Attachment 3

Roadmap and Other Items Pertaining to Each Item of Technology

- ○ This material summarizes (1) Technology overview, (2) Trend and issues in technology development in Japan, (3) Technology roadmap, and (4) International trends (current extent of diffusion, trends in technology development, international competitiveness of Japan) for each technology listed in the “Innovation Strategy for Energy and Environment”.
- ○ Technology roadmaps describe the desired level (development target, state of practical application, diffusion level, etc.) of Japan’s technology along a time axis. Some technology items lack national R&D projects for achieving the targets at the time of strategy formulation. If national R&D projects are deemed necessary for achieving the targets, considerations will be made on adding relevant projects into resources allocation plans for annual science and technology budget compilation and into Action Plans for Science and Technology Priority Measures.
- ○ The present material presents not only government-led technologies but also comprehensive public-private sector joint activities.

*** Technology Roadmap references**

- ● Japan Revitalization Strategy Short- to Mid-term Progress Schedule (2013)
- ● Comprehensive Strategy on Science and Technology Innovation Progress Schedule (2013)
- ● NEDO Renewable Energy Technology White Paper (2010)
- ● NEDO Fuel Cell and Hydrogen Technology Development Roadmap 2010 (2010)
- ● Low Carbon Technology Plan (2008)

Production • Supply	Thermal Power Generation	1. High-Efficiency Coal-fired Power Generation
		2. High-Efficiency Natural Gas-Fired Generation
	Utilization of Renewable Energies	3. Wind Power Generation
		4, 5. Solar Energy Utilization
		6. Marine Energy Utilization
		7. Geothermal Power Generation
		8. Biomass Utilization
	Nuclear Power Generation	9. Nuclear Power Generation
	CO_2 Capture, Use, Storage (CCUS)	10. CO_2 Capture and Storage (CCS)
		11. Artificial Photosynthesis
Consumption • Demand	Transportation	12, 13. Next-Generation Automobiles
		14, 15, 16. Aircrafts, Ships, Railways
		17. Intelligent Transport Systems
	Devices	18, 19, 20. Innovative Devices
	Materials	21. Innovative Structural Materials
	Energy Utilization Technology	22. Energy Management System
		23. Energy Efficient Houses/Building
		24. High-Efficiency Industrial Energy Utilization
		25. High-Efficiency Heat Pumps
	Production Process	26. Environmentally-Aware Iron Manufacturing Process
		27. Innovative Manufacturing Process
Distribution • Supply/Demand Unification	Energy Conversion, Storage, Transport	28, 29. Hydrogen Production, Transport, Storage
		30. Fuel Cells
		31. High-Performance Electricity Storage
		32. Heat Storage/Insulation Technology
		33. Electricity Transmission by Superconductivity
Others	Technology to Fight Global Warming	34. Methane etc. Reduction Technology
		35. Carbon Fixation by Vegetation
		36. Global Warming Adaptation Technology
		37. Earth Observation • Climate Change Prediction

1. High-Efficiency Coal-Fired Power Generation

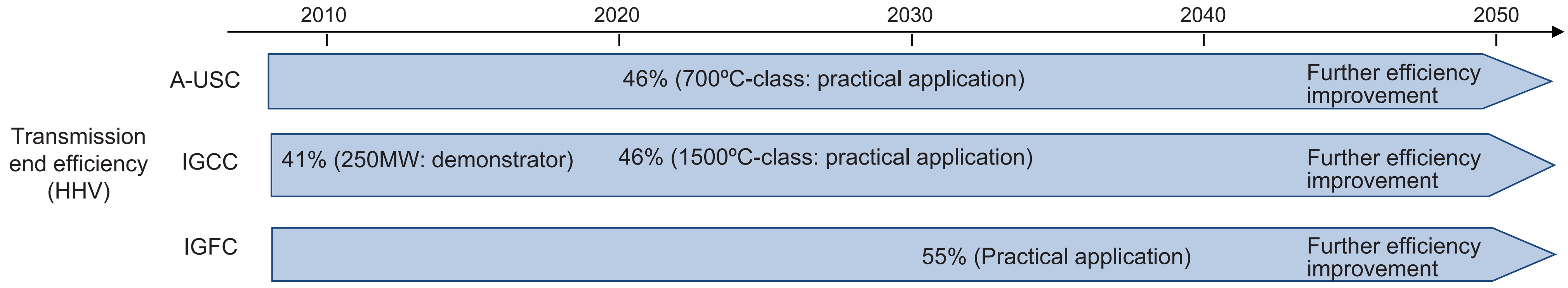
Technology Overview

- ○ High-efficiency coal-fired power generation includes: ultra-supercritical (USC) and advanced ultra-supercritical (A-USC) pulverized coal power generation where steam is at high-temperature and high-pressure, integrated coal gasification combined cycle (IGCC) where coal is gasified, integrated coal gasification fuel cell combined cycle (IGFC) where IGCC and fuel cells are combined. Some are in the study phase.
- ○ Commercialization of CO_2 Capture and Storage (CCS) in future enables reduction of CO_2 emissions to close to zero.
- ○ An estimation says introducing Japan's already commercialized USC technology to US, China and India reduces CO_2 emissions of energy-origin by 1.5 billion tons.

Trend and Issues in Technology Development in Japan

- ○ For A-USC, technology development (TD) support started in fiscal 2008. The main tasks are development of large capacity boiler turbine systems for the power industry and high temperature valve technology. Development of materials that endure high temperature steams of 700ºC or more is another task.
- ○ For IGCC, air-blown IGCC was demonstrated in Fukushima Pref.; future tasks are improvement of gas turbine efficiency and TD etc. of combustor components.
- ○ For IGFC, the base technology Oxygen-blown IGCC is currently under demonstration for overall reliability in the premises of the Chugoku Electric Power Co. Osaki Plant. Future tasks include compatibility evaluation of gasified coal and fuel cells.
- ○ TD for improving generation efficiency, utilizing various coal types, and reducing generation cost is important.

Technology Roadmap



- ○ Improve collaboration between basic researches on materials, catalyst technologies, etc. at universities and large-scale projects for demonstrating private-led plants as a system
- ○ Promote TD through development of various human resources

(* Related technology roadmap: 30. Fuel cells)

International Trend

Current state of diffusion

- ○ The majority of the world's coal-fired power generation is in US, China and India, and their generation efficiency is 35% or less. USC is already widely applied in Japan, and China has also started to introduce USC into large-scale coal-fired power generation. India is introducing SC into some plants, but a majority of coal-fired power generation are low-efficiency conventional type.

Trend in technology development

- ○ Europe is conducting various element tests using 700ºC steam under the AD700 project where power companies and manufacturers are the main entities. In addition, as a clean coal policy, funding program for promoting (1) CCS and (2) IGCC is introduced, and joint development of (3) USC and A-USC is conducted with EU companies participating. CCS aims at practical application after 2020 and A-USC will complete in-service testing by 2016.
- ○ US aims for zero or close to zero emission coal-fired power generation through the Clean Coal Power Initiative (CCPI) and the Clean Coal Technology Demonstration Program.

International competitiveness of Japan

- ○ The average generation efficiency of Japan's coal-fired power generation facilities is ~41% (transmission end, HHV) as of now, which is world highest level compared to that in a 30% range in other countries.

2. High-Efficiency Natural Gas-Fired Power Generation

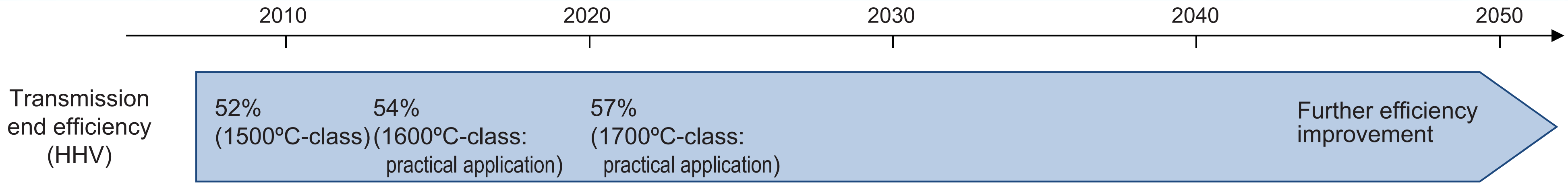
Technology Overview

- ○ High-efficiency natural gas-fired power generation technology includes combined gas and steam cycles and advanced humid air turbine (AHAT, under development).
- ○ Japan completed development of 1600ºC-class gas turbine, which is to start operation at Kansai Electric Power Co. Himeji No.2 Power Station from October 2013 (generation efficiency 54%, transmission end/HHV).
- ○ Commercialization of CCS in future enables reduction of CO_2 emissions to ~0.
- ○ IEA estimates CO_2 emission reduction potential of natural gas-fired power generation to be ~280 million tons in the blueprint (to reduce global CO_2 emissions by 50% in 2050 compared to 2005) of Energy Technology Perspectives (ETP) 2010.

Trends and Issues in Technology Development in Japan

- ○ For combined cycles, Japan aims at achieving generation efficiency (transmission end/HHV) of 54% for 1600ºC-class in ~2013 and 57% for 1700ºC-class in ~2020. Elemental TD is conducted for triple combined cycles.
- ○ For AHAT, Japan aims at achieving generation efficiency (transmission end/HHV) of 51% for 100 MW-class by ~2020.
- ○ For development of 1700ºC-class gas turbine, the main task is development etc. of highly heat resistant turbines through ultra high heat resistant alloys etc. The target is to raise generation efficiency (transmission end/HHV) from the current maximum of 52% to 57% by ~2020.
- ○ AHAT requires TD for high-efficiency compressor designs and turbine blade cooling.

Technology Roadmap



- ○ It is important to promote TD through industry-academia-government cooperation as gas turbine technologies include advanced designing and manufacturing technologies over various fields such as aerodynamics, thermodynamics, combustion, and materials. (Improve collaboration between basic researches on materials, catalyst technologies, etc. at universities and large-scale projects for demonstrating private-led plants as a system)
- ○ Promote TD through development of various human resources

International Trend

Current state of diffusion

- ○ US is planning to start operation of high-efficiency gas turbine of ~54% generation efficiency (transmission end/HHV) in Florida in 2013.

Trend in technology development

- ○ A national project of US Department of Energy (DOE) invests ~1 billion US dollars in universities and gas turbine manufacturers for the period of 2003-2015 to improve efficiency.
- ○ In Europe an initiative called CAME-GT promotes development of high-efficiency gas turbine, and currently TD for improving individual technology elements is conducted in the Seventh Framework Program (FP7).

International competitiveness of Japan

- ○ In Japan a 1600ºC-class combined generation plant of the world-class generation efficiency (54%, transmission end/HHV) where the inlet gas temperature was raised to 1600ºC is to commence operation around October 2013. The level of Japan's TD is at the world's best standard.
- ○ The temperature of gas turbines has been rapidly increased at the rate of ~20ºC per year since the appearance of combined generation systems in early 80's, and thermal efficiency has been raised. Amid active competition, the only countries able to conduct TD for higher temperatures are narrowing down to US, Germany, and Japan.

3. Wind Power Generation

Technology Overview

- ○ Wind power generation (WPG) is relatively low in generation cost among renewable energies.
- ○ However, lack of ideal locations due to restrictions arising from regional, geographical or metrological conditions may increase costs.
- ○ Additionally, further introduction of WPG in Japan requires offshore expansion.
- ○ Offshore WPG has fixed-bottom types and floating types, and is considered to be able to achieve higher operation rates than onshore WPG.
- ○ IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of WPG to be ~3 billion tons in 2050.

Trend and Issues in Technology Development in Japan

- ○ Ministry of Economy, Trade and Industry (METI) is conducting demonstration of fixed-bottom WPG off the coasts of Choshi, Chiba Pref. and Kitakyushu, Fukuoka Pref. and aims at practical application of extra-large WPG in anticipation of global demand for offshore WPG. METI also promotes advancement of components in order to improve operating rates of WPG.
- ○ Through demonstrations METI and Ministry of Environment (MOE) are, by fiscal 2015, to a) solve technical issues, b) evaluate safety, reliability and economy, c) adapt to metrological conditions, and d) establish methods for conducting environmental assessment of floating offshore WPG.
- ○ Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is conducting strategic activities for technical consideration for compiling safety guidelines of floating offshore WPG and international standardization for the International Electrotechnical Commission.
- ○ For interconnecting the power system for WPG, it is important to arrange power transmission and distribution networks and advance low-cost battery systems in addition to establishing high-accuracy electric power generation prediction technology, etc.

Technology Roadmap

	2010 – 2020 – 2030 – 2040 – 2050
Endurance/reliability improvement	Advancement of windmill parts, components and maintenance technology
Performance improvement	Development of extra-large windmill
Fixed-bottom offshore	Demonstration of fixed-bottom offshore WPG
Floating offshore	Demonstration of floating offshore WPG

International Trend

Current state of diffusion

- ○ World's cumulative introduction as of the end of 2011 was 237,669MW, in the order of China 62,364MW, US 46,616MW, and Germany 29,060MW. New introduction in 2011 was 40,564MW, where China was largest with 17,631MW, followed by US 6,810MW and India 3,019MW.

Trend in technology development

- ○ US has spent 308.7 million dollars on projects involving offshore WPG in the period of 2006-2012. Priority TD areas include: test facilities, next-generation turbine technology, floating structure basic technology, modeling simulation tools, optimization of WPG system, acceleration/expansion/facilitation of the market, analysis of resource characteristics, power system planning and operation.
- ○ EU is conducting enlargement of turbine sizes, reduction of materials used, and improvement of offshore large windmill workboats. Practical application of floating offshore WPG and new WPG concepts such as high-altitude WPG is conducted under FP7.

International competitiveness of Japan

- ○ Japan is currently working on efficiency improvement of onshore windmills and demonstration of fixed-bottom and floating offshore WPG.

4. Solar Energy Utilization (Solar Photovoltaic Generation)

Technology Overview

- Solar photovoltaic generation (SPG) is broadly classified into three types, namely silicon-type, compound-type, and organic-type. Currently a majority of application are silicon-type. Compound-type and organic-type solar cells may further reduce costs by using substituting materials for silicon, etc.
- As elemental technology, reduction of materials used and development of low-cost electrodes etc. are in progress for crystalline silicon and compound-type. Development of photo-degradation prevention technology and large-scale manufacturing technology is conducted for thin film silicon. Development of high-efficiency sensitizing dyes, organic semiconductors and sealing technologies is conducted for organic-type.
- To reduce potential overloading to the power system in future, it is necessary to materialize consistent-output SPG systems combined with power storage functions and fusion with power supply-demand adjustment of the whole region.
- IEA's ETP 2012 estimates the CO_2 emission reduction potential of development and diffusion of SPG technology to be ~1.7 billion tons in 2050.

Trend and Issues in Technology Development in Japan

- METI is conducting the following TD:
  - TD of next-generation high-performance SPG: TD for efficiency improvement and cost reduction for various SPG including crystalline silicon and common fundamental technologies such as evaluation technology
  - R&D of innovative SPG technology: Searching an approach for achieving "conversion efficiency 40%" and "generation cost as low as general-purpose electricity cost (¥7/kWh)" by utilizing new materials and new structures
  - Leading applied TD of organic-type solar cells: Designing, trial production, and demonstration of SPG systems that utilize organic-type solar cells
- The Ministry of Education, Culture, Sports, Science and Technology (MEXT) promotes R&D etc. of ultrahigh-performance solar cells by combining nanowires and high-quality silicon, whose conversion efficiency is far beyond the silicon-type solar cells.
- The main task for crystalline silicon and compound-type is manufacturing cost reduction. The tasks for thin film silicon are significant improvement in conversion efficiency and manufacturing cost reduction. The tasks for organic-type are significant improvement in conversion efficiency and improvement in reliability.

Technology Roadmap

SPG	2010	2020	2030	2040	2050
Generation cost	¥23/kWh	¥14/kWh			
Module conversion efficiency	8-18%	20%	40%		≥40%

International Trend

Current state of diffusion

- World's cumulative introduction as of the end of 2012 was 96.5GW. New introduction in 2012 was 28.4GW.
- Cumulative introduction in US as of the end of 2012 was 7.2GW. Plant capacity in the EU region as of the end of 2012 was 68.5GW. By country, Germany is 32.4GW, Italy 16.3GW, and Spain 5.1GW. Germany and Italy are prominent.
- Space SPG is currently in the R&D stage.

Trend in technology development

- US is conducting R&D on materials saving for crystalline silicon solar cells and development of ultra-thin crystalline silicon photo absorption layers, as well as development of CdTe and amorphous silicon etc. for thin film solar cells, as DOE working as the main body. Development of compound-type solar cells (III-V group compounds) and organic-type solar cells is also promoted.
- EU is conducting R&D focusing on optimization of productivity and costs in manufacturing of SPG systems, development of nanostructural materials (scale up and process of low-cost high-efficiency chalcogenide-type SPG), standardization of components where building materials are integrated, etc.

International competitiveness of Japan

- Japan had long been at the top of the world in TD, introduction and production of SPG. Due to introduction policies mainly in Europe, main introduction countries have shifted to Europe, and main production countries shifted to countries with high cost competitiveness such as China and Taiwan.
- Therefore, Japan is promoting practical application of multi-junction solar cells with world highest conversion efficiency and high added-value organic-type solar cells, as well as TD for achieving further efficiency improvement of cost reduction for crystalline and thin film silicon solar cells and compound-type thin film solar cells.

5. Solar Energy Utilization (Solar Heat Utilization)

Technology Overview

○ Solar heat utilization technology includes heat supply systems and power generation technology. Solar heat supply system (SHSS) includes hot water supply systems and air conditioners using heat pumps etc. Solar heat power generation (SHPG) technology is to converge the solar ray and generate steam etc. using high heat.
○ Integration with various heat utilization of different temperatures from household use to industrial use is the most important. Power generation may be conducted using solar light/heat converging technologies such as parabolic trough, linear Fresnel, tower-type, and parabolic dish, and thermoelectric conversion as well as steam and gas turbines.
○ IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of solar heat generation and solar heat utilization to be ~1.7 billion tones and ~0.3 billion tons in 2050, respectively.

Trend and Issues in Technology Development in Japan

○ Technologically solar heat air conditioning systems are almost fully established. However, financial restriction is suppressing introduction. Efficiency improvement and system development are required in order to reduce the introduction cost.
○ For SHPG, TD for cost reduction etc. of linear Fresnel type, tower-type, etc. is conducted. A demonstration plant is under construction in the Middle East.
○ The mainstream heat storage technology is the molten nitrate salt type. The tasks are cost reduction and performance improvement.

Technology Roadmap

	2010 – 2020 – 2030 – 2040 – 2050
Solar heat supply	Efficiency improvement and system development for reducing introduction cost
Solar heat power generation	Cost reduction of converging systems
Heat storage technology	Cost reduction and performance improvement

(*Related roadmap: 32. Heat storage/insulation technology)

International Trends

Current state of diffusion

○ Introduction of solar heat utilization equipment was ~18GW (2007, single year), especially demand in China is increasing. a 250-MW trough-type plant are under construction.
○ Introduction of SHPG was ~2.7GW (2012, cumulative), and a large majority are attributed to Spain. This was due to the feed in tariff. Since 2012 the feed in tariff does not apply to new plants, and construction of new plants in Spain may reduce drastically in future.
○ At the moment the country most actively constructing SHPG plants is US. Large-scale plants such as a 337-MW tower-type plant and to move onto cost reduction through operation temperature increase (supercritical condition) and cost reduction and efficiency improvement of relevant receivers. New introduction is also expanding in places such as Middle East North Africa and South Africa.

Trend in technology development

○ TD of SHPG is mainly conducted in US, Spain, Germany, Italy and Israel. R&D of parabolic trough type is mainly conducted in Spain, Germany and Italy, where technology is at a mature stage and in the phase of cost reduction. Linear Fresnel type is developed mainly in Germany. Tower-type is mainly developed in Spain and US, where R&D is expected

International competitiveness of Japan

○ TD of SHSS is near complete. For SHPG, Japan lacks accumulation of solar light/heat converging technologies, but many technologies etc. for steam turbines, controls and manufacturing of various components are at the highest level globally.

6. Marine Energy Utilization

Technology Overview

- ○ Marine energy power generation is a method to generate electricity by rotating turbines using energies captured from wave power, tidal power, tidal barrage, ocean temperature difference, etc. Currently development and demonstration of each technology are conducted concurrently.
- ○ Compared to SPG and WPG, tidal power generation, etc., has an advantage of less short-cycle fluctuation in power output, and has a significant potential to Japan surrounded by ocean. By solving issues such as cost reduction, their GH gas reduction effects in future are large.
- ○ Global introduction estimated by IEA (WEO2012, Current Policies Scenario) is 8 GW, 32 TWh in 2035.

Trend and Issues in Technology Development in Japan

- ○ METI is conducting development and demonstration research of generation technologies utilizing ocean energies such as wave power and tidal power.
- ○ The Port and Airport Research Institute has been conducting R&D of generation technologies utilizing wave power, etc.
- ○ The technological tasks include reduction of generation cost (e.g., improvement of generation efficiency, reduction of installation cost), improvement of durability (e.g., adaptation to the ocean environment, load mitigation pertaining to equipment), and improvement of reliability.

Technology Roadmap

	2010 – 2020 – 2030 – 2040 – 2050
Development of real machine	Development of real machine aiming at achieving generation cost of ¥40/kWh or less on practical application
Reduction of generation cost	Establishment of next-generation technologies aiming at achieving generation cost of ¥20/kWh or less

International Trends

Current state of diffusion

- ○ Global application in 2010 was 526MW (Wave power: 3.2MW, tidal barrage: 518MW, tidal power: 5.2MW, ocean thermal energy conversion: 0.3MW). Except tidal barrage, a large majority of application were demonstration facilities.
- ○ EU has been conducting industrialization of ocean energy power generation utilizing wave power and tidal power, and experimental and demonstration facility is in operation since 2008. US also commenced demonstration of wave power generation 150kW and tidal power generation 60kW in 2011, and is currently conducting construction of a platform to enable large-scale demonstrations.
- ○ Construction of commercial plants for tidal barrage power generation commenced in the 1980s due to its mechanical similarity to hydraulic power generation. Introduction is progressing in France, China and Korea.

Trend in technology development

- ○ US DOE invested research funds totaling 130 million US dollars in the fields of ocean and fluid dynamics for 2008-2012, conducting construction of test facilities, optimization of wave power capturing, designing and development of components, and development of ocean temperature difference energy conversion systems.
- ○ EU is assisting through construction of a large-scale joint experimental facility in Scotland, standardization of power transmission and distribution systems, etc. Demonstration of wave power and tidal power generation has already been progressing in EU, and currently in the process of designing and approval for construction of large-scale commercial plants.

International competitiveness of Japan

- ○ Japan is in the stage of R&D and demonstration of various forms of ocean energy power generation.

7. Geothermal Power Generation

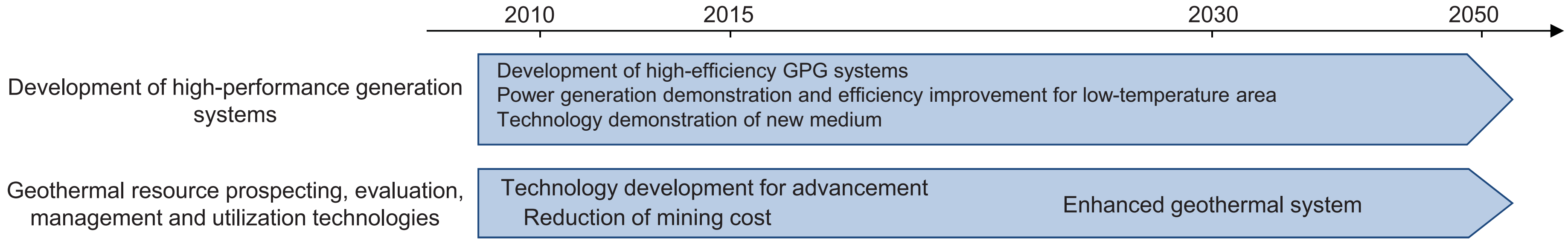
Technology Overview

- Geothermal power generation (GPG) is a method to generate electricity by rotating turbines using high temperature steam existing in the ground of volcanic zones etc. The flash-type is the conventional system that uses steam. Binary power generation that generates electricity using relatively low temperature hot water etc. has been introduced recently.
- Unlike WPG or SPG, the power output of GPG is unsusceptible to the climate or weather, being a stable power source with high capacity factor of ~70%. The generation cost of GPG is relatively low among renewable energies and CO_2 emissions during generation is almost zero. Additionally, Japan is considered to have the third largest geothermal resource potential in the world (~2.34GW).
- IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of geothermal utilization technologies to be ~0.5 billion tons in 2050.

Trend and Issues in Technology Development in Japan

- METI is conducting development of geothermal prospecting technologies (GPT) and high-efficiency GPG systems.
- MOE is conducting efficiency improvement of hot spring binary GPG, demonstration of new low boiling point medium, advancement of eco-friendly slope mining techniques.
- The technological tasks for diffusion of flash-type GPG include cost reduction (e.g. mining cost), improvement of GPT, scale issues, and efficiency improvements.
- It is important to develop technologies that accurately assess geothermal reservoirs in the ground and appropriately manage and utilize them, contributing to stable power supply. Research on efficiency improvement and new low boiling point medium is also needed for diffusion of binary power generation that effectively utilizes local low-temperature geothermal resources currently not in use.
- Along with improvement in utilization efficiency of hot spring binary power generation, demonstration on the safety of medium and development of mining technique avoiding or minimizing damage to the environment are needed.

Technology Roadmap



International Trends

Current state of diffusion

- Global application as of 2010 is 10,716MW, and generation amount is 68TWh. The average annual generation amount increase from 2000 to 2010 reached 3%.
- Generation plant capacity applied in US is 3,000MW, mainly in CA. Application for the whole EU region is 1.5GW, and a majority are attributed to Italy and Iceland.

Trend in technology development

- US is conducting technology development focusing on advanced GPG system, evaluation of hot water resources, utilization of low temperature resources, and analysis of GPG systems. Additionally, a development program targeting 2025 details R&D on technologies for selection and evaluation of low-risk spots and low-cost high-efficiency mining and finishing technologies.
- EU is conducting support for a 100kW-class pilot plant of Enhanced geothermal system in France and improvement in the basic concept of Enhanced geothermal system through investigation on earthquake induction. The technology roadmap of European Geothermal Energy Council lists technology development items targeting 2020, including improvement of generation efficiency, demonstration of Enhanced geothermal system, improvement of hear source prospecting methods and mining techniques. It also lists priority tasks targeting after 2020, including practical application of deep heat source/reservoir prospecting and development of underground fluid simulation.

International competitiveness of Japan

- For flash-type turbines, 3 major Japanese companies are dominating the share and technology, and leading GPG development in developing countries.
- For ground facilities and prospecting technology, US, NZ and Italy are side-by-side, while Japanese companies possess knowhow of prospecting complex stratums.

8. Biomass Utilization

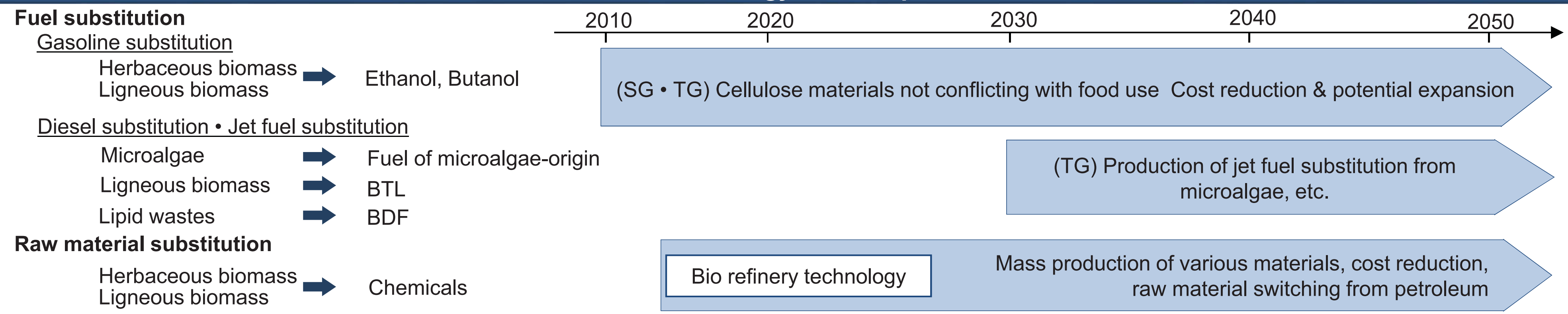
Technology Overview

- ○ The first-generation biofuels made from sugarcanes, etc., have conflicts with the use of raw materials as food. Therefore, countries are conducting activities for practical application of sustainable second-generation (SG) biofuels made from non-edible vegetation or non-edible biomass (e.g., cellulose bioethanol, Biomass To Liquid (BTL)) and the third-generation (TG) biofuels made from microalgae, as well as new conversion technologies for hydrogenated biodiesel which can be used for airplanes.
- ○ IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of power generation and transmission technologies using biomass fuels to be ~3.3 billion tons in 2050.

Trend and Issues in Technology Development in Japan

- ○ METI and the Ministry of Agriculture, Forestry and Fisheries (MAFF) are promoting R&D of technologies to produce SG cellulose bioethanol at high efficiency and low cost, and next-generation technologies such as gasification, BTL technologies, microalgae biofuels, as well as innovative process to directly produce basic chemicals from non-edible biomass using chemical catalysts, etc.
- ○ MOE is conducting technology demonstration, etc., for application of technologies to produce ethanol from wastes and advancement of biodiesel.
- ○ For bioethanol, overcoming conflicts with use as food and reduction of material and fuel conversion costs are important. The task is development of pretreatment and saccharification technologies for agricultural residues and energy crops that grow in areas not suited for food productions. For microalgae biofuel, the task is establishment, etc., of cultivation technologies. For non-edible biomass feedstock, the tasks are production cost reduction and increasing their values and performance. High-performance systemization of biomass fuel capture/transport is another task.

Technology Roadmap



International Trends

Current state of diffusion

- ○ Bioethanol consumption in Japan in FY 2011 was 350ML (210ML of crude oil equivalent).
- ○ US introduced "Renewable Fuel Standard (FRS2)" that requires use of a certain amount of biofuels for vehicle. Use rate will be increased progressively till 2022. Ethanol production in 2010 was 52.8GL, biodiesel production was 3.7GL.
- ○ EU will increase the use rate of renewable fuels for vehicle to 10% by 2020. Ethanol production in 2010 was 4.27GL, biodiesel production was 9.7GL. Ethanol consumption in 2010 was 5.9GL, biodiesel consumption was 12.7GL.

Trend in technology development

- ○ In US, the Advanced Research Projects Agency - Energy (ARPA-E) under DOE conducted invitation and selection of TD for improving energy productivity. R&D aiming at fostering of domestic bio energy industry is promoted, in order to achieving the target of RFS2 under the Energy Independence and Security Act.
- ○ EU is conducting local demonstration projects as part of the "Intelligent Energy Europe Program", promoting establishment of local biofuel supply chains.

International competitiveness of Japan

- ○ Japan is conducting TD for production of biofuels not conflicting with food use, aiming at practical application.

9. Nuclear Power Generation

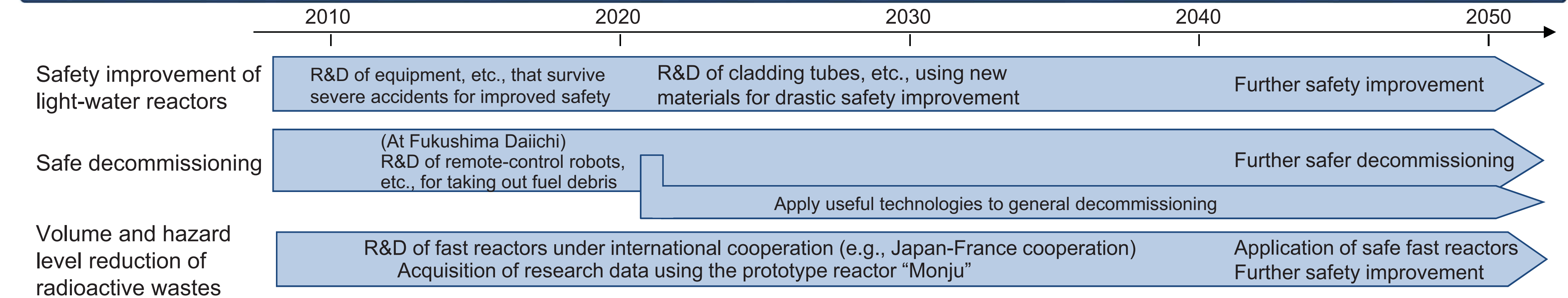
Technology Overview

- ○ Types of reactors for nuclear power generation (NPG) include light-water reactors already in use, medium- and small-sized reactors close to practical application, fast reactors whose R&D is advancing, and high-temperature gas-cooled reactors in the early research stage.
- ○ Nuclear fuel cycles reuse uranium and plutonium gained by reprocessing spent fuel used by nuclear power stations, aiming at effective utilization of uranium resources and reduction of the volume and hazard level of radioactive wastes.
- ○ "Nuclear Energy in Perspective" (OECD/NEA, November 2010) states that "using nuclear power reduces CO_2 emissions by up to 2.9 Gt (gigatonnes) per year, assuming that this power would otherwise be produced by burning coal."

Trend and Issues in Technology Development in Japan

- ○ R&D of light-water reactors focuses on decommissioning and safety improvement, based on the accident at TEPCO Fukushima Daiichi Nuclear Power Station.
- ○ R&D of radioactive waste processing techniques is an important task regardless of the direction of nuclear policies.
- ○ R&D of fast reactors which enable volume and toxic level reduction of wastes is conducted under international cooperation.
- ○ The prototype fast reactor "Monju" is currently stopped due to instrument troubles and revision of nuclear policies undertaking based on the Fukushima accident. Drastic reform plans for the Japan Atomic Energy Agency are currently under consideration including operation management systems of "Monju".

Technology Roadmap



○Develop human resources specializing in safety securement and decommissioning, and promote TD using the developed human resources

International Trends

Current state of diffusion

- ○ The share of NPG in the global power generation was 13%, and NPG in operation as of January 1st, 2013, was 429 units in 30 countries according to "World Nuclear Power Plants" (JAIF, May 2013). 76 units are currently under construction in 17 countries.

Trend in technology development

- ○ US government agencies, etc., are conducting development of plant-level safety analysis codes, R&D of advanced fuels that are highly resistant to accidents, and development and demonstration of advanced instruments and control systems. In the industrial field, a flexible and versatile accident mitigation strategy was proposed, and measures taken.
- ○ France is conducting research for knowledge accumulation on natural phenomenon risks, validation of seismic structure behavior models, understanding of aging mechanisms of equipment vital for safety, understanding of the soundness of protective systems, etc., assuming emergencies.
- ○ In countries such as US and Germany where commercial NPG is in the process of decommissioning, activities are being conducted for reducing exposure to workers and reducing the amount of waste produced.
- ○ Development of fast reactors is continuing in major countries such as France, Russia and China, even after the Fukushima accident, aiming at effective utilization of uranium resources and reduction of the volume and hazard level of radioactive wastes. Fast reactors to be developed in future need advanced safety taking into account the accident. In May 2013, safety design requirements of fast reactors were put together at the Generation IV International Forum under the international cooperation framework, where Japan was the main organizer.

International competitiveness of Japan

- ○ Even after the Fukushima accident NPG projects are considered to expand worldwide, and Japan's nuclear technologies have received strong interest from many countries including Middle East countries (e.g., Turkey, Saudi Arabia), East European countries (e.g., Poland, Czech), India, and Brazil.

10. CO_2 Capture and Storage (CCS)

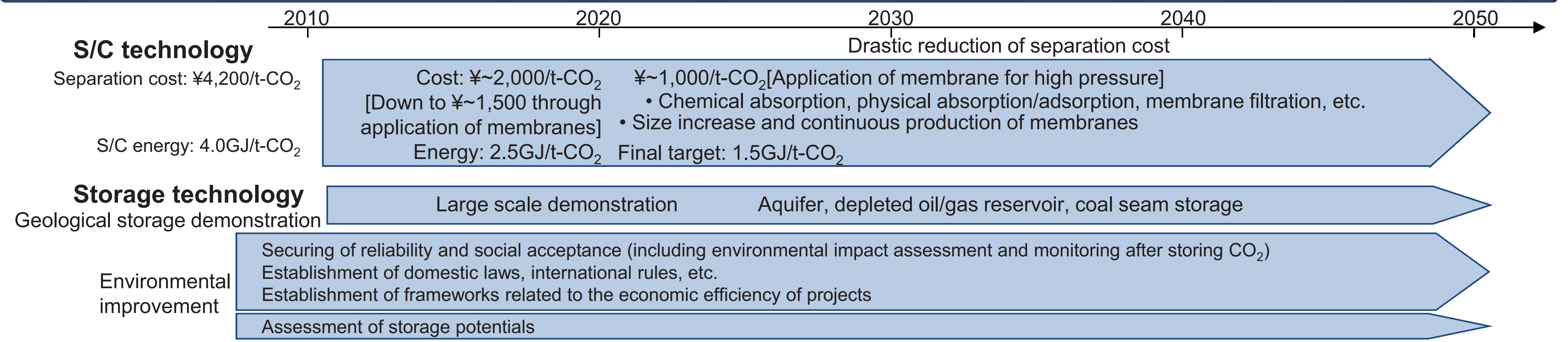
Technology Overview

- Carbon Dioxide Capture and Storage (CCS) is a technology where CO_2 is separated and captured from exhaust gas emitted from large-scale emission sources such as TPG and then stored or sequestrated in the ground or ocean on a long-term basis, and thereby contributing to a significant reduction in the global CO_2 emissions.
- CCS consists of 4 functions, namely, separation/capture, transport, pressured filling and storage. The core TD is separation/capture technologies and storage technologies.
- Separation/capture methods include chemical absorption, physical absorption, membrane filtration, physical adsorption and low temperature processing. Storage methods includes geological storage and ocean sequestration, where geological storage include aquifer storage, enhanced oil/gas recovery, depleted oil/gas reservoir storage, sequestration in coal seams.
- IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of CCS technologies to be ~7.1 billion tons in 2050.

Trend and Issues in Technology Development in Japan

- Development of novel solid absorbent based on chemical absorption liquids, advancement of chemical absorption process simulation technologies, and R&D related to establishment of safety assessment technologies suitable for specific geological conditions are conducted.
- International cooperation is promoted, such as technology collaboration at the CSLF and participation in large-scale projects overseas.
- The total cost of CCS for all process is ¥3,000-7,000/t-CO_2. The current separation/capture energy cost is 4.0GJ/t-CO_2. Future task is to reduce the monetary and energy cost of CO_2 separation/capture that account for ~60% of the total cost. It also is important to secure interface between TPG systems and CO_2 separation/capture technology as well as development of membranes suitable for CO_2 separation/capture under pressure.
- Practical application of CCS requires proper prospecting/assessing methods for storage locations and amount (including candidates), establishment of method and routes for transport, consideration on underground transition/migration of CO_2 injected into reservoirs, proper response to international standardization and relevant treaties, etc.

Technology Roadmap



(* Related roadmap: 26. Environment-conscious iron manufacturing process)

International Trends

Current extent of diffusion

- In US, commercial projects and demonstrations are in progress at several locations. About 10 large-scale demonstrations and commercial projects are planned for the next few years.
- In Europe, Norway, UK, Holland, and Spain is actively working on CCS, while large-scale demonstration projects for power generation are progressing more slowly than planned.
- CCS is also planned or conducted in Canada, Australia and China, and the large-scale projects in development is totaling 72 in the world (includes those under contemplation).
- Captures CO_2 are often used for Enhanced Oil Recovery (EOR).

Trend in technology development

- The Carbon Sequestration Program of US DOE funds averaging 150 million dollars per year for the last few years by using the American Recovery and Reinvestment Act (ARRA). ARPA-E also selected several relevant research field from invited research projects. The Program of DOE is promoting research on conversion of CO_2 into hydrocarbons, chemical synthesis, etc. Some private companies are also conducting research on CO_2 capturing from the air (geo-engineering).
- EU is conducting R&D support for prediction and monitoring of long-term transition of underground stored CO_2, etc., as part of FP7.

International competitiveness of Japan

- Japan possesses advanced technologies for low-cost low-energy CO_2 capturing which is the core of CCS. The technology includes highly energy-efficient absorption liquid.
- For geological storage, due to generally complex stratum of Japan's land, prospecting techniques and knowhow specific to regional features have been accumulated.

11. Artificial Photosynthesis

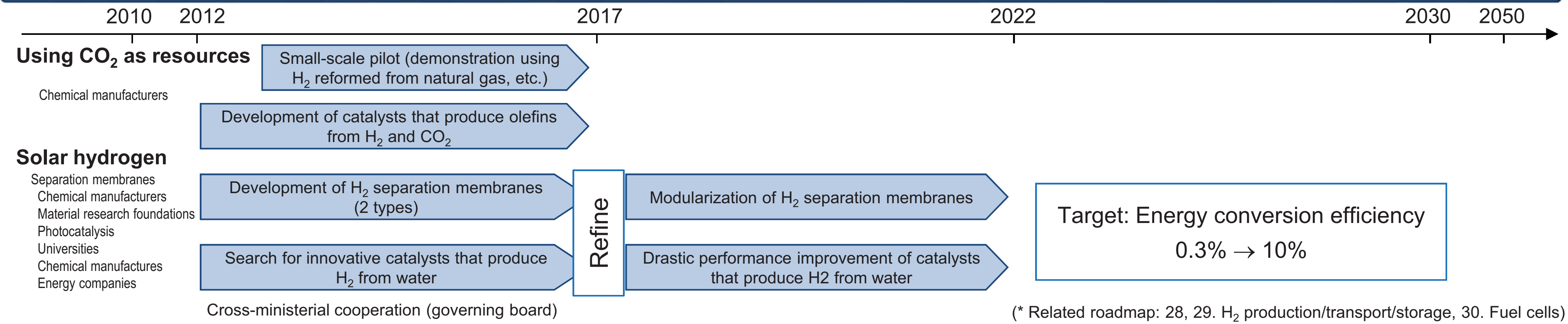
Technology Overview

- ○ Procurement of raw materials required for production of chemical products, i.e. fossil resources, relies on select producing countries, whose stable supply in future is dubious. Additionally, consumption of a large amount of fossil resources is resulting in a large amount of CO2 emissions .
- ○ Catalyst technologies are the key for realizing substitutes for fossil resources and materializing low-carbon society, where Japan has an advantage over the world. Utilization of catalyst technologies may achieve "diversification of raw materials of chemical products" and solve global resource and environmental issues. One of such technologies is artificial photosynthesis (ARP).
- ○ ARP generates H_2 and O_2 from water using solar energy and produces organic compounds from generated H_2 and CO_2 through catalysis. Technologies that directly produce organic compounds from water and CO_2 are in the basic research stage.
- ○ ARP is considered to have two CO_2 reduction effects, one is carbon fixation and another is reduction of energy required for production of organic compounds.

Trends and Issues in Technology Development in Japan

- ○ In 2012, "Japan Technological Research Association of Artificial Photosynthetic Chemical Process" (ARPChem) was established as a project of METI, and development of innovative catalysts to produce basic chemical products (e.g. raw materials for plastics) from CO_2 and water using solar energy, and TD for establishment, etc., of the process base commenced. Currently, development is being promoted for technology that produces H2 and O2 by splitting water utilizing photocatalysts safely separating H2 using separation membrane, and then producing olefins using synthetic catalysts.
- ○ ARPChem aims at development of small pilot-scale olefin synthesis process by FY 2016 and achievement of 10% level of energy conversion efficiency for photocatalysts by FY 2021. The main task is development, etc., of photocatalysts that efficiently generates H2 at the visible light region.
- ○ In its "Element Strategy Program", MEXT is conducting development of alternative non-rare metal materials that may contribute to ARP by elucidating solid/liquid and gas/liquid complex system reaction of elements through close collaboration of basic science and experimental chemistry.

Technology Roadmap



(* Related roadmap: 28, 29. H_2 production/transport/storage, 30. Fuel cells)

International Trends

Current state of diffusion

- ○ Currently in the basic research stage, remaining at the laboratory-level development phase.

Trend in technology development

- ○ US DOE is funding 122 million dollars to the construction of "Solar Fuels Energy Innovation Hub" led by the California Institute of Technology, aiming at commercial application of a technology that converts solar energy to chemical fuels. Specifically, the project aims at finding out a method to convert solar energy to fuels via light absorber, catalysts, molecular linker, separation membranes, etc., and use as automotive fuels in future. DOE also conducts development of high-efficiency ARP conversion technologies at the Joint Center for Artificial Photosynthesis (JCAP, established in 2011) , aiming at realization of substitution to existing transportation fuels. JCAP is aiming at achieving a conversion efficiency 10 times more efficient than the photosynthesis in the nature within 10 years, and necessary element technologies are currently selected and developed.
- ○ EU has selected several research projects for producing liquid fuels such as H_2 from CO_2 using ARP out of invited projects for its FP7, and development of photo catalysis materials and basic research on redox-active complexes.

International competitiveness of Japan

- ○ Japan leads the world in the photo catalysis technology that is the core of ARP, and Japan's technologies on ceramic separation membrane, synthetic catalyst technologies, etc., are also world class.

12. Next-Generation Automobiles (HV, PHV, EV, Clean Diesel Vehicle, Etc.)

Technology Overview

- ○ Hybrid vehicles (HV) use an internal-combustion engine and a motor as power sources. If the motor used in HV is powered by electricity charged at home, they are called plug-in hybrid vehicles (PHV). Electric vehicles (EV) run solely on a motor powered by electricity stored in batteries.
- ○ HV and EV reduce CO_2 emissions to 1/2-1/3 and ~1/4* compared to gasoline vehicles, respectively. EV in particular allows a significant reduction of CO2 emissions during power generation and running by using electricity with high renewable energy contribution. ** Report of 'JHFC Comprehensive Efficiency Study Results'*
- ○ IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of next-generation vehicles (PHV, EV) to be ~1.7 billion tons in 2050.

Trends and Issues in Technology Development in Japan

- ○ METI is conducting TD for further performance improvement of Li-ion batteries aiming for diffusion of EV and PHV, R&D of innovative batteries for realizing EV as drivable as gasoline vehicles, and development of standard evaluation methods for materials that contribute to performance improvement of batteries.
- ○ Further, projects are conducted for development of high-performance innovative magnets without relying on rare earth, soft magnetic materials with low energy loss, and high-efficiency motors which fully utilize the performance of the novel magnets and soft magnetic materials.
- ○ MEXT is conducting development of post Li-ion batteries, aiming at realization in 2030s in collaboration with METI on material evaluations.

Technology Roadmap

EV, PHV

		2010	2020	2030	2050
Batteries for PHV	Energy density	30-50Wh/kg	200Wh/kg		
	Cost	¥10,000-15,000/kWh	¥20,000/kWh		
Batteries for EV	Energy density	60-100Wh/kg	250Wh/kg	500Wh/kg	700Wh/kg
	Cost	¥70,000-100,000/kWh	≤ ¥20,0002/kWh	~ ¥10,000/kWh	~ ¥5,000/kWh
Mileage of EV per charge		200 km	350 km	500 km	700 km
EV		• Performance improvement of Li-ion batteries		• Development, etc., of post Li-ion batteries	

(* Related roadmap: 31. High-performance electricity storage)

International Trends

Current extent of diffusion

- ○ Global sales of HV, PHV and EV in 2011 was estimated to be ~2.5 million vehicles, where a large majority were made in US or Japan. The number of EV and PHV is still small as they are new to the consumer market, but is likely to increase in future. Diffusion of EV and PHV requires establishment of charging infrastructure, which is progressing in many countries including Japan.
- ○ Clean diesel vehicles are widely introduced in EU region, and about half of new vehicles sold was clean diesel vehicles.

Trend in technology development

- ○ US is supporting development and demonstration of Li-ion batteries, development of vehicle simulation software, cost reduction and durability improvement of fuel cells, establishment of H_2 production technologies, etc., through grants by ARRA and DOE. President Obama announced in the State of the Union Address 2013 that US would increase the number of next-generation vehicles to 1 million by 2015 and promote R&D through establishment of new TD funds.
- ○ EU is providing R&D funds of 1 billion Euro to mechanical technologies related to EV and internal combustion engines through FP7. The Green Car Initiative states that innovative electrically driven vehicles will be commercialized by ~2025.

International competitiveness of Japan

- ○ Japan plays a leading role in introduction and diffusion of HV, and Japanese manufacturers hold a large majority of shares. Japan is also strong on EV and PHV, where the first mass produced vehicles were produced by a Japanese company.

13. Next-Generation Automobiles (FCV)

Technology Overview

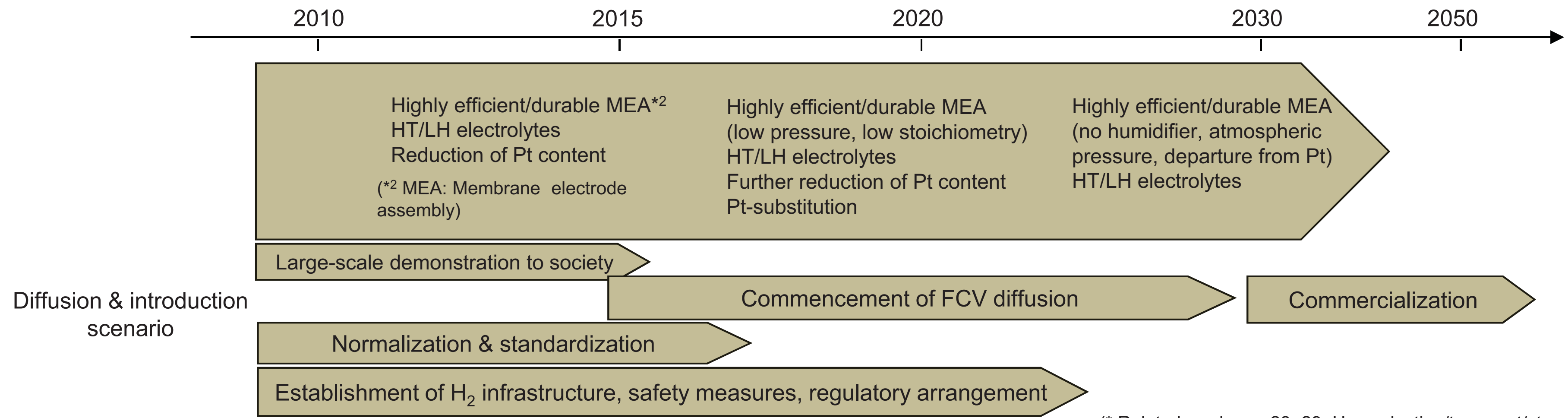
- ○Fuel cell vehicles (FCV) run on electricity generated through reaction of H_2 (fuel) and O_2 in the air.
- ○FCV may reduce CO_2 emissions to ~1/3 compared to existing gasoline vehicles*1. CO_2 emissions during H_2 production can be significantly reduced by using electricity with high renewable energy contribution.
- ○The task is development of high-performance fuel cells, high-capacity H_2 storage technology, and establishment of H_2 infrastructure.
- ○IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of HCF to be ~0.7 billion tons in 2050.

*[*1] Report of 'JHFC Comprehensive Efficiency Study Results'*

Trend and Issues in Technology Development in Japan

- ○Sales of mass produced cars have not yet started. Rental cars and demonstrative buses are introduced in places. In 2011, major Japanese car manufacturers and oil/gas companies presented a joint statement stating vehicle development and establishment of H_2 refilling infrastructure will be promoted to enable diffusion of mass produced FCV from 2015.
- ○MOE is planning to conduct development of no CO_2 emission systems by combining small-scale solar H_2 stations and fuel cells as well as development of large fixed-route fuel cell buses.
- ○TD of high-temperature/low-humidity (HT/LH) electrolytes, reduction of platinum content, platinum-substitute catalysts, etc., is essential to reduce cost of solid polymer fuel cells that are the very base of FCV.

Technology Roadmap



(* Related roadmap: 28, 29. H_2 production/transport/storage, 30: Fuel cells)

International Trends

Current state of diffusion

- ○ Sales of mass produced vehicles have not yet commenced anywhere in the world.

Trend in technology development

- ○ US is conducting R&D for DOE Hydrogen and Fuel Cells Program, aiming at thin film formation of electrolytes for fuel cells, performance improvement of catalysts, improvement of fuel cell stacks, etc. President Obama announced in the State of the Union Address 2013 that US would increase the number of next-generation vehicles to 1 million by 2015 and promote R&D through establishment of new TD funds.
- ○ The Joint Program on Fuel Cells and Hydrogen states that EU will assist large-scale demonstration of vehicles and filling facilities, development of bipolar plates, development of auxiliary equipment for filling facilities, quality assurance of H_2, etc., totaling 68.5 million Euro (FY 2013).

International competitiveness of Japan

- ○Although currently no mass produced vehicles are sold, Japanese manufacturers are promoting development of FCV aiming at practical diffusion. There also are cases of joint development through international collaborations.

14. Aircrafts, Ships, Railways (Low Fuel Consumption Airplanes (Low Noise))

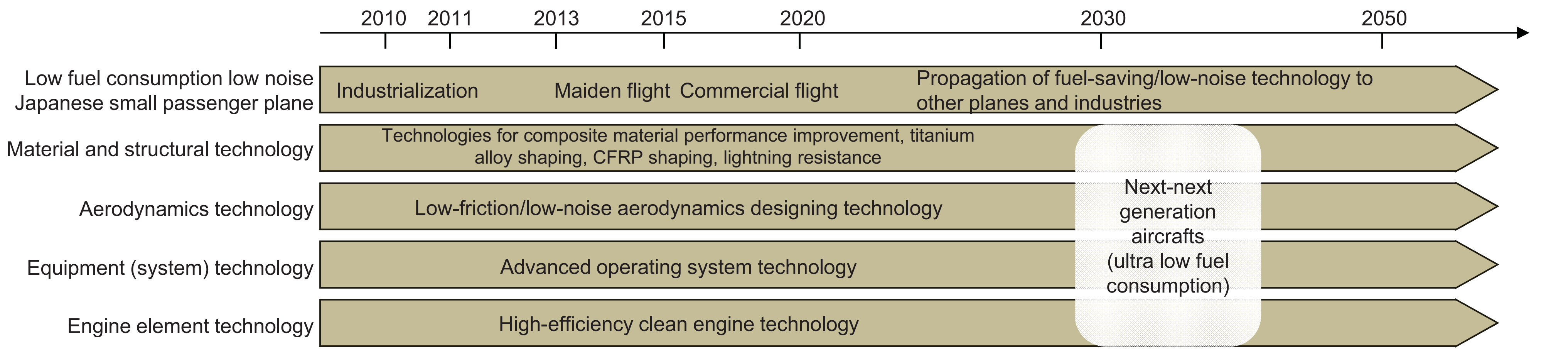
Technology Overview

- ○ Demand for aircrafts is likely to increase due to the convenience and high speed they offer. However, aircrafts emit a larger amount of CO_2 per transport volume compared to other transportation systems, and fuel-saving technologies are highly sought after.
- ○ Low-carbonization of aircrafts requires R&D on carbon fiber reinforced polymers (CFRP), low-friction/low-noise aerodynamic designing technology, advanced operating technology, high-efficiency clean engine technologies, etc.
- ○ Fuel-saving technologies of aircrafts will propagate to other transportation systems, such as vehicles, railways, and ships, contributing their energy saving.
- ○ US FAA "Destination 2025" aims for halving emissions by 2050 compared to 2005.

Trends and Issues in Technology Development in Japan

- ○ METI is conducting support for R&D of next-generation aircraft structural materials for reducing weight and fuel consumption, development of basic technologies for advanced aircraft systems.
- ○ Reduction of aircraft fuel consumption through weight reduction as well as utilization promotion of ground power units and efficient transportation systems at airports are required.

Technology Roadmap



(* Related roadmap: 21. Innovative structural materials)

International Trends

Current state of diffusion

- ○ Low-carbon technologies are diffusing. Example: Boeing 787 (Dreamliner) and Airbus A350 called as next-generation airplanes have adopted CFRP.
- ○ Usage rate of carbon fiber composite materials in large consumer planes exceeds 50%.
- ○ International Civil Aviation Organization (ICAO) takes notice of technological methods, and the general meeting resolution in 2010 adopted improvement of fuel efficiency by 2% per year until 2050.

Trend in technology development

- ○ In US, FAA and 5 aircraft manufacturers formed a collaboration system and started TD on suppression of fuel consumption and pollutant emissions in 2010. Plane body technology and sustainability and potential impacts of alternative fuels are evaluated. NASA is conducting research on light weight plane body, high aspect ratio wings, high-efficiency gas generator, alternative fuels, etc., for achieving reduction of fuel consumption by 50%.
- ○ EU is assisting R&D through FP7, on development of novel designs and new technology for fixed wing aircrafts, development of light weight planes using new structural materials, development of novel rotor blades and engines, integration demonstration of high-efficiency low-noise engine technologies, and R&D on full electrification of auxiliary engines.

International competitiveness of Japan

- ○ Japan's aircraft industry has been conducting development of small passenger planes. Many Japanese component and material manufacturers are playing core roles in the development and production of the latest large planes overseas.

15. Aircrafts, Ships, Railways (High-Efficiency Ships)

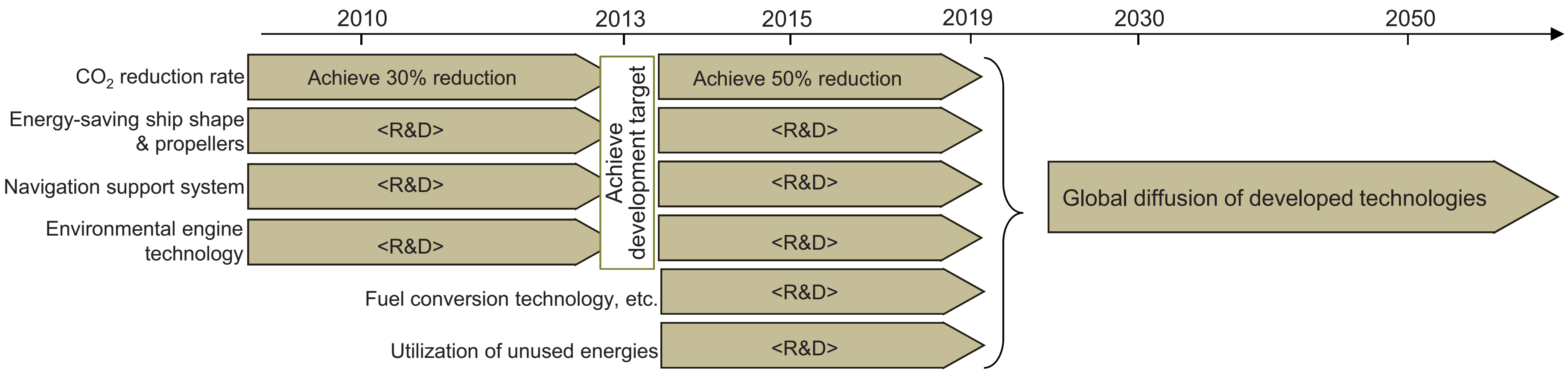
Technology Overview

- ○ CO_2 emissions by ships will be reduced by developing advanced energy-saving ships through innovative element technologies, including low-friction high propulsion efficiency ship shapes, hull friction reduction technology, high-efficiency propellers, navigation support system, environmental performance engines, and fuel conversion technologies such as LNG.
- ○ EU White Paper on Transport proposes CO_2 emissions in oceanic transport reduced by 40% (50% if possible) by 2050, compared to 2005, via ship technologies, high quality fuels, and operation controls. International Maritime Organization (IMO) estimates new type ships reduce CO_2 by 10-50% compared to conventional ships, and operation methods can achieve 10-50% CO_2 reduction for all ships, totaling 25-75% CO_2 reduction.

Trends and Issues in Technology Development in Japan

- ○ Japanese manufacturers, ship-builders and marine transportation business operators worked together in TD support projects conducted for 4 years (FY 2008-2012), resulting in establishment of element technology that achieves a 30% reduction in CO_2 emissions.
- ○ In anticipation of stricter international CO_2 emission regulations in future, MLIT will promote R&D of next-generation marine environment technologies aiming at reduction of CO_2 emissions by 50%, and thereby achieving revitalization and strengthening of international competitiveness of Japan's maritime industry as well as reduction of environmental burden arising from international shipping.

Technology Roadmap



International Trends

Current state of diffusion

- ○ IMO introduced CO_2 emission index for ships built from 2013, relevant CO_2 emissions regulations and compulsory creation of energy-saving navigation plans, expecting CO_2 emissions reduction by ~20% by 2030 and ~35% by 2050.

Trend in technology development

- ○ EU FP7 assists R&D on more efficient structure and materials, electric ships, accurate geometric simulations for optimized ship designing, environment-conscious anti-fouling technology for optimized energy use, green renovation by remodeling propelling systems, new ship engine, high-efficiency hybrid propelling systems for medium/small sized ships, innovative energy control systems for cargo ships, innovative ship propelling concept, contra-rotating propellers, tip loaded propellers, energy-saving pod propulsion. White Paper on Transport: Roadmap to a Single European Transport Area proposes CO_2 emissions in oceanic transport reduced by 40% (50% if possible) by 2050, compared to 2005, via ship technologies, high quality fuels, and operation controls, as part of the vision for competitive and sustainable transport systems.

International competitiveness of Japan

- ○ A 4-year project (FY 2008-2012) aiming at a 30% reduction of CO_2 emissions resulted in steady emergence of positive outcomes such as some Japanese ship-builders received orders for ships into which the project results are incorporated. In future discussions on economic methods such as fuel oil charging systems will develop, which Japan will continue leading based on talks for UN FCCC. Japan's energy-saving ship technologies will be further developed ahead of the world, anticipating stricter international CO_2 emission regulations in future

16. Aircrafts, Ships, Railways (High-Efficiency Railway Vehicle)

Technology Overview

○ Efficiency of high-speed railways can be improved by ~20% through weight reduction, aerodynamic analysis by genetic algorithm, reduction of speed change frequency by train tilting systems, etc. (Approximately 50% improvement compared to 1960s for the same speed range) *1

○ Efficiency improvement by ~20% is expected by using hybrid railway vehicles that enable effective utilization of damping energies, etc., compared to diesel railway vehicles.*2

○ Practical application of fuel cell railway vehicle*3 currently under development will suppress GH gas and exhaust gas emissions at non-electrified sections.

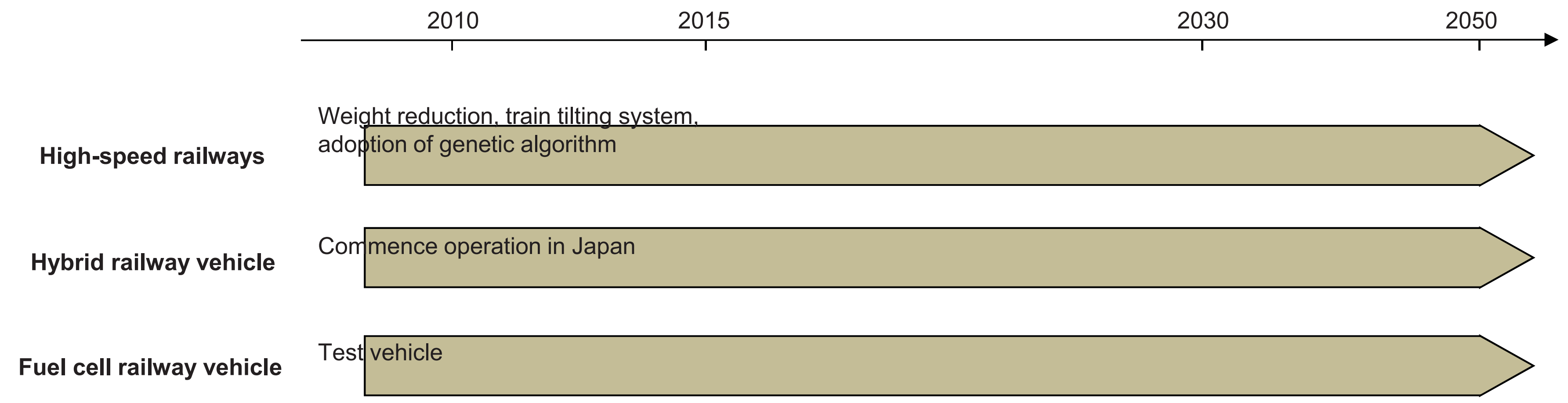
**1 Central JR webpage. Comparison between the 700 series and the N700 series. The 0 series for 1960s.*
**2 Energy-saving effects of the NE Train based on the JR East press release materials.*
**3 The NE Train based on the JR East press release materials.*

Trends and Issues in Technology Development in Japan

○ MLIT is supporting TD for establishing electricity systems using natural energies and electricity storage technologies, development of energy-saving battery trains for further improving environmental performance of trains, etc.

○ For energy conservation, diffusion of variable voltage variable frequency control, regenerative brakes, etc., is being promoted. Tasks for further energy conservation include suppression of regenerative brake failures (electricity storage, control, etc.) and reduction of vehicle weight.

Technology Roadmap



(* Related roadmap: 21. Innovative structural materials, 30. Fuel cells)

International Trends

Current state of diffusion

○ Europe is conducting activities for improving fuel efficiency through regeneration technology and eco-driving. The Railenergy project conducted until 2010 (in which 27 entities participated, such as UIC, UNIFE, and manufacturers) compiled measures for reducing total energy consumption by 8%.

Trend in technology development

○ TD of railway vehicles is conducted mainly in Europe and Japan. In Europe there are many diesel vehicles, and TD is conducted centering on efficiency improvement of engines. R&D of hybrid vehicles is also conducted.

International competitiveness of Japan

○ Japan's railway technology is world class, represented by the Bullet Train that have been in stable operation since its emergence.

17. Intelligent Transport Systems

Technology Overview

- Intelligent Transport Systems (ITS) is a technology where traffic accidents and congestion are reduced by networking passengers, roads and vehicles through advanced IT and control technologies, resulting in improved practical mileage of vehicles and CO_2 emissions reduction.
- Traffic can be optimized by dynamic navigation, lights control, etc., through simulations using V2V/V2I communications, positioning systems (e.g., GPS, radar), probe information (location, time, road condition, etc., data collect from running vehicles, allowing processing to congestion information, etc.) and such. Safer and more efficient movements and transport can be achieved through constant speed running (e.g., ACC), platooning, automatic travelling, etc.

Trends and Issues in Technology Development in Japan

- METI is conducting TD for automatic travelling and platooning and promotion projects on consolidation/communization of probe information. MLIT is conducting experiments aiming at use of real-time probe information gained from “ITS spots” for advanced distribution efficiency and traffic control, jointly with distributers and major shippers at the Hakata port.
- Effective road use requires implementation of optimal navigation systems and optimal departure time prediction systems that utilize probe traffic information, as well as development of integrated big data management systems for the information currently managed by car manufacturers and municipalities and retrofit on-board devices.
- Miniaturization, cost reduction, etc. of devices (e.g., censors) are the tasks for travel control technology, travel environment recognition technology and positioning technology required for automatic travelling and platooning technologies.

Technology Roadmap

	2010	2012	2020 – 2030 – 2050
Platooning technology	Research / testing on test courses	Demonstration experiments	Advancement, realization and distribution through conducting PDCA cycles
Automatic travelling technology	Research / travelling test on test courses		Advancement, realization and distribution through conducting PDCA cycles
Probe information utilization	Consideration on information sharing	Mutual utilization of information	Advancement, realization and distribution through conducting PDCA cycles
Advanced traffic/distribution technology (e.g., luggage management)	Demonstration experiments at model city/route		Advancement, realization and distribution through conducting PDCA cycles
Advancement of ITS communication	TD	Partial demonstration	Advancement, realization and distribution through conducting PDCA cycles
Diffusion	Constant speed running (e.g., ACC)		Utilization of probe information (2020); Platooning at optimal speed (2030); Automatic travelling (2050)

International Trends

Current extent of diffusion

- Japan started projects on fuel consumption reduction by improving travelling method of individual vehicles through advanced travelling control technology and traffic improvement through proper control of distance between vehicles.
- In 2009, US Ministry of Transport started a project called IntelliDrive for introducing V2V (vehicle-to-vehicle communication; vehicles communicate each other using roadside units) and V2I (vehicle-to-infrastructure communication; cars and roadside units communicate each other).

Trend in technology development

- US formulated and is conducting ITS Strategic Research Plan (2010-2014), funding 500 million dollars in 5 years to research topics such as vehicles connecting applications and dynamic trafficking systems. The Plan also aims at practical application of automatic travelling vehicles by 2020.
- EU is assisting development of urban multi-modal route planning services for mobile users and platooning as invited projects for FP7. EU is planning to achieve mutual utilization and high-speed standardization of ITS within the Europe region by 2020. EU Driving License Directive introduced eco-driving requirements on its revision, and states accelerated diffusion of ITS applications for supporting eco-driving.

International competitiveness of Japan

- Japan leads the world in development and introduction of car navigation systems and safe travel support systems.
- Japan holds an advantage over other countries in technological accuracy related to instantaneous information provision to cars in V2I and detection of vehicles and obstacles.
- ISO/TC 204 Organization promotes international standardization of Smartway and works on harmonization of ITS standards in collaboration with US and European governments.