Cool Earth-Innovative Energy Technology Program

March 2008

Ministry of Economy, Trade and Industry

“Cool Earth-Innovative Energy Technology Program”

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1. Introduction

The Prime Minister’s initiative on global warming, “Cool Earth 50” was announced on May 24, 2007. It includes the proposal for a long-term objective to reduce global greenhouse gas emissions by half compared to the current level by 2050. It is difficult to address such a long-term objective with only conventional technologies, and so the development of innovative technologies is considered essential.

At the Heiligendamm Summit in June 2007, climate change was one of the main discussion themes, and G8 leaders reached an agreement to “consider seriously the decision which includes at least a halving of global emissions by 2050” and to treat technology as “a key to mastering climate change and enhancing energy security.”

Since Japan has the world’s top level technology in the field of energy, we need to strongly promote international cooperation and actively contribute to substantial global emissions reductions while reinforcing and maintaining our competitiveness. This can be done both by focusing our research and development resources on the technology fields where we can lead the world and by accelerating and promoting technology development with the recognition that technology is an important resource for Japan.

We have thus decided to develop the “Cool Earth-Innovative Energy Technology Program,” and we have examined how specific measures can be taken to develop innovative technologies in the field of energy with the prospects for 2050. In this examination, we first discussed which technologies Japan should focus on developing to achieve substantial reductions by 2050, and we specified which technologies should be prioritized in order to prepare a roadmap for long-term technology development with milestones to ensure steady advances. Next, we discussed how international cooperation should be used in technology development, since the substantial reduction is considered impossible without international cooperation. A long-term approach is needed for achieving substantial reductions, and nations need to share the direction of technological development to ensure steady progress. We then discussed how international cooperation should be structured with the roadmaps as the centerpiece of international cooperation.

This report summarizes these items of discussion as “Cool Earth-Innovative Energy Technology Program.”

2. Innovative energy technologies to be prioritized

(1) Criteria for narrowing down the focus of innovative energy technology development

To promote energy technology development effectively and efficiently for the substantial reduction by 2050, we narrowed down the specific innovative energy technologies to be emphasized by using the following criteria.

Obviously the improvement and diffusion of existing technologies that are already commercialized is also important, but we considered innovative technologies that are not extensions of existing technologies as subjects in this examination.

1, Technologies expected to deliver substantial reductions in carbon dioxide emissions in the world by 2050
   - (a) Technologies that can be commercialized by 2030 considering the period required for the diffusion of the technology, and
   - (b) Technologies that can be commercialized after 2030 if the period required for diffusion is short.

2, Innovative technologies expected to deliver a substantial performance improvement, cost reduction, expansion in diffusion and so forth through one of the following methods:
   - (a) Material innovation including the utilization of new principles and the new utilization of existing materials (e.g. PV cells with new structures or materials, an alternative catalyst to platinum in fuel cells, etc.)
   - (b) Innovation in production processes (e.g. Innovative iron and steel process using hydrogen as the reducing agent, etc.)
   - (c) Demonstration of systems based on established elemental technologies (e.g. Carbon dioxide capture and storage technology)

3, Technologies that Japan can lead the world in developing (this includes areas in which Japan already has a lead in developing the foundational elemental technologies).

(2) Identified “21” innovative energy technologies

Based on the above concepts, we selected the following “21” technologies. In this figure, these 21 technologies are largely classified on the basis of their impact on the expansion of low-carbon energy utilization and improvements in energy efficiency, as well as whether they are on the supply side or the demand side.

(Power generation/transmission)

○ High-Efficiency Natural Gas Fired Power Generation

○ High-Efficiency Coal Fired Power Generation

○ Carbon dioxide Capture and Storage (CCS)
○ Innovative Photovoltaic Power Generation
○ Advanced Nuclear Power Generation
○ High-Efficiency Superconducting Power Transmission

(Transportation)
○ Intelligent Transport System (ITS)
○ Fuel Cell Vehicle
○ Plug-in Hybrid Vehicle/Electric Vehicle
○ Production of Transport Biofuel

(Industry)
○ Innovative Iron and Steel Making Process
○ Innovative Material, Production/Processing Technology

(Commercial/residential)
○ High-Efficiency House and Building
○ Next-Generation High-Efficiency Lighting
○ Ultra High-Efficiency Heat Pump
○ Stationary Fuel Cell
○ High-Efficiency Information Device and System
○ HEMS/BEMS/Local-Level EMS[1]

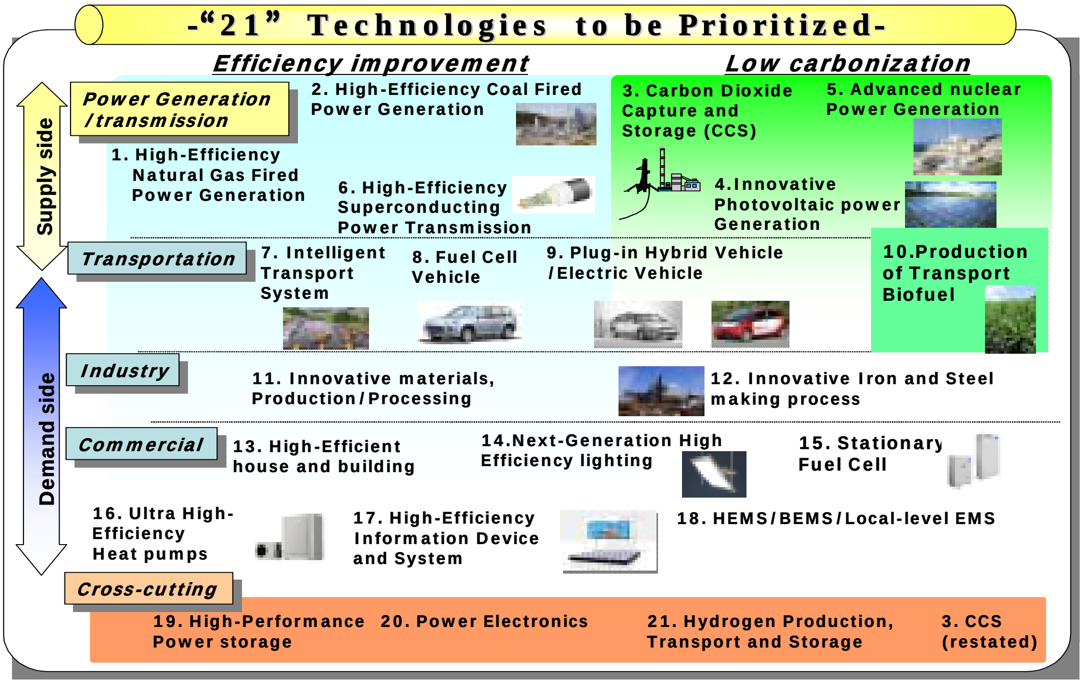
(Cross-cutting technologies)
○ High-Performance Power Storage
○ Power Electronics[2]
○ Hydrogen Production, Transport and Storage

In this program, we selected the 21 technologies based on the information available at present. It is possible that technologies that are just emerging may develop into those that can contribute to substantial reductions in carbon dioxide emissions with future research and development and some breakthroughs. Therefore, we will need to keep an eye on the

[1] HEMS/BEMS/Local-Level EMS: EMS stands for Energy Management System. HEMS (House Energy Management System) controls the energy for individual houses, and BEMS (Building Energy Management System) controls the energy in individual buildings to optimize the energy utilization. Local-level EMS is an energy control system with a wider areas.

[2] Power Electronics: Technologies for inverters, etc. that utilize semiconductors and so forth in power generation, transmission or distribution, power storage and other electric devices.

technologies that were not selected in this program such as offshore wind power generation. This is currently developed mainly in Europe due to better wind conditions and a better expected operation rate compared to land-based turbines. We plan to note progress in basic research as well as the overseas development status of the technology as necessary to provide an element of flexibility to the technology list.



(Figure 1) Innovative Energy technologies to be prioritized

(3) Innovative energy technology development roadmap through 2050

To promote technologies that require a long lead time before commercialization and great investments in research and development, it is essential that the government and private sector share the direction. We therefore developed a technology development roadmap that shows the processes from development to practical application over time for the 21 selected innovative energy technology fields, discussing the technologies in greater detail based on the knowledge of specialists (Appendix). More specifically, the time until practical application, the course of technical advancement, issues to be addressed before diffusion, etc. are provided.

It is important that this technology development roadmap will be reviewed regularly to address the changes in domestic and international trends in technologies so that related parties can share the direction of technology development.

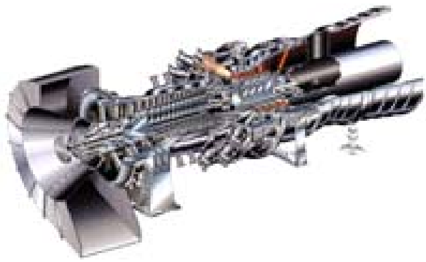
(Power generation/transmission)

○ High-efficiency natural gas fired power generation

- Outline of technology

Combined cycle power generation by both high temperature gas turbines and steam turbines using natural gas (which has less environmental impact than other fossil fuels) as the fuel, and advanced humid air turbine technologies.

Kawasaki Thermal Power Station
Courtesy of Tokyo Electric Power Co.



Courtesy of Mitsubishi Heavy Industries, Ltd.

It is possible to reduce carbon dioxide emissions by approximately 7% if power generation efficiency can be improved to 56% (transmission end[3], HHV[4]) from the current level of 52% efficiency and by nearly 10% if efficiency is improved to 60% through improved gas turbine performance. It is also technically possible to combine this with carbon dioxide capture and storage technology (CCS) and create a plant that is nearly zero-emission by putting the CCS

[3] Transmission end: Generating end is calculated based on the power generated by the generator, and transmission end is calculated by subtracting the power used by devices within the power plant from the generating end power.

[4] HHV (Higher Heating Value): Indicates the condition for expressing the heating value of a fuel, and HHV includes the condensation heat for moisture contained in fuel and steam generated by combustion (evaporative latent heat). Lower heating value (LHV) does not include evaporative latent heat. Therefore, the power generation efficiency using LHV is higher than that with HHV by about 1.05-fold in coal fired power generation and about 1.1-fold in natural gas fired power generation.

technology to practical use.

- Technology development roadmap

Thermal efficiency for power generation gas turbines has been improved since the beginning of 1980s by combustion temperature increases at the pace of 20°C per year. Japan has led the world in this field by putting 1500°C-class gas turbines on the market ahead of other nations and achieving power generation efficiency of 52%. However, Japanese turbine manufacturers only have about 10% of global market share, with large shares held by European and American manufacturers such as GE and Siemens. These manufacturers are also actively working toward this level of technological development. Therefore, our superiority does not allow for optimism.

To maintain our superiority in this field, we shall approach the development of 1700°C-class gas turbines, aiming for their commercialization with 56% power generation efficiency by around 2015. To do this, high-temperature resistant and corrosion resistant materials, cooling techniques, ceramic thermal barrier coating and so forth need to be developed. Also, technology development will be promoted to improve power generation efficiency to 60% by using a combination of fuel cell and gas turbines or steam turbine by around 2025. In this case, the development of a large-capacity fuel cell will be the largest technical challenges.

Development of 1700°C-class gas turbines is an important technology that can also be used in other power generation technologies such as integrated coal gasification combined cycle (IGCC). Technology development is also promoted in the U.S. in the federal government by the High Efficiency Engines and Turbines Programs of the U.S. Department of Energy (DOE). It is expected that early practical application and the establishment of reliability with demonstration projects can be accomplished in Japan with steady technology development through industry-academia-government cooperation.

- Challenges for effective technology development and diffusion

Development of combustion technology that recirculates exhaust gas to create low-pollution combustion is necessary, as is the advancement of various basic technologies involving various components of the gas turbine, such as the compressor, the combustor, and the turbine itself. This technology is expected to contribute to improvements in the efficiency of the subsequent carbon dioxide separation and capture by increasing the concentration of carbon dioxide in the exhaust gas.

Furthermore, it is necessary that technology development be conducted with industry-academia-government cooperation by training young engineers and working across disciplines since gas turbine technology requires advanced design and production skills in a wide range of fields including aerodynamics, thermodynamics, combustion, and materials science.

In addition to these R&D efforts, it is necessary to disseminate the high-efficiency natural gas power generation overseas through transferring our technologies and know-how, with appropriate management of intellectual property rights, to electric utilities in both developed and developing countries where electricity demand will be growing.

○ High-efficiency coal fired power generation

- Outline of technology

Coal is an important resource for the stable supply of energy since there is a large reserve and it superiors in economic efficiency compared to petroleum, natural gas, and other fuels. Japan’s coal-fired power generation technology started with subcritical pressure generation (C), advancing to practical application of supercritical pressure generation (SC), then ultra super critical pressure generation (USC), with continually improving power generation efficiency. There are also technologies called advanced ultra super critical pressure power generation (A-USC), Integrated Coal Gasification Combined Cycle (IGCC), and Integrated Coal Gasification Fuel Cell Combined Cycle (IGFC), each with more improved power generation efficiencies that can help overcome the fact that carbon dioxide emissions from coal combustion are greater than those from other fossil fuels.

<Advanced Ultra Super Critical pressure power generation (A-USC)>

A-USC is the technology to improve the power generation efficiency by increasing the steam temperature and pressure of pulverized coal fired power generation.

<Integrated coal Gasification Combined Cycle (IGCC) and Integrated coal Gasification Fuel cell Combined cycle (IGFC)>

IGCC is the technology for combined power generation that uses gas turbines and steam turbines with coal gasification. IGFC further improves power generation efficiency by combining this process with a fuel cell. Further reduction of carbon dioxide emissions can be expected by the next-generation IGFC (A-IGFC) technology that will improve power generation efficiency by collecting exhaust heat from the

EAGLE Pilot Plant

EAGLE: Coal Energy Application for Gas, Liquid & Electricity

Courtesy of Electric Power Development Co., Ltd (J-Power) fuel cell and utilizing it in gasification.

Carbon dioxide emissions can be reduced by about 30% if power generation efficiency can be improved from the current 42% (with USC technology) (transmission end, HHV) to 57%. Emissions can be reduced by 40% if efficiency is improved to 65%. In addition, emissions of carbon dioxide can be expected to be reduced to nearly zero by combining this technology with CCS.

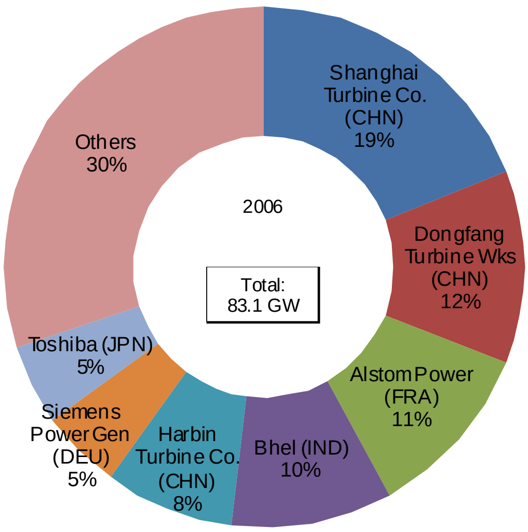
- Technology development roadmap

Along with European manufacturers such as Alstom Power and Siemens, Japanese manufacturers such as Mitsubishi Heavy Industries, Toshiba and Hitachi have global businesses in steam turbine and boiler technologies and are leading the world in technology. In addition, 3 major Chinese companies, Shanghai, Harbin and Dongfang, and the Indian national power company BHEL are beginning to obtain a large share of the global market[5] (see Fig. 2) through technical cooperation with major Japanese, European and American manufacturers. This is happening under the background of recent rapidly growing demands for power in China and India, and it indicates advances in business-based transfers of technologies.

A-USC is suitable for building and retrofiting of pulverized coal fired power plants since it has a similar system structure and operability to the existing pulverized coal fired power plants.

Japan has the experience of putting 600℃-class USC to practical use ahead of the world and is at a technical advantage. Development of new high-temperature resistant materials and innovative welding technology for steel materials will be promoted in technology development with the goal of commercializing 700°C-class turbines with 46% power generation efficiency by around 2015 and 48% efficiency by around 2020.

IGCC is a technology suited to low ash melting point coals which are difficult to use in pulverized fired power plants, and thus it is expected to



(Figure 2) Market Share of Steam Turbines
Courtesy of Mitsubishi Heavy Industries, Ltd.

5 Output based share for 2006 (including nuclear turbines). Survey by Mitsubishi Heavy Industries.

contribute to the stable supply of energy by expanding the types of coals that can be used. Internationally, four Integrated Coal Gasification Combined Cycle (IGCC) plants in Buggenum (Holland), Puertollano (Spain), Wabash River (U.S.), and Tampa (U.S.) are currently in commercial operation. All of these plants have generating end output of approximately 300MW and use oxygen blown (type) gasifier. Their operation began in the latter half of the 1990s, and their power generation efficiency was about 40%.

In Japan, technologies to achieve higher power generation efficiency are already in the demonstration stage, and we will establish reliability, safety, economic efficiency and maintenance simplicity through the operation of a demonstration plant (250MW, 41% power generation efficiency) in the future.

Furthermore, we will try to achieve 46% power generation efficiency using the wet gas cleaning method by around 2010, 48 % by around 2015 using the hot gas cleaning method and 50% by around 2025 by adopting a 1,700°C-class gas turbine.

In the long term, practical application of the next-generation IGCC is expected when the power generation efficiency will be improved to 57% by moving the exhaust heat from the gas turbine to the gasification reactor and using the steam reforming process to increase gasification efficiency by 2030 and later.

IGFC is currently at the stage of fundamental technology development in a pilot plant. It has already been confirmed that the fuel cell operates on hydrogen gas generated from coal, but it is necessary to improve the reliability of the system and reduce its cost by developing a large-capacity fuel cell and establishing a system to combine it with the coal generator. We will aim to reach a power generation efficiency of 55% by around 2025.

In the long term, we expect the next-generation IGFC (A-IGFC) to improve power generation efficiency by collecting exhaust heat from the fuel cell and utilizing it in gasification through steam reforming process, leading to a power generation efficiency of 65%.

- Challenges for effective technology development and diffusion

Due to their characteristics, IGCC/IGFC and A-USC are technologies with especially high demands from the viewpoint of a stable energy supply and effective measures against carbon dioxide emission as coal fired power generation is expected to increase mainly in East Asia in the future. Especially for IGCC/IGFC, demonstration projects in combination with the later-described carbon dioxide capture and storage (CCS) are being planned in various nations, and we need to implement efficiency improvements and implement the technologies while keeping these facts in view.

Furthermore, it is necessary that technology development be promoted while reinforcing cooperation in large-scale projects to demonstrate the basic research on materials, catalyst technology and other technologies in universities and in private plants as a system. This way, we can continue effective technology development regarding coal and maintain our technical advantage in the field.

○ Carbon Dioxide Capture and Storage (CCS)

- Outline of technology

CCS is a technology to reduce the amount of carbon dioxide released into the atmosphere and contribute to a substantial reduction in carbon dioxide emissions around the world by separating and capturing carbon dioxide from the exhaust gas of large emissions sources such as thermal power plants and storing or sequestering it in underground geological formations or in the deep ocean for a long time. It may enable the development of zero-emission coal fired power generation.

Post-combustion CO_2 Capture Demonstration Plant
Source: Website of Mitsubishi Heavy Industries, Ltd.

CCS is a process consisting of 4 stages; carbon dioxide capture, transport, injection and storage. The core in technology development is the carbon dioxide capture and storage technologies. For carbon dioxide capture process, chemical absorption, physical absorption, membrane separation, and cryogenic distillation can be used. Potential technical storage methods are geological storage or ocean sequestration. The former methods involve aquifer (deep saline aquifer) storage, Enhanced Oil/gas Recovery (EOR), storage in depleted oil/gas reservoirs or unminable coal seams. As ocean sequestration methods, dissolution type and lake type storage can be used.

- Technology development roadmap

Currently, domestic and international attention has been focused on CCS technology as a promising option to mitigate carbon dioxide emission in atmosphere in a short period. In Europe and the U.S., technology development is being actively pursued, and Enhanced Oil Recovery technology has reached the stage of commercialization. In Japan, basic research began at the end of the 1980s, and small-scale demonstrations of 10,000 ton geological injections have been implemented for storage stability verification.

Because the cost of carbon dioxide capture accounts for approximately 60% or more of the total CCS cost, our technical challenge in promoting practical application is to reduce this cost. To address this issue, the development of key technologies such as CO_2 separation membrane and high-efficiency absorbent is necessary.

The cost for separation and capture is currently about 4,200 JPY/t-CO_2, and technology development is being undertaken with the target cost of 2,000s JPY/ t-CO_2 by around 2015 and 1,000s JPY/t-CO_2 (CO_2 membrane separation method implemented to IGCC) by the 2020s.

While continuing research on domestic geological storage potentials, a large-scale RD &D project will be promoted using existing large emission sources such as thermal power plants with a goal of attaining some prospects for practical application by 2020. Furthermore, overseas transport of carbon dioxide should also be included as an early opportunity such as EOR because the domestic storage potentials (storage capacity and cost) we currently know are limited. To do this, we will begin designing of carbon dioxide transport ship and accelerate the feasibility study of overseas transport of carbon dioxide to oil-producing nations where there are possibilities for reciprocal joint projects such as EOR.

Meanwhile, additional energy is required for carbon dioxide separation, capture and injection in CCS process. IPCC-SRCCS reported that additional energy of about 10 - 40% will be required compared to the same-scale power plant without CCS. Therefore, it will be necessary to develop technologies that will improve the efficiency of the overall CCS system while accumulating data from larger scale RD&D projects.

It is necessary to develop high-resolution monitoring and prediction technologies of carbon dioxide movement to ensure long-term stability and safety of the storage system. In the long term, exploration of the storage potential will be an issue to be solved, and technologies to utilize aquifers with stratigrafical trap also need to be developed.

Ocean sequestration technology may lead to a great expansion of the storage potential for Japan, which is surrounded by the sea. It is necessary that research towards the practical application of the technology be advanced as a long-term issue while promoting technology's place in the formation of international and social confidence building. It is also essential that our ocean sequestration technology be further advanced through the utilization and contribution of related technologies in monitoring and safety assessment for carbon dioxide storage in sub-seabed geological formations.

- Challenges for effective technology development and diffusion

CCS technology development is being undertaken in the U.S., Canada, Europe, Australia, China and other countries, and several large-scale demonstration projects and commercial projects are being planned or implemented.

Since the storage potential of Japan is limited, it is necessary that we promote the exchange of information through international forums such as Carbon Sequestration Leadership Forum (CSLF) and Asia-Pacific Partnership on Clean Development and

Climate (APP) where we can provide measures that will lead to further demonstration projects while accumulating technologies and know-how through participation in large-scale overseas projects.

Furthermore, cooperation between the government and the private sector in the future needs to be examined since there are few economic incentives to add CCS technology, except in the case of some commercial uses of the technology such as EOR. In addition, the challenges to be overcome in introducing this technology include the evaluation of environmental impact, the establishment of related domestic laws, regulations and international rules, and the formation of confidence in building CCS by the public. It is also necessary that the environment for domestic commercialization of the technology be improved steadily through international bodies of cooperation such as the IEA while further studies of the technology take place.

Since CCS can be utilized for EOR in oil-producing nations, technology development must be promoted from the viewpoint of ensuring stable supply of resources to Japan as well.

Because the scientific and social recognition of ocean sequestration is not sufficient at present, it is essential to promote international and social confidence building to recognize the development results and safety of ocean sequestration technology.

○ Innovative photovoltaic power generation

- Outline of technology

Photovoltaic power generation technology tries to improve efficiency drastically with innovative materials and structures like quantum nanostructures and to reduce costs with the adoption of organic PV cells, ultra thin-films and other technologies. PV cells emit no carbon dioxide, and they are classified as first, second or third generation depending on the degree of technology advancement.

Solar Power Generation System at Kunijima Water Purification Plant
Source: Website of Osaka City Waterworks Bureau

<First generation>

These are PV cells that utilize crystalline silicon. They are the type of PV cells widely available in the market.

<Second generation>

These include thin-film silicon, ultra-thin crystalline silicon, compound thin-film PV cells and organic PV

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

cells utilizing organic materials and dyes. They have largely resulted from attempts to reduce the cost by reducing the amount of silicon through thin-film development or by adopting an alternative material to silicon.

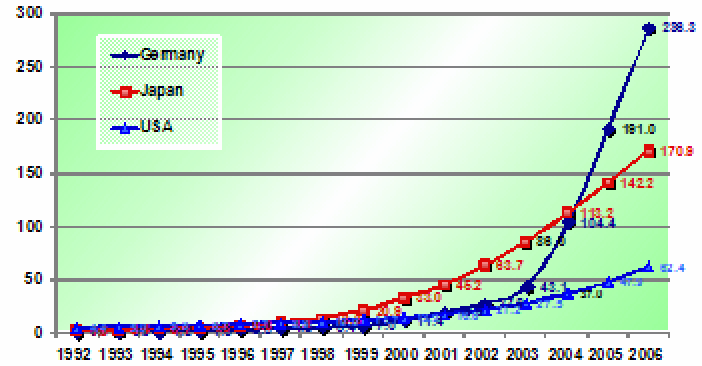
<Third generation>

These are PV cells that try to achieve both drastic improvements in efficiency and reductions in cost by utilizing innovative materials and structures such as multi-junction and quantum nanostructure.

It is necessary that the development of second and third generation technologies that are still in the research phase be promoted on a medium- and long-term timeline while expanding the diffusion of first and second generation technologies that are already commercialized.

- Technology development roadmap

The full-scale development of PV cell technology in Japan began with the Sunshine Project in 1974. As a result of technology development over the past 30 years that has sought to improve efficiency, reduce costs and encourage deployment, the production volume and the amount of installed PV power in Japan are among the highest in the world. The relative position of Japan has been lowered due to the fact that Germany exceeded Japan in the total amount of installed PV power in recent years while the production volume in Japan has not been growing so well (Fig. 3). Outside of Europe, Suntech Power in China has recently seen its production levels grow rapidly because of



(Figure 3) Cumulative Installed PV Power in Selected Nations

Source: Trends in Photovoltaic Applications, IEA Photovoltaic Power Systems Programme (IEA PVPS)

Program members: Australia, Austria, Canada, Denmark, France, Germany, Israel, Italy, Japan, Korea, Mexico, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States of America

(Table 1) PV Cell Production by Company

Prepared by METI referring to a report by RTS Corporation

	Company	Production in 2006		2006/2005
		(MW)	(%)	(%)
1	Sharp (JPN)	434.0	17.4	101.5
2	Q-cells (DEU)	253.1	10.1	152.5
3	Kyocera (JPN)	180.0	7.2	126.8
4	Suntech (CHN)	157.5	6.3	192.1
5	Sanyo Electric (JPN)	155.0	6.2	124.0
6	Mitsubishi Electric (JPN)	111.0	4.4	111.0
7	MOTECH (TWN)	110.0	4.4	183.3
8	Schott Solar (DEU)	83.0	3.3	101.2
9	SunPower (PHL)	62.7	2.5	272.6
10	Isofoton (ESP)	61.0	2.4	115.1

its buyout of MSK, a Japanese special PV cell module manufacturer in 2006.

It has nearly caught up with Japanese companies Sharp and Kyocera and the German firm Q-Cells in production (see Table 1). In addition to such rises of overseas corporations, active technology development is being promoted by venture capitalists in the U.S. making our advantageous position an unpredictable one.

While some of the world's top-level research is conducted in universities and private corporations in Japan, it is essential that technology development and diffusion of its outcomes be promoted under industry-academia-government cooperation with a medium- to long-term vision in order for us to maintain this position.

The market for first generation crystalline silicon PV cells has reached the mature stage, and so the subsidy for their installation in residences ended in Fiscal Year 2005. It is necessary in the future to promote their installation at public and industrial facilities where their presence is not as widespread.

Furthermore, there is a global silicon shortage due to the rapid increase in silicon PV cell production in the recent years, and it is one of the causes of the increase in PV cell production cost. Thus thin-film silicon PV cells and tandem thin-film silicon PV cells with reduced amount of silicon use are becoming commercially available. Developments are being made on ultra thin crystalline silicon PV cells, ultra high-efficiency thin-film PV cells which attempt to use less silicon more efficiently, as well as organic PV cells that adopt materials other than silicon like organic thin-films and dye-sensitized materials. For these 2nd generation PV cell technologies, steady technology development needs to be promoted with the objective of achieving a power generation cost of 14 JPY/kWh and a conversion efficiency of 10 – 19% in 2020 and a power generation cost of 7 JPY/kWh (equivalent to thermal power generation costs) and a conversion efficiency of 15 – 22%[6] in 2030. We will also promote technology development to foresee 40% conversion efficiency by around 2030 by developing concentrated multi-junction light-collecting PV cells that try to improve efficiency by adopting multiple junctions of materials to collect solar radiation at different absorption wavelengths, giving wide wavelength sensitivity to the cell.

In the long term, innovative PV cell technology development with drastic improvements in conversion efficiency from the current level of 10 – 15% as well as large cost reductions will be necessary by around 2050. Specifically, the development of ultra high-efficiency technologies such as quantum nanostructures and other technologies based on new concepts and principles that can expand the wavelength range of solar

[6] This efficiency indicates the efficiency of solar cell module. Note that conversion efficiency varies depending on the material such as compounds and organic pigments. For details see the attached technology development roadmap.

radiation that can be utilized and increase the efficiency of the cells will be necessary.

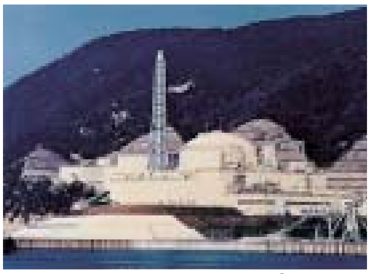
Since many of these technologies are still at the stage of basic research, we need to approach this with a long-term vision to reinforcing basic research at universities and institutes with an objective to improve the efficiency of the cells to 40% or higher by 2030 or later.

- Challenges for effective technology development and diffusion

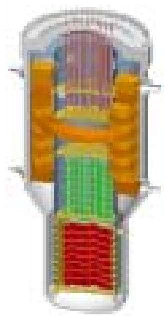
As described previously, the innovative PV cells in the third generation are still at the stage of basic research, and only the basic principles by which they function has been confirmed. Thus we need to establish a COE in Japan and invite domestic and international top-level researchers to concentrate research and development.

There are effects on the overall grid voltage, frequency and so forth when a large-scale photovoltaic power plant is connected to a large supply grid or when even a small-scale photovoltaic power generation is connected concentrated to grid. That is because photovoltaic power generation depends on the weather and fluctuates in output. Therefore, it may disturb the frequency of the entire grid in the same way that normal demand fluctuations or accidents cause power outages if it is connected to a grid in a certain production level or larger compared to the system capacity. Technologies to stabilize the output with power storage, grid connection improvements and other means will be necessary.

In addition to the technological development of PV cells, proper combination of deployment measures such as field tests, introduction into public sector, the RPS, and the green power certificate program are needed. In addition, cooperative activities between the government and the private sectors facilitate diffusion and smooth introduction of the advanced products of research and development into the marketplace.



Fast Reactor "Monju"
Courtesy of Japan Atomic Energy Agency



○ Advanced nuclear power generation

- Outline of technology

Nuclear power has excellent supply stability, and it emits no carbon dioxide in its generation process. It is currently the only clean base load energy source in Japan. It is a source of energy that can address both carbon dioxide emissions reductions and economic development since it is capable of stably supplying electrical power necessary for economic development at a relatively low cost.

It is necessary to improve domestic and international mainstream light-water reactor application technologies and to develop advanced nuclear power generation technologies such as the innovative fast reactors through 2050. More specifically, the matters to be addressed include technology development for the next-generation of light-water reactors to improve safety, economic efficiency, and reliability drastically; fast reactor cycle technology to improve the efficiency of the uranium resource utilization considerably; and the development of small and medium reactors in compact sizes to address power demands in developing nations and islands states.

- Technology development roadmap

Japan has successively constructed light-water reactors, and it currently has 55 light-water reactor units with nuclear power providing about 30% of Japan's total generation. The light-water reactions have a considerably lower frequency of unplanned stops compared to those reactors in other nations. We thus have the world's top-level technology, human resources, and industry size in all aspects, from technology development to design, production, construction and operation. On the other hand, our nuclear reactor manufacturers have been slow to enter the international market, and international recognition of the nuclear reactors we have developed is low. In addition, there is little standardization of reactors because nuclear power plants have been individually designed and constructed for each site to address the individual demands of the domestic utility companies.

While drastic expansion in the international market is expected, the nuclear reactor manufacturers in the U.S., France and Russia have been actively expanding their businesses so that they can participate in new construction markets over the world with support from their respective governments. The nuclear reactor manufacturer in Korea is competitive with certain components. China is also developing its own reactors based on technologies introduced from other countries. In such circumstances, Japan needs to maintain and improve its level of technological development with the government's assistance through its investment in research fields with high investment risks and large ripple effects.

To address the domestic needs for the replacement of reactors expected around 2030, we will promote the development of next-generation light-reactor application technology to drastically improve safety, economic efficiency, reliability while utilizing the achievements that our light-water reactor development programs and operations have yielded so far. Specifically, technologies to reduce the generation of spent nuclear fuel and to address seismic isolation will be developed. Meanwhile, cooperation between the government and the private sector will be necessary to address the development of innovative technologies that may become the domestic and global standard with international standardization while there is a global trend of re-recognition of the use of nuclear power and an increase in international cooperation on the issue.

Furthermore, we will promote the development of fast reactor cycle technology to improve the efficiency of uranium utilization drastically and reduce radioactive waste substantially, with an objective to build a demonstration reactor and a related cycle facility by 2025 and commercialization of the technology before 2050. It is important to seek to obtain a position as a global standard reactor through multilateral or bilateral forums for cooperation such as GNEP (Global Nuclear Energy Partnership and GIF (Generation IV International Forum) with this research and development.

Moreover, the development of small and medium reactors to address the needs of developing nations and island states will be promoted in order to expand our technology into an international market different from that of our large next-generation light-water reactors. Specifically, we will promote the development of innovative basic technologies while advancing both the international expansion of our nuclear industry and international cooperation under the framework of GNEP and other organizations. This will utilize our experience and skills to improve the economics of reactors with drastic size reductions and maintenance cost reductions.

- Challenges for effective technology development and diffusion

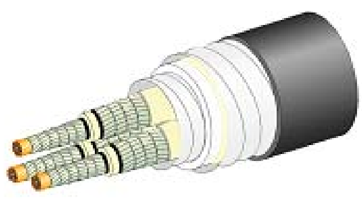
As to technology development on next-generation light-water reactors, it is important that we will consider not only domestic but also the international markets in our vision to address innovative technologies that may become the global standard.

For the development of fast reactor cycle technologies, we will need to expand the development cooperation among Japan, the U.S., and France strategically while promoting steady technological development in Japan. In addition to these measures, we will have to work on supporting legal system establishment, human resource development and financial assistance to nations which will try to introduce nuclear power plants so that utilization of nuclear power can be expanded while ensuring nuclear nonproliferation, safety, and security.

○ High-efficiency superconducting power transmission

- Outline of technology

Superconductivity is the phenomenon without electrical resistance at very low temperatures. It is a technology which could reduce energy loss. Superconducting materials with critical



temperatures higher than the boiling point of liquid nitrogen (77K) are called as "high-temperature superconductors". It is possible to reduce the transmission loss, which is currently about 5%, to about 1/3 by utilizing these high-temperature superconducting wire/tape in power transmission cable. This is a technology to efficiently use the electric energy by suppressing transmission loss in construction of some power supply networks to address increasing demands for electric power in urban areas and in developing nations in the future.

- Technology development roadmap

The contributions by Japanese researchers in the field of high-temperature superconductors have been remarkable including the discovery of Bi-system high-temperature superconducting materials. Especially regarding Bi-system high-temperature superconducting tapes and cables, Japan has been leading the world as only some of the Japanese corporations being capable of supplying at present. In technology development on Y-system coated conductors, Japanese corporations such as Sumitomo Electric Industries, SWCC Showa Holdings, Fujikura, Furukawa Electric and Chubu Electric Power are among those that are competing and leading the world along with the U.S. SuperPower by participating in national projects.

First, we will promote application by demonstration on Bi-system superconducting cables, and technology development is being advanced on superconducting power transmission with Y-system superconducting tapes with expected application in 2020 or later. These are planned as national projects in Japan, and Japanese corporations play an important role in superconducting power transmission projects around the world. Specifically, they are trying to address further improvement in power transmission capacity and cost reduction with Y-system superconducting tapes and are working on technology development for long tape and cost reduction as well as that on the cooling system for high efficiency, scaling-up and low cost.

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- Challenges for effective technology development and diffusion

Since superconducting power transmission can enable large-capacity transmission in addition to reducing transmission loss, its use in underground cables is being anticipated as a way to address increasing power demands in urban areas. To succeed in developing this, it will be necessary to develop technologies that can provide stable power transmission, including low-loss cable connections and transformers in addition to new tape materials and cooling system technologies. Also, its introduction in other power devices which may be used in long-distance, large-capacity power transmission, especially with the development of renewable energy can be expected in the future if technologies can be developed to realize longer tapes and increase their capacity.

Superconducting technology is a field in which Japan is in an advantageous position, and we proactively work on its development in concurrence with the promotion of international standardization through the activities of the ISO and the IEC to ensure the smooth introduction of the technology and contribute to the solution of international environmental problems.

From a long-term perspective, it will be effective to cooperate with overseas research institutes with leading research findings.

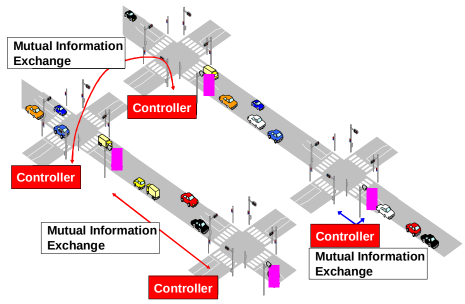
(Transportation)

○ Intelligent Transport System (ITS)

- Outline of technology

ITS (Intelligent Transport Systems) tries to develop new vehicles for society by adapting to an advanced information society while also solving the traffic problems such as accidents and traffic jams. It can do this by connecting people, roads, and vehicles in a network that uses leading-edge information & communication technology.

In terms of energy and environmental protection, it is expected to improve vehicles' fuel efficiency by improving driving practices and improving and facilitating traffic flows. It will also promote fuel efficiency measures for individual vehicles and shifts to next-generation fuels. To efficiently address carbon dioxide emission reduction measures using ITS, it is important that an internationally recognized method to evaluate its effects should be established. According to an estimate by the Energy ITS Study Group, it is possible to reduce the carbon dioxide emission generated when 1 vehicle runs 1km by 25% or more by 2050[7].




Source: Energy ITS Study Group

- Technology development roadmap

The technologies that must be developed to contribute to energy savings with ITS vary from those expected to be adopted in a relatively short term to those that will require further study before widespread use. They

7 Source: Document prepared by "Energy ITS Study Group"

need to be promoted efficiently by considering the maturity of the technology as well as its emissions reduction effects. In addition, all of the technologies within ITS that can contribute to energy savings are promising as future technologies in vehicle electronics, and strategic measures are required in promoting technology development in energy ITS.

One example is cooperative driving (automated driving), which is an operation control and vehicle platooning technology with potentially large effects and technical difficulty expected to be widely introduced around 2040 – 2050. The potential development scenario for this technology is to advance the systems by utilizing current technology that successfully incorporates external information such as the road environment or traffic signal information. Therefore, phased measures to solve the technical issues in traffic signal control advances, operation control, and vehicle platooning will be important.

First, we will try to commercialize the signal control function utilizing probe information, which is expected to deliver effects in a short timeframe, in 2012. In addition, we will begin the research and development of advanced traffic signal control systems, such as signal linked ECO driving, operation control, and vehicle platooning at an early stage with an objective to see successful practical applications in the 2020s.

- Challenges for effective technology development and diffusion

At present, most of the measures in ITS technologies are utilized actively as safety measures but the application of these measures as devices for mitigating global warming has only just begun. The evaluation of the effects of such technologies and services when they are widely adopted is extremely important in making policy and investment decisions. Thus it is desired that the establishment of an internationally reliable effect evaluation method be considered at an early stage.

In additional to technology development, it is necessary that the usefulness of the technologies be promoted domestically and internationally through demonstration projects and model projects, along with technology development. To do this, we will promote the introduction of methods expected to have large effects at early stages such as technical exchanges through joint research with European nations or the U.S. and symposiums that will occur alongside technology development. To clarify the carbon dioxide reduction effects of these technologies, an evaluation method that can obtain international recognition will be developed and its international standardization will be promoted.

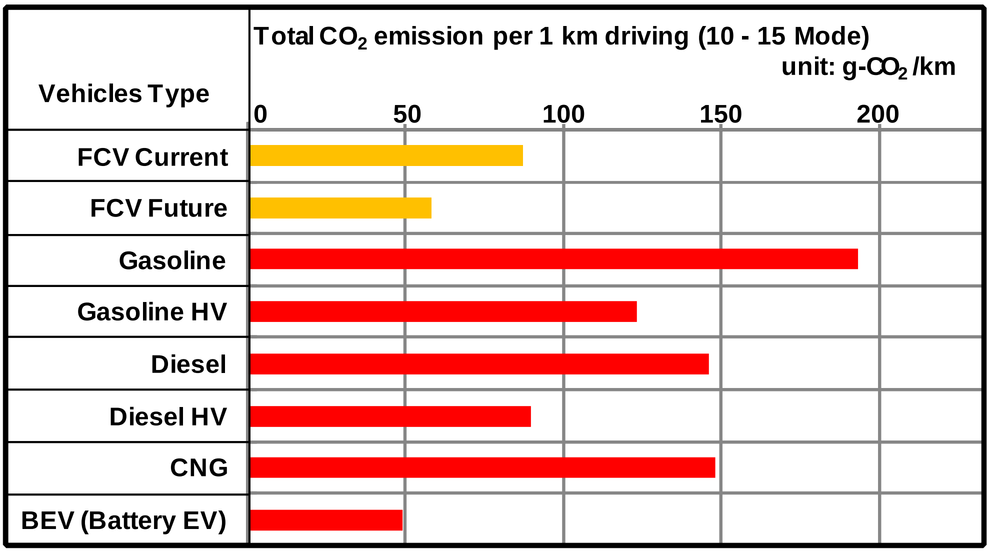
○ Fuel cell vehicle

- Outline of technology

Fuel cell vehicles use hydrogen as the fuel and run on electricity generated by fuel cells. We will try to achieve drastic cost reductions by utilizing alternative catalysts to platinum and creating ranges equivalent to those of gasoline vehicles by improving the performance of hydrogen storage materials. Carbon dioxide emissions can be reduced to about 1/3 that of the gasoline vehicles[8] (see Fig. 4). Furthermore, carbon dioxide emission can be reduced drastically if the hydrogen fuel is produced from renewable energy or from fossil fuel resources that use CCS technology.

Toyota's FCHV
Source: Website of Toyota Motor Corporation

Honda's FCX CONCEPT
Source: Website of Honda Motor Co., Ltd.



(Figure 4) Summary of Well-To-Wheel CO_2 Emission Analysis.
Source: Report by Japan Hydrogen & Fuel Cell Demonstration Project

- Technology development roadmap

Japan has been actively working on the development of fuel cell system technologies and battery technologies, and we currently have the most advanced technology of this

[8] Value evaluated by Well to Wheel total CO2 emissions: Well to Wheel total emissions are the amount of emissions calculated by comprehensively evaluating the efficiency of the entire energy processes including the extraction of fuels, power generation, hydrogen purification, transport, storage and filling, and the efficiency of the automobile itself. It supposes that power generation is conducted by the present power source configuration of Japan.

kind in the world. Prominent researchers can be found both in industry and academia, and major automobile manufacturers have developed fuel cell vehicles and commercialized them. However, there are many technical problems remaining to be solved before the vehicles can be diffused.

The first problem is cost. FCVs cost about 100 million JPY per vehicle at present. We must reduce this to about 1% of the current level. While economies of scale will help to lower costs to about 3 to 5 times that of the goal of 4,000 JPY/kW for the fuel system, it will be necessary in the future to develop the technologies to reduce cost of using a platinum catalyst or to replace the platinum catalyst entirely. Furthermore, it will be necessary to develop an electrolyte membrane to improve the durability of the system so that it can last for 10 years or longer. It is also necessary to develop a storage technology to replace high-pressure hydrogen containers, and to store the hydrogen fuel more compactly and at lower cost so that a range of 500 km, the equivalent of that of a gasoline vehicle, can be achieved.

We will try to reduce the cost through such technology developments to an objective vehicle price of 3 – 5 times that of ICV (internal combustion vehicle) by 2010 and to 1.2 times ICV by 2020. Regarding durability, we will try to improve to 3,000 hours by 2010 and to 5,000 hours by 2020, and we will attempt to improve the cruising distance to 400 km by 2010 and to 800 km by 2020.

- Challenges for effective technology development and diffusion

In addition to emphasizing research and development, it will be necessary to promote demonstrations and standardization in an integrated manner. Specifically, it is necessary to achieve fundamental cost reductions and durability improvements by feeding back the outcomes obtained in demonstrations utilizing hydrogen station to basic research, while promoting active introduction of technologies as public service vehicles.

We also need to promote studies of hydrogen infrastructure depending on the progress of technology development. In addition, we will actively participate in discussions on international standards regarding fuel quality, and hydrogen stations.

To accelerate basic technology development, we will need to promote technology development effectively based on the technological trends of other nations by utilizing the international frameworks such as IPHE (International Partnership for the Hydrogen Economy) in basic technology development.

○ Plug-in hybrid vehicle/electric vehicle

- Outline of technology

A plug-in hybrid vehicle is hybrid vehicle whose battery is charged by an external power source and that operates on an electric motor using the charged power over short distances. Hence, it is possible to reduce carbon dioxide emissions to about 1/2 to 1/3 of the levels of gasoline vehicles depending on the driving condition.

Plug-in Hybrid Vehicle
Source: Website of Toyota Motor Corporation

Electric vehicles operate on electric motors using power contained in the battery as the source of energy instead of conventional internal combustion engines, and it is possible to reduce carbon dioxide emissions to about 1/4 those of gasoline vehicles (see Fig. 4).

Electric Vehicle (i MiEV)
Source: Website of Mitsubishi Motors Corporation

It will be possible to reduce carbon dioxide emissions drastically by using power from efficient sources such as nuclear power generation and renewable energy for charging plug-in hybrid vehicles and electric vehicles. They are also expected to help level power consumption loads by charging at night when demand is low.

- Technology development roadmap

Batteries in electric vehicles require drastically different durabilities and capacities from the small batteries found in cell phones and other devices that Japan has much experience developing and producing.

While the battery industry of Japan has a large global share and is considered to be at an advantageous position, the U.S., Europe, Korea and China have recently activated the development of automobile batteries though programs led by the national governments, and many overseas battery manufacturers are actively developing automobile batteries. Therefore there is a concern on Japan’s advantageous position. The competition from China and Korea has been especially growing with the global share of Lithium ion batteries changing from BYD (China) 2.9%, LG Chemical (Korea) 1.3% and Samsung SDI (Korea) 0.4% in 2000 to BYD 7.5%, LG Chemical 6.5% and Samsung SDI 11% in 2005. Samsung SDI had the third largest share of the market then (see Table 2). The relative share of Japanese companies in the world market has dropped below 50% and production of mobile batteries in the East Asia has been drastically growing.

Under such circumstances, it is necessary that we should promote further technology development to maintain our advantageous position. We will need to develop batteries designed to many specifications since the required battery capacity in each plug-in hybrid and electric vehicle varies by the vehicle type.

At present, the possible distance plug-in hybrid vehicles can drive on electricity is only about 13 km, and there are technical problems such as battery energy density improvement and miniaturization to extend the cruising distance by driving with electricity.

(Table 2) Market Share of Lithium-ion Battery

Prepared by METI referring to a report by Institute of Information Technology, Ltd.

2000				2005			
	Manufacturer		Share		Manufacturer		Share
1	SANYO Electric Co., Ltd. SANYO GS Soft Energy Co., Ltd.	JPN	33 %	1	SANYO Electric Co., Ltd. SANYO GS Soft Energy Co., Ltd.	JPN	28 %
2	Sony Corp.	JPN	21 %	2	Sony Corp.	JPN	13 %
3	Matsushita Battery Industrial Co., Ltd.	JPN	19 %	3	SAMSUNG SDI Co., Ltd.	KOR	11 %
4	Toshiba Corp.	JPN	11 %	4	Matsushita Battery Industrial Co., Ltd.	JPN	10 %
5	NEC Tokin Corp.	JPN	6.4 %	5	BYD Co., Ltd.	CHN	7.5 %
6	Hitachi Maxell, Ltd.	JPN	3.4 %	6	LG Chem Ltd.	KOR	6.5 %
7	BYD Co., Ltd.	CHN	2.9 %	7	Tianjin Lishen Battery Joint-Stock Co., Ltd.	CHN	4.5 %
8	LG Chem Ltd.	KOR	1.3 %	8	NEC Tokin Corp.	JPN	3.6 %
9	SAMSUNG SDI Co., Ltd.	KOR	0.4 %	9	Hitachi Maxell, Ltd.	JPN	3.3 %

Steps to commercialize these technologies are being taken by automobile manufacturers, and many believe that this will be achieved in the near future, with some manufacturers obtaining certification by the Minister of Land, Infrastructure and Transport for driving on public roads. To reach the stage of diffusion, however, safety, durability, robustness and energy density are still insufficient in lithium ion batteries currently being developed for utilization in hybrid vehicle, and improvements in these performance as well as cost reduction will be necessary. We will promote technology development to address these challenges and try to achieve 50% higher performance and reduce cost to 1/7 of current level by 2015.

In order for electric vehicles to be put into full-fledged practical use, further extension of the cruising distance by the development of large capacity batteries with low cost is essential. We have to develop new batteries based on innovative concepts since the current lithium ion batteries are said to have limitations.

In such developments regarding batteries, it has been currently estimated that the price will be 8 million JPY[9] for energy density of 100 Wh/kg. We will work on technology development with an objective to improve capacity to 3 times the current level and reduce costs to 1/10 their current levels by 2020, and to 7 times capacity and 1/40 cost by 2030 so that the cost will be equivalent to that of gasoline vehicle. We will also try to extend the cruising distance to 500 km by 2030 through technology development.

Furthermore, capacitors are expected to be use in auxiliary power supplies for hybrid vehicles and electric vehicles since they are able to rapidly charge and discharge. A hybrid capacitor that combines a capacitor with a secondary battery that utilizes oxidation-reduction reaction is under development. In the longer term, we will need to conduct basic research to develop a hybrid capacitor which can sustain rapid charging and discharging capability.

- Challenges for effective technology development and diffusion

Electric vehicles are expected to be commercialized first as commuter vehicles and then as full-scale electric vehicles as technology development advances. First, it is necessary that technology development be undertaken to allow for the adoption of commuter vehicles for limited use. There must be advances in basic research in order to ensure the successive development of general commuter vehicles and electric vehicles that reduces costs and improves ranges to those gasoline vehicles, but there are many technical challenges to be overcome, making it necessary for technology development to be undertaken with unified industry-academia-government cooperation

It will be also necessary to examine issues such as standardization to ensure safety, the establishment of charging stations, the identification of stations by car navigation systems, the elimination of fears about running out of electrical power, and the reduction of charging infrastructure installation cost to create the initial demands for vehicles and allow for their smooth introduction and diffusion in the market.

Furthermore, we need to promote the development of alternative materials to rare metals that are used in electrical motors from a long-term viewpoint in concurrence with the widespread adoption of hybrids, plug-in hybrids and electric vehicles in the future.

○ Production of transport Biofuel

- Outline of technology

This is a technology to produce liquid fuels by utilizing microorganisms, enzymes, gasification and other means from cellulosic biomass. It is expected to lead to reductions in carbon dioxide emissions from bioethanol and provide alternative to diesel to provide

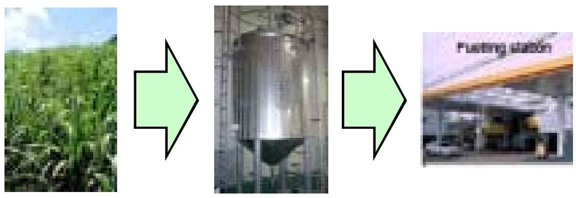
[9] Source: “Proposal for the Future of Batteries for the Next-Generation Vehicles” (August 2006). Estimate when a 40KWh battery is loaded.

fuel for the growing number of clean diesel vehicles. Although carbon dioxide reduction effects need to be verified in the lifecycle, these biofuels have been considered carbon neutral in the Kyoto Protocol and reduction effects can be expected if considerable volumes of the fuel can be supplied.

- Technology development roadmap

Japan has had traditional strengths in fermentation and is at an advantageous position mainly thanks to the corporations in the fermentation industry. However, we have relatively little available biomass and collecting biomass like forest residue entails high costs.

The main problem to be solved with bioethanol is a reduction in ethanol production cost from cellulosic biomass, since it can ensure high production volumes without using feedstocks that compete with the food supply. To address this problem, we will need to develop the processing technology to separate cellulose from biomass and to search for or develop microorganisms and enzymes to enable high-efficiency conversions of cellulose into sugar or ethanol so that ethanol can be produced at a low cost.



Ethanol Production
Source: NEDO, etc.

National technology development programs have been actively implemented in European countries and the United States as well, and research on cellulosic ethanol is especially widespread. The main players here are venture companies in the U.S. In Japan, we will promote technology development and try to achieve a production cost of 100 JPY/L as the benchmark (index) from raw materials that are mainly generated from existing agriculture and forestry (rice straw, forest residues and so forth) by 2015 and the production cost of 40 JPY/L as the benchmark (index) with drastic innovation when using resource crops which can be produced in large volumes. This benchmark takes into consideration the price competitiveness of gasoline and development projects in the U.S. To achieve these objectives, we will need to develop technologies to utilize things like microorganisms and enzymes with gene recombination techniques and energy crops with high-efficiency photosynthetic performance.

Furthermore, the development of low-temperature gasification technology to allow for the utilization of unused exhaust heat will be necessary in Biomass-to-Liquid (BTL) applications to produce biodiesel through biomass gasification and chemical synthesis reaction.

- Challenges for effective technology development and diffusion

  We will need to learn how to overcome the problems of economic efficiency and stable supply as we develop these technologies, while promoting the adoption of new technologies through demonstrative projects. It is also essential that introduction of biofuels should be promoted in concurrence with the establishment of necessary regulatory systems to ensure quality so that exhaust gas quality does not deteriorate and that ethanol mixing processes do not affect the safety and security of the citizens and protect consumers.

  For BTL applications, we will need to consider future introduction of the fuel and establish the foundation for introduction of biodiesel by promoting diesel vehicles through the proactive introduction of clean diesel vehicles by the government.

(Industry)

○ Innovative material, production/Processing Technology

- Outline of technology

  These are production processes and energy-saving material technologies to improve energy efficiency in Japanese production industries

  .Specifically, they include:

  - Energy saving glass production technology to melt glass using plasma, etc. to lower energy consumption to about 1/3 of the conventional processes,
  - Drastic efficiency improvement technology in nonferrous metal material production processes,
  - Chemical production technology using biomass, etc.,
  - Separation membrane technology to drastically reduce energy consumption in water treatment regarding river water, etc.,
  - Material technology and innovative design technology to save energy in transport devices such as airplanes,
  - Heating process technologies such as steam-generation heat pump, etc.

- Technology development roadmap

  While the industrial sector has been actively promoting energy saving, fundamental process improvement beyond the conventional concepts will be required in order to improve the efficiency further.

  <Glass production process>

There has been no innovation in the basic production method over 140 years in the glass industry, one of the industries with the largest energy consumption. To fundamentally improve the process and save energy, we will promote the development of technologies to melt small granule glass materials instantly using plasma, and other materials. We will try to establish a process with glass melting that takes less than half a day and address practical application of small melters by around 2015 and large melters by 2030.

<Nonferrous metal material production process>

In nonferrous metal material field, there has been no innovation in the basic production processes of metal titanium smelting in industrial scale since the invention of the current method. The current smelting method requires 2-3 weeks from a reaction to cooling time after reaction even in industrial scale systems since the materials are produced in batches.

Fundamental process efficiency improvement is necessary, and we will promote technology development to establish drastic energy savings by developing a series of processes with an objective to achieve widespread industry use in the 2010s.

<Chemical production process>

To implement fundamental reductions in the amount of carbon used in current petrochemical production processes, bio refinery technology utilizing biomass-related materials as the raw materials will be developed. The current technology requires production efficiency improvements and reductions in production cost. To address these issues, we will develop production processes for trunk substances which are intermediates to chemical products and general-purpose chemical products with large production volumes.

<Other industries>

There is a global concern that energy consumption may increase drastically the need for water treatment from sources such as rivers, and the development of membrane separation technology to efficiently remove trace hazardous substances and microorganisms to purify water will be promoted.

<Material technologies and innovative design technologies for energy savings in transport devices such as airplanes>

To address drastic diffusion of carbon fiber composite materials, we will develop material technologies and innovative design technologies to address energy saving in transport devices including airplanes and vehicles, which will contribute to improvement in fuel efficiency by 20% or better.

<Cross-cutting energy-saving technologies>

Coproduction, which is one of the cross-cutting process technologies, is a technology to collect the energy lost in combustion processes as electrical power or substances such as hydrogen. Its application is considered possible in various production processes including petrochemical processes, IGCC, and IGFC.

Although steam is also widely utilized in various heating and drying processes such as painting processes in a cross-cutting manner, its production process has not been improved for a long time. Therefore, we will promote the development of processes to generate steam by utilizing the heat of the air, electricity, and heat pumps which can enable more efficient use of energy. There are problems to be solved including high-temperature endurance in compressors and efficiency improvements in heat exchangers. We will try to solve these problems and address COP 4.0 by around 2020.

- Challenges for effective technology development and diffusion

It will be necessary to promote large-scale technology development in stages from basic technology development under industry-academia-government cooperation to enable the smooth introduction of energy-saving technology into the industry sector. To address this, we will need to examine measures such as tax benefits or preferential financing in addition to technology development as necessary.

○ Innovative iron and steel making process

- Outline of technology

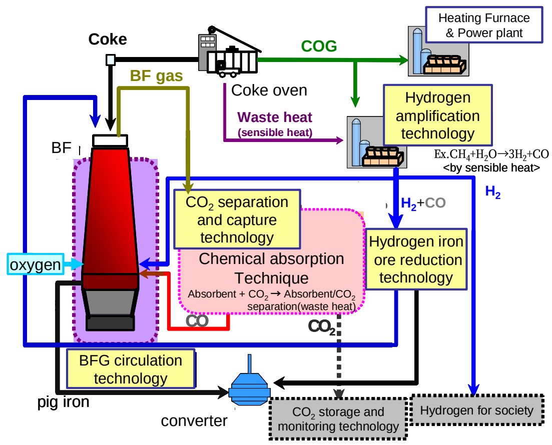
Technology is to address drastic reductions in carbon dioxide in the iron and steel making process, in which about 70% of the energy is consumed in integrated steel works. Specifically, it is iron and steel making technology to separate and capture carbon dioxide from blast furnace gas and to use hydrogen as a partial alternative for coke as reductant. This technology is expected to enable substantial reductions in carbon dioxide emissions.

Nippon Steel Kimitsu No.4 Blast Furnace
Source: Website of Nippon Steel Corp.

- Technology development roadmap

Our iron and steel making processes have contributed to the reduction of carbon dioxide so far by addressing the world’s best specific energy consumption through waste heat recovery and waste recycling which includes energy-saving facilities. However, conventional methods of measurement, such as the introduction of energy-saving facilities, are limited in order to further reduce carbon dioxide emissions. It is necessary that innovative technology development have to be moved into action from a long-term standpoint.

Under such circumstances, technology development is discussed by steel engineers in the International Iron and Steel Institute (IISI) and promoted into the ULCOS project led by European Confederation of Iron and Steel Industries (EUROFER). To establish innovative technologies for practical use in 2030 – 2050 in Japan, we will promote the development of technologies to separate and capture carbon dioxide efficiently from Blast furnance gas by utilizing unused low-temperature waste heat and to apply hydrogen which is amplified from coke oven gas, as iron reductant. Our objective is roughly at least 30% reduction in carbon dioxide emissions from iron and steel making processes by combining these technologies.



- Challenges for effective technology development and diffusion

Hydrogen amplification technology with low energy by using catalyst in coke furnace gas is currently being checked for its behavior on the bench plant level, and it is necessary that hydrogen amplification technology and hydrogen reduction technology development be implemented under industry-academia-government cooperation.

As to carbon dioxide capture technology from large-scale inflammable gas like Blast Furnance gas, industrially feasible economic efficiency level and stabilization technology for successive operation need to be established. Challenges to be addressed in this area include technical development items, such as absorption solution and expansion of waste heat application range.

Meanwhile, external supply of low-carbon power to the plant will be essential since both technologies accompany large fluctuations in energy balance in steel works.

Japan will promote technology development in this field through the innovative development program CO_2 Ultimate Reduction in Iron and steel process, by innovative technology for Cool Earth 50 (COURSE50) and active participation in joint programs operated by the International Iron and Steel Institute (IISI) and the EU to grasp the latest trends in technology development and examine possibilities for joint research in basic fields in European nations

(Commercial/residential)

○ High-efficiency house and building

- Outline of technology

Energy saving technology for home building will use new heat insulation materials, room air quality improvement to improve insulation and shielding. Heat insulation for building walls and windows will be enabled by the development of heat insulation materials that use multi-ceramics layer. It is possible to reduce air conditioning energy use by 50% through high heat insulation conditioning, shielding and other technologies, which are expected to contribute to a reduction of carbon dioxide emissions.

- Technology development roadmap

Our technology regarding heat insulation materials has been improving and glass wool (about 0.05 W/m・K), resin foam type insulation materials (about 0.02 W/m・K) and others have already been put into practical use. 30% of heat loss in houses takes place through openings such as sashes and doors. While heat insulation by multi-layer glass have been advanced and are being diffused with some effect of heat insulation because of the multi-layer structure including air inside, it is difficult to deliver high heat insulation performance compared to the heat insulation in walls.

Therefore, we will promote the development of vacuum heat insulation materials as a technology with better performance than these insulation materials in the future. The new insulation material, which uses multi-ceramics layer, is capable of suppressing all three of the elements that conduct heat (lattice vibration, convex and radiation), and we will try to put it into practical application by around 2015. High-strength (compression), heat insulation ceramic particle technology, ceramic polymer complex development technology, high-efficiency radiation prevention coating technology, and transparent, high-efficiency heat insulation material technology will be used to develop enhanced wall and window materials. This wall material will have a conductivity of 0.002 W/m・K and a heat transmission coefficient of 0.3 W/m^2・K. The enhance window material will have a conductivity of 0.003 W/m・K, and a heat transmission coefficient of 0.4 W/m^2・K

- Challenges for effective technology development and diffusion

To expand the diffusion of heat insulation materials and evacuated glass in houses and buildings, we will need to guide market expansion using the Rationalization in Energy Use Law[10] and Housing Quality Security Promotion Law[11], and promote the smooth introduction of products with excellent technologies by supporting the introduction of products within a certain technological level. It may also be necessary to

10 Law on rationalization of energy use.

11 Law on promotion of ensuring quality of houses and so forth.

examine financing and preferential tax treatment to promote diffusion.

○ Next-generation high-efficiency lighting

- Outline of technology

Lighting technology with drastically improved luminous efficiency and high color rendering properties compared to the conventional fluorescent lamp will be developed.

It is possible to reduce carbon dioxide emissions by addressing efficiency (150 lm/W) that exceeds the luminous efficiency of incandescent lamp (15 - 25 lm/W) or the fluorescent lamp (80 - 100 lm/W) This will be done using next-generation lighting technologies such as high-efficiency LED, organic EL and microcavity.

Pendant Lamp using Organic Electro-Luminescence (OEL) . Prototype by Matsushita Electric Works, Ltd.
Source: Website of Research Institute for Organic

Replacing all incandescent lamps (roughly 9.6% of the total lamp power used for general consumption) and fluorescent lamps (roughly. 73.1%of total general consumption power use) with the next-generation high-efficiency lighting of 150 lm/W results in power consumption for lighting estimated to fall by 50%. These technologies are expected to contribute reductions in carbon dioxide emissions and potential for further power consumption reduction may be achieved by combining them with optical sensors, human sense sensors, HEMS, BEMS and so forth.

- Technology development roadmap

In the field of LED lighting, we will promote development of high-efficiency LED elements, high-efficiency fluorescent materials for white LED, and other areas to reach 100 lm/W around 2010, and 200 lm/W around 2020. Regarding organic EL lighting, the theoretical limit is about twice as high when compared to fluorescent lamps, although the current luminous efficiency is equivalent to that of incandescent lamp. Thus, we will promote improvement in luminous efficiency and technology development to extend its lifetime and reach 100 lm/W around 2020, and 200 lm/W around 2030. While microcavity and cluster luminescence are also next-generation lighting technologies with potentials for high efficiency, they are still at the basic research stage, and we will promote necessary technology development from a long-term viewpoint.

- Challenges for effective technology development and diffusion

It is necessary that technology development be promoted under industry-academia-government cooperation, while utilizing the advantageous position of our material technology. Diffusion of these technologies will be promoted by utilizing the energy saving top-runner program and other such programs as technology advances.

○ Stationary Fuel cell

- Outline of technology

Stationary fuel celltechnology will be used to directly extract electrical power by an electrochemical reaction between fuels such as hydrogen and oxidizing agents such as oxygen, without using heat. Since energy is converted directly from chemical energy into electric energy, it has high theoretical power generation efficiency. It may also enable high overall efficiency (>80% HHV) in this cogeneration system because it is virtually unaffected by the system's size. It is expected to contribute to the reduction of carbon dioxide emissions and work as an energy source that covers diverse applications and scales, including mobile devices such as notebook PCs and cell phones, automobiles, commercial and industrial cogeneration and power plants.

Solid Oxide Fuel Cell (SOFC) Cogeneration System for Residential Use.
Source: Website of Kyocera Corp.

- Technology development roadmap

Fuel cells are classified by the type of electrolyte, such as Polymer-Electrolyte Membrane Fuel Cell (PEFC), Solid-Oxide Fuel Cell (SOFC) and Molten Carbonate Fuel Cell (MCFC), and application and technology development must be implemented to suit each of these technologies. Furthermore, Phosphoric Acid Fuel Cell (PAFC) and Alkaline Fuel Cell (AFC) already have practical applications.

In Japan, steady R&D and introduction supporting policies have led to introduction of about 2200[12] PEFC units into the market.

Most of the foreign progress in these cells has been in the development or demonstration phases, although PEFC of Plug Power and MCFC of Fuel Cell Energy are both in the market introduction phase in the US.

PEFC is a fuel cell that uses thin solid polymer membrane as the electrolyte, and it is

12 As of March 2008.

easy to handle because it operates at temperatures ranging from room to 90 . Miniaturization is relatively easy because it has a high output density. It is being developed for application in home cogeneration, mobile devices and vehicles. The technical challenges to be overcome include reduction in system cost, improvement in durability and power generation efficiency, and it is necessary to develop a non-Pt catalyst, improved electrolyte membrane, new electrolyte membrane, etc. The objective is to reduce the current system price of 4 - 5 million JPY per kW to 400 thousand JPY in 2020 - 2030 and improve the durability to 90,000 hours from the current 40,000 hours and the power generation efficiency to 36%, from the current 32% rate.

SOFC uses ion-conducting ceramic with high permeability of oxide ions as the electrolyte. Applications are projected in home cogeneration, distributed power supply and large-scale power generation. The operation temperatures are rather high, in the range of 700 – 1000(C, and it is advantageous in the point that utilization of exhaust heat is possible. Various fuels can be used, including coal, and high power generation efficiency of 60% or larger (HHV) can be delivered in combination with a gas turbine. It is also advantageous in that it does not require an expensive platinum catalyst. However, there are problems of material deterioration and so forth, since the operation temperatures are very high. Cost reduction, durability improvement and power generation efficiency improvement are also issues to be solved in the future, and technology development will be promoted with an objective to address 40% power generation efficiency, 40,000 hours durability and system price per kW of 1 million JPY around 2020.

MCFC is a fuel cell that uses molten carbonates, such as lithium carbonate and potassium carbonate as the electrolyte, and it is capable of using natural gas, coal gas and even biogas as the fuel in addition to hydrogen. It also has the ability to concentrate and capture the carbon dioxide in exhaust gas into its fuel electrode side when combustion exhaust gas is injected into its air electrode side. Trials have been already made to apply MCFC as technology to recover carbon dioxide in method of CCS. Applications in combined power generation with gas turbine are expected to be achieved around 2030.

- Challenges for effective technology development and diffusion

For PEFC, large-scale demonstrations are being implemented in addition to technology development, to enable early commercialization. It is currently at the stage to consider marketability pf the products. It is necessary that measures to create the initial demands should be promoted through further scale increases in demonstrative projects, in addition to technology development.

While development of SOFC small devices have advanced rapidly, including 700 W home cogeneration devices, issues of durability and reliability as commercial devices must also be addressed in future demonstrative projects. Although more time will be required for the development of large-scale power supply devices, it is necessary that the technology development be promoted steadily in Japan, considering the development of large-scale SOFC in the U.S.

We will need to promote measures for international standardization through IEC with a view to international market expansion in addition to technology development and demonstrative projects to facilitate its diffusion.

○ Ultra high-efficiency heat pump

- Outline of technology

Heat pump is a technology that obtains heat necessary for air conditioning and hot water supply by transferring heat. Unlike room heating and hot water supply created by the combustion of fossil fuels, it is possible to achieve efficiency exceeding 100% drastically by actively using solar heat via heat of air or ground. It is possible to apply this technology in the air conditioning and hot water supply, which comprise nearly 50% of carbon dioxide emissions in the commercial/residential sector. Further reduction can be expected with heat pump technology that has drastically improved efficiencies over conventional technology. It is also possible to have applications in the air conditioning and cooling/heating process used in the industrial sector

"ECO CUTE" - CO2 Heat Pump Water Heaters
("Design Eco Cute" by Corona Corp.)
Source: Website of Corona Corp.

- Technology development roadmap

Japan has the world's top-level high-efficiency heat pump technology, such as the practical application of high-temperature hot water supply technology using carbon dioxide coolant for the first time in the world. We have also been expanding business globally, which includes exporting and overseas production.

Our technology that utilizes carbon dioxide coolant in the high-temperature hot water supply has had a record of diffusing 1 million units in only 6 years. On the other hand, global competition is beginning as Chinese companies have just begun the development of high-temperature hot water suppliers using carbon dioxide coolant.

Even at the current level, our household heat pump air conditioners have COP at 6 or higher, which is a better efficiency than European and U.S. heat pump air conditioners with COP of 2.2 - 3.8., They were also evaluated highly in the 4th IPCC report.

Meanwhile, high-efficiency devices are being introduced in large turbo freezers, thanks to the technical advances in Japanese corporations. However, this is a field in which U.S. companies such as American Standard Train have a large share, as well as advances in conventional technical abilities

The best methods to address current problems in heat pump technology include efforts at cost reduction and efficiency improvement. We expect to address efficiency improvement to 150% and cost reduction to 3/4 of the current level by 2030 and efficiency improvement to twice and cost reduction to 1/2 by 2050 through efficiency improvement in coolants and heat exchangers, as well as development of elemental technologies. Other technical challenges include miniaturization for better installation properties, reduction in raw material consumption, and measures for cold regions to expand the areas where it can be installed (room heating, hot water supply and snow melting).

- Challenges for effective technology development and diffusion

High initial cost is the problem about high-efficiency heat pumps compared with combustion-type heating and hot water supply systems or low-efficiency heat pumps. It will also be necessary to implement measures that can shorten the period between market release and diffusion. These policies specifically include the utilization of the energy saving top-runner program and financial support for the introduction and diffusion of the current technology, in addition to promoting technology development. Given that there are movements in Europe and the U.S. to evaluate heat utilization by heat pump as a renewable energy, room remains for examination of such treatment in Japan as necessary.

○ High-efficiency information device and system

- Outline of technology

This is an innovative, energy saving technology for the overall network, in addition to the individual devices, in order to develop an environment-friendly IT society and address the increasing power consumption by IT devices under the large amount of data flowing through thee network. It is expected that it may double the consumption efficiency

Upper: Next Generation LC Television,
Lower: Inverter Circuit for Air Conditioner
Source: Courtesy of Sharp Corp

in IT devices.

- Technology development roadmap

Electronic and information technologies have enabled improvements in productivity of every economic and social activity, as well as energy efficiency. They have contributed to the reduction of environmental loads through efficiency improvements in production, distribution, and processes by advanced control and management, in addition to energy saving in the devices themselves.

Meanwhile, it is expected that the amount of information handled in the society will reach 200 times current levels in 2025 as various IT services, including moving image distribution are diffused as IT society is being formed. Along with such an explosion of information, the number of information-processing IT devices and the amount of information handled by each device has been increasing drastically. This is becoming a serious problem, with the expected amount of information processed by IT devices in 2025 expected to be 5 times the current level. In the U.S. the power consumption at data centers have multiplied in the past 6 years, and it is also becoming a globally recognized problem. Under such circumstances, we will promote technology development of the so-called “Green IT” with energy saving technology for the entire network system including, energy efficiency improvements in individual devices and drastic energy saving technology development to construct an environment-friendly IT society.

Specifically, we will promote technology development to address energy-saving air conditioning for data centers and energy management technology to suit the information load, and increase efficiency in server and power supply systems. The objective here is to put into practical application energy saving technologies for data centers, which will be the core of information distribution in the future as well as servers around 2015.

Furthermore, technology development will be promoted on network devices such as energy-saving routers necessary for construction of energy-saving network. One of the objectives will be a 30% power consumption reduction in the router itself by developing an innovative router to optimize the power consumption dynamically to meet the amount of data flowing by 2015.

Regarding displays, we will try to reduce the power consumption to half of the current level and address 2.7 kWh/year・inch with a 52V-size LCD TVs around 2012 by developing a technology to further increase the efficiency if LCD backlight. We will try to achieve luminous efficiency of 70 lm/W by organic EL displays around 2010, which delivers high luminous efficiency, simplicity for large screen development and high color rendering properties. We will also try to achieve durability of 50,000 hours around 2020.

Furthermore, technology development will be promoted on the next-generation semiconductor devices with an objective to achieve an 11 nm line width by 2022 through microfabrication, development of transistors with new structures, etc. This will enable reduction of power consumption to about 1/10 compared to the current level with 65nm line width. We will also promote development of heterogeneous, multi-core technology to further reduce power consumption.

- Challenges for effective technology development and diffusion

To address further efficiency improvement by utilization of IT and electronics, it is necessary that technology development and diffusion be promoted in a unified fashion by industry-academia-government cooperation. Specifically, the “Green IT Promotion Council” we recently founded through an industry-academia-government partnership will implement enlightenment activities and international cooperation to promote energy saving by holding international symposiums and so forth. We will also promote the introduction and diffusion of energy-saving products and systems by utilizing the top-runner program. In addition, it is necessary that we should examine more fundamental energy saving technologies such as DC development in homes and office buildings in the long-term.

○ HEMS/BEMS/Local-level EMS

- Outline of technology

This is an energy saving technology to implement energy measurement and management for houses, buildings or regions via a network.

HEMS/BEMS is a system to control the room environment and energy usage conditions in houses or business buildings by utilizing IT and optimize energy consumption by effective control of networked devices such as air conditioners and lighting.

Using HEMS/BEMS and local-level EMS, it is possible to reduce carbon dioxide emission by 10 – 15%.

Local-level EMS is a system to enable energy management by coordinated control on HEMS/BEMS, network and distributed power supplies utilizing IT technology, network and so forth, and it is expected to contribute to reduction in carbon dioxide emissions.

- Technology development roadmap

HEMS/BEMS requires the development of telecommunication hardware technology, home/building sensor network (communication among all devices), microsensing technology and forecasting technology. For Local-level EMS, technologies to connect with local cogeneration systems and renewable energy such as photovoltaic power generation, technologies for the evaluation and optimization of electricity and heat energy utilization, heat and power storage need to be developed in addition to HEMS/BEMS technologies.

- Challenges for effective technology development and diffusion

We will promote introduction in stages, depending on the progress in technology development, while promoting the above technology development. Specifically for HEMS/BEMS, it is necessary to demonstrate an overall efficient energy management system. We will need to construct a business model in addition to developing energy saving technologies such as DC power supply, while promoting ESCO projects to provide a comprehensive energy management service

As to the local-level EMS technology to enable energy management in wider areas, we need to continue examination on its effects by demonstration, while also implementing cooperation with other systems such as renewable energy and distributed power supplies.

(Cross-cutting technologies)

○ High-performance power storage

- Outline of technology

This technology includes storage batteries essential for large-scale grid connection of renewable energy such as solar power and wind power and for electric vehicles, as well as power storage technology utilizing capacitor with high output density. It will lead to carbon dioxide emission reductions by diffusing hybrid vehicles and electric vehicle into the market, and expanding renewable energy introduction such as solar power and wind power. Effects of power load leveling can also be expected.

- Technology development roadmap

(For power storage technologies in vehicle, see the section on Plug-in hybrid vehicle and electric vehicle (P.24 – 25).)

As described previously, Japanese battery manufacturers have led the world mainly in the field of battery technology in mobile devices. National projects have been launched in the U.S., Europe, China and Korea and the situation does not allow our current advantages to be taken for granted.

Pumped storage generation as a stationary power storage system has been put into practical application for leveling of power loads. Development of storage battery systems with few installation restrictions and capable of reducing transmissions have been promoted, which has led to practical application of NAS battery[13]. For combined application with wind power or photovoltaic power generation, development of batteries with long lifetime, low cost and small auxiliary power consumption that are even better than those of batteries for power load leveling is demanded. Although nickel hydride batteries are considered promising for application in load leveling of new energy, development of a battery capable of charging and discharging larger currents with good maintainability is required. Furthermore, lithium ion batteries have urgent issues to be solved, such as capacity increase, lifetime extension and cost reduction, although they are promising candidates regarding the characteristic of high charging and discharging efficiency.

However, there still remain problems such as the requirements for capacity increase, extension of life and the reduction of cost. For lithium ion batteries as stationary installation application, developments of a battery system that are not extension of mobile application batteries are needed. We will need to develop an improved lithium ion battery with high performance, a long lifetime, high safety, and low cost. This will be accomplished by developing cathode materials with high safety and large capacity, anode materials such as alloy types, electrolytes with high conductivity, safety and low cost, high-reliability, low price separators ,etc. We will promote technology development with an objective to address lifetime equivalent to PV cells and wind power generation (20 years), and the cost of 15,000 JPY/kWh by 2030.

Electric double layer capacitors are beginning to be used in power storage (uninterruptible power supply system, also known as UPS) as well as in output leveling of momentary load fluctuations from photovoltaic power generation and wind power generation, and flicker compensation. In the future, further performance improvements and cost reductions will be necessary.

- Challenges for effective technology development and diffusion

We can expect the diffusion of large lithium ion batteries for applications other than vehicles, such as a backup power supply, stabilization of wind power or photovoltaic power generation, accelerated by mass production effects. In addition, we will need to promote development of low-cost sensor technology to monitor the voltage, temperature, pressure in the battery to maintain the battery life and ensure safety, as well as battery module development technology necessary for using combination of any battery cells to stabilize the system, battery module operation technology and high-efficiency inverter DC converter that matches the battery system. We will need to make examinations for

[13] A storage battery using liquid sodium, liquid sulfur and special ceramic. Has a large energy density compared to lead storage batteries.

the establishment of rare metal recycling chain for batteries such as lithium, and standardization to allow smooth market expansion of the outcomes as technology development is actively implemented overseas.

○ Power electronics

- Outline of technology

Power electronics technology is the technology to save energy in inverters and electric devices by utilizing the next-generation semiconductors, in power generation, transmission and distribution.

Left: ϕ100 mm 4H-SiC Single Crystal
Source: National Institute of Advanced Industrial Science and Technology (AIST)
Right: Inverter
Source: Yasukawa Electric Corp.

Inverters are popularly used in various fields including commercial, transportation, industry, and conversion sectors. This technology has also been used in equipment such as motors, various power supply systems, information appliance, home appliances, DC power transmission, variable pumping systems and power quality improvement devices in power generation field.

Power electronics semiconductors improve the energy efficiency through energy saving from these inverters. For example, expected efficiency improvements are about 2 – 10% (varying on the load conditions) in transportation field such as hybrid vehicle and electric vehicle, 4-5% in computer power supplies, and approximately 2% in the industrial field in general-purpose inverters for pump/fan motor operation when SiC device is applied in each of these. It has also been reported that it may contribute to reductions of power loss in the power generation field.

- Technology development roadmap

In addition to energy saving technologies centering on silicon semiconductors, new semiconductors, such as SiC and GaN[14] are expected to enable practical device applications as a breakthrough to deliver innovative technology progress in the future.

In manufacturing SiC devices, it is important that the technology allow stable epitaxial film growth on the substrate (wafer), and that large-diameter, high-quality substrates should be supplied at low costs. The next essential issue to be addressed is the

14 Sic (silicon carbide) and GaN (gallium nitride) are the semiconductor compounds that are to be the main players of the next generation and it is possible to reduce the loss compared to Si (silicon). At present, expectations are high for GaN as the device in the medium withstand voltage range (several hundred volts) and SiC as the device in the high withstand voltage and large power due to the difference in ease of crystal growth, cost, thermal conductivity coefficient and so forth.

establishment of process and device technologies with high production efficiencies. It is also necessary that we should establish packaging technologies capable of enduring higher operation temperatures than conventional levels, and peripheral technologies such as soft switching and measures against radio frequency.

Regarding GaN, it exhibits superior high-frequency performance to SiC, and there are high expectations for addressing high-voltage switching devices. Research and development are being made for application in telecommunication, power conversion and aerospace fields. For much larger power applications, there is also a great demand to develop vertical transistor devices.

While diamond devices are being touted as the ultimate device, the U.S. has given up its development due exceeding difficulties. Meanwhile, in Japan, we maintain the basic research of demand devices with a view to achieving superior power performance capable of competing with SiC and GaN in the future.

Under such circumstances, we will try to address practical application of SiC and GaN power devices around 2015. We will promote technology development with objectives of wafer diameter and dislocation density, which are the indices of mass productivity and device properties. Specifically, we will try to address 4-inch wafer diameter and $10^3/cm^{-2}$ dislocation density around 2008 and 6-inch diameter and $10^2/cm^{-2}$ dislocation density[15] around 2015 for SiC power devices.

For GaN power devices, we will try to address 3-inch wafer diameter and $10^4/cm^{-2}$ wafer dislocation density around 2010 and 4-inch diameter and 10^3cm^{-2} dislocation density around 2020. For the diamond device, we will promote technology development with objectives to address 2-inch wafer diameter and 10^3cm^{-2} dislocation density around 2010, 3-inch diameter and 10^2cm^{-2} dislocation density around 2020 and practical application around 2020.

- Challenges for effective technology development and diffusion

While competition in technology development is fierce among Japan, the U.S. and Europe, there is an oligopoly by certain corporations in terms of substrate supply. Our processes, devices and mounting technologies in the semiconductor field are at the world's top level. It is necessary that technology development be promoted by utilizing these technologies for which we are at advantage and investing resources (funding, facilities and human) efficiently in the consortium method and we should promote technology development while constructing a network among related parties to ensure international competitiveness in power electronics. It is also necessary that measures to

15 Wafer dislocation density is the density of linear lattice defect and it is used as an index for wafer defects.

lead to international standardization of technology be promoted in addition to developing the technology.

○ Hydrogen production, transport and storage

- Outline of technology

This is a technology for highly efficient production/transport and storage of hydrogen to be used in fuel cell vehicle and stationary fuel cell. It is expected to contribute to the reduction of carbon dioxide emissions by utilizing hydrogen produced by renewable energy or with combination of CCS as the fuel for fuel cell vehicles

- Technology development roadmap

Hydrogen production technologies include hydrogen production from fossil fuels, water electrolysis, and the utilization of renewable energy. The technology to produce hydrogen from fossil fuels has matured, but the technical challenges include reforming efficiency and the miniaturization of production systems for on-site station. In the area of water electrolysis, solid polymer and alkaline water analysis technologies are to be established, and improvements in their efficiency, endurance, economic efficiency are yet to be overcome. While production technologies from renewable energy include hydrogen production from biomass, gasification of woody materials is a conventional technology applied in heat utilization. Optimization of processes such as hydrogen reforming efficiency improvement is necessary. In addition, methane fermentation and hydrogen fermentation are still at the research stage, including the search for efficient fermenters.

Hydrogen Fuelling Station, JHFC Project by METI
Source: Website of Japan Hydrogen & Fuel Cell Demonstration Project

Possible methods for hydrogen transport include compressed hydrogen transport, liquid hydrogen transport, organic hydride transport in trailers, and pipeline transport. Since there are already records of compressed hydrogen transport in copper containers, we need to develop technologies that will increase transport volume through further pressure increases or the use of composite material containers. The issues for liquid hydrogen transport are improvement in liquefaction process efficiency and heat insulation performance for the liquid hydrogen tank truck and liquid hydrogen container. We will promote technology development with an objective to reduce the cost to 7 JPY/Nm^3 for high-pressure transport, and to 3 JPY/Nm^3 for liquid transport around 2020.

Hydrogen storage technologies include storage as gas, liquid hydrogen and hydrogen storing alloy. For storage by high-pressure gas, pressure increase from 35 MPa to 70

MPa, as well as cost reduction in containers is technical challenge we face. Similarly to transport technology, the issues for liquid hydrogen storage include efficiency improvement in liquefaction process and heat insulation performance for liquid hydrogen tank truck and liquid hydrogen container. As for hydrogen storing alloy, we need to search for materials, improve endurance and develop hybrid tanks.

We will promote such technology development and try to address price reduction to 40 JPY/Nm^3 around 2020.

- Challenges for effective technology development and diffusion

To produce hydrogen from fossil fuels, an examination on the combination of carbon dioxide capture and storage technology to further reduce carbon dioxide emission will be necessary. We must also advance technologies to utilize renewable energy to produce near-zero emission hydrogen.

In addition, preparation of hydrogen supply infrastructure, establishment of safety protocol supported by commercialization of component such as hydrogen detector, and development or amendment of regulatory framework should be addressed as enabling policies and technologies. It is important for Japan to exercise global leadership in such standardization arenas as ISO, IEC and SAE for the global diffusion of hydrogen energy system.

As for hydrogen supply infrastructure, hydrogen utilization will start from stationary fuel cell, integrated with fossil fuel reformer and fueling from facility attached to gas station. Technological development and increase in hydrogen demand will lead to the use of dedicated hydrogen station and the local supply system utilizing low pressure hydrogen pipeline. In the future, a national-scale hydrogen supply infrastructure is expected by an optimal combination between local hydrogen supply systems and transport in containers from large-scale production sites.

3. Promotion of international cooperation in innovative energy technology development

(1) Current status of energy technology development in the world and situation of technology roadmap development

(Stagnating energy research and development investment in the world)

The importance of developing energy technology to tackle the climate change has been addressed at various scenes of international discussion, such as the United Nations and G8 Summit since last year. However, investment in technology development in the energy field has shown the tendency to stagnate in the recent years, indicating the following situations:

(See Figs. 5, 6 and 7.)

- Although global investment in energy technology development increased after the two oil crises, it has been stagnating after the peak of 1980 as the crude oil price became stable.
- It is not always easy for private corporations to make continuous investments in energy technology, which typically requires a large investment over a long period of time. Governmental investment in research and development plays a key role in addressing this.
- Investments in the nuclear energy field take up a large portion of governmental research and development investment in the energy field.
- Japan, the U.S. and Europe are leading the world in governmental investment in research and development by nation.
- Research and development investment by the Japanese government has been among the world's largest in aggregate figures, and it has been investing actively on the issue of ensuring energy security and addressing climate change.

Cool Earth 50 (May 2007)

●Japan proposed a policy package named "Cool Earth 50"on 24 May 2007.
【Proposal of a long-term strategy to reduce the emissions of greenhouse gases globally】
○Propose a long-term target of cutting global emissions by half from the current level by 2050 as a common goal for the entire world.
○Present a long-term vision for developing innovative technologies and building a low carbon society to achieve the goal.

G8 Summit Heiligendamm Declaration - Growth and Responsibility in the World Economy (Jun. 2007)

"Technology is a key to mastering climate change as well as enhancing energy security. We have urgently to develop, deploy and foster the use of sustainable, less carbon intensive, clean energy and climate-friendly technologies in all areas of energy production and use."

Japan-U.S. High-Level Consultations on Climate Change (Aug. 2007)

Agreed upon the importance of Japan-US partnership on technology innovation and the significance of energy efficiency.

Sydney APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development (Sep. 2007)

Joint research, development, deployment and transfer of low and zero emission technologies will be crucial in our shared efforts to address climate change.

Major Economies Meeting on Energy Security and Climate Change (Sep. 2007)

Key to This Effort will be the Advance of Clean Energy Technologies - By developing new, low-emission technologies, the world's major economies can meet the growing demand for energy while reducing air pollution and greenhouse gas emissions. (Fact Sheet: Toward a New Global Approach to Climate Change and Energy Security, Whitehouse)

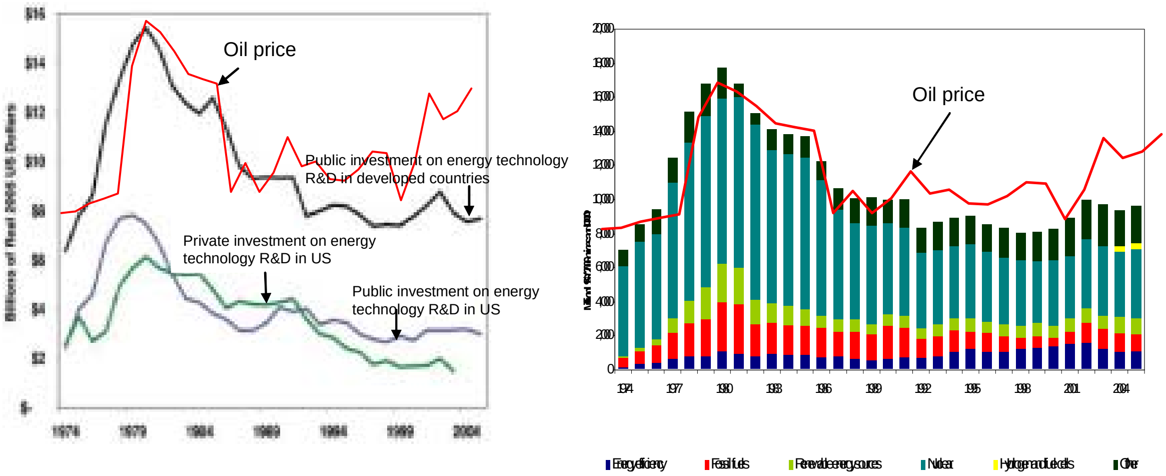
Japan-U.S. summit meeting (Nov. 2007)

○ Two leaders affirmed that Japan and United States would continue close cooperation to enable promoting development of innovative technologies and peaceful use of nuclear energy in order to challenge climate change while strengthening economic growth.
○ To continue our leading role in research and development of clean energy and climate technologies and encourage other major economies to increase public funding, as the United States and Japan have, for research and development of clean energy and climate technologies.. (Fact sheet: U.S.-Japan Cooperation on Energy Security, Clean Development, and Climate Change)

COP13 (Dec. 2007)

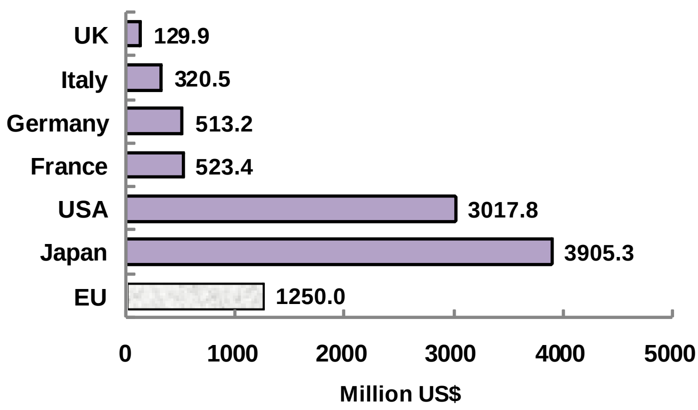
Bali Action Plan stresses the importance of "Cooperation on research and development of current, new and innovative technology".

(Figure 5) Growing recognition on the importance of energy technology development



Source：JGCRI 「Global Energy Technology Strategy」） Source：IEA

(Figure 6) Public and private investment on energy technology R&D in US (left), and public investment on energy technology R&D in developed countries (right)



(Figure 7) Governmental investment on Energy Technology R&D

Note:

1) Budget for EU is for 2007, derived from EC document
2) Budgets excluding nuclear are 2,573 M$ for USA, 1,397 M$ for Japan, 343 M$ for Germany, 221 M$ for Italy and 90 M$ for UK.

Source: IEA Statistics

(Movements for development of technology roadmap in Japan, the U.S. and Europe)

To promote technology development effectively and efficiently, efforts are being devoted domestically and internationally to develop a “technology development roadmap” to indicate the technical problems that must be overcome and technical performance achieved along the time line. For example, the International Technology Roadmap for Semiconductors has been developed by industry-academia-government cooperation to lead the technical innovations in the semiconductor field with rapid technical innovations and severe competition.

Japan has developed the “Energy Technology Strategy” (April 2007) to show the long-term roadmap on technology development in energy field based on New National Energy Strategy. Similarly, the U.S. developed the “Climate Change Technology Program/Strategic Plan” in 2007 to indicate the roadmap for technology development to be addressed in the short, medium or long term. This is being done by projecting 100 years into the future to support research and development necessary as measures against climate change. In Europe, the technology strategy within the European region to address climate change has been developed with an eye for the year 2020, 2030 and 2050. As such, there are movements to develop long-term technology strategies and technology development roadmaps to address climate change and focus on the importance of energy technology development in Japan, the U.S. and Europe.

(2) Basic view on international cooperation

To reinforce and accelerate energy technology to address the climate change, it is necessary that the nations of the world cooperate in ensuring research and development investment, and work steadily toward technology development. Following measures can help promote international cooperation effectively and accelerate technology development internationally for energy technologies that require long term and continuous efforts:

(International sharing of technology development roadmap)

Currently, there is no mechanism or framework to confirm or promote the progress of technology development that each country or region has achieved. An International collaboration framework has been promoted on specific technology areas on an ad hoc basis, and there is no framework to accelerate the collaboration systematically. Therefore, it is necessary to promote energy technology development more systematically, beginning with analysis of current status of technology development in each country or region and of international collaboration, and then by sharing the view on the long-term technology development depicted on the technology roadmaps. Consequently, common understandings will be fostered on milestones which indicate the timing of the technology development, e.g. practical use, commercialization, etc. These efforts will lead to sound progress of technology development by confirming the status and progress of such efforts in each country or region, and to secure investments to accomplish the goal. It is also beneficial to take a comprehensive and panoramic view of various technology development efforts being carried out in each country and region, which will facilitate identification and accelerate the progress of specific technological areas to be addressed under international collaboration. The consideration is needed to establish a potential framework in cooperation with IEA, to foster steady technology development under the common vision formed by sharing technology roadmaps.

(Acceleration in research and development by international cooperation)

As the speed of technical innovation influences global competitiveness, there are many cases in which private corporations cooperate with overseas research institutes while closely watching the global trends, and advance research and development efforts more efficiently by compensating for necessary research and development resources. Promoting international cooperation will also be effective in facilitating research and development in energy technology development.

A major advantage of this approach is that it distributes high risks associated with R&D projects that require long term investments that Japan alone could not address. It also accelerates research and development by using technology seeds and human resources that we do not have, improves the efficiency in research and development by rapidly grasping leading-edge technical trends and findings in overseas through a strong information exchange, and allows for the smooth market introduction of outcomes by the promotion of international standardization.

(Notes to be made in promoting international cooperation)

To promote international cooperation without interfering with the aspirations of private corporations who are the final players of technology development and diffusion, it is essential that proper balance be taken between competition and cooperation with consideration to protect intellectual property rights and prevent unintended technology drain.

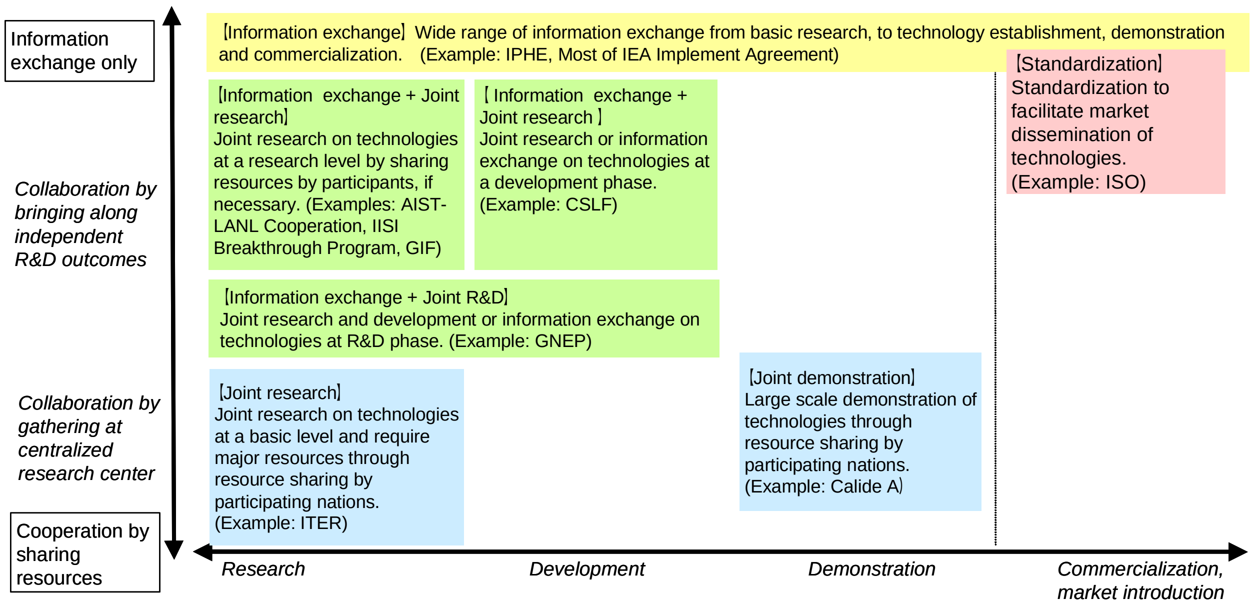
One such an effort is seen in the Japan China Business Alliance for Energy Saving and Environmental Protection, which promotes cooperation in energy saving technologies on the business base between Japan and China. The Alliance establishes committees with participation of governments of both nations to specify the model projects and attempts to prevent problems or solve problems, including the consideration of intellectual property rights. Consideration to the issues such as intellectual property rights needs to be made beforehand between governments to allow for the smooth transfer of developed technologies.

(3) Current status of international cooperation in energy field and future directions

International cooperation is already being advanced on various technologies such as nuclear power, zero-emission coal fired power generation and fuel cells (see Table 3). These include various forms of cooperation from only information exchange to assigning the share of funding as well as theme for each nation (Fig. 8). The cases in which researchers gather at one or several sites to conduct research and development are limited on cases that need large funding, such as ITER. Many cases in which funding and resources are assigned have the participants gather the research and development outcomes from each nation. Meanwhile, information exchange is implemented in a wide range of stages of research, development and deployment, as shown in implementing agreements in IEA. Based on such circumstances, it is appropriate to start cooperation with information exchange, build upon existing international partnerships, and explore new areas for cooperation based on the technology status and needs of countries.

(Table 3) Current situation of technological cooperation in the field of energy

Partnership	Establishment	Objectives	Members / Partners
International Energy Agency (IEA), Implementing Agreements	Nov. 1974	To cooperate under the framework established in 1975, to support energy R&D in IEA member countries. Currently, 41 implement agreements have been signed upon and provide forums for information exchange on research, development, demonstration and deployment, cooperative research and development, etc. on various technology areas such as end-use technologies, renewable energy technologies and fossil fuel technologies, and cross-cutting area including climate change issues.	IEA's member countries including Japan, Europe and United States, etc. and non-member countries are participating according to their own interests.
Generation IV International Forum	Jan. 2000	To work together R&D for the fourth generation nuclear reactor. Six type of nuclear reactor systems that could be deployed by 2030, i.e. Sodium-Cooled Fast Reactor, Ultra-High Temperature Reactor, Gas-Cooled Fast Reactor, Supercritical-Water-Cooled Reactor, Lead-Cooled Fast Reactor and Molten Salt Reactor, will be developed under the international cooperation.	12 countries and 1 organization (Japan, United States, Canada, United Kingdom, France, Switzerland, Russia, Argentina, Brazil, South Africa, China, South Korea) and Euratom.
FutureGen Project	Feb. 2003	To demonstrate, under the international cooperative framework, an integrated system of zero-emission coal fired plant consists of coal gasification, combined cycle power generation, and capture and geological storage of CO2. Currently, the project is under restructuring and the new approach will focus on CCS part of the system.	Under consideration
Carbon Sequestration Leadership Forum (CSLF)	Jun. 2003	To promote R&D of improved cost-effective technologies for the capture, transport and storage of carbon dioxide, and to facilitate international acceptance on CCS technology for its commercial use.	21 countries and 1 region(Japan, United States, Canada, United Kingdom, Germany, France, Italy, Netherlands, Kingdom of Norway, Denmark, Greece, Russia, Brazil, Mexico, Colombia, Australia, South Africa, China, India, South Korea, Saudi Arabia) and the European Commission.
International Partnership for the Hydrogen Economy (IPHE)	Nov. 2003	To accelerate research, development, demonstration and commercialization of hydrogen and fuel cell technologies. Also, IPHE provides a forum for advancing relevant policies, and common technical codes and standards.	16 countries and 1 region(Japan, United States, Canada, United Kingdom, Germany, France, Italy, Russia,Kingdom of Norway, Iceland, Australia, New Zealand, Brazil, India, China, South Korea) and European Commission.
Asia-Pacific Partnership on Clean Development and Climate (APP)	Jul. 2005	To work together to meet goals for growing energy demand, energy security, and climate change in Asia-Pacific region through regional cooperation which includes development, deployment and transfer of clean and efficient technologies. Specific joint project includes Callide-A to demonstrate a oxy-fuel pulverized coal fired generation with CO2 capture under Japan-Australia partnership.	7 countries (Japan, United States, Canada, Australia, South Korea, China, and India).
Global Nuclear Energy Partnership (GNEP)	Feb. 2006	To develop worldwide consensus on enabling expanded use of nuclear power, while simultaneously promoting non-proliferation and safety. The goal include the construction of fast reactors and recycling facilities and the promotion of R&D on fast reactor technologies, recycling technologies, small and medium reactor technologies, etc.	20 countries (Japan, United States, France, Italy, China, Russia, Australia, Republic of Bulgaria, Ghana, Hungary, Jordan, Kazakhstan, Lithuania, Poland, Romania, Slovenia, Ukraine, Canada, South Korea, Senegal).



(Figure 8) Categorization of existing international RD&D cooperation

(Promotion of international cooperation utilizing the existing frameworks)

As discussed above, many international partnership projects have already been established, and it is necessary that cooperation be reinforced based on these efforts. Cooperation may be promoted specifically in the following technologies:

○ Carbon dioxide capture and storage (CCS)

Cooperation regarding leading-edge technologies (separation membranes and monitoring technologies) of the CCS technology will be reinforced through APP, CSLF and other programs. In addition, we will try to demonstrate our technical advantages in overseas demonstration projects such as Callide A by unified cooperation between government and private sector. We will also reinforce cooperation with overseas research institutes and demonstration projects since the storage potential in Japan is currently limited. Cooperation on establishing the environment for diffusion of technologies such as the environmental impact evaluation and ensuring adequate public outreach can be reinforced through IEA

○ Fuel cell

While reinforcing information exchange in IPHE, we will also be promoting international standardization of hydrogen fuel and the presumption of smooth overseas expansion. In cooperation between two nations, we will reinforce cooperation through technological information exchange and joint research efforts with Los Alamos National Laboratory regarding hydrogen storage materials and so on.

○ Advanced nuclear power generation

In the area of fast reactor technologies, we will conduct an examination on reactor design concept, requirements and basic specifications for the fuel through Japan-U.S. cooperation within the framework of GNEP and GIF, and try to accelerate research and development while sharing the findings of different nations.

As to small and medium reactor technologies, we will summarize the design requirements based on the survey needs of developing nations by IAEA, and investigate the design concepts that are already discussed in the framework of Japan-U.S. cooperation. We will also examine possibilities for joint research and development in mutually beneficial fields regarding small and medium reactors.

○ Intelligent transportation system

To promote an intelligent transportation system that contributes to energy saving, we will reinforce the three-party cooperation among Japan, the U.S. and Europe in the ITS world conference held every year. Specifically, we will regularly exchange information on ITS technological trends to contribute to environmental health and energy efficiency, and reinforce cooperation in joint hosting of workshops to exchange information on development of autonomous driving, cooperative driving, and the joint development of carbon dioxide reduction assessment methods.

To diffuse ITS globally, it is necessary that we promote international standardization by ISO/TC204 (ITS). Since we are to lead the discussion on international standardization by ensuring the positions of TC vice chairperson and WG14 (driving control) chairperson, we will promote ITS to contribute to energy saving in cooperation with other nations.

(Promotion of new international cooperation)

It is also necessary to examine the possibilities of new international cooperation in fields that need more acceleration or that lack in international cooperation. Furthermore, we will need to reinforce the cooperation in project or partnership in fields where international cooperation is already made. Specifically, we will promote cooperation on the following technologies:

○ Carbon dioxide capture and storage (CCS)

Regarding the CCS technology, we will utilize the findings in the past to contribute to the promotion of overseas demonstration projects in China, Australia and other countries, and try to accumulate our experience in its demonstration. We will also develop the mechanism to promote cross-linking among different domestic and international projects under IEA cooperation and so forth. Japan will also actively participate in FutureGen with a new framework focusing on carbon dioxide capture and storage technology.

○ Innovative photovoltaic power generation

Regarding the third generation photovoltaic power generation technology for which basic research has only been started on the academic level, we will begin by establishing a research site in Japan. We will also construct a network with overseas research institutes through the invitation of prominent researchers from overseas and by holding several symposiums to foster information exchange on research and development trends in other nations while also coordinating efforts with the IEA.

○ High-performance power storage

As previously mentioned, Japan is still at an advantageous position in battery technology. However, development of new materials depends on the research in the U.S. and Europe, where researchers are conducting research with large sources of funding. Research in new cathode materials has been identified by American and European researchers for this reason Therefore it is necessary to consider cooperation with overseas research institutes in basic research efforts. We will also promote international standardization of battery technology.

○ High-efficiency superconducting power transmission

In the area of high-efficiency superconducting power transmission, we will promote cooperation to address the technology at an early stage by encouraging Japanese corporations to participate actively in demonstration projects on superconducting cables implemented overseas and contribute to the promotion of demonstrative research.

We will also implement information exchange on research and development trends in other nations regarding high-temperature superconducting materials, since it is considered effective to cooperate with overseas research institutes with leading-edge findings from a long-term standpoint.

○ Innovative iron and steel making process

Regarding iron and steel process, we will continue to grasp the latest technological trends in European nations by participating in International Iron and Steel Institute (IISI) and joint programs in the EU, and examine the possibilities for joint research in basic and fundamental fields.

○ High-efficiency information device and system

We will emphasize our contributions in the environmental IT field by holding an international symposium to form a common recognition on the effectiveness of green IT, while also sharing information on research and development trends in other nations to accelerate energy innovative energy saving technology development. We will also try to reinforce the measures in cooperation with other international projects.

While we will promote international cooperation on these technologies and acceleration of technology innovation is necessary, it is possible that there could be fields other than those described above, in which promotion of technology development by international cooperation is effective. We will need to flexibly examine bilateral and multilateral cooperation frameworks, depending on the progress in technology development in Japan, overseas trends and so forth.

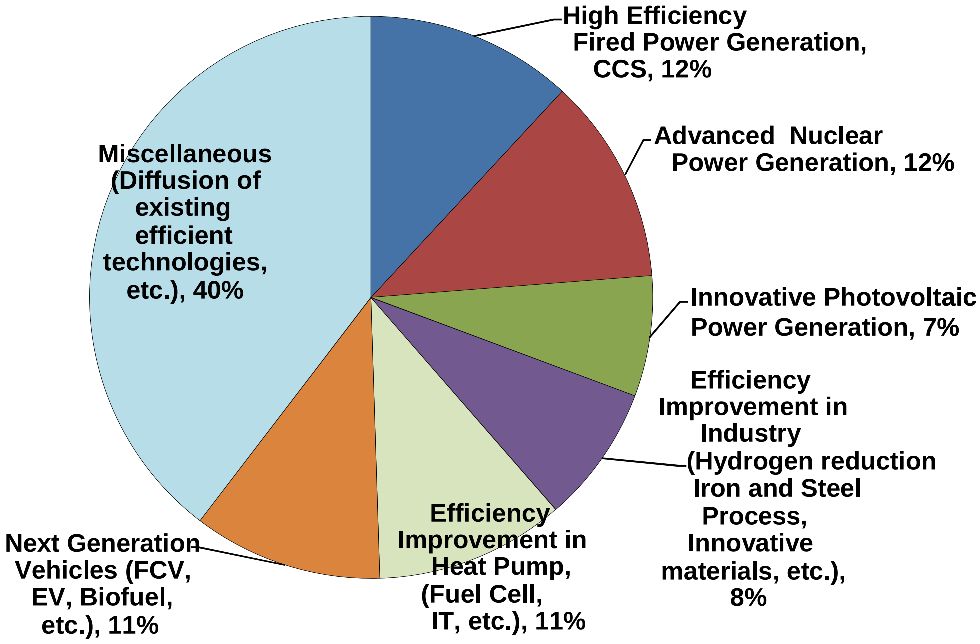
4. Picture of a future social system in 2050 seen from the aspects of energy technology

(Image for reducing carbon dioxide emission from energy sources to half in 2050)

Several estimates suggest that it will be necessary to reduce carbon dioxide emission from energy sources by more than 40 billion tons[16] (t-CO2) when global economy grows smoothly and we try to reduce the carbon dioxide emissions from energy sources by half from the current level, which is estimated to reach about 27 billion[17] tons in 2005.

In this section, we have made some examinations based on a trial calculation[18] of how the innovative energy technologies selected will contribute to substantial reduction in global carbon dioxide emissions, assuming that technology development is accelerated following the roadmaps. We have also pictured a possible future social system in which these technologies are introduced.

The "21" innovative technologies included in this estimation contribute to nearly 60% of the necessary reduction, indicating that development and diffusion of innovative technologies are essential in reducing carbon dioxide emissions by half in 2050 (Fig. 9). In this estimate, those in power generation and transportation fields such as nuclear power, CCS and photovoltaic power



(Figure 9) Contribution of Innovative Energy Technologies for the 50 % Emission Reduction in 2050
Source: An estimation by the Institute of Applied Energy

16 IEA "Energy Technology Perspective", etc.
17 IEA "World Energy Outlook 2007"
18 A trial calculation made by the Institute of Applied Energy

have relatively large contributions. However, it is necessary that we address technology development with all our powers in all fields, including industrial and commercial sectors, instead of addressing only one of these technologies to achieve substantial reduction. We should take a leading role in developing those technologies.

[Image for a social system in 2050 assumed from the estimation (example)]

Let us try to have a look at the image for the society with carbon dioxide emission reductions cut in half by 2050. The global society will have thoroughly advanced efficiency and carbon reduction efforts while addressing sustainable growth thanks to innovative technologies. Drastic energy saving will have been realized on the demand side due to the optimization of energy consumption by IT devices, and there will be an environment-friendly automobile society with major diffusion of next-generation vehicles. On the supply side, substantial reduction will have been realized under the energy supply system with advanced zero-emission technologies such as innovative photovoltaic power generation, nuclear power generation and CCS. We expect that there will be a society in which rich life and substantial reduction in carbon dioxide emissions are both supported by the establishment of an advanced energy demand system.

<Power generation and conversion sector including transmission>

CCS will reduce carbon dioxide emissions for thermal power plants, and advances will have been made in zero-emission development and power generation efficiency areas. In addition, with a great premise of securing safety, application of advanced nuclear power generation will expand.

Introduction of renewable energy will advance drastically, and photovoltaic power generation will accelerate in diffusion due to cost reductions nearly equivalent to that of thermal power generation. Applications will expand significantly including utilization on building walls as built-in units in houses, and megawatt-class photovoltaic power generation will also be possible. In combination with such large-scale photovoltaic power plants, storage batteries to stabilize the system will be installed at these plants.

Furthermore, a high-efficiency power transmission system utilizing superconductors will be introduced to address the power demands in urban areas and the introduction of distributed power supplies such as renewable energy and fuel cells will be advanced in a coordinated form with the system while utilizing the characteristics of the regions.

<Industry sector>

In the iron and steel industries, both of which consume large amounts of energy, carbon dioxide emissions will be reduced drastically with the development of efficient carbon dioxide separation and absorption technology from the Blast furnace and partial introduction of hydrogen reduction.

In chemical production processes, efforts in biomass production will have advanced. Low-carbon production processes will have been advanced including the introduction of heat pump technology on heat demands, such as steam used in multiple industries.

<Transportation sector>

In transportation sector, most of the conventional gasoline engine vehicle will have been replaced by the introduction of electric and fuel cell vehicles, with the advanced introduction of biomass fuels. There will be proper control of traffic flow by ITS and dramatic improvement in energy efficiency by diffusion of electric and fuel cell vehicles. Electricity stations and hydrogen fuel stations to support such considerable diffusion of electric and fuel cell vehicle will also be established.

<Commercial/residential sector>

Energy saving will have been realized through the development of high efficiency houses and buildings with high heat insulation, the introduction of stationary fuel cells, and high efficiency heat pumps in the air conditioning system, room heating and hot water supply. Energy saving household appliances, devices, and power electronics will also have advanced. Energy will be measured and managed without waste by IT utilization in combination with photovoltaic power generation at home, leading to advanced energy saving in the entire society. Moreover, power will be utilized more effectively, including the utilization of excess power at night for charging electric vehicles.

5. Steady implementation of the program

(Sharing of roles by government and private sector depending on the progress in technology development)

When the government makes investments in research and development according to the prepared technology development roadmaps, it is necessary that there be an appropriate role sharing between the government and the private sector based on the progress in technology development, especially for technologies near market introduction. In addition, it is necessary that appropriate resources be distributed, depending on the technology development progress, to both technologies that need basic research and development, and technologies for which application and demonstration should be focused.

It is also necessary that we promote technology development and diffusion of its outcomes by cooperation over the walls of different industry fields, as well as close industry-academia-government partnership.

(Smooth diffusion and market introduction of research and development outcomes)

It is necessary that the introduction and diffusion of the outcomes of technology development based on this program be promoted by cooperative efforts, such as proactive introduction in public organizations, active participation in discussions for international standardization, and concurrent examination to establish the necessary systems and infrastructures.

(Regular reviewing of the technology development roadmap and so forth)

As competition in technology development becomes fiercer and technology innovation is accelerated, it is necessary that we flexibly review the milestones on the roadmap. To do this, this program shall be promoted, considering 10 years as the first phase, and the technology development roadmap prepared in this program shall be reviewed regularly based on discussions of related parties in industry, academia and government.