, a Japanese household with two or more people consumes 86kg of rice, 45kg of bread, and 36kg of noodles annually[1] (these are three major staple foods for the Japanese). The food self-sufficiency rate for rice has increased from 95% to almost 100%, but the rate for wheat, a main ingredient for bread and noodles, is extremely low at about 13%. In particular, the rate for bread wheat is only 1%. The remaining 99% depends on imported wheat.

Of the total of imported wheat, about 50% come from the United States, and the rest come from Australia and Canada[2,3] (Table 1). Most of the wheat from the United States and Canada is used for bread and ramen noodles, and most of the wheat from Australia is used for udon noodles. Representative products include Dark Northern Spring wheat (from the United States), Western Red Spring wheat (Canada), and Standard White wheat (Australia). The

Table 1 : Import and Production of Wheat by Japan in 2009

Countries of production		Volume (10,000 tons)	Percentage
Total of imported wheat		480	86.8%
	United States	296	53.5%
	Australia	96	17.4%
	Canada	88	15.9%
Total of domestically produced wheat		73	13.2%

Prepared by the STFC based on reference[2,3]

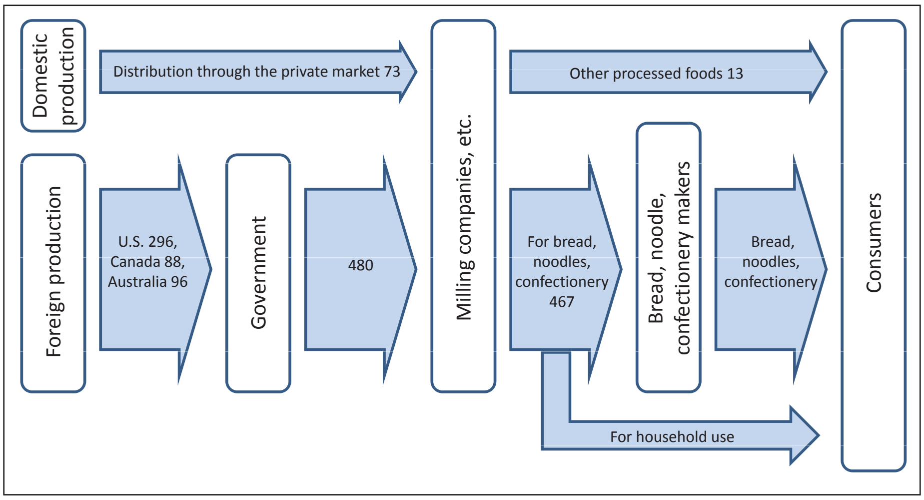


Figure 1 : Outline of Wheat Distribution and Volume (10,000 tons)
Prepared by the STFC based on reference[2,3]

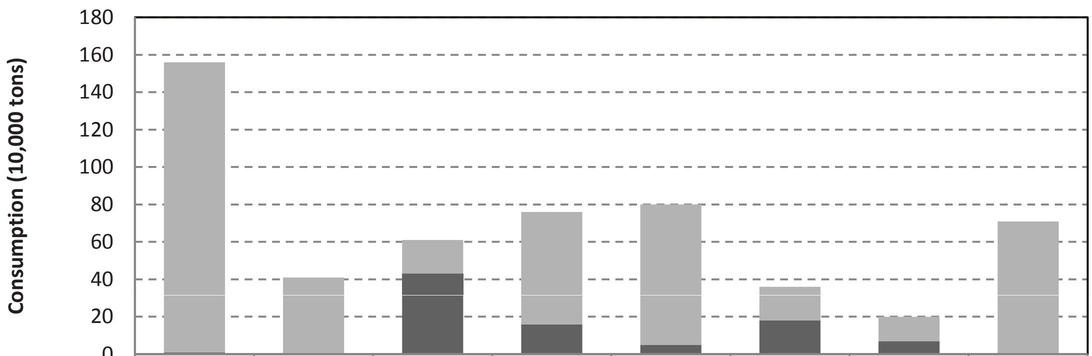
government buys all imported wheat, adds a markup (profit margin), and sells it to milling companies and others. The wheat is then processed into bread, noodles, etc. and delivered to consumers[2,3] (Figure 1).

Along with rice and corn, wheat is one of the most produced crops in the world. However, in Japan, strong wheat varieties (for bread and ramen noodles) are hardly cultivated. Mostly, medium wheat varieties (for udon noodles and confectionery) are cultivated[4] (Figure 2). This is because most domestically grown wheat varieties (for udon noodles) have been modified to suit Japan's humid climate and food culture since the Yayoi period (an Iron Age era), and other wheat varieties that are suitable to dry regions are difficult to cultivate since, in rainy Japan, they tend to suffer or their seeds sprout before harvesting.

However, demand is growing for bread and ramen noodles made from domestically produced wheat. This is attributable not only to the growing need for a variety of foods but also to anxiety surrounding imported foods, a desire to improve the food self-sufficiency rate, and (due to the increase in the population of wealthy people in emerging countries and climate change) rising and destabilized wheat prices.

This article discusses changes in wheat production around the world as well as expectations for domestically produced wheat and trends in research and development in Japan. It also examines the direction for the development of domestically produced wheat. Wheat is categorized into strong, medium, and weak flour depending on protein contents (Table 2), and this article focuses on strong wheat, the production of which is extremely low but the demand is high.

Incidentally, in terms of domestically produced bread and other products, attention has been drawn to rice bread and rice noodles. However, this article does not discuss these products because the taste and texture are different from wheat-based products as well as because it is expected to take substantial time for the industry to become large-scale.



	Bread	Ramen noodles	Udon noodles	Confectionery	Other noodles /pasta	Miso/soy sauce	Household use	Animal feed, etc.
Import	155	40.5	18	60	75	18	13	71
Domestic production	1	0.5	43	16	5	18	7	0

Figure 2 : Self-sufficiency Rates for Wheat by Use

Prepared by the STFC based on reference[4]

Table 2 : Wheat Varieties, Characteristics, and Protein Contents

	Weak flour	Medium flour	Strong flour
Protein content	6–9%	9–11%	11–13%
Gluten quality	Weak	<<<<	Strong, stretchy
Kneading	Less kneading	Regular kneading	More kneading
Major uses	Castella (sponge cake), Cake, Japanese confectionery, Biscuit, Tempura flour	Instant noodles, Udon noodles, Biscuit, Japanese confectionery	White bread, Sweet bun, French loaf, Bread crumbs, Ramen noodles
Major wheat varieties imported to Japan	Western White (WW) from the U.S.A.	Standard White (ASW) from Australia	Western Red Spring (1GW) from Canada, Dark Northern Spring (DNS) from the U.S.A.

Prepared by the STFC based on reference[2,3]

2 World Wheat Production and Consumption

2-1 Concentrated Wheat Growing Regions and World Wheat Imports

Wheat has long been improved worldwide to adapt to relatively cold and dry climates. Japan has hot and humid weather during the harvesting season for wheat (around June and July), and so diseases such as wheat yellow mosaic virus, Fusarium head blight, and pre-harvest sprouting occur often, making harvesting impossible. In particular, strong wheat varieties used for bread and ramen noodles (which are in high demand in Japan) have these tendencies. Therefore, Japan depends on imports for strong wheat.

Of course, these characteristics make other regions in the world with hot and humid climates difficult places to cultivate wheat. Therefore, wheat-growing regions are heavily concentrated in parts of the world that have adequately fertile land, that have a small amount of rain during the harvesting season, and that are suitable for large-scale farming. Figure 3 (left pie chart) illustrates world wheat output between 2009 and 2010, and the top eight producers including the EU (the largest producer) and Canada (the eighth) produce 78% of world wheat[5,6].

The populations who eat wheat as a staple food do not necessarily live in the wheat-growing regions. As such, many countries import wheat from a small number of wheat-producing countries. During the 2009–2010 period, the amount of wheat imported by the top 26 importing countries combined is still less than 70% of the total amount of wheat imported worldwide (Figure 3, right pie chart). This means that countries are competing to acquire wheat.

As discussed, wheat-producing countries and wheat-consuming countries are substantially different. Countries that have large populations and are located mostly in the monsoon, tropical, or excessively dry regions (which are not suitable for wheat cultivation) in, for example, Southeast Asia, Africa, and the Middle East, heavily depend on countries like the United States, the European Union countries, Russia, Australia, and Canada, which have small populations relative to their wheat production and have high production technology. If these producing countries limit their wheat exports, many importing countries will immediately run short of wheat, and prices will skyrocket. It is also expected that the populations in the wheat exporting countries will increase.

2-2 Rise in Demand for Cereals Due to the Increase in the Population of Wealthy People

The world consumption of cereals (including wheat) is expected to increase during the twelve years between 2008 and 2020 by 500 million tons to reach 2.7 billion tons[7]. In contrast, cereal production is expected to remain at 2.65 billion tons in 2020. So the ratio of cereal carryover stocks to utilization is expected to drop from about 20% in 2008 to 15% in 2020, lower than the food security indicator (17–18%) set by the Food and Agriculture Organization of the United Nations. Therefore, all cereal prices are expected to trend upward. Wheat is no exception, and in 2020, nominal wheat prices are projected to rise to a level comparable to the highest price recorded in 2008. These are about three times higher than the prices in 2000, the previous base year[7].

The underlying reason for the rises in cereal

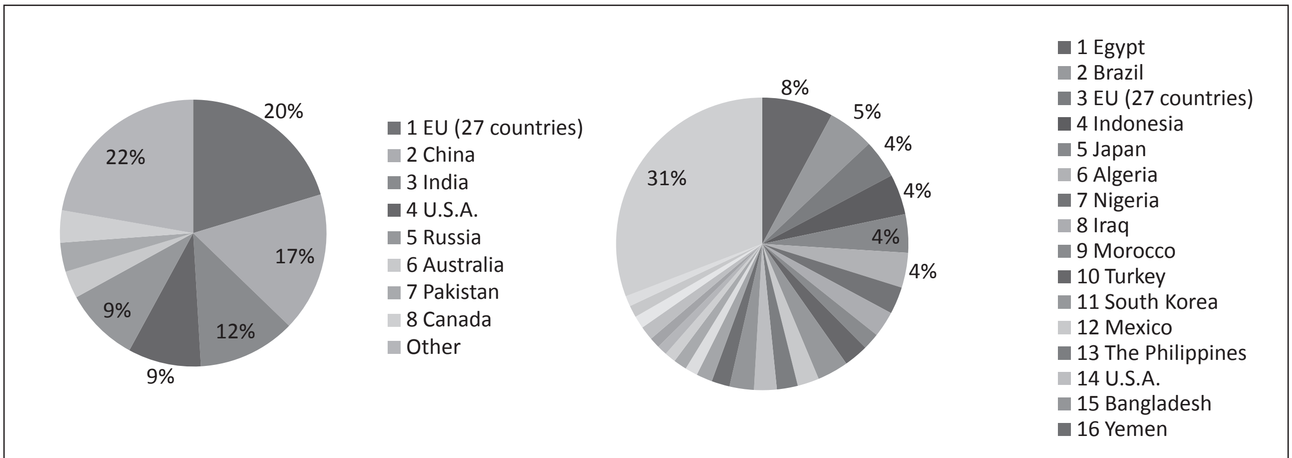


Figure 3 : World Wheat Growing Countries (Left) and Importing Countries (Right) between 2009 and 2010

Prepared by the STFC based on Reference[5,6]

prices and the tight supply and demand situation is the increase in the population of wealthy people in emerging countries. Despite the impact of the stagnant world economy following the financial crisis in developed countries and elsewhere, emerging countries' economies continue to grow at a high pace and are likely to lead the world economy. As these countries become richer, their meat consumption increases, and so more cereals will be needed for animal feed. In addition, the consumption of processed wheat foods, including bread and noodles/pasta, is likely to increase. As a result, China and India may become importers even though their wheat self-sufficiency rates are now close to 100%. There is a concern that this may also have a heavy impact on the wheat market.

Moreover, cereal consumption in other Asian countries, Africa, and the Middle East is projected to increase rapidly. Cereal production in these regions has been increasing, but the demand is growing at a faster pace, and so the dependence on imports is also growing every year. Among some of the top importers of wheat, including Egypt, Indonesia, Nigeria, and Bangladesh, the volumes of imports have already increased in the past five years. In particular, cereal consumption in Africa is expected to reach about 270 million tons (10% of the world consumption) in 2020 due to a substantial increase in the population and economic growth[5]. In contrast, production is not likely to catch up with demand, and so, in 2020, Africa is projected to expand its imports of cereals to 80 million tons, twelve times larger than in 1996.

2-3 Instability in Production Due to Climate Change

The recent abnormal weather has spurred the global competition for cereals. In 2010, more than ten countries limited their exports of wheat due to poor harvests caused by abnormal weather.

Russia is the world's fourth largest wheat producer (about 9% of the world's share in 2009) and the world's fourth largest wheat exporter (about 14% of the world's share in 2009). However, in 2010 Russia announced a ban on exports of wheat and other cereals between August 15 and the end of December. This action was taken to prioritize domestic supply because about 20% of the wheat planted in fiscal 2010 was damaged and not harvested due to drought. Wheat exports are usually concentrated in the latter half of the fiscal year due to seasonal factors. If we suppose that half of Russia's exports vanished from seaborne trade, 7% of the world's annual exports would have disappeared. In addition, Ukraine and other neighboring countries were also affected by similar drought conditions.

Australia announced that only half of the wheat cultivated in 2010 would be able to be used for flour due to its inferior quality caused by that year's floods. Standard White (ASW) from Australia is used for udon noodles in Japan, and there is concern that the Japanese market may be directly affected.

There is also concern that farmland may decrease worldwide. Currently, deserts are increasing globally by five million hectares annually. This is equivalent to Japan's total farmland (4.65 million hectares). Moreover, increasing urbanization and water shortage may make it difficult to increase farmland globally.

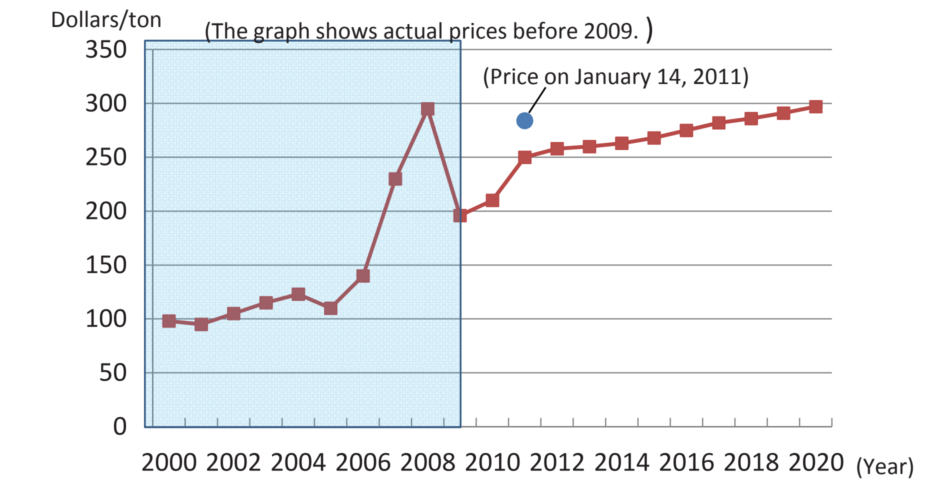
In response to this situation, Korea announced that it secured 2.1 million hectares of farmland in Sudan. China also secured 2.8 million hectares in Congo and 2 million hectares in Zambia. Additionally, Saudi Arabia and the United Arab Emirates are trying to secure farmland abroad in exchange for oil. Japan has historically protected domestic farmers and currently does not aim to secure inexpensive farmland overseas.

Due to the recent situation, the international wheat prices rose about three times higher compared to 2000 or roughly doubled from 2006. Expecting that the prices will continue to rise in the long term, investors have been pouring speculative money into the market, which is also considered to have spurred the price hikes. The impact of climate change, unlike the increase in the population of wealthy people, is difficult to predict and makes wheat prices unstable.

3 Outlook for Domestically Produced Wheat

3-1 Consumers' Expectations for Domestically Produced Wheat

In response to the recent global trends, wheat prices are also rising in Japan. Currently, the Japanese government imports all wheat and determines the selling prices to milling companies and others. In recent years, the prices have gone up dramatically: by 10% in October 2007 and by 30% in April 2008.



Note : The graph shows actual prices before 2009. The prices skyrocketed in 2008 and fell again, but they are expected to rise slowly. The price recorded on January 14, 2011 already greatly exceeded the predicted price, and there is a view that the predictions are optimistic.

Figure 4 : International Wheat Prices (Nominal) and Their Prospects

Source: Reference[9]

The Ministry of Agriculture, Forestry and Fisheries has just raised the selling prices of imported wheat to milling companies by 18% on April 1, 2011 on the ground that international prices of wheat continue to rise substantially. In response, major baking companies have raised the prices of their main products by 5–10%.

Amid concerns over global competition for cereals, the demand for domestically produced wheat has been growing in Japan. Enhanced awareness for food safety is a major factor. For domestically produced wheat, agricultural chemicals are used, but not post-harvest chemicals. The impact of agricultural chemicals on human health is not yet very clear. However, there is a new and growing inclination among consumers to pay more for locally-grown, safer food. Some major turning points for this change in values are the two cases that occurred in China in 2008: 1) dumpling poisoning and 2) a contaminated formula that harmed the health of 300,000 infants.

The number of consumers who are interested in domestically produced wheat and the number of bakeries that are conscious about safety have been increasing. The Japanese government imports a substantial amount of wheat that is cultivated in large-scale farms, and most of the wheat is processed into bread, ramen noodles, pasta, etc. before it is provided to consumers. As such, consumers had not paid much attention to different varieties, compared to rice. However, demand for good-quality domestically produced wheat is growing as the awareness of local production for local consumption grows and as, due to improved baking technology, more people make homemade bread and the number of bakeries increases. In addition, consumers have gradually begun to pay attention to wheat varieties and where they come from[8].

We conducted a small-scale market survey in front of a bakery in Sapporo city in January 2011 (Figure 5). The bakery uses both imported and domestically produced wheat for their bread, Thirty-two people who bought bread at the shop responded to the survey and were asked "Even though domestically produced wheat is more expensive, how much more are you willing to pay?" The respondents answered that they would pay up to 2.3 times more on average.

However, while the demand for domestically produced wheat has been growing, domestic wheat production has not changed much in the past several years. Figure 6 illustrates changes in bid prices for wheat in Japan. Haruyokoi is the highest priced and is a representative domestic strong wheat variety used for bread. The price for Haruyokoi is about two times higher than imported varieties used for bread. Changes over the years show that the trading price of Haruyokoi has been increasing, indicating higher demand for domestically produced wheat. To fill the price gap, the Ministry of Agriculture, Forestry and Fisheries buys all imported wheat, adds a markup (profit margin), and sells it on the market. By raising the price of imported wheat, the government uses the profits to provide subsidies to those who buy domestic

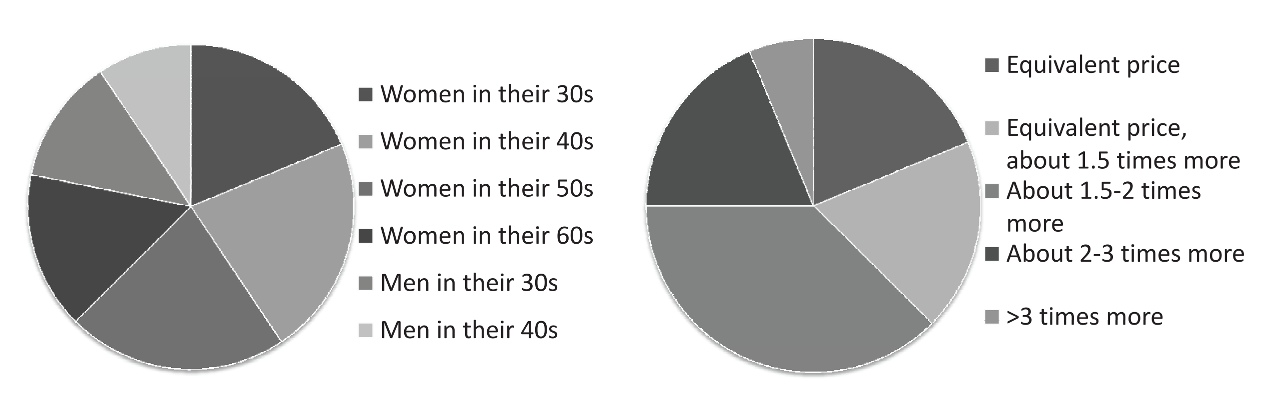
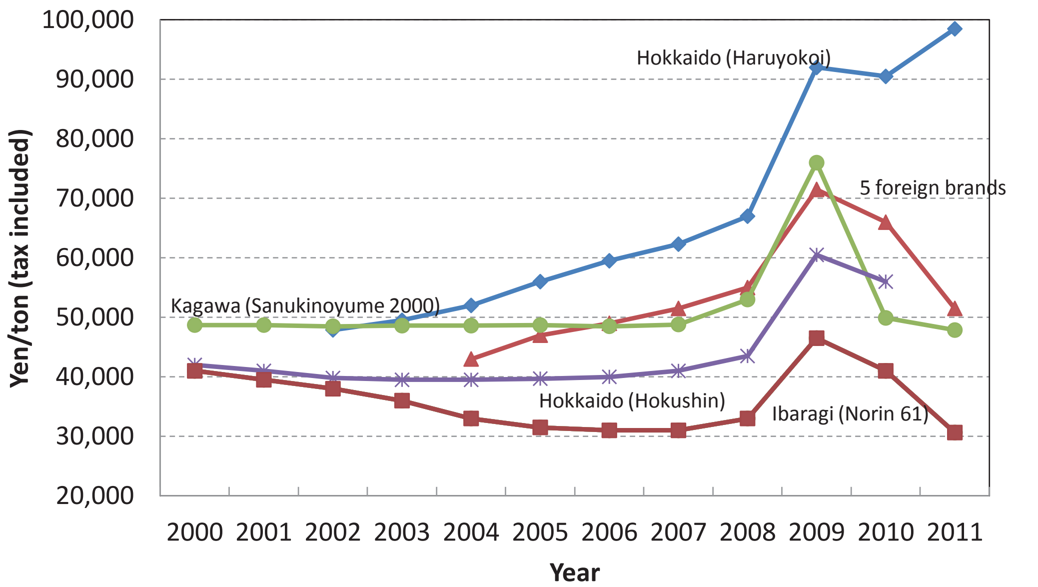


Figure 5 : Survey Results Regarding Buying Motivation for Bread Made from Domestically Produced Wheat: Ages and gender of the respondents (left); Answers to the question, “Even though domestically produced wheat is more expensive, how much more are you willing to pay?” (right)

Source: Reference[8]



Note : The prices of imported wheat are the government’s selling prices announced at the time of bidding for domestically produced wheat. After April 2007, the average selling prices for five brands are shown. The prices are revised twice a year.

Figure 6 : Changes in Bid Prices of Wheat in Japan by Major Production Region (Brand)

Prepared by the STFC based on reference[3]

brands to help them buy domestically produced wheat.

3-2 Food Security

In Japan, Article 2, paragraphs 2 and 4 of the Food, Agriculture and Rural Areas Basic Act stipulate the following regarding food security. They also directly apply to domestically produced wheat.

(Article 2, paragraph 2) In consideration of the fact that the world's food supply and demand and trade have some uncertainties, stable food supply to the citizens shall be secured by increased domestic agricultural production as a base together with appropriate combination of import and reserve.

(Article 2, paragraph 4) Even in the case when the domestic food supply and demand get stringent or likely to be so for a considerable period of time due to poor harvest or interrupted imports, the minimum food supply shall be secured so that no significant adverse effect is generated to the stable life of the citizens and smooth operation of national economy.

As discussed earlier, wheat is used to make bread and noodles and, along with rice, is a staple food for the Japanese. The global supply and demand of wheat has been unstable due to increasing populations in emerging countries and frequent occurrences of abnormal weather. The situation is clearly a threat to food security in Japan. Therefore, domestic wheat production shall be increased (Article 2, paragraph 2), and the wheat supply shall be secured to avoid significant adverse effects to the national economy (Article 2, paragraph 4).

Regarding food security, Article 2, paragraph 1 of the same act also stipulates that a stable supply of high-quality food at reasonable prices shall be secured for the future, not only to prepare for unforeseen circumstances but also to maintain the basis for healthy and fulfilling lives (Article 2, paragraph 1).

As such, it is necessary to develop good-quality domestic wheat varieties comparable to imported wheat and to improve product development technologies, such as for the cultivation of new varieties, processing, milling, and bread- and noodle-making.

4 Policy Surrounding Domestically Produced Wheat and Trends in Research and Development

4-1 Changes in Agricultural Policy Surrounding Domestically Produced Wheat

Wheat production in Japan was stagnant until the 1970s. However, since wheat was positioned as one of the alternative crops to cultivate in rice fields, its production has been gradually increasing. The new wheat policy outline published in 1998 suggests a policy to cultivate wheat as a main crop in rice fields, and projects to develop new technologies have been gradually accelerating[9].

To improve research and development on wheat and barley, the policy outline suggests the following: reflecting the requests from producers and users into variety development; clarifying targets to promote variety development; facilitating the transfer of research results; and establishing an urgent research and development project. In 1999, the urgent development project concerning new wheat and barley varieties launched. Research continued as a project related to domestically produced wheat, and cultivar improvement and technological development were conducted. For example, Nishinokaori, Kitanokaori, and other strong wheat varieties were cultivated to adapt to different regional environments, and their qualities for milling, baking, and processing were studied[10].

The Integrated Research for Providing Fresh and Delicious “Brand Nippon” Agricultural Products, which launched in 2003, aimed to address pre-harvest sprouting and Fusarium head blight, to study reasons for low quality, and to develop new uses in order to expand the demand. Against hard-to-control diseases such as pre-harvest sprouting, Fusarium head blight, and wheat yellow mosaic virus, resistant genes were introduced, integrated technology was developed, and resistant varieties were developed[11].

In 2005, the Basic Plan for Food, Agriculture and Rural Areas was revised, and in 2006, the new demand wheat and barley research project was conducted. Currently, a project (launched in 2010) is underway to develop technology for effective year-round use of agricultural land by maximizing the potential of rice fields. This project aims to improve the food self-sufficiency rate by effectively using rice fields in winter (and so using agricultural land all year around), and research and development has been conducted to improve the productivities of high-quality varieties that have been developed.

In addition, in March 2010, the Cabinet determined the second revision of the Basic Plan for Food, Agriculture and Rural Areas. Recognizing that the world’s supply and demand situation for cereals is expected to be tight in the medium and long terms, and the plan aims to improve the food self-sufficiency rate by 50% (on the calorie basis) in 2020. The plan lays out some issues to address regarding production including the following: cultivating varieties for bread and ramen noodles with good quality and good yield performance; promoting double cropping in rice fields by cultivating good-quality late-maturing wet rice varieties; and extending the use of domestically produced wheat currently used in udon noodles into bread and confectionery by, for example, establishing processing technology. The plan has set a quantitative target and aims to increase wheat production to 1.8 million tons, about double the current amount[12].

4-2 Trends in Research on Genetic Characteristics of Wheat

When flour is kneaded with an adequate amount of water, gluten and gliadin (major components of protein contained in flour) mix to form visco-elastic gluten. This occurs because the water and the kneading action give rise to a large net-like polymer structure[13] (Figure 7). The characteristics of bread and noodle dough depend on the quality and quantity of gluten, and appropriate types of flour must be used

Table 3 : Major Recent Agricultural Policies Concerning Domestically Produced Wheat in Japan

1998	The new wheat policy outline was published.
1999	The urgent development project concerning new wheat and barley varieties launched.
1999	The Food, Agriculture and Rural Areas Basic Act was enacted.
2000	The Basic Plan for Food, Agriculture and Rural Areas was created.
2003	The Integrated Research for Providing Fresh and Delicious “Brand Nippon” Agricultural Products launched.
2005	The Basic Plan for Food, Agriculture and Rural Areas was revised (1st time).
2006	The new demand wheat and barley research project launched.
2010	The project to develop technology for effective year-round use of agricultural land by maximizing the potential of rice fields launched.
2010	The Basic Plan for Food, Agriculture and Rural Areas was revised (2nd time).

for different processed foods. Gluten-rich elastic strong flour is used for bread and ramen noodles, while medium flour (with intermediate quality and quantity of gluten) is used for udon noodles.

Cystines, a type of amino acid contained in glutenin, are bound together by a disulphide bond to form a large polymer structure with many intertwined molecules (Figure 8, left). Gliadins are present as monomers, loosely associated by hydrogen bonding, etc. (Figure 8, right). Due to these characteristics, glutenin expands and contracts like rubber, creating elasticity (strength), and gliadin is related to the viscosity of gluten[14].

Glutenin can be categorized into high-molecular-weight subunits (molecular weight: 80,000–160,000) and low-molecular-weight subunits (molecular weight: 30,000–46,000). Even if overall protein content is kept the same, the viscosity and elasticity of gluten varies greatly depending on the glutenin subunit content ratio, composition, and degree of polymerization of each variety. There are four different types of gliadin: three types with molecular weights between 25,000 and 46,000 and one type with a molecular weight between 46,000 and 70,000. Due to these factors, their processing suitability differs substantially.

Among various genotypes of high-molecular-weight glutenin subunits, it is becoming clear which subunits are more effective for making dough strong. More specifically, the shape of a polymer differs depending on the number of cystines, which bound together intermolecularly, and either low elastic straight-chain polymers or high elastic net-like polymers are formed. As to the effects of the genotypes of low-molecular-weight subunits on dough properties, the difference in the number of cystines does not matter, but the number and quantity of subunits and the difference in conformations affect dough properties[14].

As such, extra strong dough can be made from wheat varieties that have a combination of high-molecular-weight and low-molecular-weight subunits such that the dough is strengthened. The dough is very elastic, and by mixing medium flour into this flour, one can create flour that is suitable for bread-making, etc., similar to strong flour. As such, extra strong flour is used for blending with other flours.

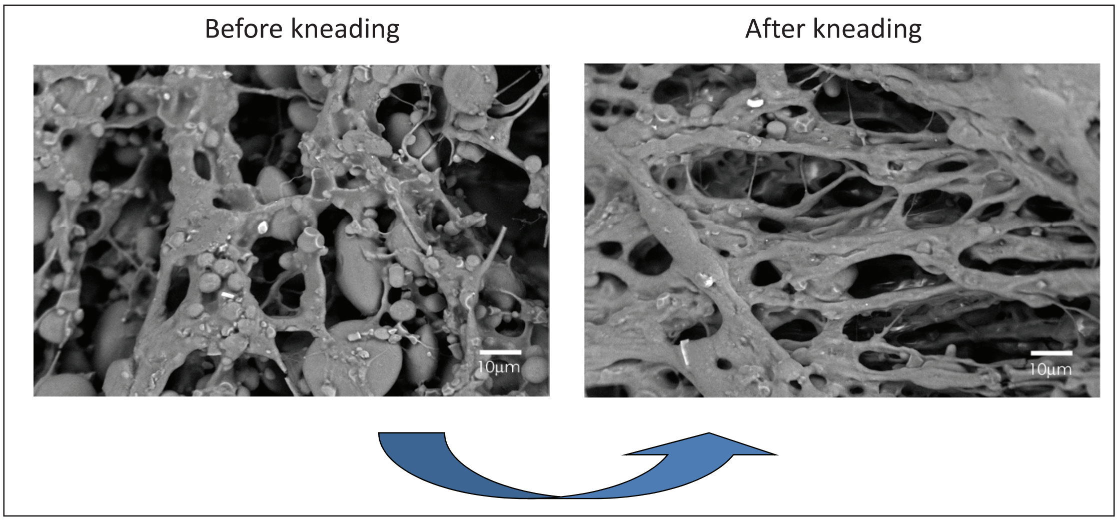


Figure 7 : Scanning Electron Microscopic Image of Gluten[15]

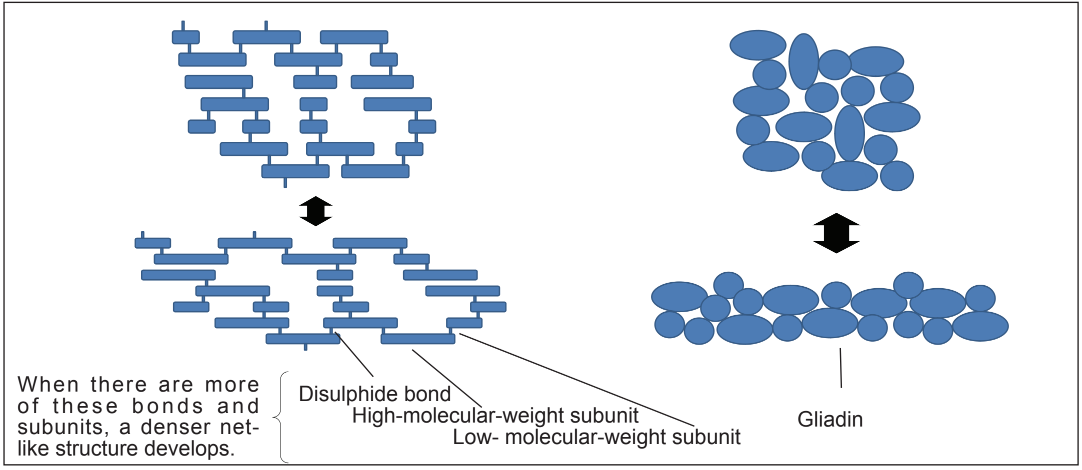


Figure 8 : Protein Characteristics for Visco-elasticity: Glutenin forms polymers through disulphide bonds and affects elasticity by expanding and contracting like rubber (left). Gliadin, aggregations of monomers loosely bound by hydrogen bonding, etc., affects viscosity (right)

Prepared by the STFC based on reference[14]

Yumechikara, a new domestically grown wheat (which will be discussed in the next section)[16], is known to have the same characteristics, and its dough properties are as strong as or even stronger than those of Dark Northern Spring wheat from the United States.

As discussed, it is possible to estimate dough properties to a certain extent from the combination of genotypes of glutenin subunits. It is also becoming possible to select high-quality wheat optimized for different processing purposes.

4-3 Trends in Cultivar Improvement and Action against Pre-harvest Sprouting and Wheat Diseases in Hokkaido

Hokkaido is the largest wheat producer in Japan, making up 60–70 % of the total wheat production in the country. Most wheat is vulnerable to high temperature and humidity, and its cultivation is suitable in regions where it is dry and cold during the harvesting season. Hokkaido does not have a rainy season and is suitable for growing wheat. In addition, large-scale farming is feasible in Hokkaido. For example, the Tokachi district's land area is larger than Tokyo, Chiba, and Kanagawa prefectures combined and has long developed large-scale farming. Its average cultivated acreage per farm is twenty-four times larger than the country's average. In addition, the Ishikari district has been emphasizing the cultivation of new strong wheat varieties with support from Ebetsu Flour Milling Co. Ltd. and other locally operating companies[8].

Haruyutaka and Haruyokoi are representative domestically produced wheat varieties used for bread and which are in demand. However, Hokushin, a medium flour, makes up about 90% of wheat production in Hokkaido, followed by Haruyokoi (~4%), Kitanokaori (~1.5%), and Haruyutaka (~0.6%), and so the production of bread-making wheat is still rare.

The National Agricultural Research Center for Hokkaido Region of the National Agriculture and Food Research Organization focuses on improving winter wheat rather than spring wheat in order to reduce wheat diseases through earlier harvesting. Yumechikara is one such new extra strong gluten wheat variety that shows excellent resistance to wheat yellow mosaic virus and Fusarium head blight[16]. Since extra strong flour can be blended with Hokushin and other domestically produced medium flours to make the dough properties suitable for bread and ramen noodles, there is an expectation that the consumption of domestically produced wheat will increase.

Yumechikara was created in 1996 by crossing Satsukei 159/KS 831957 (F1) with Tsukikei 9509 (Kitanokaori). Satsukei 159 has excellent over-winter ability[17]. KS 831957 (F1) (introduced from Kansas State University) has excellent bread-making quality and extra strong dough quality traits. Yumechikara was adopted as a good-quality variety in Hokkaido in 2008 for its excellent resistance to wheat yellow mosaic virus (which has been causing damage to the wheat growing regions in Hokkaido) and for its excellent processing properties when it is used in blends.

Processing adequacy evaluation is also conducted for blends with other wheat produced in Hokkaido[16]. Bread-making properties were tested for blends of Yumechikara and Hokushin, Japan's core variety, with different blend ratios. As the ratio of Yumechikara goes up, the elasticity and consistency improve, the volume increases, and puffier bread can be made. However, dough made from 100% Yumechikara is too strong and less workable, causing the bread to fail to rise and to thus become hard and distasteful. Testing has shown that a blend of Yumechikara with 25–50% Hokushin improves the workability of the dough, and the bread becomes puffy, increasing the overall evaluation score (Figure 9).

5 For the Future Development of Domestically Produced Wheat

5-1 Promoting the Research and Development of Wheat

As discussed earlier, the world's wheat prices are rising and becoming unstable due to the concentrated wheat production regions, the increase in the population of wealthy people in emerging countries, and global climate change. Expectations for domestically produced wheat are growing because of concerns over food security and the rise in the awareness of food safety among consumers.

However, as illustrated in Figure 6, the prices of domestically produced wheat are still much higher than imported wheat. As discussed in Section 1 of Chapter 4, since the late 1990s, the Ministry of Agriculture, Forestry and Fisheries and other organizations have been trying to improve technologies concerning high-yielding varieties and cultivation. However, the scale of such research and development is small and scattered, and human resources are scarce.

Milling companies, bread-making companies, noodle-making companies, and others strongly desire a stable supply of domestically produced wheat of consistent quality. High-quality, good varieties have been researched and developed, but production and quality still vary greatly depending on the year and location. For example, there are many orders for Haruyutaka, a domestically produced strong wheat introduced in Chapter 4, but production is not able to meet demand. As a result, sales had to be scaled back in 2009 and 2010.

As such, it is important to develop particularly stable quality wheat and improve yields. To this end, it is essential to substantially enhance research and development of domestically produced wheat at public research institutes and universities. In addition, it is hoped that related companies will improve milling, bread-making, noodle-making, and quality assessment technologies.

Table 4 : Wheat Varieties Produced in Hokkaido

	Variety	Use
Winter wheat	Hokushin	Japanese noodles
	Kitahonami	
	Horoshirikomugi	
	Kitamoe	
	Kitanokaori	Bread, ramen noodles
	Yumechikara	
Spring wheat	Haruyutaka	
	Haruyokoi	
	Harukirari	

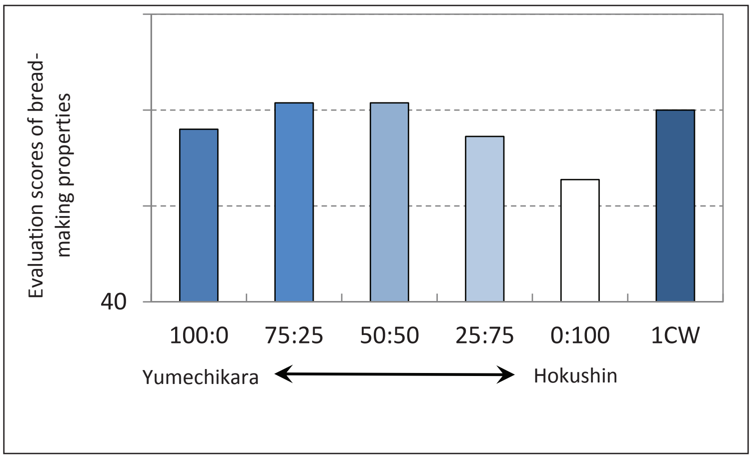


Figure 9 : Ratios between Yumechikara and Hokushin and Bread-making Properties (ICW: Western Red Spring from Canada)

Prepared by the STFC based on reference[16]

To realize lower costs as well as consistent quality and stable supplies, the following two issues should be addressed through wheat-breeding research.

Firstly, diseases that occur right before harvesting during the hot and humid season (such as Fusarium head blight, wheat yellow mosaic virus, and pre-harvest sprouting) must be prevented. Rival wheat varieties from overseas do not need to have resistance to Fusarium head blight and pre-harvest sprouting, and so this is a unique problem for Japan to overcome since the country has a rainy season.

The DNA marker selection technique has been drawing attention as a way to accelerate research. Each wheat variety has slightly different DNA base sequences, and with these differences as markers, it is possible to indirectly select for good tastes and other useful qualities based on genetic differences. By doing this, one can substantially reduce the selection time compared to the conventional selection based on repeated crossings and screenings. For example, by combining the conventional selection technique and the DNA marker selection technique, one only needs to extract DNA from a leaf at the seedling stage in order to select useful qualities from different varieties, and it is possible to check multiple qualities in a short time without taking much time and effort for crossings and cultivation. As such, it is desirable to effectively use the DNA marker selection technique.

Secondly, improving wheat cultivation properties should be addressed in breeding research. Even if disease-resistant, high-quality varieties are developed, it is meaningless without a technique with which each farm can stably cultivate wheat. Some high-quality domestic wheat varieties have been developed, but a cultivation technique to secure a stable yield every year has not yet been established. This is because producers have slightly different ways of growing wheat, and so they cannot keep the qualities at the same level. As a result, the food-processing costs become high. It is essential to establish a stable and versatile cultivation technique and to create a system to provide accurate information and support to producers by, for example, educating on different types of additional fertilizers and when to use them to combat various diseases.

5-2 Establishing Wheat Brands and Further

The Strategies of Assuring Intellectual Property for the Ministry of Agriculture, Forestry and Fisheries was formulated in March 2007, and intellectual property policy began to really take effect in agriculture, forestry, and fisheries18]. In these fields, there are various intellectual properties, including new crop varieties at production and processing stages (plant breeders' rights), technology development results (patents, utility models), gene patents, designs at the sales stage (design rights), naming (trademark rights), on-site technologies and know-how, and intangible information on local brands and food culture[19]. The Strategies aim to comprehensively create, protect, use intellectual properties in agriculture, forestry, and fisheries to enhance competitiveness in agricultural, forestry, fishery, and food industries, and realize regional improvement[20]. In March 2010, to facilitate this trend, the New Strategies of Assuring Intellectual Property for the Ministry of Agriculture, Forestry and Fisheries were formulated[21]. In particular, emphasis is placed on local brand strategies for survival of domestic producers, and through the strategies, unique local value is identified and then sold as valuable products. As such, it is essential to realize regional improvement and vitalize the food industry by improving the quality of domestically produced wheat and establishing brands.

Agricultural and marine products and food fit naturally into the concept of local brands[22]. When creating a brand, it is important to establish the inherent value of the product. In the case of wheat, the quality (taste, nutritional value, etc.) of the food processed from wheat must be high. However, local brands cannot be based on this alone. It is essential to have sales strategies to appropriately convey the food value and the connection to the region. As discussed earlier, cultivars, cultivation techniques, naming, etc. can be protected by intellectual property rights. To promote local brands, it is necessary to manage and use these intellectual properties in an integrated manner.

As an extension of local brand strategies, it is also essential to examine international strategies for domestically developed wheat. While Japan's food market is expected to shrink in the long term, the world's food market is projected to grow due to the increase in wealthy people in Asian countries and elsewhere, the globalization of Japanese food, etc. The production of conventional wheat varieties is concentrated in certain regions due to their strong environmental affinities. As such, it is critical to, first, establish intellectual property rights for cultivars (that are resistant to a hot and humid climate) and cultivation techniques, and to take them overseas and cultivate them locally. Through this process, one should convey the appeal of Japanese food and improve the recognition for high-quality Japanese agricultural products. Farmers and the agricultural cooperative association are, of course, the center of these activities, but the National Agriculture and Food Research Organization, regional agricultural research centers, and regional independent administrative institutions have accumulated advanced knowledge concerning cultivar improvement, new cultivation techniques, gene technology, etc. In addition, the Japan External Trade Organization (JETRO) provides excellent know-how and support concerning business localization overseas. These individuals and organizations are expected to cooperate to produce and sell Japanese wheat overseas.

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Glossary:

- Pre-harvest sprouting: Seeds sprout on spikes before harvesting. The phenomenon can happen to wheat, rice, corn, etc. due to rain and other climate conditions. It decreases yield and reduces quality. To address this problem, breeding has been conducted to select for early-maturity cultivars (that can be harvested before the rainy season) and cultivars that have genes with a strong latent tendency such that they do not easily sprout even upon absorbing water.
- Fusarium head blight: One of the most serious diseases for wheat and barley. When disease-causing fungi infect spikes, seeds may not become larger and entire wheat heads may wither.
- Wheat yellow mosaic virus: Symptoms appear as dashes and, later, yellowish-white streaks in young leaves. The virus lives in soil and is transmitted through soil by a soil-borne fungus. The virus can remain in soil for a long period of time. It is difficult to eliminate the virus and the transmitting fungi from the soil.
-Post harvest chemicals: Pesticides, fungicides, etc. used on agricultural produces after harvesting. In Japan, the use of post harvest chemicals after harvesting is banned. However, such chemicals are sometimes used on products when they are transported from the United States and elsewhere.
- Disulfide bond: A disulfide bond is a covalent bond with a bridged structure and is formed from the oxidation of SH groups (two cystine residues). The overall structure is R-S-S-R.

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2

New Type of Nucleic Acid Drugs: Recent trends in micro RNA research

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1 Introduction

Now small RNAs that are transcribed from genomic DNA are commanding considerable attention. With the emergence of the high-throughput next-generation sequencer (NGS)[NOTE 1], there has been an advancement in large-scale transcription analysis (transcriptome), which symbolizes progress in the post genomic era. Consequently, this reveals the great number of RNAs were transcribed from non-protein-coding DNA regions (non-coding RNA: ncRNA) in human genome. It was also revealed that protein-coding DNA sequences account for only 2% of human genome, with the remaining 98% is represented in non-coding DNA. In addition, it gradually became clear that ncRNA, formerly believed to have no physiological activity, was equipped with important functions, such as transcription regulation.

The length of ncRNA transcribed from genomic DNA varies from 20 bases to more than 200 bases in length. Among these, microRNA (miRNA), which constitutes group of small ncRNA generally 18-25 bases in length, is receiving a considerable attention[1]. miRNA belongs to a member of the small RNA molecular family (Figure 1), and negatively regulates gene expression (gene silencing)[2], an RNA interfering (RNAi) molecule. While a well-known RNAi molecule, small interfering RNA (siRNA), is a small RNA that is artificially synthesized, miRNA exists endogenously in the cell. This means that there is an innate gene-silencing mechanism in our bodies. Ever since this was confirmed, miRNA research has been advancing drastically.

Small RNA Group

small interfering RNA (siRNA)
micro RNA (miRNA)
PIWI interacting RNA (piRNA)
repeat asociated small interfering RNA (rasiRNA)
small nuclear RNA (snRNA)
small nucleolar RNA (snoRNA)

Figure 1 : Molecular Family of Small RNA
Prepared by the STFC

Here, I report the research trends, with a focus on the clinical application of miRNA, a new category of RNA.

2 Biological property and function of miRNA

2-1 Discovery of miRNA

The first miRNA was discovered in 1993. At this point the concept of miRNA did not exist. Lee et al from Harvard University (at the time) captured a small RNA that bound to messenger RNA (mRNA) coding a certain protein-coding gene in *C. elegans*[3]. This phenomenon, however, was believed to be specific to *C. elegans*, and together with the immature extraction technique of small RNA at the time, there was no subsequent progress in the project. On the other hand, Fire from the Carnegie Institute for Science and Mello et al from the University of Massachusetts discovered that transcription inhibition occurred on the same gene that was responsible for the phenomenon found by Lee et al when they injected a small double stranded RNA (siRNA) that constructed to bind to a part of the mRNA sequence in *C. elegans*. Both teams reported the results in 1998[4], making this the first report on RNAi.

[NOTE 1] Next-generation high-speed sequencer: Genetic analysis equipment, introduced around 2006, that can do the exhaustive analysis. The term "next-generation" was originally applied during its development. The third generation, which is currently under development, is called the "next next-generation," and has a sequencing ability that is 300–1000 times that of the first generation.

This discovery turned over all the classic central dogma[NOTE 2], and RNAi technology, now a daily experimental tool, was diffused immediately in the wold. Now RNAi has become widely used as a standard experimental tool for molecular biology. It is also applied for medical research, whereby the concept of siRNA drug innovation targeting to suppress the expression of disease-related genes was developed, and animal research started within a few years of the first discovery[7]. Drug innovation venture companies specializing in siRNA drugs were founded one after another. Some siRNA drugs have already advanced into Phase III clinical trial. In 2006, Fire and Mello were both awarded the Nobel Prize.

miRNA started to gain attention several years after siRNA, when small RNA discovered by Lee et al was found to be preserved in several species, including mammals[5]. In other words, there was a possibility that mRNA is regulated post-transcriptionally by miRNA, and this possibility attracted great interest. This was confirmed immediately using *C. elegans*[6-8]. The term "micro RNA" came around this time. Subsequently, locked nucleic acid (LNA) technique which has high affinity for complimentary DNA sequence was applied to ncRNA research, enabling the detection of a small amount of nucleic acid. This novel technique enabled the gene expression analysis of small RNA, and pushed forward the miRNA research.

This is evidenced in the change in the number of research articles. The number of articles detected by a single-word search with "miRNA" has been increasing since 2002, and the increase has been especially rapid in the recent few years. The number is reaching to that of RNAi as a whole in 2010 (Figure 2). Recently, miRNA function is also studied in the field of higher brain function research, such as learning and memory[9]. The most widely expanding, however, is the disease-related miRNA research based on miRNA expression analysis, probably due to the fact that generalized functional mechanisms were discovered for all miRNA.

One can take the initiative in drug development by discovering how each miRNA regulates the expression of important genes. Massive money has been already invested for nucleic acid development targeting miRNA in Europe and the United States.

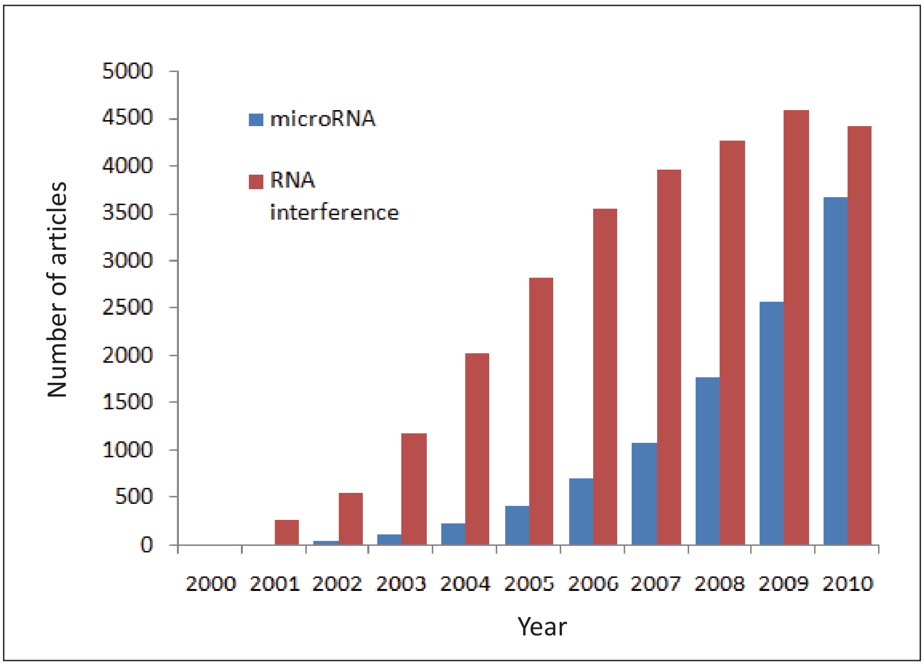

Figure 2 : Annual increase of miRNA-related articles published (Search data on PubMed)
Search key word was either "microRNA" or "RNAinterference".

Prepared by the STFC

[NOTE 2] Central Dogma: A general molecular biological doctrine of genetic information flow where genetic information in the DNA is transferred and expressed in protein via RNAs. It was proposed by F. Crick in 1958. However, the doctrine has since been adjusted from the original due to the discovery of such phenomena as reverse transcription and splicing.

2-2 Sequence length of miRNA

miRNAs are single strand RNAs with 18–25 nucleotides, and widely exist in viruses, plants and animals. The most unique property of miRNA is that its own sequence is integrated in the DNA sequence. The miRNA sequences are usually within the regions[10]. Recently, miRNA had also been found in exons. This property provides a medical advantage over the exogenous siRNA. For example, siRNA can elicit an immunological response (side effect) similar to the one against RNA virus. On the other hand, since miRNA is a nucleic acid molecule that already exists inside the cells, it is unlikely to trigger an explicit reaction. This is an extremely useful property for drug development.

2-3 miRNA Synthesis

The synthetic pathway of miRNAs on the DNA is shown in Figure 3. Hundreds to thousands of base-long primary miRNA (pri-miRNA) including miRNA sequence are generated by specific enzyme (RNA polymerase II) from long single-stranded RNA transcribed from DNA in the nucleus. Multiple stem-loop structures develop in a sequence-based manner on pri-miRNA, and another enzyme (Drosha) cleaves its root, producing small hairpin-like single-stranded RNA. This is the precursor (pre-miRNA) to miRNA, and is transported into the cytoplasm from the nucleus by Exportin-5, a nuclear export protein. Although discussion about the maturation of pre-miRNAs into single stranded miRNAs is still ongoing, it is generally believed that a pre-miRNA is spliced on both sides by a complex made of the enzyme called "Dicer" and a cofactor "TRBP" to arrange double-stranded miRNA of about 22 bases. Very recently, a miRNA that did not rely on Dicer splicing was discovered[11]. The double strands miRNA separate later, with one, guide strand, selectively remaining to mature and another one, passenger strand, breaking down. Complete miRNA is taken in by a complex made of ribonucleic acid RISC (RNA-induced silencing complex) and Argonaute protein, and turned into a functional miRNA-RISC complex (miRICS) (Figure 3).

2-4 Function of miRNA

The function of miRNA is to negatively control gene expression (Figure 4). In general, miRNAs suppress mRNA translation at the posttranscriptional level. In plants and *C. elegans*, it has been reported to suppress the transcription itself from the DNA[12,13]. This suppression is not a complete shut out, but rather miRNAs are now revealed to act like a fine tuner by modulating the rate of mRNA.

There are still a few different hypotheses on the mechanism of miRNA's action, however, in general, miRISC with miRNA moves toward the target mRNA, and binds miRNA in the complementary region in the 3' untranslated region (3' UTR) to either terminate the translation or to lead to degradation of the mRNA to interfere with the gene expression[14, 15]. When miRNA is bound to the completely complementary region of mRNA, like siRNA, mRNA gets degraded. What is interesting is that for miRNA, the sequence does not have to be a perfect match with the target-binding region. In this case, the strength of the inhibition varies depending on the sequence. However, the

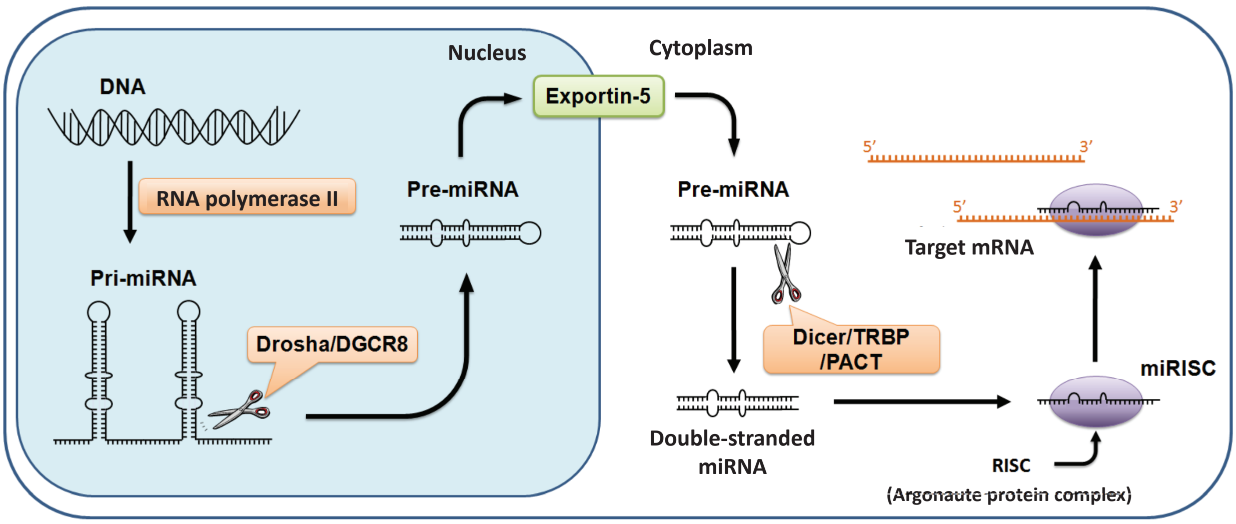

Figure 3 : Synthetic Pathway of microRNAs

Prepared by the STFC

7-base sequence between 2nd and 8th nucleotide from the 5' end is called "seed region," and a complete match of the sequence is required. Therefore, miRNA does not function one-to-one relationship like siRNA, but rather one-to-multiple. This property is extremely important when finely tuning the gene expression. However, how it is done at good balance remains to be revealed. In addition, one miRNA targets 200 mRNAs on average[16]. In other words, one mRNA regulated by multiple miRNAs. This means that 1/3–1/2 of the genes coding proteins come under the control of miRNA after their transcription.

There are 16,772 miRNAs registered on the website miRBase (as of May 2011). Among them, human miRNAs number up to 1424; and though it was once predicted that there were only about 900 human miRNAs, the number is currently at 2000.

3 miRNA and Diseases

Since the RNA programs, including RNA silencing, are closely involved in homeostatic maintenance, their disruption lead to potentially life-threatening situations. In terms of the relationship between miRNA and diseases, the field of cancer research is the most advanced. When the biological property of miRNA was revealed, many researchers predicted the implication of miRNA in cancer development. In 2006, Croce et al from Ohio State University conducted miRNA expression analysis in various types of cancer. They found expression profiles that differed from the ones in the normal specimen in all analyzed cancers (breast cancer, lung cancer, stomach cancer, colon cancer, pancreatic cancer and prostate cancer[17]). Table 1 shows the list of miRNA that changes expression in major cancers. The expression of miR-21 is increased in all cancers listed here. Subsequently, the increase of miR-21 expression was found in papillary thyroid cancer and acute myelocytic leukemia as well. Therefore, it is speculated that miR-21 is strongly involved in cancer onset, and in fact, multiple transcriptional repressors including NFIB are now found to be the target genes of miR-21[18]. The increase of miR-21 is believed to inactivate these transcription factors, which consequently weakens the tumor suppressive activity. In addition, the expressions of mir-191 and mir-221 are now found to be increased in many cancers.

On the other hand, there are miRNAs whose expression decreases in cancer (Table 1). The expression of the let-7 miRNA, found to be involved in cell proliferation in *C. elegans*, is decreased in human cancer cells including breast cancer, lung cancer and stomach cancer. The target genes of this miRNA include so-called oncogenes such as Ras and HMGA2[19-21], suggesting the possibility that the decrease of let-7 expression activates these oncogenes. The strong involvement of let-7 in cancer can be found clinically as well. The cases of lung cancer in which the let-7 expression decreased do not indicate favorable prognosis.[22]

There are miRNAs which show changes of expression levels in specific types of cancer (Table 1). Although a detailed relationship with their target

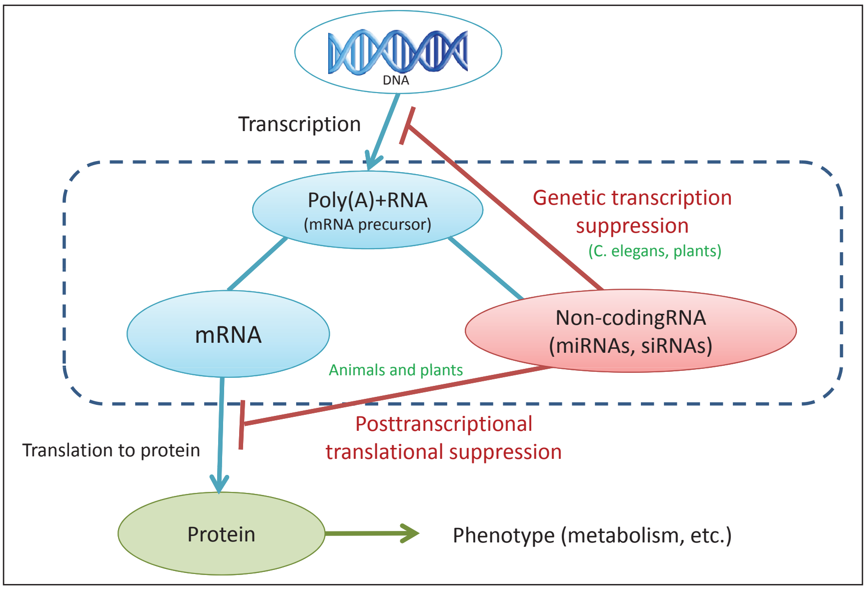

Figure 4 : Active Sites of miRNAs

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Table 1 : miRNAs with Cancer-specific Expressional Alteration

Types of Cancer	Elevated Expression (onco-miR)	Reduced Expression (suppression-miR)
Cererbral cancer	miR-21, 221	miR-128,181
Breast cancer	Mir-9-1, 10b, 17-5p21, 21, 29b-2, 34, 146, 555, 181b-2, 213	lit-7, miR-9, 26a-1-p, 27b, 29b-2, 32, 33, 30a-5p, 95, 101-1, 124, 124a-3, 125a, 125a-p, 126, 140, 143, 145, 181c-p, 198, 192-p, 199b-p, 216-p, 218-2, 219-1, 220, 224
Lung cancer	miR-17-5p, 17-92, 21, 24-2, 106a, 128b, 146, 150, 155, 191, 192, 197, 199a-1, 203, 205, 210, 212, 214	miR-203, 205
Esophageal cancer	miR-21, 93	let-7
Gastric cancer	miR-21, 24-1, 24-2, 29b-2, 30c, 31, 32, 96, 106a, 107, 128b, 135b, 155, 183, 191, 221, 223	let-7, miR-34, 127, 133b, 143, 145
Colorectal cancer	miR-17-5p, 20a, 21, 24-1, 24-2, 29b-2, 30c, 31, 32, 96, 106a, 107, 128b, 135b, 155, 183, 191, 221, 223	let-7, miR-34, 127, 133b, 143, 145
Hepatic cancer	miR-15b, 18a, 21, 106b, 221, 222, 224	let-7, mir-101, 122a, 125a, 195, 199a, 200a
Pancreatic cancer	miR-17-5p, 20a, 21, 24-1, 24-2, 25, 29b-2, 30c, 32, 92-2, 100, 106a, 1-7, 125b, 128b, 146, 155, 181a, 181b-1, 191, 196a, 196b, 199a-1, 212, 214, 221, 223, 301, 376a	miR-139, 142-p, 345,375
Prostate cancer	miR-17-5p, 20a, 21, 25, 30c, 32, 92-2106a, 146, 181b-1, 191, 199a-1, 214, 223	miR-15a, 16, 143, 145, 218-2
Uterus cancer	miR-21, 199a	miR-143, 145

[NOTE] miRNAs are numbered according to the order of discovery. “Let” was discovered in C. elegans in the early stages.

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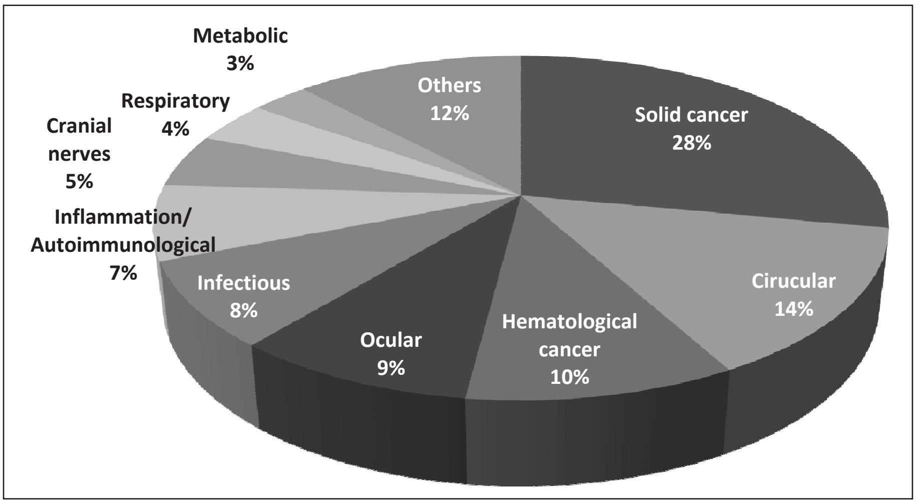

Figure 5 : Proportion of Diseases Targeted for Nucleic Acid Drug Development

Reference : “Current Neucleic Acid Drug Development in the World and Its Future, 2010 edition” by courtesy of Seed Planning Inc.

genes remains unknown in most cases, there are cases like miR-19, which has been identified as suppressor of apoptosis of lymphocytes, thereby turning them cancerous[23]. These miRNAs are expected to be useful as specific biomarkers for individual cancer (discussed later).

For diseases other than cancer, miR-29 is found to be involved in cardiac fibrosis, whereas among viral infectious diseases, miR-122 is found to be involved in the replication of hepatitis C virus. One interesting example is that human cytomegalovirus has miRNA sequences encoded within its viral genomic DNA, enabling it to pass through the human immunological system[24]. In metabolic diseases, miR-375 is identified to be involved in insulin secretion and miR-146 in the pathology of arthroreumatism. In Alzheimer’s disease, miR-101 and miR-29 clusters were discovered to be involved in amyloid β formation, the cause of the disease, and now research on it is being extensively conducted.

These disease-specific miRNAs are the targets of nucleic acid drug development. Figure 5 shows the proportion of the target diseases of the whole nucleic acid drugs including siRNA at the moment, but the proportion would be similar even if it were specific to miRNAs. In each disease, however, the very basic question as to whether the increase or decrease of miRNA expressions actually cause the disease or if they are a consequence of the disease is not yet clear. While research for clinical application progresses, basic research is also being conducted simultaneously. Since the identification of disease-specific miRNAs that cause the onset or exacerbation will lead to intellectual property as well as drug development, great efforts are made to research and develop them worldwide.

4 Trends of miRNA Research Aimed for Clinical Application

4-1 Development of drugs targeting miRNA

There are two main strategies for developing drugs targeting miRNA: (1) by suppressing the disease-specific miRNAs whose expression are increased in diseases and (2) by supplementing miRNA whose expression decreased.

For (1), siRNA for miRNA maybe evoked, but it is mostly impossible due to the short length of miRNA sequence. Therefore, development is generally done with agonistic nucleic acid molecules at this point. The most advanced in nucleic acid drugs using this method is the drug for chronic hepatitis C developed by Santaris Pharma based in Denmark, and is already in Phase II of the clinical trials. Hepatitis C virus (HCV) is known to use the host's miR-122 when replicating itself. Therefore, Santaris Pharma designed an agonistic nucleic molecule for miR-122, and aimed to block HCV multiplication by suppressing miR-122 action. Last year, results of a preclinical study using primates were reported in Science[25]. The number of virus in the blood decreased and the hepatic function recovered without noticeable side effects. In the near future, the first nucleic acid drug targeting miRNA is likely to come out.

Alnylam and ISIS with reputable technique to synthesize nucleic acid molecules founded a merged company, Regulus Therapeutics (California, US) specifically for miRNA drugs, and started the development of HCV drugs targeting miR-122. They are scheduled to start clinical studies in 2012.

Many other pharmaceutical companies are also conducting research and development of nucleic acid drugs (Table 2), and are expected to proceed to clinical trials in the near future.

On the other hand, the method to supplement miRNAs in (2) is to recover miRNAs by injecting synthetic miRNAs. The technique of siRNA drugs can be applied for this type of nucleic acid drugs. Ochiya and his colleagues from National Cancer Center identified 9 miRNAs whose expression was decreased in the prostate cancer cell lines. Among them, they focused on miR-16 which seemed most involved in malignant alteration of the cancer. miR-16 is a miRNA involved in the regulation of cell cycles. When the researchers conducted an experiment to induce miR-16 with the mouse model of bone metastasis of prostate cancer, the metastasis to the bones was suppressed significantly after injection in the mice without side effects (Figure 6)[26]. This means that the recovery of miR-16 triggered apoptosis in the cancer cells. As seen here, for the downregulation of the miRNA expression in a disease, a certain amount of effectiveness can be achieved by putting it back to the body. A lung cancer drug with let-7 (Mirna) and a hepatic cancer drug with miR-24 (Regulus) are under development (Table 2).

The development of a drug delivery system (DDS) to transfer the drug to the target organ will be an important key for the development of nucleic acid drugs such as miRNA and siRNA. At present, direct injection to the affected area is the main method. However, intravenous injection or oral administration is favorable. As for DDS, various ways had been studied since the antisense DNA research had been the mainstream. However, solid DDS technology has yet to be established. For miR-16 induction in Figure 6, the biomacromolecule known as atelocollagen was used for DDS. Atelocollagen was developed for artificial organs, and the FDA certified it as the molecule with the best biocompatibility. Ochiya et al injected the complex of miR-16 and atelocollagen from the tail vain for systemic delivery, and that was effective at least in mice. Although there are many more hurdles for DDS, atelocollagen has great potential for clinical use for humans.

Table 2 : Examples of Corporations Developing Nucleic Acid Drugs Targeting miRNAs

Target miRNA	Target Disease	Developing Company
[miRNA Suppressors]		
miR-122	HCV Infection	Santaris Pharma A/S
miR-122	HCV Infection	Regulus Therapeutics, Inc.
miR-21	Cardiac Disease, Cancer	Regulus Therapeutics, Inc.
miR-208/499	Chronic Cardiac Failure	miRagen Therapeutics
miR-15/195	Post-cardiac Infarct Remodeling	miRagen Therapeutics
miR-206	ALS	miRagen Therapeutics
miR-451	Erythrocytosis	miRagen Therapeutics
[miRNA Supplement]		
let-7	Lung cancer	Mirna Therapeutics
miR-34	Prostate cancer	Mirna Therapeutics
miR-34	Hepatic cancer	Regulus Therapeutics, Inc.
miR-29	Cardiac fibrosis	miRagen Therapeutics

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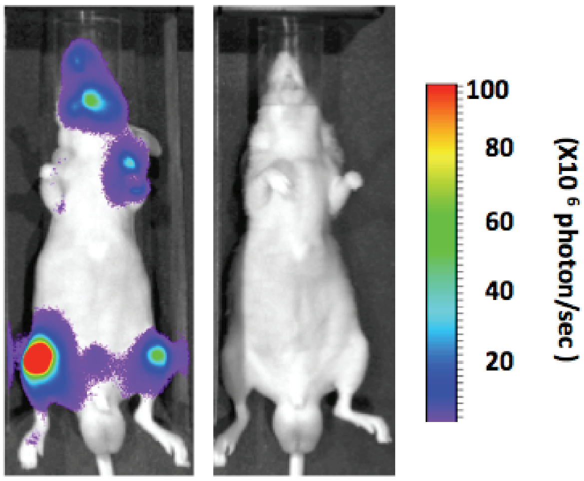


Figure 6 : Disappearance of Metastatic Foci of Prostate Cancer by miR-16 Administration
In the mouse model of bone metastasis of prostate cancer (left), cancerous foci is spread through the body (a luciferase gene is injected in the cancerous cells to make them visible).
When miR-16 was injected, the cancer foci disappeared (right).

By courtesy of Dr. Takahiro Ochiya (National Cancer Center)

4-2 Application of miRNAs as biomarkers

The usefulness of miRNA, that siRNA does not have, is its application for biomarker development. There is hope for the development of disease biomarkers for diagnosis as well as screening. In particular, there is a great necessity for cancer detection. In recent years, there has been a widely conducted search for biomarker molecules based on proteome analysis, but they have yet to be discovered.

The expression profile of miRNA differs largely depending on the organ as well as healthy and diseased ones. Around 2005, when only about 200 miRNAs were identified, categorization of hematological cancer could be done more accurately than the array analysis of 20,000 mRNAs[14]. miRNAs were indicated to be useful not only for diagnosis but also for predicting the outcome, as previously mentioned of let-7 in lung cancer[22].

The diagnostic service for three types of cancer provided for medical facilities by Rosetta genomics in Israel. Asuragen from the United States commercialized a diagnostic kit that differentiates cancer and pancreatitis by measuring the expression levels of miRNA in a biopsy specimen of pancreas.

These preceding examples are evidence of the increased usefulness of miRNAs as disease markers.

Recently, even more interesting results were reported. In 2008, two research groups independently reported that miRNAs exist stably in blood[27,28]. Since blood serum contains a rebonuclease (RNase) that breaks down RNAs, the presence of miRNA in the blood was unimaginable. Consequently, similar reports were published, and now, miRNAs in blood are in the spotlight as novel seeds for a biomarker development with little invasion.

Tewari et al at Fred Hutchinson Cancer Research Center found two miRNAs derived from cancerous cells by comparing serum miRNAs of healthy mice and mice transplanted with human prostate cancer cells. They also reported that miR-141 was useful as an early-detection marker for prostate cancer. In addition, a group from University of Texas MD Anderson Cancer Center has identified miRNAs in the blood that can be a biomarker for pancreatic cancer. Since biopsy tests are invasive, less invasive tests are favorable for early-detection of cancer. Kuroda et al from Tokyo Medical University discovered that miR-92a decreased significantly in patients with lymphoma[29]. Furthermore they verified that miR-29a was a great biomarker for therapeutic monitoring of lymphoma.

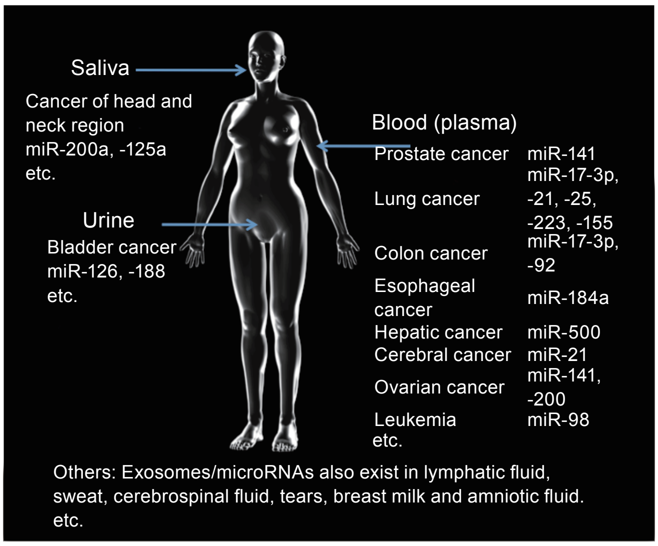
As in the cases described above, more research findings related to a bio-marker of miRNAs will be published in near future.

4-3 A new challenge derived from the discovery of serum miRNAs

The fact that miRNAs stably exist in the blood provided a new question of how they can stay in the environment where RNAs cannot.

One year before the discovery of miRNAs in blood, Valadi H. et al from the University of Gothenburg in Sweden discovered that mRNAs and miRNAs were included in exosomes, visicles with 30–100nm diameter that are released from cells[30]. They are believed to be secreted into body fluid, such as blood. Exosomes themselves had been known since the 1980s as a transportation system to bring waste out of the cell. However, no one imagined that they contained miRNAs. Furthermore, Valadi H. et al found that exosomes derived from murine cells were taken up and that they synthesized murine protein by human cells. This suggests the existence of intercellular communication through exosomes. In other words, miRNAs that circulates in blood is predicted to be taken up by another cell and function there. There is a high possibility that blood miRNAs are not only a simple biomarker but that they have a biological function; and therefore, research on intercellular communications via circulating miRNAs will be important in the future.

Secreted miRNAs are present outside of blood as well. They are also present in other body fluids such as urine, saliva and breast milk (Figure 7). Some of them are believed to be useful for diagnosis, and the research has already started.



200–300 types of miRNAs were found in the exosome in blood, saliva and urine.

Figure 7 : Potential Diagnostic Marker miRNAs in Body Fluid

By courtesy of Dr. Takahiro Ochiya (National Cancer Center)

In addition, the movement to use aforementioned exosomes themselves as diagnostic drugs is becoming active in venture companies in Europe and the United States. For example, Exosome Diagnostics Inc. of an American-German joint capital already raised 20 million dollars by May 2010 and is on its way to starting business in body fluid diagnosis.

4 Conclusion

Ever since the discovery of the RNAi system preserved in the body, the research in this field has been rapidly advancing mainly in the West. Although the development of siRNA drugs are ahead in the development of nucleic acid drugs expected to be the next generation drug after antibody drugs, the focus of the target is shifting to miRNA drugs. One of the reasons is the biological property that one miRNA targets multiple genes.

"One drug, one protein"- one antibody drug targets one protein. This strategy sometimes shows strong curative effects. However, there have been many cases where the effect had been less than expected or had caused serious side effects during development. Since a one-to-one relationship between antisense RNA and target gene underlies the siRNA drugs, it is similar to antibody drugs in that sense.

On the other hand, miRNA is endogenous molecule and is fine tuning the multiple gene expression in the cells. Since a disease is caused by the disruption of regulatory network of multiple gene/protein expression, miRNA-targeting therapy is expected to improve the 'network', not one gene expression.

Another reason that miRNA drug development is active is the fact that it is synthesizable without special know-hows for development, unlike antibody drugs, providing opportunities for many pharmaceutical companies.

In Japan, the Japanese Association for RNAi Interference was founded in 2008. This association is not only a place for people in academia but is also an all-Japan consortium-like place for researchers and engineers from pharmaceutical as well as technological companies to come together to innovate RNAi-related technology in Japan. There are still many challenges, such as the stability and retention of synthetic miRNAs in the body, DDS development, as well as problems with how to handle the intellectual property, so the association is expected to make progress on them. In addition, people outside of the industry should also pay attention to the research trends of miRNAs, which have high expectations for the future in nucleic acid drug development.

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Profile

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3

Report on the Annual AAAS Forum on Science and Technology Policy (2011)

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Life Science Innovation Unit

1 Introduction

The American Association for the Advancement of Science (AAAS) held its annual Forum on Science and Technology Policy in Washington D.C. on May 5 and 6, 2011[1]. The topics for the Forum include trends in the federal budgets for science and technology and key public policy issues that the science community is facing. The Forum brings together scientists, policy-related professionals, and others to understand such trends and issues and provides an important opportunity for discussions. At this year's 36th Forum, the outlines of President Obama's science and technology policies and R&D budget proposed for fiscal 2012 were introduced. The topics at plenary and concurrent sessions included national innovation strategies, American research universities, emerging issues in scientific integrity, and communicating science issues for policymakers.

Fiscal conditions in the United States have been deteriorating and, due to the divided Congress, the implementation of the fiscal 2011 federal budget has been long-delayed. The report on last year's Forum also mentioned deteriorating fiscal conditions[2]. Among OECD nations, the United States ranked 15th in the accumulated government debt-to-GDP ratio in 2007, and the country is expected to rise to a higher rank by 2020. The fiscal deficit in fiscal 2010 (October 2009 to September 2010) was about $1.566 trillion (10.6% of GDP), larger than the deficit in fiscal 2009 (October 2008 to September 2009), which amounted to $1.413 trillion (9.9% of GDP). (See Chapter 3 of this article.) On April 14, 2011, a divided Congress passed the fiscal 2011 (October 2010 to September 2011) federal budget (Appropriations Act: H.R. 1473), and on April 15, President Obama signed the act. However, from the beginning of fiscal 2011 until the passing of the budget, a provisional budget was used to maintain government functions. There were even concerns that federal institutions might shut down.

Under such circumstances, this Forum held a series of sessions with the following question as the basis for discussion: In which areas of science and technology should money be invested and based on what policies?

2 President Obama's Science and Technology Policies—From the Keynote Address by Dr. J. Holden (Assistant to the President for Science and Technology)

Dr. Holden, Assistant to the President for Science and Technology, pointed out some of President Obama's significant efforts to enhance science, technology, and innovation, including appointments of scientists to administrative positions and PCAST studies. He mentioned that five Nobel Laureates in science were appointed to key posts at the Department of Energy (DOE), the Office of Science and Technology Policy (OSTP), the President's Council of Advisors on Science and Technology (PCAST), and the National Cancer Institute (NCI). He also mentioned that more than 25 scientists from the National Academy of Sciences (NAS), the National Academy of Engineering (NAE), the Institute of Medicine (IOM), and the American Academy of Arts & Sciences were appointed to administrative positions. He also mentioned that the president actively called on PCAST for advice, and studies were requested and completed for, e.g., 2009 H1N1 Influenza pandemic, the assessment of the National Nanotechnology Initiative, implementing K–12 STEM education, accelerating the pace of change in energy technologies, and realizing the full potential of health IT to improve healthcare. He also referred to PCAST studies that are underway, including biodiversity preservation and ecosystem sustainability, carbon offsets, and STEM higher education.

In addition, Dr. Holden introduced initiatives on stem-cell guidelines, Visa MANTIS procedures, streamlining reporting on federal grants, and scientific integrity principles, guidelines, and policies. He also elaborated on NASA's programs and human spaceflight, the setting up of three initial energy-innovation hubs[3], National Oceans Policy (EO 14547, July 2010)[4], other energy and environment topics, as well as international ST&I (Science, Technology, and Innovation) cooperation.

Dr. Holden referred to five challenges surrounding science and technology policy in the United States. 1) Sustaining support for science and technology despite budget cuts: the DoD's basic science, NASA's James Web Space Telescope and advanced technology, NOAA's polar orbiting satellites and climate service, DOE's Carbon Capture Sequestration, NSF's social science, USDA's peer-reviewed agricultural science, EPA and FDA's regulatory science, USGCRP's[5] climate science and sustainability science. 2) Getting key messages across: why science and engineering matter to economy, environment, and security and how science works. 3) Advancing a coherent energy-climate policy. 4) Implementing public-interest IT initiatives: health IT, government efficiency and openness, and public safety. 5) Addressing weak teacher competence and systemic weaknesses in K–12 STEM education. He reiterated that President Obama regarded this as the single most important thing to do for the future of the United States.

3 Budgetary and Policy Context for R&D in Fiscal 2012

According to the Budget Message of the President for fiscal 2012 (October 2011 to September 2012) released in February 2011, the total budget is $3.73 trillion down by 2.4% from fiscal 2011(comparisons with fiscal 2011 are shown in parenthesis here and below). According to the AAAS estimate based on the Budget Message, the total R&D budget is $149.1 billion (up 3.3%) and the details are shown below.

The growth rate for non-defense R&D was significant. In contrast to the proposed budget for defense R&D at $82.3 billion (up 0.2%), the proposed budget for non-defense R&D is $6.68 billion (up 7.3%). The Research Funding is $66.9 billion (up 10.5%), among which $32.6 billion (up 11.1%) is for basic research and $34.3 billion (up 9.9%) is for applied research. Some $79.5 billion (up 0.2%) is for development and $2.7 billion (down 39.4%) is for equipment and facilities. The budget places emphasis on basic and applied research, but the establishment of new facilities is expected to cut back substantially. Education is also emphasized, and $100 million are proposed to educate K–12 STEM teachers.

By agency, $13 billion (up 22.1%) are proposed for the DOE. The energy programs have the most significant increase at $3.5 billion (up 68.2%). Other significant increases are $874 million (up 52.5%) for the NIST and $1.05 billion (up 48.1%) for the DHS. Some $6.1 billion (up 14.6%) are proposed for the NSF: $998 million for climate and energy (SEES: Science, Engineering, and Education for Sustainability[6]), $576 million for clean energy, and $117 million for CIF21 (Cyberinfrastructure for 21st Century Science and Engineering)[7].

During the session titled "Budgetary and Policy Context for R&D in FY2012", demographic patterns that are driving public policy decisions as well as trend analyses of the United States economy were also discussed. Concerning demographic changes, the following five issues were discussed: 1) The growth rate of the United States is declining and the country is an aging society, 2) the number of immigrants is increasing, pushing up the country's population (immigrants made up 12.5% of the total population in 2009), 3) income disparity in the population is growing, 4) the Hispanic and Asian populations are growing in size and dispersing spatially, creating language and education-related issues, and 5) these two populations are exhibiting very different human capital investment trajectories (school education and OJT). The speaker, Dr. R.M. Groves (Director of the United States Census Bureau) stated that other industrialized countries also have issues surrounding immigrants but that the aforementioned five issues should be addressed by American science and technology policy.

Dr. C.L. Mann (Professor at Brandeis University) began her presentation on American economic and innovation prospects by proposing a question: "Global Headwinds or Global Support?" She stated that even though there were some concerns over exports, oil prices, and bank problems at home and abroad, exports to Asia were recovering. She also mentioned that the total fiscal deficit of the United States in fiscal 2010 (October 2009 to September 2010) was about $1.6 trillion (10.6% of GDP), up from $1.413

trillion (9.9% of GDP) in fiscal 2009 (October 2008 to September 2009).

4 Other Topics

This Forum also covered issues regarding strengthening American competitiveness from an engineering perspective, national innovation strategies, emerging issues in scientific integrity, communicating science for policy, and the future of American research universities. The following sections introduce some of the topics that are particularly notable.

4-1 Issues Regarding Strengthening American Competitiveness

The presentation by Dr. C.M. Vest (National Academy of Engineering) was titled "U.S. Competitiveness in the 21st Century—Why an Eternal Optimist Is Worried." He looked back at American science and technology policy in the past and pointed out some issues regarding strengthening American competitiveness. He mentioned that the percentage of undergraduate degrees in engineering in the United States was lower compared to Asian and European countries separately and stated that the United States should produce more engineers. He also proposed that engineering should be promoted in a way that addresses four engineering grand challenges: 1) enhancing energy, water, and climate sustainability, 2) improving medicine and healthcare delivery, 3) ensuring security against human and natural threats, and 4) expanding and enhancing human capability and happiness.

4-2 Communicating Science for Policy

Dr. S. Doney (Woods Hole Oceanographic Institution) pointed out that science communication paradigms are changing. He used ocean acidification and its effects on American fisheries as an example to state that the science communication paradigm was shifting from an old model (scientists to the general public to the government to laws and regulations) to a current model (two-way dialogue between stakeholders). He also stated that efforts by the National Academies and science societies, releasing peer-reviewed syntheses targeting broader audiences, and improving Web-resources were important for community consensus and assessment.

4-3 Prospects of American Research Universities

American research universities are in critical financial condition. State universities are in a financial crisis due to declining tax revenues, and private universities have difficulty managing funds due to the crisis in the financial markets. These conditions have adverse effects not only on research activities but also on education for undergraduate and graduate students. In addition, the future of university assessment and the outlook for financial independence were also discussed at this Forum.

Some speakers pointed out issues surrounding educational program assessment, and they all agreed that such assessments should be stricter. For example, one discussion was that unsustainable or broken educational systems (where students are forced to leave their research field early during their academic careers) should be assessed critically. Another discussion was that graduate programs should be strictly assessed based on the years that students take until graduation and the number of students who acquire degrees. There was also a discussion on whether graduate schools should incorporate corresponding training and skills into their programs, since many doctorate students end up finding jobs in non-academic fields.

There was also a discussion concerning the management of state research universities. In the State of Pennsylvania, the state government substantially decreased its support to state universities. The state government proposed a 52% reduction in General Fund Appropriation for state universities for fiscal 2012 compared to the previous year[8]. Dr. I. Feller (Professor Emeritus, Pennsylvania State University) suggested that this trend actually shifted higher education from a product provided for the public to a private product and that undergraduate and graduate education might be privatized in the future.

5 Conclusion

The United States continues to be in a severe fiscal and economic condition. On February 4, 2011, an updated national innovations strategies entitled "Strategy for American Innovation: Securing Our Economic Growth and Prosperity" was released, and there are movements to strengthen American economic development and international competitiveness. This Forum also contained presentations and discussions on how to simultaneously pursue fiscal reconstruction, economic growth, and competitiveness.

In the United States, the role of science and technology has been emphasized in order to resolve different kinds of national issues surrounding, for example, public finance, the economy, and education. This recent trend is exemplified by the increase of the total R&D budget proposed for fiscal 2012 by 3.3%. In particular, attention should be paid to the direction of future R&D investments surrounding energy policies. The 2010 Forum[2] referred to the severe financial conditions at state research universities. As the case of Pennsylvania State University illustrates, conditions are deteriorating. Attention should also be paid to opposing trends of emphasized investment in K–12 STEM education by the federal government and decreasing fiscal support of state research universities by state governments.

I would like to express my deep appreciation to Dr. Fumihiko Kakizaki (Senior Research Fellow, National Institute of Science and Technology Policy) and Mr. Kenichi Fujita (Director, National Institute of Science and Technology Policy) for their valuable opinions.

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Profile

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4

The Direction of Embedded Software Development: Focusing on Japan's Social Characteristics
—Reinforcing the basis for software development in electronics-driven durable goods—

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1 Introduction

From the viewpoint of strengthening a common foundation to gain higher industrial competitiveness, the 4th Japan's Science and Technology Basic Plan discussed issues surrounding the measures to cope with ever-diversifying market needs.[1] It sets out upgrading development technology of embedded systems, as well as other objectives such as integration of element technologies and the R&D for linking hardware and software.

To achieve sustainable growth, every advanced country inarguably needs to strengthen its internationally competitive industrial sectors. Among these countries, Japan is characterized by the fact that her visible trade balance heavily depends on the secondary industries. This trend, however, is undergoing drastic changes: the white paper on the economy and public finance for FY2011 gives a detailed discussion on the circular relationship among globalization, productivity, and research and development, wherein the paper places stress on the mounting importance of non-physical assets under the global knowledge-based economy environment.[2] Software is one type of typical non-physical assets, and as such, this sector is required to cope proactively with the promising global market, and to move towards the creation of new added value.

Japan's manufacturing sector, however, has already been exposed to fierce competition with the developing countries in East Asia. We must note that the improved technical capability in developing countries is the engine for their upgraded competitiveness, supported by lower production costs and their distinctive market capturing strategy. Typical industrial sectors that find themselves in such situation include those producing home electric appliances and automobiles (hereinafter simply referred to as durable goods). Ever increasing use of advanced electronics in these products in recent years – typically reflected in abundant use of embedded computers – has effected a change in the constitution of development cost in the products; the cost for embedded software development is surging its proportion in the total development expenditures. East Asian countries have also gained increasing capabilities in this area of development efforts, threatening the superiority of Japan.

Against the backdrop of these situations, this report discusses the development methods of software embedded in electronics-intensive durable goods, as one of the objectives conducive to strengthening a common basis for increased industrial competitiveness. It presents discussion on the objectives toward which we should focus our strengthening efforts, paying attention to some of the aspects in the social characteristics of Japan and how to leverage these for achieving our goal.

2 Embedded Software

2-1 What is embedded software

A general-purpose computer, typically PCs, can perform a variety of functions depending on the application program running on it. For example, a PC can be used for a variety of purposes including electric mail transmission, Web browsing, word processing, and scientific computation. The types of tasks it performs are determined solely by the application program running on it. In contrast, embedded computers are application-specific devices used, for example, to control engines and implement mobile communications. They constitute an integral part of automobiles, mobile phones, household appliances, and industrial equipment. The embedded computer, as it is a type of computer, also needs software to run on it – namely, embedded software.

Embedded computers are employed in a variety of equipment and apparatuses, from high-end devices that require the highest level of performance – space, defense, and communication sectors – to commercial-off-the-shelf products for general consumers (Table 1). Availability at low cost is rigorously pursued in the mass produced general consumer-oriented products, while reliability is of utmost importance for the specific-user oriented products. Reliability in the extreme is of critical importance for some of the high performance and large-scale equipment.

The trend in recent years shows prolific use of embedded computers in an increasingly wider area of products, and the number of embedded computers incorporated in one product is also increasing. The automobile exemplifies this trend: a modern automobile has many - several tens to in excess of one hundred – computers on board not only for engine control but also for such various applications including: air conditioning, air bag control, ABS (Anti-lock Braking System), power windows, car navigation, and audio systems (Figure 1).

2-2 Requirements for embedded software

The embedded computer is required, as a part of a product, to work smoothly in synchronization with other parts. It must meet the following requirements.

(1) Real time capability

Real time capability means that each required process must be completed in a given time. A PC takes some length of time for starting up, and processing time may be obscure: these are some of the properties that are taken for granted. The majority of embedded computers, on the other hand, must boot up immediately in sync with the system's power on, and its processing time is much more rigorously stated. Control equipments, in many situations, must respond to requests from the external world frequently, and often times these requests arrive simultaneously. In such situations, the embedded software must ensure the real-time nature of the equipment by completing the task without any delay.

(2) High reliability and safety

As exemplified by the brake control on board an automobile, some of the embedded computer controlled products are directly linked to the safety of human lives. On the other hand, some must assume use under harsh operating conditions such as severe vibration, under the scorching sun, and in intense cold. Some must handle multiple sensor signals coming

Table 1 : Examples of embedded computer driven device

	Specific user oriented (Low-volume production)	General user oriented (High-volume production)
High performance, large scale	・Communication infrastructure ・Satellite	・Mobile phone ・Automobile
Low performance, small scale	・Lighting control of structures ・Measurement instrument	・Washing machine, refregerator ・PC, peripheral device

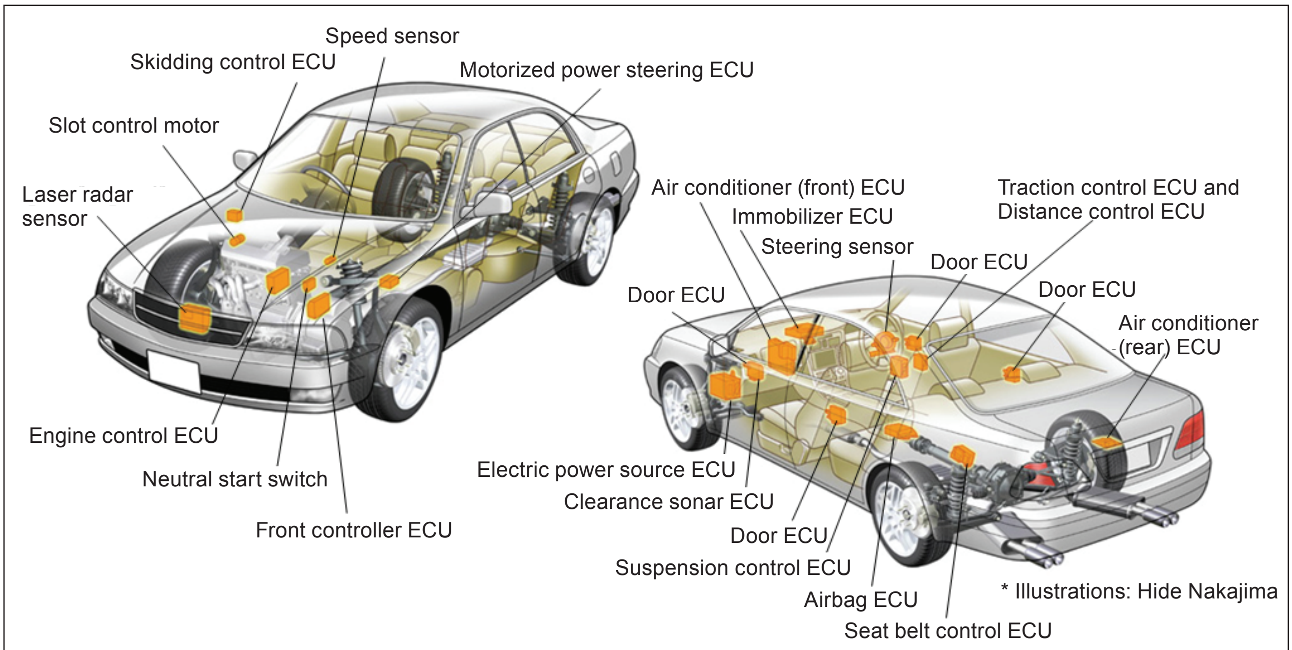

Figure 1 : Embedded computers used in an automobile

in randomly, and even go through unexpected usage caused by the operator's erroneous operations. A PC placed in such a situation may freeze up and come into a halt, but booting it again by electric power is a tolerated rescue practice for a PC. In contrast to this, embedded computers implemented in such devices as an automobile are required to maintain the highest level of reliability and safety at all time, enduring all input conditions and operating situations.

(3) Severely restricted resources for development

Some of the products that harness embedded computers, such as mobile phones, are subject to severe limitations on their physical size. High-volume products for the general users often have to highly compromise their internal specifications as a cost-cutting measure. These situations may force the products to abandon implementing sufficient resources, typically memory size, and the development efforts of embedded software also have to assume severe resource restrictions.

(4) High perfection level

General-purpose computers, suc as PCs, have most of their software on external storage devices (e.g. HDD) and load it into memory on an as-needed basis. This allows upgrading of the software by simply replacing it on the external storage device. Embedded software, on the other hand, is implemented in ROMs (Read Only Memory) during manufacture, almost eliminating the possibility of replacement/modification/deletion by the user.[4] Therefore, a high level of perfection must be achieved in the development phase on the understanding that there will be no maintenance by the user.

3 Current Status and Challenges of Embedded Software Development in Japan

3-1 Scale of development cost

Although embedded software is implemented in a multitude of products, this sector has not long been recognized as an individual industrial sector, due mainly to the fact that embedded computer, constitute a component of integrated combination. It was as late as in 2007 that the sector was added to Japan Standard Industry Classification (JSIC).[5]

The expenditure for developing embedded software surpassed even the level of ¥4 trillion in several recent years, and has shown by and large an upward trend in subsequent years. This is not a negligible amount in view of the total sales amount of Japan's software sector (¥15.6 trillion: June 2009). The cost ratio of embedded software development over the total development budget is also increasing: it occupies more than 40% of total development cost.[4, 7] (Figure 2)

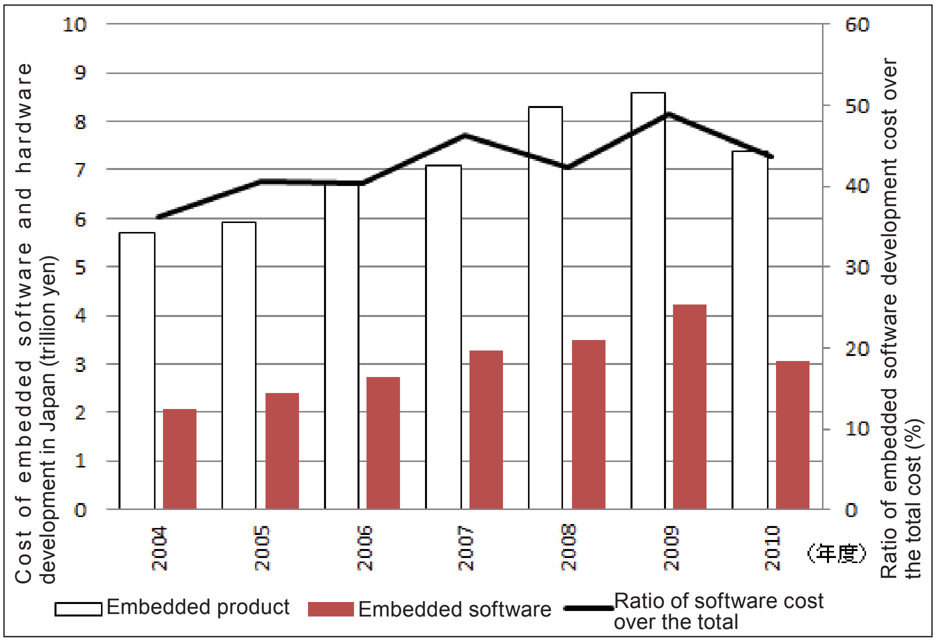

Figure 2 : Trends of development cost: embedded software controlled hardware (embedded product) vs. embedded software

Prepared by the STFC based on Reference[8]

3-2 Changing situations surrounding the development

A fierce development race of embedded computer controlled durable goods – automobiles, household apparatus and others – has spurred its way toward further sophistication and higher functionality. A short life cycle is one of the aspects that characterizes many of these products, which induces entries from many other countries especially leveraging their cost merits. The technological capability of developing countries is steadily improving.

The situations surrounding the development of embedded software are drastically changing as described below.

(1) Sophistication, complexity, and bloating

As products incorporate more and more functions with a higher level of sophistication, embedded software is also moving toward sophistication, higher complexity and bloating. For example, the volume of software implemented in state-of-the art mobile phones exceeds several hundreds of thousands of steps even in model-dependent portions. The total volume of development – including OS and middleware software – far surpasses those of the backbone systems in major commercial banks, a representative example of enterprise information systems. The volume of the software implemented in a hybrid car (a vehicle with both a gasoline engine and electric motor) surpasses the level of ten million steps: this volume roughly equals the amount of software possessed by each of the major commercial banks in around 1990. [10]

The emergence of multiprocessors - a computer with multiple core (arithmetic circuitry) mounted in it – and networking among products provide factors leading to further sophistication, higher complexity, and bloating volume. (Figure 3)

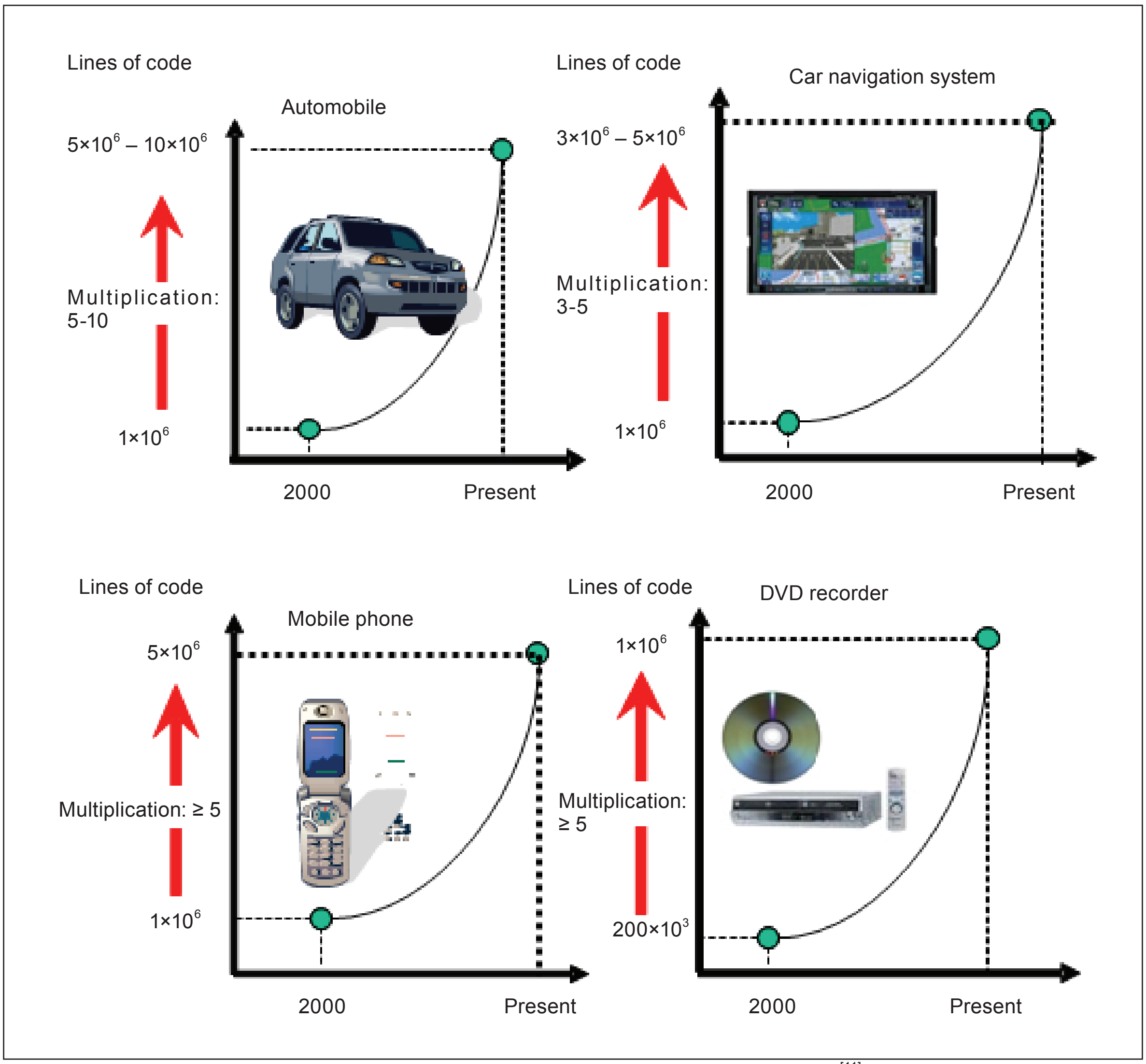

Figure 3 : Rapidly growing size of embedded software[11]

(2) Shortening of delivery schedule

Shortening of products' life cycles is particularly prominent in the Japanese market. Quarterly release of brand-new products is a common practice in the individual-oriented market that includes home electronics and information terminals. For this reason, a delivery schedule for embedded software as short as three month is not uncommon.[12]

(3) Requirements for quality upgrade and cost reduction

Nearly 60% of malfunctions found in embedded software-controlled products are caused by software failures (Figure 4). Upgrading of quality is needed to cope with this situation. In addition, efforts to reduce development cost are also required. These two factors are ever-present requirements, but they are gaining a higher profile against the backdrops of the increasing size, sophistication, and complexity of software, and the shortening of delivery schedules.

(4) Offshoring

As with other categories of software, the development of embedded software is basically characterized by its labor-intensive nature. As software development, especially in Japan, has given rise to a common conception that it is tough and demanding, the current situation will not allow a substantial increase of software developers in spite of the increasing demand. The situation leads to wider outsourcing (offshoring) to overseas developers in the areas centered in China and India, driven by the strong requirements for cost reduction (Figure 5).

3-3 Challenges facing the current R&D system in Japan

The manufacturing sector is the main engine in Japan's visible trade balance, wherein embedded software plays a substantial role especially in the areas such as automobile and electric equipment (these two areas command around 60% of the total volume of export).[14]

In general, development of a product involves several steps from planning to prototyping. If it is embedded computer-controlled, both hardware and software have a direct bearing on each step of the development effort (Figure 6). Because of a close link with the physical entity, the development of embedded software is an area where *suriawase* can make a significant contribution. High quality gained through *suriawase* has much to do with the international competitiveness of Japanese products.

Stages for *suriawase* can exist in each of the development steps - planning, design, and prototyping. This means engineering and work processes involving fine coordination of each component to achieve higher performance and quality as an integrated whole.[15] On the other hand, *kumiawase* (combination) means assembling parts by clearly defining interface specifications and

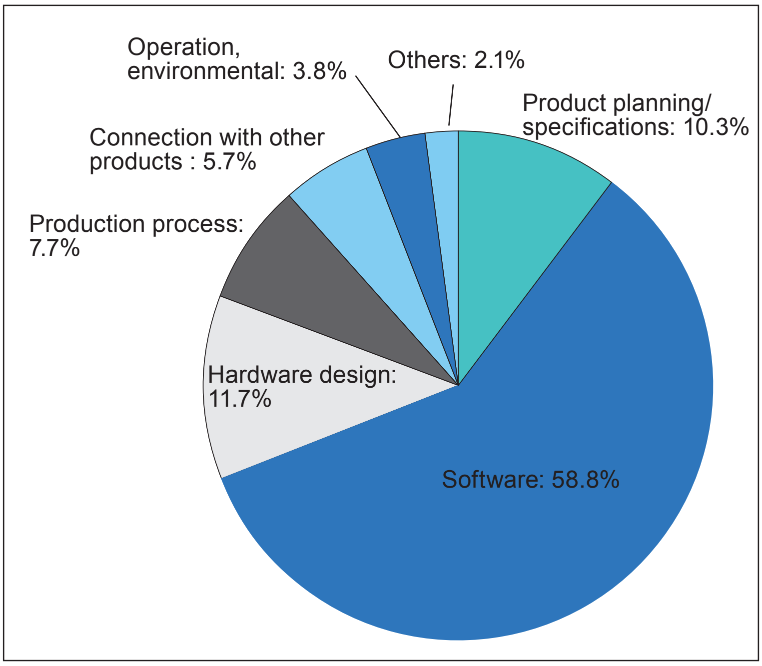

Figure 4 : Classification of failure causes of embedded devices (software and hardware) (FY2008)

Prepared by the STFC based on Reference[7]

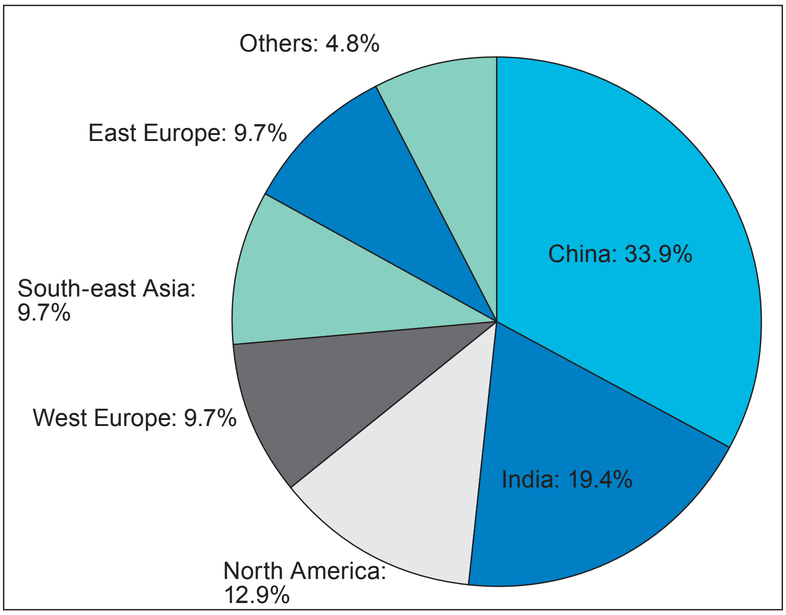

Figure 5 : Offshoring destination of embedded software development from Japan

Prepared by the STFC based on Reference[13]

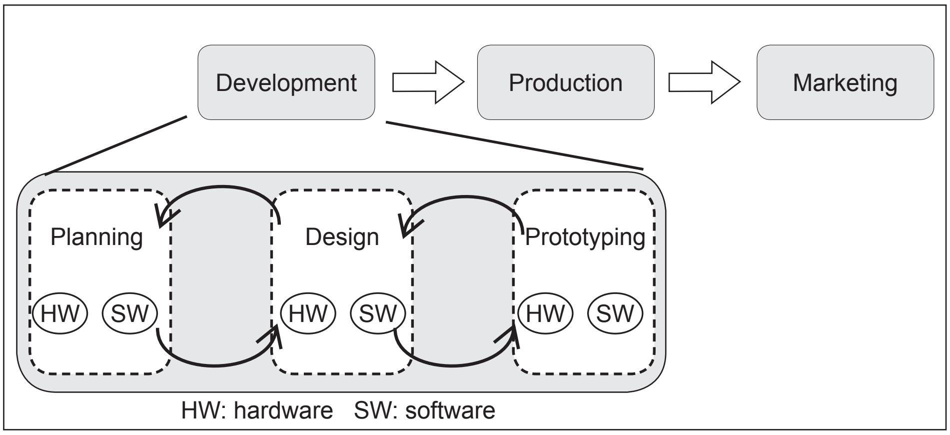

Figure 6 : Development processes of computer controlled embedded devices

purchasing an optimum set of components.

Many of the factors that change situations surrounding development, as described in Section 3-2, have an effect of reducing the effect of the suriawase approach. In Japan, embedded software was traditionally positioned as an ancillary part of hardware, and was developed as such. Although software development became detached from hardware as the size of system development grew increasingly larger, the development environment has still been dominated by the craftsmanship of software engineers who are quite knowledgeable about hardware. But the craftsmanship approach naturally shows its limitations, as the scale and complexity of software become so overwhelming.[16] The suriawase approach represents repetitive coordination for better understanding among the involved parties aiming at an optimized product. But progressively shortening the delivery schedule does not allow enough time for these reconciliation efforts, i.e. *suriawase.*

It will not be easy, in the future like in the past, to move out of touch with Japan's longstanding forte, suriawase, and move to kumiawase. It is not necessarily beneficial for Japan to abandon its traditional source of superiority easily in view of research and development competition with other countries. Therefore, what we need is our efforts to overcome the current situation while maintaining our traditional forte, suriawase. The following challenges must be achieved to that end.

Challenge 1: Establishment of development processes capable of rapidly meeting diverse needs

We should establish the method to take in the diverse needs in development processes and rapidly reflect them in the products, while leveraging the features of suriawase.

Challenge 2: Further upgrading of quality and cost reduction

We should aim at improved quality and reduced development cost taking advantage of the benefits of suriawase.

4 Basic Concept for Strengthening Embedded Software Development

(1) Avoidance of cost competition and pursuit of high added value

Highly sophisticated and complex products generally have a modularized internal structure. If the inter-module interface is clearly defined and made open, purchasing and combining an optimum set of modules – in terms of both performance and pricing – will constitute the main part of the development (i.e. kumiawase). This scheme enables relatively straightforward product development, opening up a wider market for new entries. In the areas where de facto standardization of the modules has well advanced, there is little space left for product differentiation, resulting in fierce price competition. On the other hand, in the area where inter-module interface denies rigorous definition, newcomers who desire to enter the market must develop the product starting from modules. Inability to define a rigorous interface forces the developers to undergo repetitive fine-tuning and coordination processes among the modules in their hands (i.e. suriawase).

Product characteristics can be broadly classified into two categories: those capable of an explicit specification such as price, quality, and functions (hereafter referred to as “type A”), and those that deny an explicit specification such as design, convenience, and quietness (hereafter referred to as “type B”). The type A characteristics allow relatively easy access by the kumiawase approach. Therefore, latecomers often probe the market by providing type A products first, and shift gradually to type B products as its market share grows. Many latecomers try to enter into the market taking full advantage of low prices, and existing manufacturers often find it difficult to compete with them in a price rivalry strategy. The existing manufacturers, therefore, try to evade head-on price competition and place priority in exploring high value-added products – i.e. type B products. One aspect pertinent to type B products is the need to clarify the characteristics of the product that can attract the targeted users. The elements that attract users naturally differ for each user; assessment of user needs should be given a priority to realize “attractive quality.”

(2) Value of suriawase approach in mature products development

When an existent manufacturer mulls over type B products, it must take into view the maturity of the product in which embedded software is implemented. Return from kumiawase to suriawase is often observed as the product reaches its stage of maturity. [17]

Let us take the automobile for example. In the early stage of its emergence, there was only unclear correspondence between the parts and functions to be realized. As its use became pervasive, correspondence between a part and function became distinctive and clear: a car body provides loading capacity, the engine provides driving power, and the suspension provides vibration absorption. Further diversification of automobile usage was accompanied by growing needs that could only be met through systematic considerations. An integrated approach – as well as elemental aspects such as fuel efficiency, quietness, and safety – is essential to cope with these needs (Figure 7). The reason leading to this situation is based on the widespread acceptance of automobiles in society and their growing maturity as industrial products. At this stage of maturity, a suriawase approach – fine-tuning between the parts to achieve a higher degree of completion as an integrated entity - becomes more suitable than a kumiawase approach – purchasing parts from the open market for assembly.

On the other hand, in the emerging stage of personal computers, it was a common practice for the technologically knowledgeable users to purchase parts (AP, OS, CPU, etc.) and perform assembly themselves. As it entered into a proliferation stage, delivery of pre-assembled computers by manufacturers became the mainstream. We are still in the transitional stage toward maturity, and performance of personal computers is represented in terms of the specifications of the parts included in the assembly - typically the CPU performance (manufacturer, type name, and clock rate in GHz). Of intrinsic importance for the majority of users, however, is the total performance – robust security, stable long-hours operation without causing excess fatigue and without occurrences of

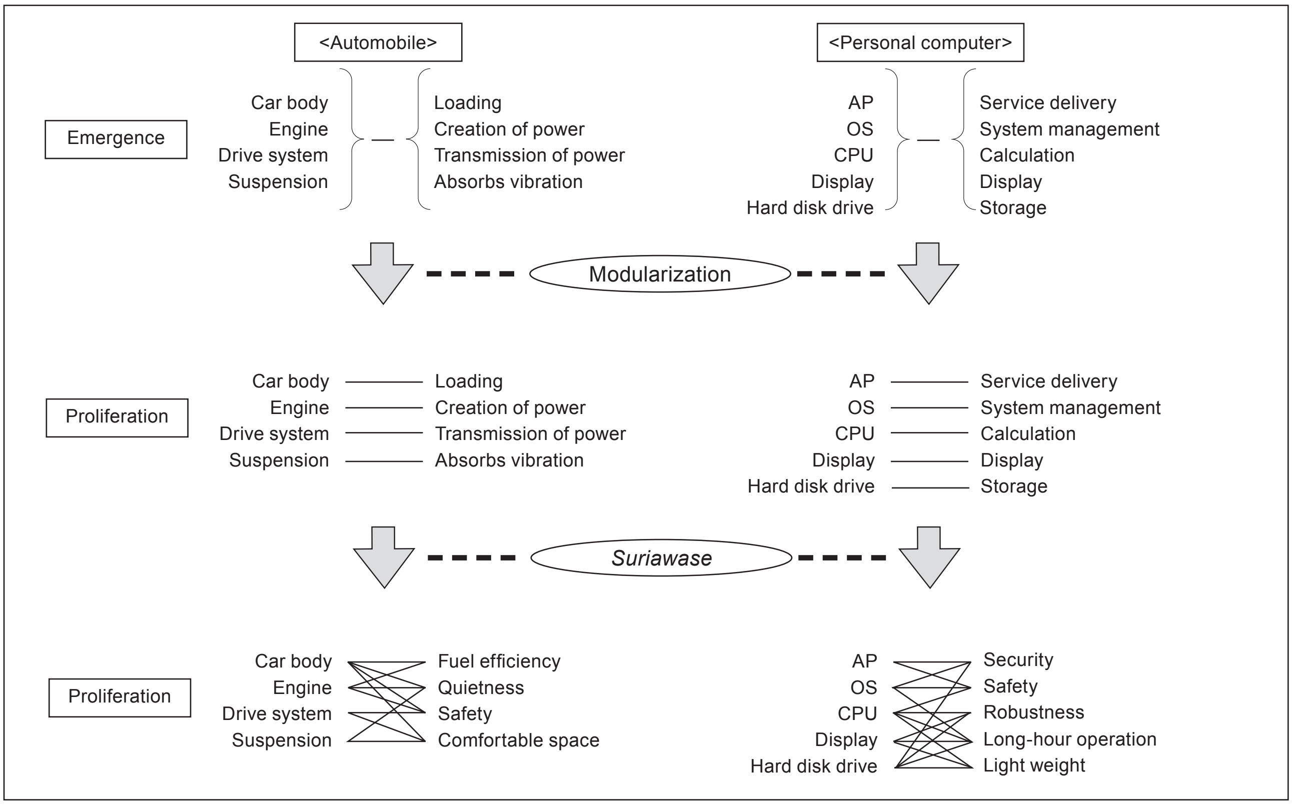

Figure 7 : Transitions of market deployment and inter-component interfacing

Prepared by the STFC based on Reference[17]

hang-up - rather than the superb specifications of the parts included. The need for total performance provides a wider space for suriawase to play an important role (Figure 7).

What is required for the products in their stages of maturity is the development capability to cope with the needs of the majority of users, typically represented in the term "user friendliness." This requires seamless integration of the capacity of each part, which often lies beyond the written details of specifications. To achieve this objective, the conventional process – purchasing optimum parts from the open market and assembling them – will come up short of expectations. Total optimization of the product is needed, where the suriawase approach plays an essential role. Note that, in the later stages of product maturity, the suriawase approach may become unnecessary because of further sophistication of part-to-part interfaces, in which case, advanced modularization using the highly sophisticated parts is expected to proceed again. In other words, the modularization approach and suriawase approach come and go in a spiral fashion as the product evolves.

(3) Two natures inherent to embedded software: package software vs. custom software

Embedded software has a similarity with package software in the sense that each single product is sold in high volume. The former, however, is a material (or an intermediary good) for producing a final product, and as such, does not attract visible awareness from the end users. It also shares certain characteristics with custom software, whose development proceeds all the way accompanied by close references to the hardware to achieve an optimum system.[18]

5 Embedded Software Development features from the Viewpoint of Japan's Social Characteristics

Amid the drastically changing environment for embedded software development, we must have our own edge in the R&D efforts to maintain Japan's competitiveness. Since developing countries are quickly catching up with Japan, it is highly desirable that our forte is invulnerable to imitation. The need for technological innovation is beyond controversy. But, because the fruits of science and technology are based on universal knowledge, they easily propagate and diffuse around the world. In contrast, the knowledge that based on social characteristics does not easily propagate or diffuse in foreign society. Therefore, it is not vulnerable to imitation. That is, recognition of the features of Japanese society and the effort to leverage those features effectively are of utmost importance, in addition to innovations in science and technology, for maintaining and upgrading our long-term competitiveness in embedded software development.

From the viewpoint of characteristics of our society, the following can be pointed out as the strength of embedded software development.

(1) High context nature of communication

In human-human communications, the sharing of context – awareness, value judgment, and experience - is considered to play an important role, in addition to the verbal expression of what a person would like to convey. A higher degree of context sharing (i.e. high context) enables better communication, because it allows getting the message through without expressing all of the content verbally. Japan is considered to be a representative high context society.[19]
Especially, those who have shared time and experience become stable mates facilitating the forming of a social environment where anticipation of other's wishes and tacit understanding work quite effectively. In contrast, in societies with low context sharing (low context society) – typically Europe and America – communication basically depends on verbal expressions. Assigning greater value in expressed language naturally leads to attaching heavier weight to logical coherence, expressive power, and persuasive power.

We cannot simply say which is superior over which: it depends on the situation. Still, we can say that the cost relating to establishing communication is lower in a high context society than in its counterpart, because the suriawase-development does not require renewed detailed verbal expression every time a small modification is made. We, living in a high context society, have a potential to take advantage of the merits inherent to the suriawase approach. On the other hand, there are concerns over the lack of logical coherence in communications, which may present negative aspects in face of the need to compile clearly-stated documents, such as specifications, where pursuit of logical coherence is essential.

(2) Presence of high quality consciousness

The quality of Japanese products is generally highly evaluated, and the signature "Made in Japan" carries a selling advantage outside of Japan. Factors behind the inexhaustible pursuit of quality, sometimes criticized as immoderate, include the attitude of business operators trying to insure the highest quality and highly quality-conscious on-site workers. The strong desire for higher quality on the supply side, however, may be futile if the demand side lacks such needs. The capacity of the supply side and the needs from the demand side must go hand in hand in a quest to achieve high quality products. In fact, Japanese consumers are the most demanding in terms of quality in the world. They are not satisfied with the provision of basic functionality: their request level is so high that they sometimes make complaints about a tiny dint or dirt on the surface of a package.[NOTE 1] Japan has both a highly capable supply side and highly quality-conscious consumers.

(3) Diversified consumptive orientation

As materialistic sufficiency goes widespread, the consumptive orientation of ordinary citizens diversifies. For example, when a citizen ponders buying durable goods, he/she places focus on the product design and fitness to his/her life environment, in addition to its functionality and performance. In the market that embraces a range of diversified needs as in Japan, detailed examination of, and well-suited response to, customer needs is required: provision of products and services designed from a unilateral view of the producers will not be accepted as "pressing."

(4) Experience in custom software construction

Japan has been traditionally evaluated that its international competitiveness in software development is weak as compared to hardware, especially in the field of package software. On the other hand, Japan is said traditionally to have more custom software applications than other countries such as the USA. The custom software is basically developed on a

[NOTE 1]
Some of the overseas electronics companies have established design research laboratories in Japan because: "Annealing our design responding to the most demanding customers in the world will make our product more competitive in the global market." (Nikkei Business, 2009.10.12)

product-by-product basis, and as such, its development requires close and sufficient coordination among system elements including the hardware. Ample accumulation of experience in custom software development, therefore, is viewed to work to the advantage of suriawase-oriented embedded software development.[18]

6 Measures to Strengthen Embedded Software Development That Takes Full Advantage of Japan's Social Characteristics

(1) Construction of rapid prototyping infrastructure involving customers

Let us think of an automobile. The manufacturer knows the basic performance requirements inside out, including such aspect as secure control of the engine and brake system, and these are reflected in its products. On the other hand, to meet the demanding needs of general drivers in value-added aspects - a sense of security in driving and pursuit of comfortableness in variety of situations – the automobile must be put into actual usage to gain hands-on information. But, efforts to improve a product, typically a durable good, after if is put into the market, through feedback from the users, will require a vast amount of cost and time. Therefore, construction of infrastructure for rapid prototyping is required; it should enable taking in user evaluations at an early stage of development, and feeding the modifications pointed out by users directly back into the product development. The prototyping infrastructure should be so constructed that it links Japan's underlying strength in software development – cultivated through custom software development – with the highly quality-conscious consumers, and should also be conducive to picking up the needs that's not documented specifications.

Several attempts have already been made to construct prototyping infrastructures, but they were of seeds-driven nature rather than needs-driven. What we need here is an infrastructure that enables close and timely communication with consumers, leading to the implementation of needs-driven approaches. The construction of such prototyping infrastructure is expected to serve as a mechanism to reject false presumptions on the provider side in the early state of development: assumed functions may be totally unacceptable from the viewpoint of the users and seemingly trivial features may be quite attractive to the users. To facilitate this scheme, diversified

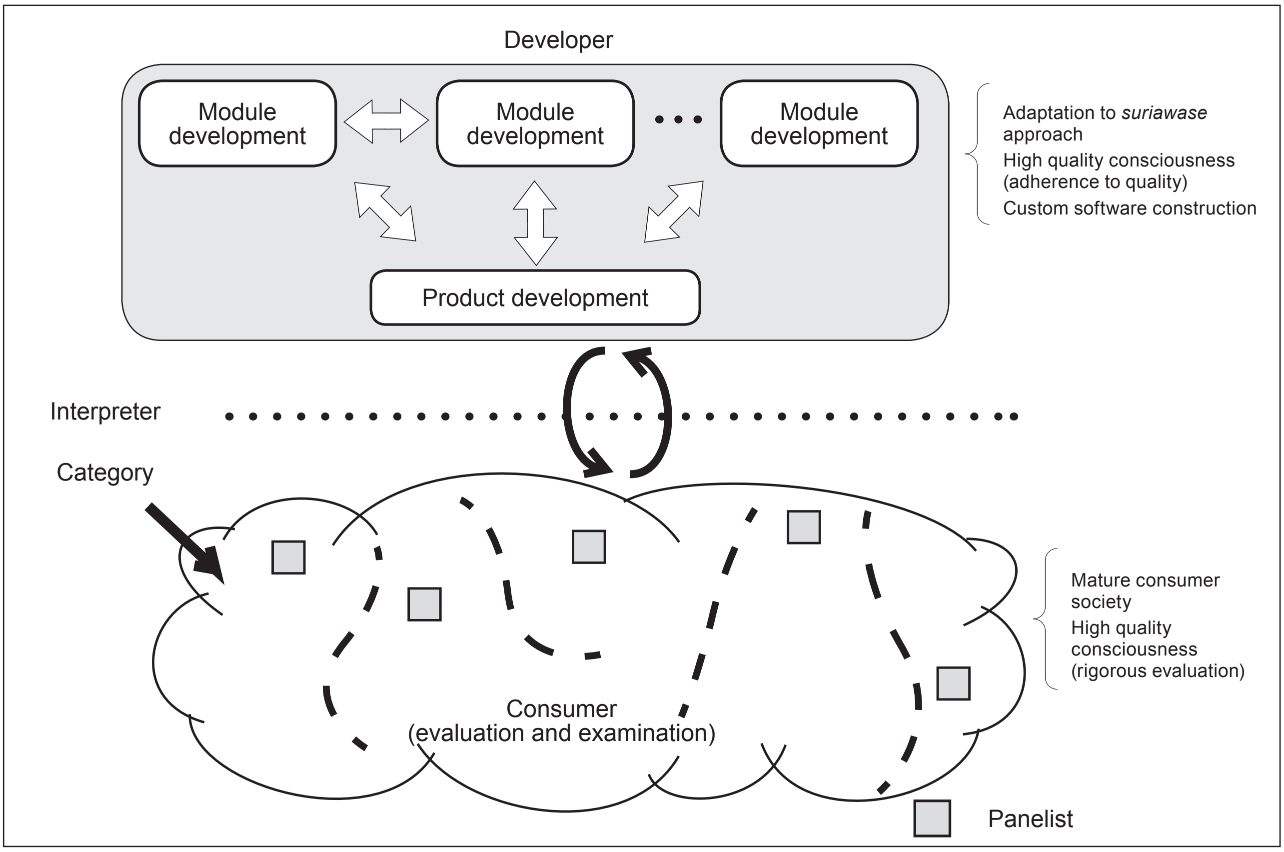

Figure 8 : Needs-driven rapid prototyping infrastructure

consumers may need classification into several categories. For example, a panel consisting of users each representing a category may be an effective tool to entrust the examination tasks of the prototypes. Analysis of information prevailing in cyberspace – Internet websites, blogs, SNS – will also be effective. To exploit this wealth of information most effectively, cultivation and assignment of special personnel will become necessary: relevant persons should be trained to select/extract information for analysis, and serve as interpreters linking developers and consumers (Figure 8).

(2) Build up of logical thinking and communication capacity

The high context nature of our society supports the power of the suriawase approach, but it also raises concerns over the lack of logical coherence in communication. Communication in this context is not limited to simple exchanges of views, nor does it mean affective communication. This means the capacity to persuade others based on clear logical thinking; this requires faithful understanding of the ideas of others, and the ability to build disciplined purposes of one's own. The fact that Japan is suited to the suriawase approach in development by no means eliminates the need to set up inter-module interfaces and purchase optimum parts from outside. Logical thinking is required, for example, to compile the specifications as a clearly written document. Negotiating skill is also required to have discussions with the persons in charge of other processes on an equal basis.[21] The need for such communication skills was also pointed out by a survey that was conducted for business managers and persons in charge in the embedded software sector (Figure 9). There is a sense of apprehension that the software engineers in Japan are currently lacking these communication skills.[NOTE 2]

Language education, especially enriched linguistic education centered in the national language, is of importance to cultivate such skills. Language education in Japan has traditionally shown a propensity to place importance on the emotional aspects of language. There is a view in favor of this propensity that it will serve as a source for strengthening the competitiveness of content software (i.e. animation and games). But, this is not necessarily a suitable approach to cultivate logical thinking. Language education conducive to assimilating logical reasoning should be an integral part of education starting from elementary and secondary stages.[22] In considering the ways of future education, it has been pointed out that closer links among dissimilar subjects – national language, mathematics, science, and social studies – are of vital importance in view of cultivating the capacity of thinking, judgment, and expression. [23] Especially, information education in high schools should enhance proactive coordination with logic education.[NOTE 3]

At present, Japan has around 300 thousand embedded software engineers, and this work force is gaining 10 to 30 thousand recruits every year. [12] Education will take a long time before it begins to exert effect, and may seem to be a roundabout approach, but it has a widespread effect over the whole of software industries in the long run - not limited to human resources cultivation in the embedded software sector. It is expected to have a spillover effect in human resources cultivation in many fields, and thus constitutes an essential part of our future efforts to maintain sufficient international competitiveness in the future.

[NOTE 2]
A software manager made a mockery of the current situation as "ordering parties incapable of writing strict specifications and developers who undestand nothing else but specifications." Business operators in the embedded software sector almost unanimously pointed out that the element in need of strengthening in school education for engineers is communication (dialog) skills, rather than technical ability and business skills. (Ministry of Economy, Trade and Industry, Commerce and Information Policy Bureau: "Actual condition on Embedded Software Industry Survey 2008 – A survey for business managers and persons in charge of operation," 2008)
http://www.meti.go.jp/policy/mono_info_service/joho/downloadfiles/2008software_resarch/keiei_houkokusho.pdf)

[NOTE 3]
The new Education Ministry guidelines stipulate such subjects as "Society and Information" and "Information Science" in ordinary high schools, but stress has not necessarily been placed on logical education.

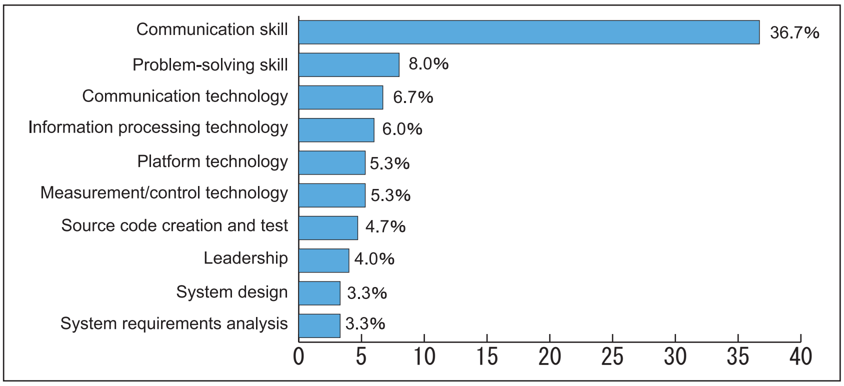

Figure 9: System requirements analysis

Prepared by the STFC based on Reference[13]

7 Concluding Remarks

In this report, the author discusses measures to strengthen the development capability of embedded software in Japan amid the drastically changing situation of rapidly growing capabilities in other countries, especially in the area of durable goods. The author focuses on the underlying characteristics of our society – high context nature, high quality-consciousness, mature consumption propensity, and sophisticated ability to construct custom software - and proposed the following measures based on them: construction of rapid prototyping infrastructure involving the end users, and building up of logical thinking and logical communication capacity.

Automobiles and home electric appliances will be connected to their own network systems, and in turn, these networks will be interconnected with the transportation system and energy system. Integrating them all, a huge cross-cutting social system is expected to emerge in the future that includes all of these networks and electronics driven durable goods in all areas. Embedded software is expected to play a role of enhanced importance in such a huge and complex system. Building up of systematic approaches toward interdisciplinary and cross-organizational review – starting from safety, reliability, and security – is now underway.[NOTE 4] In such social system, convenience and compatibility with life as perceived by the users will become so diverse that the providers will find it very hard to grasp the needs by themselves. Under such situation, rapid prototyping that involves end users, as described in this report, will come into play, and the need for logical thinking and logical communication will increase.

Acknowledgement

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[NOTE 4]
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5

Trends in Globalization around Supercomputers

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1 Introduction

High Performance Computing (hereinafter referred to as HPC) refers to a computing process that requires an enormous amount of complicated computations, such as simulations of natural phenomena or analysis of biological structures. More specifically, simulations and analysis of phenomena beyond human prediction and control, such as the global meteorological system or automobile-collision simulations, are included in HPC. They would require huge costs by experimental measures. Although HPC is often performed by using grids[NOTE 1] as well as supercomputers, this article will focus on supercomputers and give a general view of the current situation.

At the International Supercomputing Conference, June 2011, the 37th TOP500 was released, with the Japanese next-generation supercomputer "Kei" ranked at the top. This K Computer has been jointly developed and enhanced by the Institute of Physical and Chemical Research (hereinafter referred to as RIKEN) and Fujitsu Ltd.,

Supercomputers used in large-scale scientific computations will have a critical role in the future of individual countries in both science-technology and economy. Such a notion has been spreading across the globe. Therefore, countries around the world are now in fierce competition in supercomputer development and installation. Analyzing the situation of world's supercomputers on the basis of a series of TOP500 lists, there seems to be three types of globalization going on: the first is a globalization in installation; the second is a globalization in development of supercomputers with a rise in the number of countries who developed supercomputers domestically; and the third is a globalization in research and development through international collaborations. This article will introduce at first a general view of the situation of world supercomputers in Chapter 2, and then, in Chapter 3 to Chapter 5, present an analysis of the actual situations of the three types of globalization.

2 World Supercomputers shown in the TOP500

2-1 About TOP500

TOP500 list provides the top-to-500th ranking of supercomputers by the performance measured in LINPACK Benchmark[NOTE 2]. The list is updated twice a year, in June and November, by a group of researchers from Mannheim University, Germany, University of Tennessee, the United States, and NERSC / LBNL (refer to the glossary for the full name), the United States. The latest ranking (released in June 2011) is the 37th version of the list.

[NOTE 1]
Supercomputer and Grid: A supercomputer refers to an ultra-high-speed computer for scientific computing. Various types of architecture are employed in supercomputers, depending on their applications. So the range of performance is wide, from high to low. A grid refers to an environment where a variety of computing and information resources distributed on a network, such as computers, memory systems, visualization systems and large-scale monitoring systems, are available as a single virtual computer to members belonging to the virtual organization.

[NOTE 2]
LINPACK Benchmark: LINPACK (LINear equations software PACKage) Benchmark is a program for solving a system of linear equations for floating point operations, developed by Dr. J. Dongara of the University of Tennessee, et al. The benchmark has been widely used for a wide range of computers from supercomputers to workstations or personal computers, and their performance values have been published. LINPACK performance is shown as the number of floating point operations executed in a second, as FLOPS (Floating point number Operations Per Second).

In the list, we can see general trends in supercomputers. However, the list is sometimes called into question, as whether supercomputers developed for different purposes can be appropriately compared using a single benchmark such as LINPACK. While LINPACK puts emphasis on the performance of the computation processes using mainly floating-point operations, in actual situations, where computational environments are widely different, over-all performance is important and is affected by other factors such as data-transmission time between memories and CPUs or communication time between CPUs[2]. So, for the evaluation of system performance, various methods or indexes have been developed, and the rankings based on those have been released[3].

2-2 Findings in the Latest (the 37th) TOP500

The latest version of TOP500 was released at the "International Supercomputing Conference 11: ISC 11" held in Hamburg, Germany from June 20 to 23 in 2011. Most relevant to Japan, the Japanese next-generation supercomputer "Kei," which has been developed and enhanced jointly by RIKEN and Fujitsu Ltd. as a part of the Next-Generation Supercomputer Project[NOTE3], was ranked at the top. As for other Japanese supercomputers listed in recent versions of TOP500, "Earth Simulator" was ranked at the top in June 2002 and held the top position until June 2004. After that, the position was held mainly by U.S. supercomputers, but this year, the Japanese supercomputer came back to the top.

The LINPACK performance of "Kei" is 8.162 Peta FLOPS (where Peta means one thousand trillion, so Peta FLOPS means one thousand trillion floating point operations per second, hereinafter referred to as PF), three times faster than the Chinese supercomputer "Tianhe-1A" which was at the top in the 36th list six months earlier. "Kei," now under development and enhancement and aiming at a roll-out in November 2012[4], stood at the top position despite being in the middle of development.

All of the top 10 supercomputers on the list have higher than 1 PF LINPACK Performance. This means that the world supercomputers have already been racing at PF performance in the international track. From now on, the more fierce international competition will be expected to aim for around 10 PF performance.

In the following sub-sections, several findings to note in the present version of TOP500 will be introduced.

2-2-1 Number of Supercomputer Systems

In TOP500, "country" refers to a country that has supercomputers (hereinafter referred to as systems). So even systems developed in other countries are counted as systems belonging to the country. The number of countries with systems in the latest list is 28 (more details later).

2-2-2 Progress in LINPACK Performance

Figure 1 shows the line-plot of the total of LINPACK Performance values of the five hundred systems listed in a series of TOP500 along with those of the top and the 500th. It should be noted that there are two parts of the rapid progress in the performance of the top system in June 2002 and June 2011 in the chart (marked by a circle in the chart). Both were attained by Japanese systems: "Earth Simulator" in 2002 and "Kei" in 2011.

By extrapolating the trends in performance, we can predict that the performance of supercomputers will reach Exascale (thousand-fold of Petascale) around 2018 or 2020.

In the top 10 of the latest TOP500, five systems belong to the United States, two belong to Japan, two belong to China, and one belongs to France. The Tianhe-1A of China (by the National Supercomputer Center in Tianjin), which topped the previous list (November 2010), was ranked second this time, with the same performance as the previous one, 2.566 PF. The Jaguar, from the United States (DoE Oak Ridge National Laboratory), which topped the list in June 2010, was ranked third this time, with the same performance as the previous one, 1.759 PF. The performance value of "Kei" is larger than the sum of

[NOTE 3]
Next-Generation Supercomputer Project: The project, started in 2006, consists of three core objectives as follows: development of the 10 Peta FLOPS supercomputer "Kei"; development of application software available on the computer; and enhancement of research and education facilities focused on the next-generation supercomputers. The project has been updated to a development project of "High Performance Computing Infrastructure (HPCI)" through discussions triggered by the screening process in November 2010.

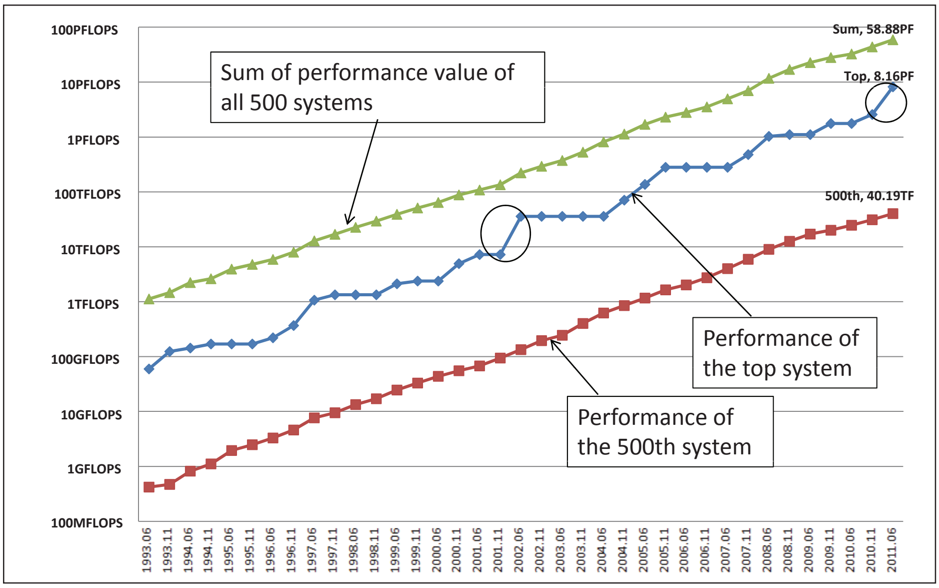


Figure 1: LINPACK Performance of Systems in TOP500: Sum of the performance values of all systems, Performance of the top system and Performance of the 500th system

Prepared by the STFC based on a series of TOP500 in the past

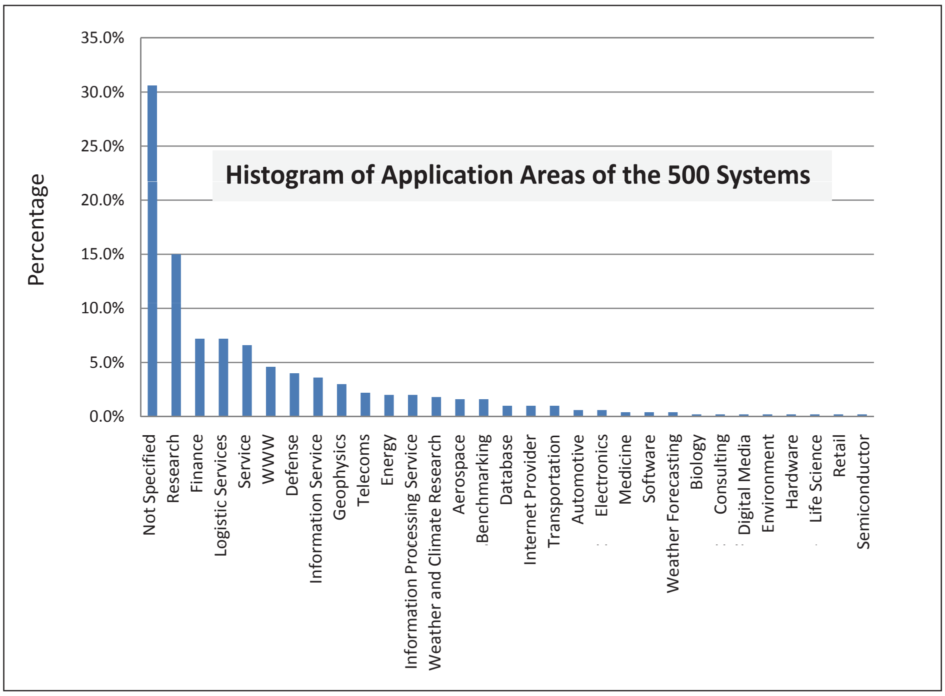


Figure 2 : Histogram of Application Areas

Prepared by the STFC based on the 37th TOP500

the LINPACK Performance values of the five systems ranked below "Kei."

2-2-3 Application Areas

Figure 2 shows the distribution of the major application-areas ("Application Area" registered in TOP500 List) of all five hundred systems, and reveals that those application areas distribute in a wide range of fields. Those areas were declared by the countries that own the systems and registered as the major application areas of systems. However, for the systems with an application area such as "Not Specified" or "Research," we can believe that the application area is not open to the public. Furthermore, for the declared application-areas of the top 50 systems, which are ten percent of all listed systems, forty percent are "Not Specified" and another forty percent are "Research." So it is unclear for what purpose those systems are used actually.

2-2-4 Variety in Hardware Architecture (Configuration)

A variety of hardware architectures (configurations) came to be employed in supercomputers[6] as follows:

systems whose computing parts consist only of CPUs (Central Processing Unit), called CPU based systems; and systems that have a combination of CPUs and accelerators (GPUs, Graphics Processing Units, etc.), called accelerator-embedded systems or hybrid systems. Each type of architecture has advantages and disadvantages, and it is hard to say that there is a single type capable of satisfying all the requirements of high performance operations in a wide range of applications. Most of the systems listed in the 37th TOP500 are CPU based, and only nineteen are accelerator-embedded systems, although the number has increased from eleven in the 36th list.

By using the TOP500 list, we can calculate a proportion of the LINPACK Performance (corresponding to the Rmax value in TOP500 list) to the peak performance (corresponding to the Rpeak value) of a listed system. We will call it LINPACK Efficiency. Figure 3 plots each TOP500 system by LINPACK Efficiency and LINPACK Performance, where, because the horizontal axis corresponds to the ranking order in the TOP500, the systems are plotted from right to left according to the ranking, with the top at the rightmost position and the 500th at the leftmost. There, "Kei" and the Jaguar are CPU based, and the Tianhe-1A is accelerator-embedded.

We can see from Figure 3 that "Kei" is a very-high performance computer both in LINPACK Performance and in LINPACK Efficiency. As the world's top large-scale supercomputer, "Kei" showed a remarkably high execution efficiency of 93.0 percent. RIEKN announced[4] that "this is the result of the integration of all the technologies, such as several tens of thousands of CPUs, interconnections of those CPUs and software making the hardware run at the maximum speed." Moreover, "Kei" is ranked at a high position (0.82 billion operations per 1 W) in Green500[7], where supercomputers are ranked by power efficiency. Because of such superiorities, "Kei" has attracted the attention of the world's experts.

3 Supercomputers Spreading Worldwide (Globalization in Installation)

In this chapter, through analyzing the latest and the past versions of the TOP500 list, the trends that supercomputer-installing countries are going will be described.

3-1 Petascale Supercomputer Development

Figure 4 shows the number of systems of twenty-eight supercomputer-installed countries in the latest TOP500, and the total LINPACK Performance value of each country, which is the sum of the LINPACK Performance values of the listed systems owned by a country in TOP500.

We can see from Figure 4 how widely and how equally spread the supercomputer-installation is to the countries. Sorting the countries in specific regions in a descending order according to the number of systems owned, we can see the following: the United

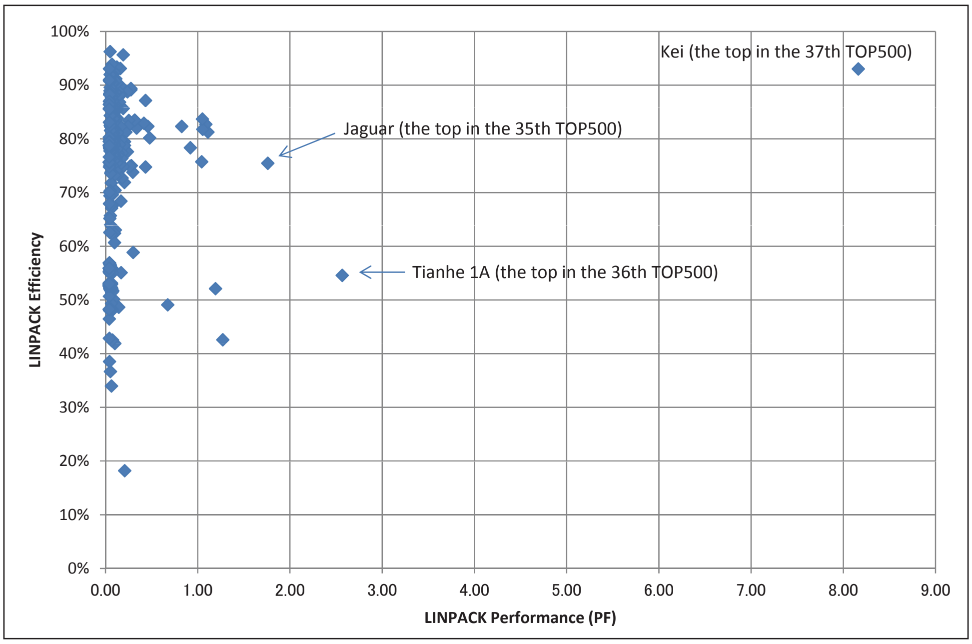


Figure 3 : Scatter Plot of TOP500 Systems on LINPACK Performance-LINPACK Efficiency Plain

Prepared by the STFC based on the 37th TOP500

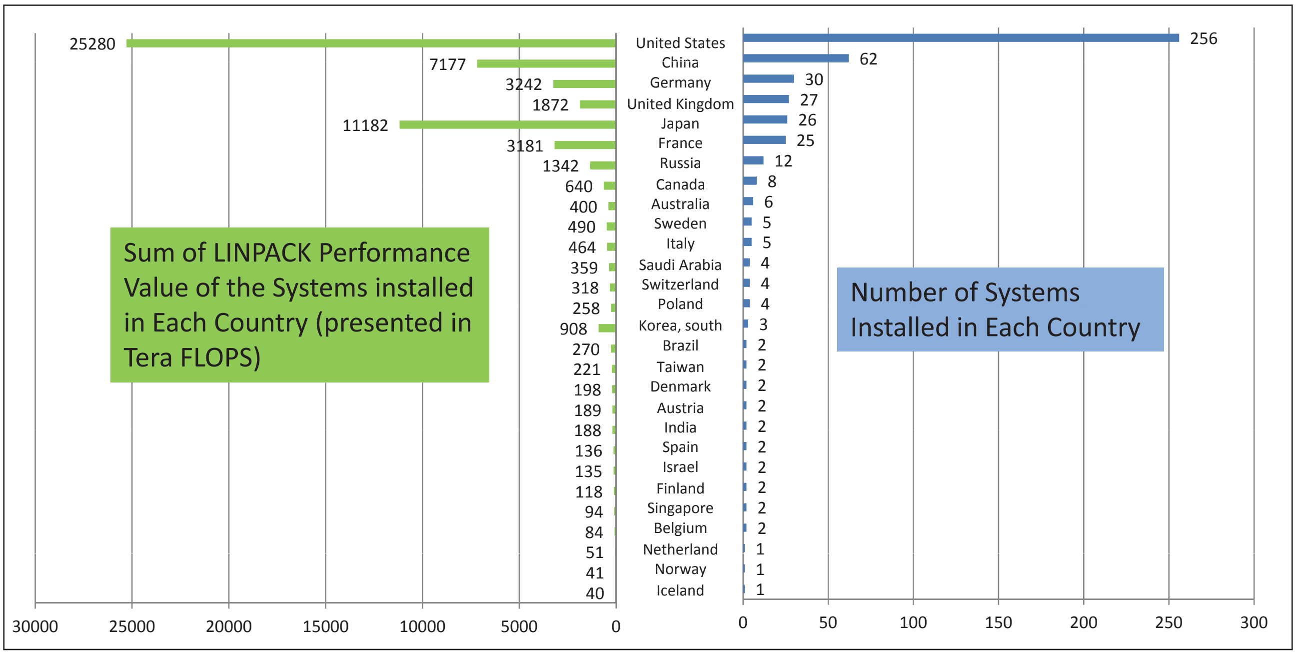


Figure 4: Number of Systems and Sum of LINPACK Performance Value in Each Country

Prepared by the STFC based on the 37th TOP500

States has 256 systems (274 listed in the 36th TOP500 in November 2010); Europe has 126 systems (125 listed in the 36th), where Germany has 30 systems (26 listed in the 36th), the UK has 27 systems (24 listed in the 36th), France has 25 systems (26 listed in the 36th), and Russia has 12 systems; and Asia has 103 systems (83 listed in the 36th), where China has 62 systems (42 listed in the 36th) and Japan has 26 (the same number listed in the 36th).

What we should pay more attention to is the increase in countries that have Petascale performance supercomputers (with a peak performance of over 1 PF). As of June 2011, six countries have Petascale supercomputers; and in seven countries, the total LINPACK Performance value exceeds 1 PF, for which countries Figure 5 shows the history of the total LINPACK Performance value in the past ten years.

We can see from Figure 5 the following:

The United States is still in the lead position; other than the United States, although Japan had kept the second position until 2007, no country has kept the position since then; as of June 2011, the order after the United States is Japan, China, France, Germany, the UK, and Russia; the six countries except the United States can be divided into two, a group of European countries and two Asian countries; those European countries and Asian countries can be said forming the second group; and the second group has recently been showing a remarkably steep progress.

Figure 6 shows the system names and performances of the Petascale supercomputers that have been installed or are planned in the prominent HPC countries. We can see from the figure that supercomputer-enhancement plans will be coming one after another. Therefore, a lot of supercomputers with performance over 10 PF are expected to appear on the scene after 2012.

3-2 Changes in the Last 20 Years in the World

Figure 7 shows five-year changes of the total of LINPACK Performance values in the last twenty years of the systems held by the United States, Europe, and Asia. The latest distribution of regional shares of the United States, Europe, and Asia looks similar to that of 1996, which shows Asian countries' revitalization.

Looking into the Asian countries, we can see the big growth of China's share since 2006, threatening Japan which had 95 percent share of Asian supercomputers in 1996. The European share has remained unchanged for twenty years.

Although not so distinguishable in Figure 7, the present movements in Korea toward supercomputer installation are notable. The Korean government announced the National Supercomputing Promotion Act in May 2011, aiming for the promotion of supercomputing with government funds. The purposes of the Korean act are well-balanced investments on HPC infrastructure, and coordination of the activities of the individual government ministries and agencies. The funds will mainly be applied to supercomputing facilities, applications, research and development, and education / training. For example, the establishment

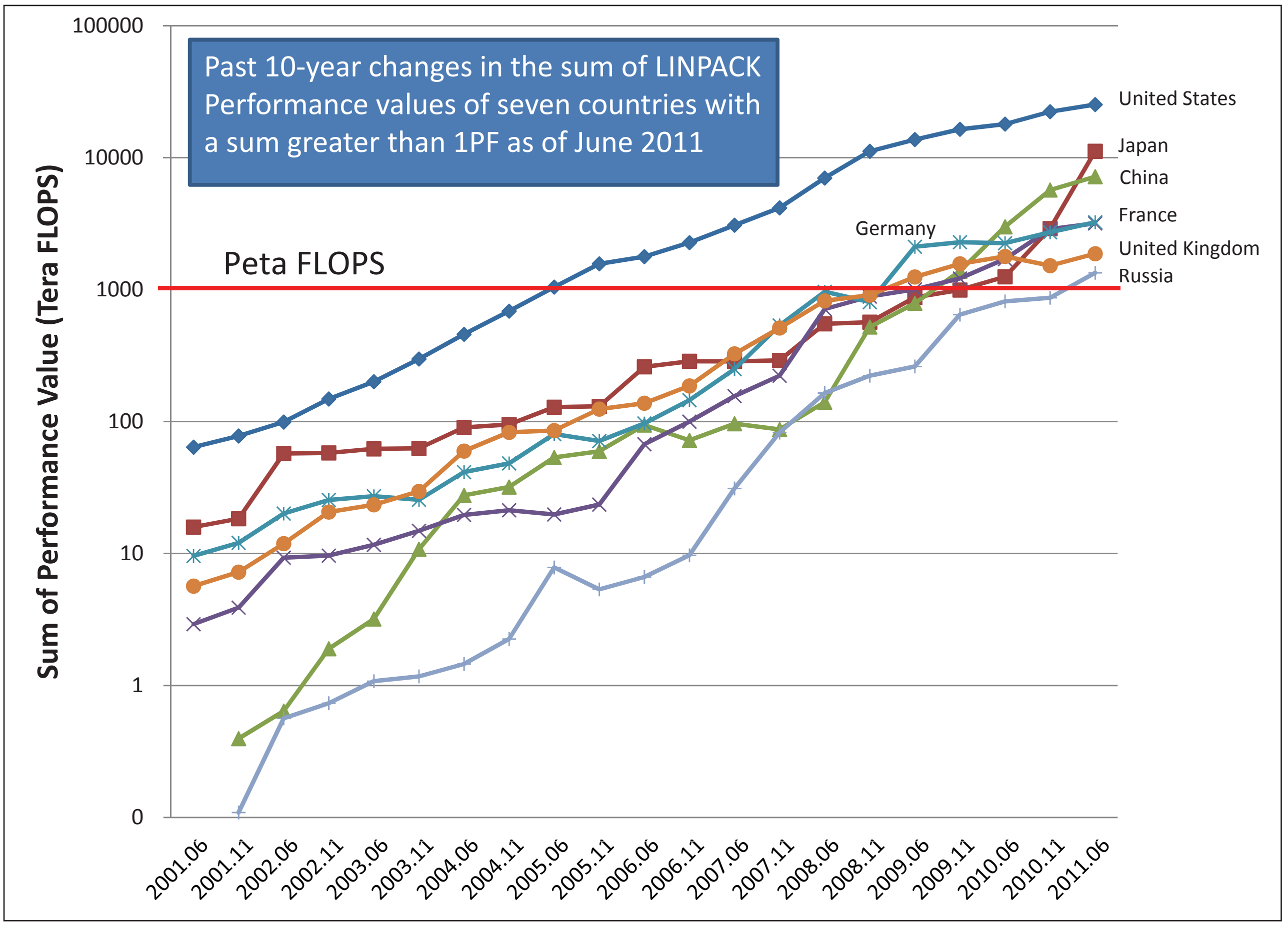
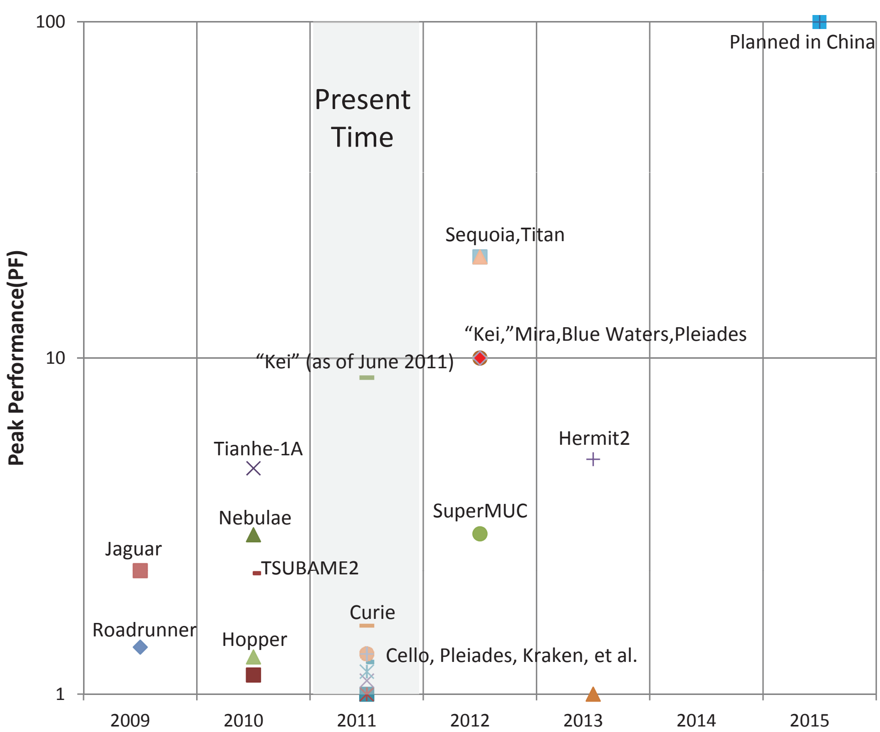


Figure 5: Line Plot of the Sum of LINPACK Performance Values of Countries with a Sum Greater than 1 PF (as of June 2011)

Prepared by the STFC based on the past versions of TOP500



Country	Name of System	Year	Peak Performance (PF)
China	Mole-8.5	2010	1.14
	Nebulae	2010	2.98
	Tianhe-1A	2010	4.7
	Dawning 6000	2011	1
	not yet determined	2012	10
	not yet determined	2015	100
Japan	TSUBAME2	2010	2.29
	Kei	2011	8.77
	Kei	2012	10+
Italy	not yet determined	2012?	1?
Spain	not yet determined	2013?	1?
Germany	JUGENE	2009	1
	Hermit	2011	1
	SuperMUC	2012	3
	Hermit2	2013	4-5
France	TERA-100	2011	1.25
	Curie	2011	1.6
Russia	LOMONOSOV	2011	1.37
United States	Roadrunner	2009	1.38
	Jaguar	2009	2.33
	Hopper	2010	1.29
	NOAA/ORNL	2011	1.1
	Kraken	2011	1.17
	Pleiades	2011	1.32
	Ceilo	2011	1.37
	Mira	2012	10
	Blue Waters	2012	10
	Pleiades	2012	10
	Sequoia	2012	20
	Titan	2012	20

Note that the scheduled completion date of Blue Waters Project of the United States, although scheduled to be shipped in 2012 to the Center for Supercomputer Applications, NCSA, University of Illinois, is unclear because IBM Corp, which used to be in charge of the development, announced in August 2011 that it would withdraw from the development of the system.[8]

Figure 6: Status of Petascale Supercomputers and Future Plans of Prominent HPC Countries

Prepared by the STFC based on the 37th TOP500

of the National Supercomputing Center is planned through the participation of nine government ministries and agencies[9].

4 Spreading Independent Development

Recently, the "domestic production" of supercomputers has spread. In the past, only the United States and Japan developed supercomputers. However, several countries such as China, France, Russia, and India, have started domestic production of supercomputers. Especially, China has been moving toward the development of the critical components of supercomputers—microprocessors.

The following sections will introduce situations around the world as related to supercomputers, country by country, showing that not only installation but domestic production of supercomputers is spreading worldwide.

4-1 China

The Chinese National High-tech R&D Program (widely known as the 863 program) has allowed China to put efforts on HPC. The 863 program, one of the national science and technology research and development programs in China, was proposed by four senior scientists in March 1986 to Deng Xiaoping, the president of China at the time, and approved. The program has been called "863" to commemorate the year "86" and the month "3." The program included HPC as one of its targets.

Since 1990, China has created supercomputer research and development plans every five years. The goal of the plan of 2001 – 2005 was to develop Tera-FLOPS supercomputers and HPC environments. According to the plan of 2006 – 2010, the development of Peta-FLOPS supercomputers and the enhancement of grid-computing environments have been promoted. The 11th National Five-Year Plan focused on the development of Peta-FLOPS class supercomputers, the development of grid-service environments, and the development of software for supercomputers and grid computing[10, 11].

A two-phased approach was adopted for supercomputer development as follows: in the first phase, two supercomputer systems with performances of 100 Tera-FLOPS were to be developed; and in the second phase, three systems with performances of Peta-FLOPS were to be developed. As an achievement of the first phase, Dawning5000A (installed in the Shanghai Supercomputer Center) and LenovoDeepComp7000 (installed in the Supercomputing Center, Computer Network Information Center, Chinese Academy of Sciences) were developed. As an achievement of the second phase, Tianhe-1A (installed in the National Supercomputer Center, Tianjin), Dawning6000 (installed in the National Supercomputing Center, Shenzhen), and Sunway Bluelight (installed in the National Supercomputing Center, Jinan / Shangdong) were produced[12].

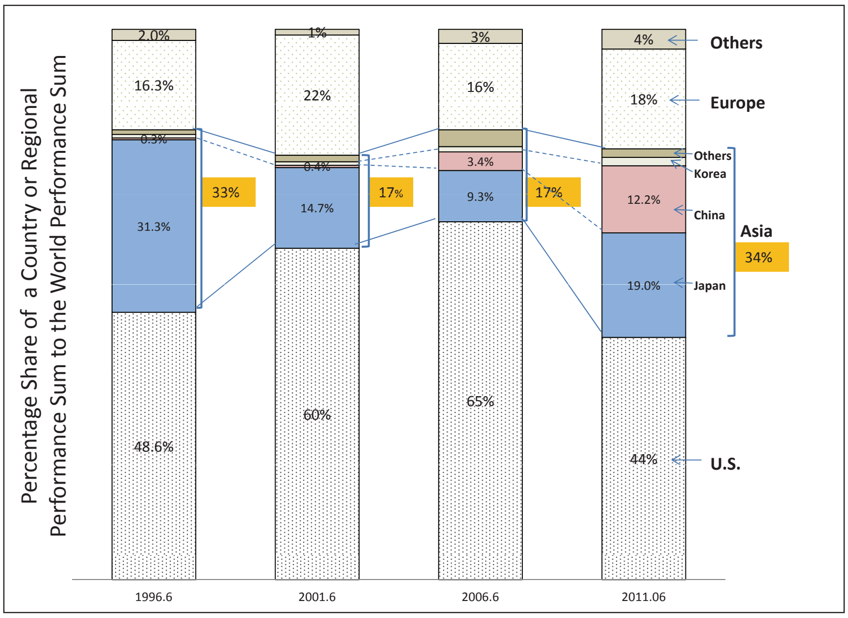


Figure 7: Past 20-year Changes in the Shares of Sum of LINPACK Performance Values of Countries or Regions

Prepared by the STFC based on the past versions of TOP500

In the 2010 version of the top 100 list of supercomputers installed in China, which has been published every autumn since 2002, the top seven slots are occupied by Chinese domestically made supercomputers. According to an official announcement, although about seventy percent of the supercomputers on the list were imported around 2003, in 2010 the share of the Chinese domestically made supercomputers reached about fifty percent, and furthermore, in the performance ranking, eighty-one percent of the listed systems are made by Chinese vendors[13, 14].

The Chinese Ministry of Science and Technology mentioned in an announcement, as achievements realized through the support by the National Project, He-gao-ji, the following as well as "Tianhe-1A" of NUDT, National University of Defense Technology: "FT-1000" microprocessor; "Kylin OS," high security OS; and "Godson / Loongson" microprocessor of the Chinese Academy of Science. It shows that China has also put a great deal of effort into the development of domestically made microprocessors[15].

A report[16] says that the "Indigenous Innovation" policy, which has been employed since the 11th National Five-Year Plan, means in some sense "Made By Chinese Companies." It can be said that the "Indigenous Innovation" policy is what's behind the strong driving of supercomputer and microprocessor development activities in China.

4-2 France

In the past, European countries imported supercomputers from the United States or Japan under a strategy of becoming superior in the development of software for supercomputers. However, Bull, a corporation in France, recently put a great deal of effort into the development of supercomputers themselves. The company has already shipped a supercomputer TERA-100 to the CEA, Commissariat à l'Energie Atomique. The system has a peak performance of 1.25 PF (1.05 PF LINPACK Performance). Supercomputers made by Bull occupied ten places in the latest TOP500 list. Bull's supercomputers were installed in Germany and the UK as well as in France.

4-3 Russia

It was reported in July 2009 that the Russian President Medvedev seriously admitted "the Russian lag in supercomputers or grid computing." The number and the sum of LINPACK Performance values of supercomputers installed in Russia at the time of the Medvedev's comment were less than about one fiftieth of those of the United States, and less than about one third of those of Germany, the UK, France, Japan, or China. So, it is true that Russia was largely behind the other countries. The Russian government reportedly announced a program to offer 2.5 billion ruble (approximately 7 billion yen at the currency rate in June 2011) to develop supercomputers with 1 Peta-FLOPS class performance by 2011 to catch-up with others[17].

This plan has been realized so completely that, in 2011, a Russian company, T-Platforms, is doing business in supercomputer development, and has largely increased their sales mainly in Russia. The company shipped a supercomputer, Lomonosov, with a peak performance of 1.37 PF (674 TF in LINPACK Performance) to Moscow State University in 2011.

4-4 India

In the past, there were domestic supercomputer developing companies in India. However, high-performance supercomputers were never developed. Recently, the Indian Space Research Organization (ISRO) and Wipro Technologies Limited developed the fastest supercomputer in India, called SAGA-220 for aerospace applications, which is a hybrid-architecture system configured with CPUs and GPUs and has a peak performance of 220 TF[18]. Before SAGA-220, the fastest in India was an imported supercomputer with a peak performance of 172 TF.

5 Globalization in Research and Development

This chapter will show the status of the activities of supercomputer research and development through collaborations with other countries, which can be called the third globalization around supercomputers. As the requirements to supercomputers have expanded limitlessly, technical problems have also piled-up in a variety of fields, such as hardware, software pulling out the performance of massively parallel supercomputers to the limit, and applications. To tackle those problems, research and development activities have become the subject of multi-national collaboration in which knowledge and power are gathered from countries around the globe.

5-1 Research and Development in Europe

5-1-1 Activities toward Exascale

(1) European Exascale Software Initiative (EESI)

EESI is an activity funded by the EU. The goals of EESI are as follows: to clarify the technical problems to be solved for executing scientific computations on supercomputers with a performance of multi Peta-FLOPS in 2010 and Exa-FLOPS in 2020; then to determine technical problems on which Europe should put research and development efforts; and to create a roadmap. To work toward the goals, they are now performing activities under working groups. More specifically, they are working to clarify the advantages and disadvantages of Europe to win the global competition, to prioritize the activities, to create education / training programs for computational scientists of the next generation and to find and promote the opportunities of collaboration including countries outside Europe. The project period is eighteen months from the first day of June 2010. At present, one hundred fifteen experts from fourteen countries in Europe are working on the project[19].

(2) EU-Call ICT-2011.9.13

EU-Call ICT-2011.9.13, which is one of the research public offerings in the ICT (Information and Communications Technology) field of the Seventh Framework Programme of EU (FP7), aims for Exascale computing. Its official name is "Exascale computing, software and simulation," and it is the first offering dedicated to Exascale computing in FP7. In January 2011, the three projects[20] that follow, with which several EU countries are involved, were selected to receive a grant of 8 million euro each:

- MontBlanc: European scalable and power efficient HPC platform based on low-power embedded technology;
- DEEP: Dynamical Exascale Entry Platform, Hierarchical Concurrency Approach;
- CRESTA: Collaborative Research into Exascale Systemware, Tools, and Applications.

(3) Opening Research Facilities and Establishing Partnerships for International Collaboration

European countries have been vigorously establishing research facilities and partnerships seeking international collaborations for realizing Exascale. Table 1 summarizes the research facilities and partnerships established recently.

European countries are seeking to enhance the European presence through such collaborations.

5-1-2 Collaboration in Supercomputer Installation and Sharing in Europe

European countries have already established the PRACE Initiative[27-29] (Partnership for Advanced Computing in Europe, hereinafter referred to as PRACE) for the purpose of providing scientists and engineers in Europe across the borders with world-class supercomputer-power. There are twenty-one member countries as of June 2011.

The first of those world-class supercomputers (called Tier-0 systems) available to European countries was JUGENE (with peak performance of 1 PF) of FORSCHUNGSZENTRUM Jülich, Germany. The system has already been in operation. Other Tier-0 systems are also expected to start services as follows: CURIE (with peak performance of 1.6 PF) of the Alternative Energies and Atomic Energy Commission is expected to be the second, and scheduled to start services in the second half of 2011; HERMIT (with peak performance of 1 PF) of Stuttgart HPC Center at the end of 2011 and Upgraded HERMIT (with peak performance of 4 to 5 PF) in 2013; and SUPER-MUC (with peak performance 3 PF) of Leibniz Super Computing Center, Germany in the middle of 2012.

I can predict that the activities observed in PRACE for sharing world-class supercomputers will lead to the sharing of forthcoming Exascale systems.

5-2 International Trends

By extrapolating the plots shown in Figure 1, we can predict that Exaflops systems will come into existence approximately between 2018 and 2020. An international project, called the International Exascale Software Project[30] (hereinafter referred to as IESP), has been working on discussions of what type of architecture Exaflops systems should employ or what will be the problems for software executed on the systems.

There are a lot of major technical challenges in system architectures for the realization of Exaflops performance. In order to attain 1 Exaflops, a large enhancement in performance is required. For example, in comparison with 2 PF, which is the best peak performance in the TOP500 as of June 2010, 500 fold enhancements in performance are required. However, the power dissipation of an Exaflops system

Table 2: Research Facilities and Partnerships Aiming at Realization of Exascale

Name	Location	Participant Organization
Exascale Innovation Center[21] (EIC)	Germany	FORSCHUNGSZENTRUM Jülich and IBM Corp.
ExaCluster Laboratory[22] (ECL)	Germany	FORSCHUNGSZENTRUM Jülich, Intel Corp., and others
EX@TEC[23]	France	CEA, GENCI, Intel Corp., and others
Flanders ExaScience Lab[24]	Belgium	IMEC, Intel Corp., and others
Exascale Stream Computing Collaboratory[25]	Ireland	Trinity College, Dublin, IBM Corp., and others
Exascale Technology Center[26]	UK	The University of Edinburgh, Cray Inc.

should be limited within 20 MW, approximately three fold of the power dissipation of 6 MW in 2010, because, by a simple extrapolative extension of the present technologies, an enormously large power would be required and, as a result, realistic system construction with reasonable operational cost would become impossible. For this reason, the 20 MW in power-dissipation has been set as the upper–limit goal. On the way to the goal, there stands a formidable challenge requiring the development of breaking-through low-power technologies. Regarding the scale of the computing unit, in comparison with that of 2010 that contains 18,700 nodes (a node refers to a computing processor containing computing cores), 100,000 to 1,000,000 nodes will be contained in that of an Exaflops computer. It means the scale will be expanded to about 50 folds maximum of that of 2010. In a situation where such a huge number of nodes run simultaneously in parallel, the total performance will be limited by the data transfer time between cores within or across nodes. It means that a primary requirement is to speed up data transmission. By an estimation, data transmission speed between nodes should be 200 Gigabytes per second (GB / s), more than 130 folds of 1.5 GB / s[31] of Petascale. It also means that ultra-high-speed interconnections enabling such high-speed data transmission are required. In addition, high reliability and resiliency of the system is inevitably required for running such a huge amount of hardware. Moreover, software, software development environments, and application software that extracts hardware power to a limit and enables massively parallel processing under such a configuration are required.

The IESP project focuses especially on software, because at present the development of software falls behind that of hardware[6]. The existing software used in Terascale or Petascale computing is suspected of being insufficient for Exascale computing. Breakthroughs in software are considered critical to the realization of software working efficiently in Exascale environments.

The IESP activities were originated with the workshops that have been held by the supercomputer experts in the United States since 2007. Since then, supercomputer experts around the world have been invited and have started collaborating. At present, researchers from Europe, Japan, and China are working collaboratively with U.S. researchers. In February 2011, a roadmap of common technologies expected to be indispensable to the realization of Exaflops systems was released. There, technical challenges in software to attain the goals were presented in general categories as follows: system software, development environments, applications, and cross-cutting dimensions. Also, the predicted technical elements in each category are discussed. The roadmap listed the names of the sixty-five contributors from around the world, including seven from Japan[32, 33]. From now on, discussions will be shifted from “What to make” to “How to make.”

6 Conclusion

In this article, I looked into the world’s supercomputers listed in TOP500, suggested the current status of three types of globalization, and described their statuses. The reason those types of globalization became distinguishable is considered to be that, among the countries in the world, the recognition has be widely shared that the application of supercomputers would influence the future of their own in science and economy.

The globalization in installation is considered to suggest that supercomputers enabling various kinds of simulations have become acknowledged as a foundation to support national power through science technology. Because numerical simulations are widely acknowledged as "the third science" next to "theory" and "experiment," supercomputers enabling such simulations have been installed aggressively. It is quite natural to demand higher-performance systems and, as a result, several countries have already installed Petaflops peak performance supercomputers.

The expansion of supercomputer-developing countries is considered to be a result of the spreading notion that scientific and technological advantages should be obtained through the domestic development of supercomputers. Such trends are expected to continue in future. However, it is true that, in the way of the development of higher-performance supercomputers, technological problems are piling-up and it would not be easy for a single country to solve.

Therefore, the third globalization, collaborative development with other countries, has appeared as a solution. Research and development activities where the wisdom and power of researchers are gathered from the world have been going-on.

I can say that it is natural that the three types of globalization occurred sequentially. The international collaboration in the development of future high-performance supercomputers will be essential. However, we should take note that maintaining our own superiority will be inconsistent with international collaboration. It is desirable to know our own advantages first, and then promote collaborations with others while effectively using those advantages.

Most important to the promotion of international collaborations is to actually possess the advantages that the world will acknowledge. If a country were to have no advantages, the world would not pay attention to the country, naturally. Japan has technological power for producing "Kei," which is ranked at the top of the world's supercomputers. The power that enabled "Kei" is definitely an advantage for Japan.

Also, it will be effective to show tangible results by fully utilizing the performance of "Kei." A variety of application technologies (application software, etc.) are under development for utilizing "Kei," as follows[5]: "Next-Generation Integrated Simulation of Living Matter" Research and Development and "Next-Generation Integrated Nanoscience Simulation Software" Research and Development included in the Grand Challenge Application Development Program; and "Computational Life Science and Application in Drug Discovery and Medical Development," "New Materials and Energy Creation," "Projection of Planet Earth Variations for Mitigating Natural Disasters," "Industrial Innovation," and "The Origin of Matter and the Universe" included in the Strategic Programs for Innovative Research. It is necessary to show the world Japan's advantages through attaining such achievements that the world acknowledges as Number 1 in those programs. If Japan can impresses upon the world that Japan has advantages not only in supercomputer system technologies but also in application technologies, it will present big opportunities to garner a great deal of attention from the world.

Researchers are always attracted by environments where they could perform the world's best research or where they could use the world's best technologies, and they flock to such places. It would be desirable for Japan from now on to promote activities around "Kei," show the advantages of Japan, go forward in international collaborations, absorb the wisdom of the world's top researchers, and as a result elevate Japan's technological power.

Glossary

- EESI: European Exascale Software Initiative
- FLOPS: Floating point number Operations Per second
- FP7: 7th Framework Programme
- HPC: High Performance Computing
- IESP: International Exascale Software Project
- LBNL: Lawrence Berkeley National Laboratory
- LINPACK: LINear equations software PACKage
- NERSC: National Energy Research Scientific Computing Center
- PF: Peta FLOPS

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Profile

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6

Discussion on Emission Reduction Targets for Individual Countries in Tackling Climate Change

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1 Introduction

Japan experienced extreme weather events, such as record high temperatures and record rainfall last year and this year. Such extreme weather events have been occurring more frequently around the world, and it is widely acknowledged that climate change is the cause. It is considered that the increase in greenhouse gases (such as carbon dioxide and methane) concentration in the atmosphere contributes to climate change. Atmospheric greenhouse gas concentrations have been increasing during the past 200 years and are expected to rise further, and as such, climate change is likely to accelerate.

Climate change is likely to bring adverse effects to food production, ecosystems, and human health through heat waves and changes in rainfall patterns. To minimize climate change, it is necessary to substantially reduce greenhouse gas emissions, which are causing climate change. The United Nations Framework Convention on Climate Change (UNFCCC) (adopted in 1992) and the Kyoto Protocol (an agreement adopted in 1997 under the UNFCCC) have been seeking ways for countries to reduce greenhouse gases for the past 20 years. However, the burning of fossil fuels produces carbon dioxide (a major greenhouse gas), and since the burning of fossil fuels is closely related to a country's energy use and economic activities, countries are reluctant to substantially reduce their own emissions. Since 2007, countries have been negotiating internationally over a future multilateral agreement including reduction targets for 2020, but the negotiations have been facing serious challenges, and it is unlikely that a consensus will be reached anytime soon.

One of the reasons for the stymied negotiations is that countries do not agree on the required amounts of emission reductions for individual countries. The United States was the world's largest emitter of greenhouse gases until few years ago. However, it decided not to participate in the Kyoto Protocol in 2001 because the country thought that emission reductions would have adverse effects on the economy. With reduction targets imposed by the Protocol, Europe and Japan continue to ask the United States to make equivalent efforts. Developing countries are not required to reduce emissions under the Protocol but are increasingly being asked by developed countries to be responsible due to the rapid increase in their emissions in recent years. Developing countries, however, may wonder why they need to reduce emissions when even the United States is not participating in the Protocol. At international negotiations on climate change, the most deep-rooted disagreements concerning reduction targets for individual countries. Therefore, this article introduces trends in and the substance of the discussion, and aims to explore future developments.

There are two approaches to setting targets for greenhouse gas emission reductions. Aiming to minimize the adverse effects of climate change, the first approach seeks a range of global average temperature increases within which adverse effects are kept to an acceptable level and then estimates atmospheric greenhouse gas concentrations to keep temperature increases within the acceptable range. This approach moves in a counterclockwise rotation from stage 5 to 2 in the climate system illustrated in Figure 1 and proposes the amounts of global greenhouse gas emissions that should be reduced to protect the climate. The second approach estimates reductions attainable through individual measures, such as energy conservation and the introduction of renewables, and, based on the cumulative sum, it proposes reductions for individual countries and the world. This approach moves in a clockwise rotation from stage 1 to 2 in Figure 1 and suggests the amounts that can be reduced through the envisioned measures.

A great gap between the amounts that should be

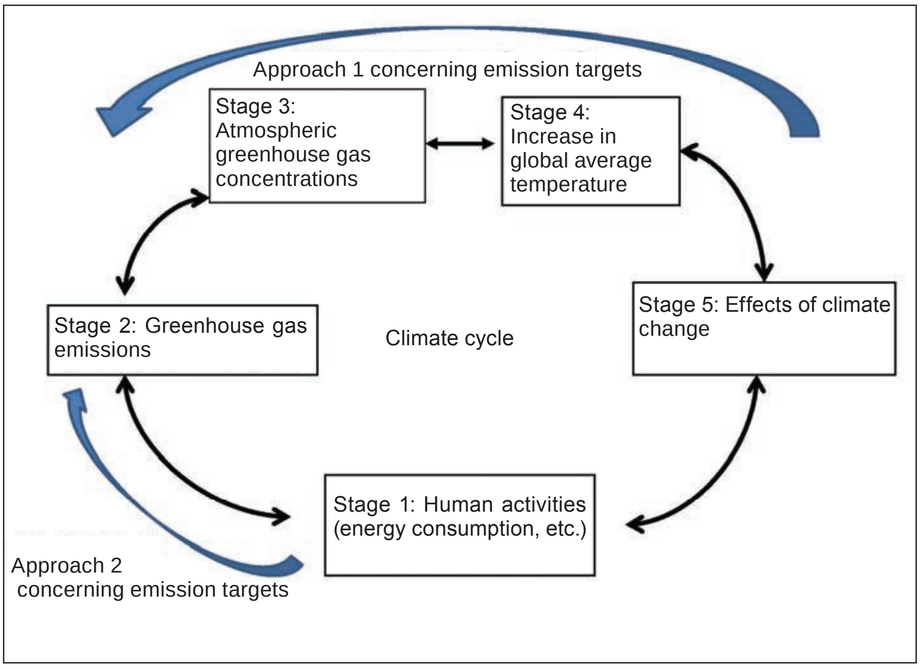


Figure 1: Climate Cycle and Two Approaches for Determining Emission Targets

Source: Adapted from Pershing and Tudela (2003).

reduced to protect the climate and the amounts of reduction that are perceived to be feasible makes it difficult to solve the problem. In Japan, the discussion of reduction targets is often limited to the latter approach and fails to consider the bigger picture, including to what extent emissions need to be reduced to solve the problem. Discussion of the big picture almost never occurs in the policy making process in Japan. This article introduces the basic concepts of the first approach.

2 Scientifically Required Reductions in Global Emissions

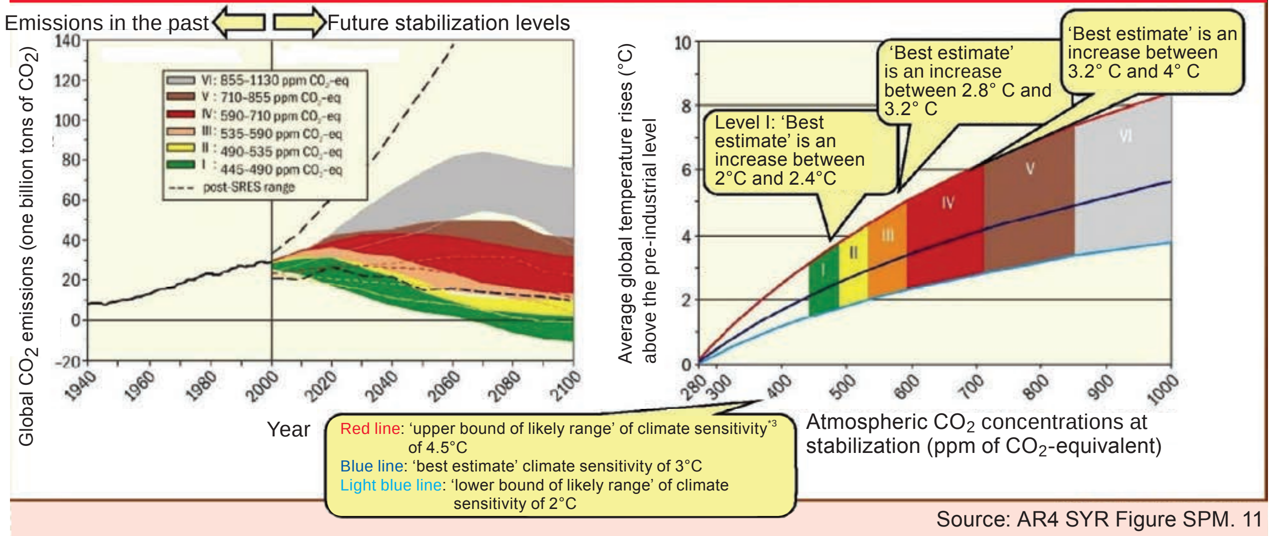
The Fourth Assessment Report (AR4) (released in 2007) of the Intergovernmental Panel on Climate Change (IPCC) suggests that if a global temperature rise is limited to less than 2°C above the average temperature before the industrial revolution (when the use of fossil fuels began at the end of the 18^{th} century), many regions will face adverse impact of climate change while some other regions on earth could experience favorable effects, including growth in cereal yields due to higher temperatures. However, the report also suggests that if the temperature rises around 4°C, all regions on earth will experience more adverse effects than favorable effects (IPCC, 2007). In response to this report, ongoing international negotiations under the UNFCCC propose that the ultimate global temperature rise should be stabilized within 2°C above the pre-industrial average.

Scientific studies have made clearer the relationship between the different stages in Figure 1 (the process from stages 5 to 4 to 3 to 2) (Figure 2). The right-hand panel in Figure 2 illustrates the relationship between temperature rises and atmospheric greenhouse gas concentrations. The left-hand panel shows the relationship between the concentrations and global emissions. For example, as discussed earlier, if the goal is to limit the global average temperature rise to within 2°C above the pre-industrial level, the right-hand panel in Figure 2 shows that this goal is in Category I. To suppress atmospheric greenhouse gas concentrations within Category I, we must control global carbon dioxide emissions within the range of Category I on the left-hand panel. In other words, to reach the target of 2°C, there will be hardly any room for the world to be able to increase CO_2 emissions.

3 Expressions of Concerns and Discussion of Equity: What is Each Country's "Fair Share" of the Burden?

As illustrated in the previous chapter, levels of global emissions required to mitigate climate change can be estimated by knowledge of natural sciences. However, natural science alone cannot find solutions concerning the ranges of reductions required for individual countries in order to achieve the goal, because not all

Relationship between Six Stabilization Scenarios, Equilibrium CO_2 Emissions,[*1] and Global Average Temperature Rises[*2]



Source: AR4 SYR Figure SPM. 11

*1 Emission ranges of the stabilization scenarios (shown in colored shadings in the left-hand panel) comprise CO_2-only as well as multi-gas scenarios, and correspond to the 10th to 90th percentile of the full scenario distribution.

*2 Approaching equilibrium can take several centuries, especially for scenarios with higher levels of stabilization.

*3 It shows changes in temperature in the case where atmospheric CO_2 concentrations rise to twice the pre-industrial level.

*4 CO_2 emissions in most models do not include emissions from the decay of above ground biomass that remains after logging and deforestation, or those from peat fires and drained peat soil.

Figure 2: Relationship between Long-term Targets and Greenhouse Gas Emissions

This author made modifications to the material prepared by the Ministry of the Environment based on the figure in the IPCC

countries agree on a specific allocation method.

Atmospheric concentrations of greenhouse gases are calculated by subtracting amounts absorbed (by forests, etc.) from amounts released through the burning of fossil fuels, etc. To avoid further increases in greenhouse gas concentrations, it is essential to both reduce emissions and increase absorption. Forests have been decreasing in size due to land-use policies of developing countries, and thus different approaches are being explored. It is also not realistic to ask developing countries (which are currently aiming to realize economic development) to reduce emissions, and therefore, developed countries need to substantially reduce current emissions.

There are two types of assessment criteria when individual countries set up their targets: equity (*koheisei* in Japanese) and cost effectiveness (Figure 3). Equity means that allocations differ depending on the circumstances of the participants. (The word 'fairness' [also *koheisei* in Japanese but written with different characters] is used when participants in the same circumstances receive the same treatment.) Cost effectiveness means that it is desirable to achieve the same goal at a lower cost. However, these terms are not usually used under such strict distinction. In Japan, *koheisei* may be written phonetically (so there is no distinction in meaning) and is often used interchangeably.

In addition, indicators to measure equity can be categorized into two groups. The first group is based on degree of responsibility. The Polluters-Pay Principle (PPP) has been long proposed over the discussion on costs to cover compensations for damage caused by pollution, etc. This is a policy principle where the more environmentally harmful substances a polluting party produces, the larger costs it needs to pay. For example, equalizing per capita emissions and proposing reductions based on accumulated historical emissions are categorized into this group.

The second group determines reductions based on ability to pay and is called the ability–to-pay principle. According to this principle, relatively wealthier parties should pay more than relatively poorer parties. Systems like the cumulative taxation system are based on this principle. Per capita GDP and a country's total GDP are categorized into this group.

The Japanese people often say, "Why does Japan need to further reduce emissions when the country is conducting so much effort to conserve energy?" However, based on the categorization above, this discussion is not about equity, it is about cost effectiveness. From an outside point of view, it can be explained that relatively stringent reduction

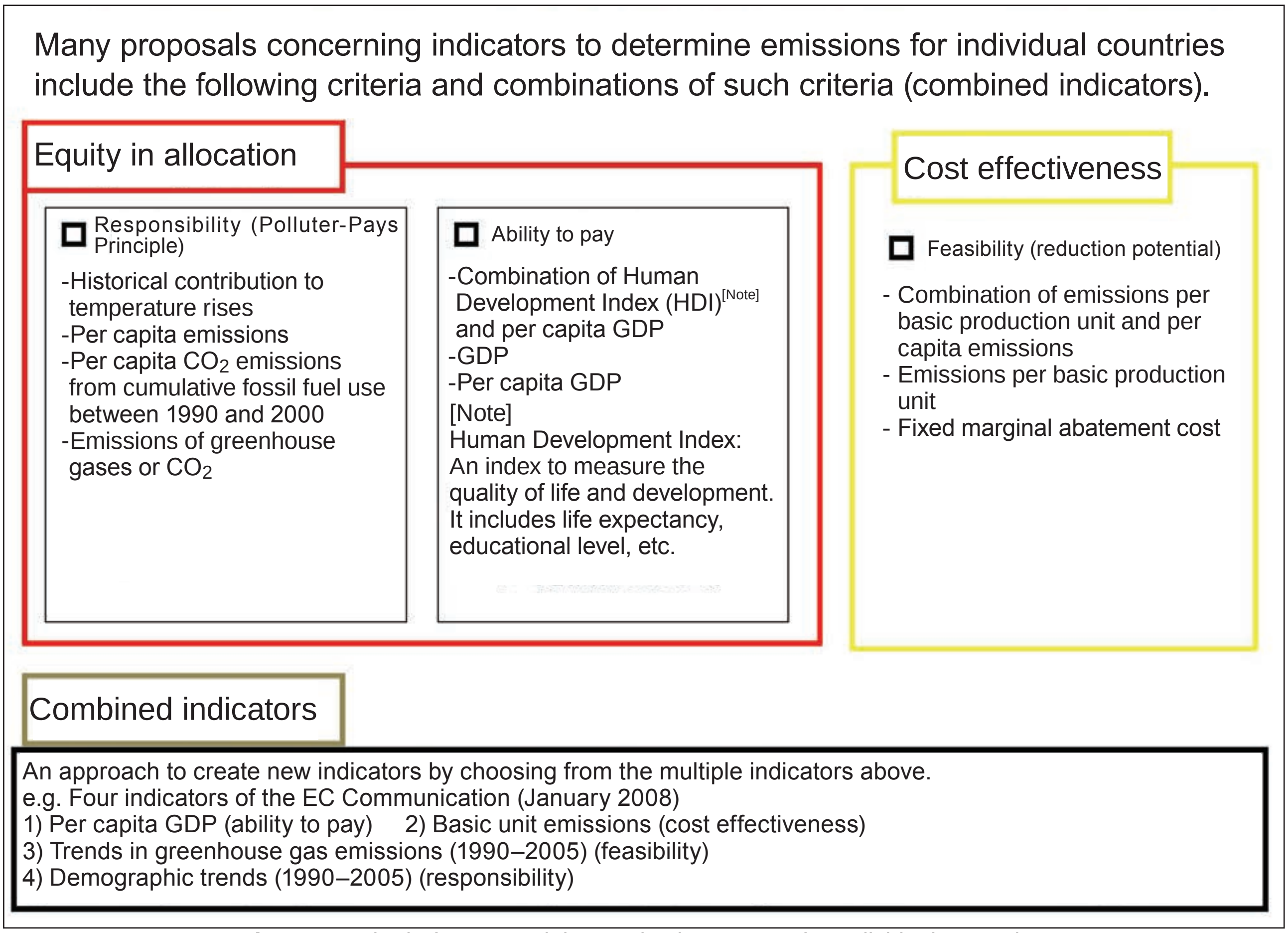


Figure 3: Criteria for Determining Reduction Targets for Individual Countries

targets are imposed on Japan because the country's per capita emissions are large (at least compared to the world average) and the country is wealthy. In particular, when using systems like the Kyoto Protocol's emissions trading schemes and offset schemes, whereby reducing emissions overseas at relatively lower costs can be counted towards a country's reductions, the country does not necessarily need to reduce domestic emissions. In such cases, the country's cost effectiveness indicators do not mean anything, and the ability-to-pay indicators are more justifiable. As such, indicators should be chosen depending on systems that can be used to achieve goals.

Paying attention to such differences in the indicators, the European Union (EU) created combined indicators using multiple indicators from different indicator groups to achieve consensus among countries.

4 Provision of Information to Reduction Target Estimates for Individual Countries

While there are many different indicators, what are valid reduction targets for Japan and other countries to propose from an equity point of view? Figure 4 reviews countries' various proposals on how to set emission reduction targets and illustrates estimated reduction targets for individual countries based on some major proposals. Some estimates show that, by 2020, developed countries (Annex I) should aim to decrease their total emissions by 25% compared to 1990 levels in order to control the temperature increase within 2°C. The multi-stage indicator (in the "existing research" section in Figure 4) illustrates a combined indicator created from several indicators concerning equity and cost effectiveness, and it is an approach to determine the levels of severity of action for country groups at different stages of economic growth (developed, emerging, and developing countries). The Contraction and Convergence (C&C) strategy sets a target for, for example, 2050 and 2100 so that per capita emissions around the world will be the same in the distant future and determines linear emission pathways towards the goal. Different estimates used different preconditions, including the world's emission reductions, and so it is not easy to make comparisons, but generally speaking, indicators that emphasize equity propose stricter reduction targets for developed countries that have relatively larger per capita emissions. In contrast, many developed countries have relatively more advanced technology and tend to use indicators that emphasize cost effectiveness and, as a result, smaller amounts of reductions are estimated by cost-effectiveness indicators. For example, if Japan uses an indicator emphasizing equity, it will be required to propose reductions of approximately 30% compared to 1990 levels by 2020. In contrast, if the country uses an indicator emphasizing cost effectiveness, no reductions will be necessary compared to 1990 levels. Japan has been arguing that this is the case since it is more advantageous to use an indicator emphasizing cost effectiveness. However, current negotiations have shown that other countries are not convinced by this argument, believing it is not equitable.

Due to immigration and other effects, the United States has a relatively high rate of population growth compared to other developed countries and is expected to maintain that high level. Therefore, even though per capita emissions in the United States are higher than other developed countries, the emissions reductions required of the United States are not large, based on a rule aiming to equalize per capita emissions. However, as the population grows, energy consumption also increases, and it is not easy to achieve a target even if the range of reductions is small. Given the current American economy and politics, any range of reductions is hard to accept, as has been shown by the country's attitudes.

Among emerging countries, the Chinese economy is rapidly developing, and its reduction targets have characteristics that are more similar to other developed countries than to other developing countries. India is recognized as an emerging country, but in many ways, the country remains at the level of a developing country. As such, an indicator emphasizing per capita emissions in particular shows that India will be allowed to have an increase that is more than twice as large as the 1990 level.

Figure 4 suggests that, as the world aims for 2°C, Japan's current target to reduce emissions by 25% compared to 1990 levels by 2020 is reasonable in order to show that the country accepts its fair share from an equity point of view. In other words, if Japan fails to meet this reduction target, the country will lose its moral authority to demand other countries to follow suit. According to Figure 2 (prepared by the IPCC), it is also clear that Japan needs to reduce emissions continuously between 2020 and 2050. It is, of course, essential to discuss specifically how to achieve the target (the second approach mentioned in the introduction), but it is also important to be aware how much effort is required to solve climate change.

5 Need for Structural Shift in Negotiations

As discussed in the introduction, since 2007, there have been ongoing negotiations on international cooperation to tackle climate change, but progress has not been made. One of the reasons for stalled negotiations seems that the United States (which used to be the world's largest emitter of greenhouse gases until recently) has not accepted the approach of international "cap and trade" as under the Kyoto Protocol. As long as countries see emission reductions as a burden and continue to negotiate over the allocation of the burden, the United States is not likely to accept the approach, and as long as the United States does not accept it, countries are not likely to reach an international consensus on how to solve climate change.

Rather, the solution for the deadlock is to change the negotiation structure. What is needed is a structural shift away from negotiations concerning burden allocation and toward competition for gain (e.g., Barret 2008, and Bodansky and Diringer 2010). It is essential to incorporate, into the current international system, a structure where countries and companies will reap economic benefits from being the first to develop technology to reduce emissions.

This trend has already been seen. Global competition has been fierce in new businesses to contribute to reducing CO_2 emissions, such as solar power systems, wind power generators, hybrid cars, electric cars, and bio fuel-related products. In order for companies to acquire global competitiveness, it is important for a government to create policies to help such new industries grow. For example, (As of 2020, compared to the 1990 levels) Equity | Cost effectiveness | Combined

Emission reduction percentages by country & region for 2020 (compared to 1990)		Japan	U.S.	EU25	Russia	Annex I countries (total)	Reference. China	Reference. India	Reference. Non Annex I countries	Reference. World
Existing research (e.g. for stabilizing CO_2 at 450 ppm) Höhne, N., D. Phylipsen, Moltmann, S., 2007: Factors underpinning future action 2007 update, for the Department for Environment, Food and Rural Affairs (DEFRA), UK	Multi-stage (combined indicator)[1]	-31%	-38%	-36%	-52%	-41%	62%	235%	89%	9%
	Contraction and Convergence (C&C) (responsibility)[2]	-31%	-18%	-34%	-48%	-32%	62%	168%	76%	10%
	Common but differentiated convergence (CDC) (responsibility)[3]	-33%	-9%	-35%	-47%	-29%	48%	180%	72%	10%
	Triptych (combined)[4]	-29%	-8%	-31%	-45%	-26%	65%	103%	69%	10%
The Mid-term Target Committee (2009) Analysis by NIES & RITE	Equal MAC (cost effectiveness)[5),10)]	+1 ~-5%	-19% ~-24%	-23% ~-27%	-32% ~-47%	-25%	-	-	-	-
	Equal cost/GDP (capability)[6),10)]	-8% ~-17%	-7% ~-18%	-30 ~-31%	-31% ~-54%	-25%	-	-	-	-
Estimate by NIES, Kyoto University, & Tokyo Institute of Technology	Equal cost/GDP converge (cost effectiveness)[7),10)]	- 3%	-10%	-26%	-52%	-25%	114%	65%	74%	14%
	C&C (responsibility)[8),10)]	-16%	-13%	-26%	-46%	-25%	72%	98%	74%	14%
	Emission/GDP equal rate reduction (cost effectiveness)[9),10)]	-30%	-19%	-33%	-21%	-25%	160%	81%	74%	14%

1) Commitment levels are divided into four stages. The strictest stage determines absolute reductions depending on per capita emissions.
2) Equalizing global per capita emissions by 2050.
3) Growth of Non-Annex I countries is added to C&C. Annex I countries will converge per capita emission by 2050. Non-Annex I countries are allowed to increase emissions up to a threshold and will later converge, taking the same amount of time.
4) Domestic emissions are divided into three sectors: electricity, industry, and domestic, and each sector reduces emissions based on a different standard.
5) Analysis (2): Calculated result by NIES (AIM global technology model) and RITE (RITE global model) for equal MAC (marginal abatement cost) cases.
6) Analysis (4): Calculated result by NIES (AIM global technology model) and RITE (RITE global model) for equal cost/GDP cases.
7) Emission/GDP will be the same globally by 2050. Assumes world emissions are halved by 2050.
8) Same as 3), but assumes world emissions are halved by 2050.
9) Emission/GDP will be improved at a certain rate for all countries. Halving global emissions by 2050 is required. This indicator requests developing countries (other than China and India) to substantially reduce emissions.
10) The base year emissions specified by the Kyoto Protocol (1990 for CO_2, CH_4, and N_2O; 1995 for HFC_s, PFC_s, and SF_6) are used to calculate reductions compared to the 1990 levels. All Annex I countries are required to reduce emissions by 25% compared to the base years.

Figure 4: Emission Reduction Targets for Major Countries by Different Indicator

Sub-committee for Mid- and Long-term Roadmap toward Low-carbon Japan, Global Environment Committee, Central Environment Council

Germany was eager to adopt feed-in-tariff (FIT) for the renewable energy , not only because of the environmental reasons to reduce CO_2 emissions but also for the purpose of cultivating German industries (Wada 2003). China became the world's top producer of solar panels in 2009 (PV News 2011), and boosting the Chinese makers is the driving force for the Chinese government to request developed countries to set stricter reduction targets. The United States is planning to keep using coal-fired power generation and swiftly develop clean coal technology (especially carbon capture and storage, CCS) and sell the technology to China and India, which are planning to continue using coal.

There have been some proposals, at least at the expert level, to create an international system that emphasizes promoting such competition (Barrett 2003, Victor 2011). These proposals include methods to establish international technology standards and energy efficiency standards by type of business. However, the greatest weakness of these proposals is that they put so much emphasis on promoting competition that they neglect the first approach discussed in the introduction (i.e. verifying gross emissions required to minimize climate change). In particular, Victor even finds a solution in geoengineering (e.g. artificially blocking sunlight by scattering particles in the stratosphere). We should not abandon our efforts to control emissions. It will be necessary both to promote competition and to maintain the current UNFCCC and Kyoto Protocol as a way to verify gross emissions.

Japan has been increasingly interested in a bilateral credit system as a trial to change the structure. In the system, Japan and developing countries have technology partnerships. When Japan helps a developing country with its technology, part of the reductions achieved in the country will be counted as Japan's reductions. This is basically the same as the CDM under the Kyoto Protocol, but it is advantageous because it can avoid complicated procedures, which have been a problem of the CDM. By using such mechanism and adopting technology from developed countries, developing countries can become low carbon societies. At the same time, Japanese companies can develop markets overseas.

6 Conclusion

International cooperation for tackling climate change is at a crossroads. On one hand, even though a substantial amount of emission reductions is required, governments are reluctant to accept strict reduction targets. On the other hand, based on the vision to create low-carbon societies in the long term, companies have been conducting technological innovation and product development. If private technological innovation, product development, and their popularization make progress at a rate faster than expected, governments may become willing to accept the substantial reduction targets that they now hesitate to agree on.

At the same time, it is essential to better understand climate change in order to increase public interest and understanding. Constant and steadfast efforts are required depending on the role of each individual and party.

To solve climate change, we cannot avoid the process of international consensus building. Experts in international negotiations or in natural sciences alone cannot achieve this. The establishment of a domestic system where specialists from various fields, including natural sciences, humanities, and social sciences, gather, is the precondition for successful international negotiations.

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Profile

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