18. Innovative Devices (Information System, Lighting, Display)

Technology Overview

○ Ultra-low power consumption (ULPC) devices in information systems are high-efficiency high-performance electronics parts and components such as highly integrated semiconductors, non-volatile memories, and displays.

○ Optical communication technology in information systems includes optelectronics technology where optical wiring and optical elements are used for energy saving, speed improvement and miniaturization, and technologies to achieve energy saving and larger capacity for optical elements and optical signal processing LSI that compose optical networks.

○ High expectations are placed on high-efficiency LED and organic EL lightings as high-efficiency next-generation lightings, for less energy consumption, longer life and higher color rendering properties compared to incandescent lamps and fluorescent lamps.

○ High expectations are placed on organic EL displays for realizing less energy consumption than LCD.

○ Efforts with above technologies have energy conservation potential of ~110Mt-CO_2 p.a. in Japan in 2050.

Trends and Issues in Technology Development in Japan

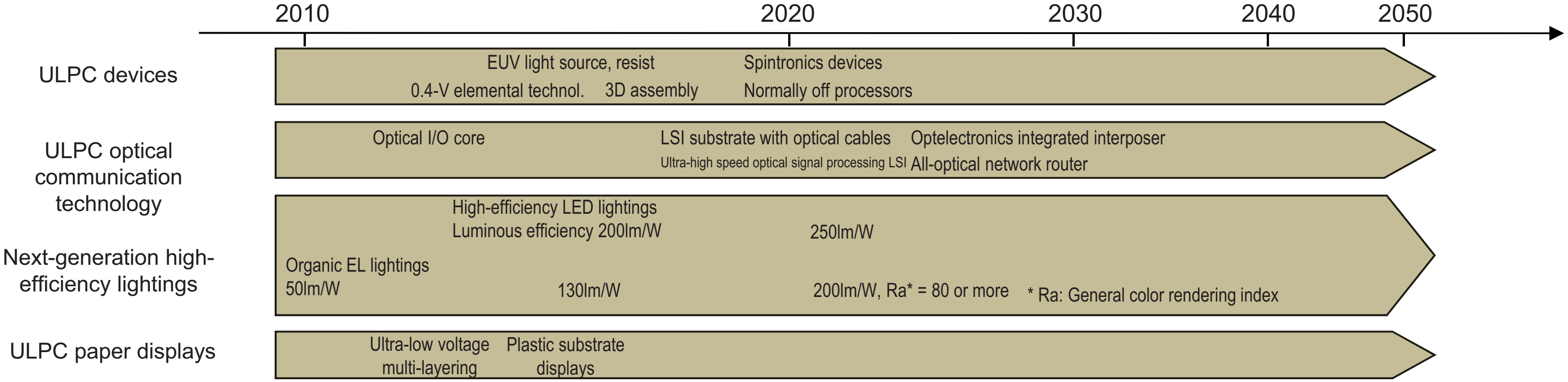
○ As new technology seeds, research on ULPC devices is promoted, including ‘next-generation lithography system’ for microfabrication, ‘3D implementation’ for higher integration, ‘ultra-low voltage devices’ for realizing low resistance and energy saving through new structure and materials, ‘normally off computing’ which uses energy only when needed, and ULPC ‘spintronics devices’ that replace silicon devices.

○ ULPC optical communication technology aims at miniaturization and energy saving of data centers and capacity improvement and energy saving of optical networks through development of ‘optelectronics technology’.

○ For high-efficiency next-generation lightings, performance of high-efficiency LED and organic EL lightings has been improved. Practical application and diffusion are awaited.

○ For ULPC paper displays, assuming use in smartphones and tablets, development of light, thin, non-fracturing, full-HD interactive paper displays is promoted.

Technology Roadmap



2010 2020 2030 2040 2050

ULPC devices: EUV light source, resist; 0.4-V elemental technol.; 3D assembly; Spintronics devices; Normally off processors

ULPC optical communication technology: Optical I/O core; LSI substrate with optical cables; Ultra-high speed optical signal processing LSI; Optelectronics integrated interposer; All-optical network router

Next-generation high-efficiency lightings: High-efficiency LED lightings Luminous efficiency 200lm/W; 250lm/W; Organic EL lightings 50lm/W; 130lm/W; 200lm/W, Ra* = 80 or more

* Ra: General color rendering index

ULPC paper displays: Ultra-low voltage multi-layering; Plastic substrate displays

Require promotion of task solution and demonstrations for promoting commercialization and practical application along with development of innovative devices, in order to fully exert energy-saving potentials of each technology

International Trends

Current extent of diffusion

○ The markets of LAN switches and routers are transitioning positively. The optical device market is anticipated to rise rapidly.

○ LED lighting products with existing performance are spreading. Diffusion of high-efficiency next-generation lightings is anticipated in future.

○ Permeation of organic EL displays has commenced in mobile phone and some TV. The global market is ~700 billion yen in 2012.

Trend in technology development

○ ULPC devices are under R&D competition according to global roadmap, etc.

○ Projects on optical electronics technologies are conducted in Europe and US at the national expense.

International competitiveness of Japan

○ Japan possesses competitiveness in technologies on materials used in IT devices.

○ For optical communication, Japan’s elemental technologies on optical electronics systems produced world-class outcome. R&D on implementation technology is needed.

○ Japan’s share for large-sized displays is small, while that for medium- and small-sized displays is strong (~30%, 2012) which is expected to grow in future centering on smartphones and tablets.

19. Innovative Devices (Power Electronics)

Technology Overview

○ Power electronics allows electricity control (change of voltage and frequency, DC/AC conversion) via semiconductors (semicons), contributing in energy conservation of home appliances, information systems, next-generation vehicles, renewable power sources, etc.

○ Semiconductive material currently used is silicon (Si). Innovative semicon. devices use new materials such as silicon carbide (SiC), gallium nitride (GaN) and diamonds to further reduce power loss.

○ Use of new materials may halve the power loss due to heating, etc., and are expected to become the key in improving energy conservation of home appliances and information devices.

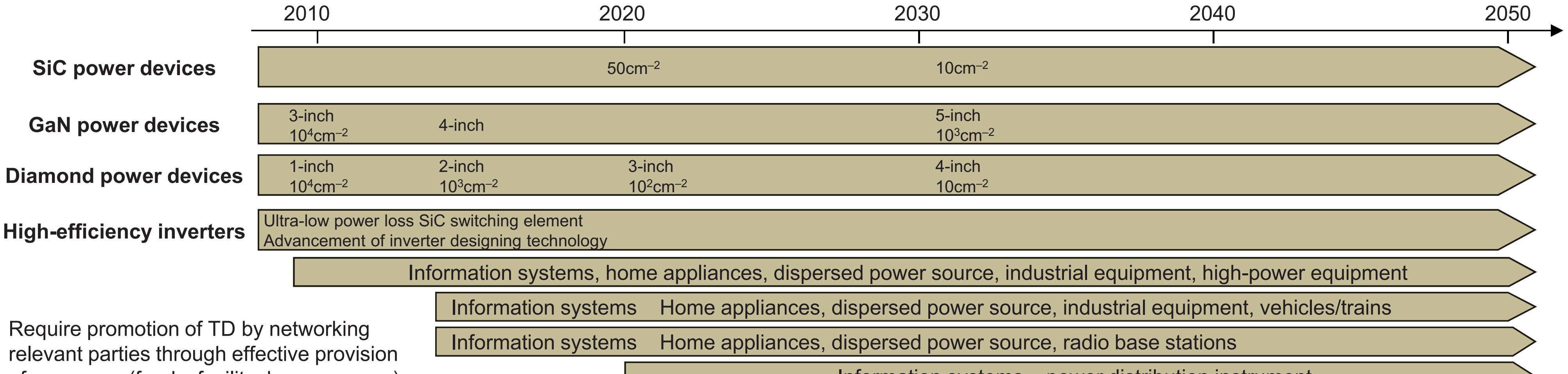
Trends and Issues in Technology Development in Japan

○ For the differences in ease of crystal growth, cost, thermal conductivity and so on, GaN is expected to be used in low-voltage devices (several hundred volts), and SiC in medium- to high-voltage high-power devices (several thousand to several dozen thousand volts). GaN is also expected to be used in power devices and high-frequency oscillation devices that operate on higher frequency than SiC. Recently, technology to mount GaN devices on Si substrates is developed to reduce the cost. Diamonds are expected to be used in higher-voltage higher-power devices than SiC devices.

○ METI is conducting basic TD for introducing SiC semicons and supporting R&D for application of GaN semicons. MEXT is conducting leading research for application of diamond semicons. Cabinet Office (CAO) is developing technologies on high-voltage SiC semicons (10kV class) for power systems.

○ To materialize substitution of Si, it is necessary to develop technologies to mass produce large-area high-quality substrate using new materials and stable high-yield production processes of devices.

Technology Roadmap



2010 2020 2030 2040 2050

SiC power devices: 50cm^{-2} → 10cm^{-2}

GaN power devices: 3-inch 10^{4}cm^{-2} → 4-inch → 5-inch 10^{3}cm^{-2}

Diamond power devices: 1-inch 10^{4}cm^{-2} → 2-inch 10^{3}cm^{-2} → 3-inch 10^{2}cm^{-2} → 4-inch 10cm^{-2}

High-efficiency inverters: Ultra-low power loss SiC switching element
Advancement of inverter designing technology

Information systems, home appliances, dispersed power source, industrial equipment, high-power equipment

Information systems　Home appliances, dispersed power source, industrial equipment, vehicles/trains

Information systems　Home appliances, dispersed power source, radio base stations

Information systems – power distribution instrument

Require promotion of TD by networking relevant parties through effective provision of resources (funds, facility, human power) using a consortium method

(* Related roadmap: 12,13. Next-generation vehicle, 16. Airplanes, ships, railways, (high-efficiency railway vehicle), 18. Innovative devices (information system, lighting, display))

International Trends

Current extent of diffusion

○ Use of SiC semicons has commenced in some home appliances such as air conditioners, and R&D for train/car application is in a demonstration stage. TD of GaN semicons for implementation is being accelerated, yet still some technological problems need to be overcome. Diamond semicons are in the basic research stage; research using public funds continues.

○ Use of SiC has also commenced in railway inverters, etc.

Trends in technology development

○ US Power Electronics R&D Program Plan lays out a long-term TD plan aiming at practical application of 20kV-class GaN semicons within 5-15 years. For that, refinement of package designs, inspection reliability improvement, advancement of GaN semicon. control systems, evaluation of impact on power transmission/distribution facilities, etc., will be conducted.

○ EU promotes practical application and cost reduction of SiC and GaN semicons, targeting 30% cost reduction by 2020, 50% cost reduction by 2030, as well as size increase and energy loss reduction of wafers.

International competitiveness of Japan

○ Japan, US and Europe compete in TD, while substrate supply is in an oligopoly of some companies. Japan's semicon. process, device and assembly technologies are world class., Acquisition of international competitiveness in power electronics requires promotion of TD by networking relevant parties through effective provision of resources (funds, facility, human power) using a consortium method, with taking advantage of existing technologies.

20. Innovative Devices (Power Electronics (Telework))

Technology Overview

○A technology to reproduce the sense of existence of objects and persons at distant places by integrally controlling transmission and presentation technologies of ultra high definition images, stereoscopic images, stereophonic sound, etc.

○Telework and teleconferencing drastically reduce movement of persons/objects, significantly reducing CO_2 emissions due to commuting or travelling. Energy consumption at offices will also be reduced by improved work efficiency resulting in less work hours and less office works.

○It will also contribute to establishment of work-life balance by freeing commuting time (1 hour 40 minutes* in average).

○Reduction effect of CO_2 emitted by commuting or travelling is 7.14 million tons (Rate of total telework users: 35%, rate of home users: 14%, use time rate: 60%)

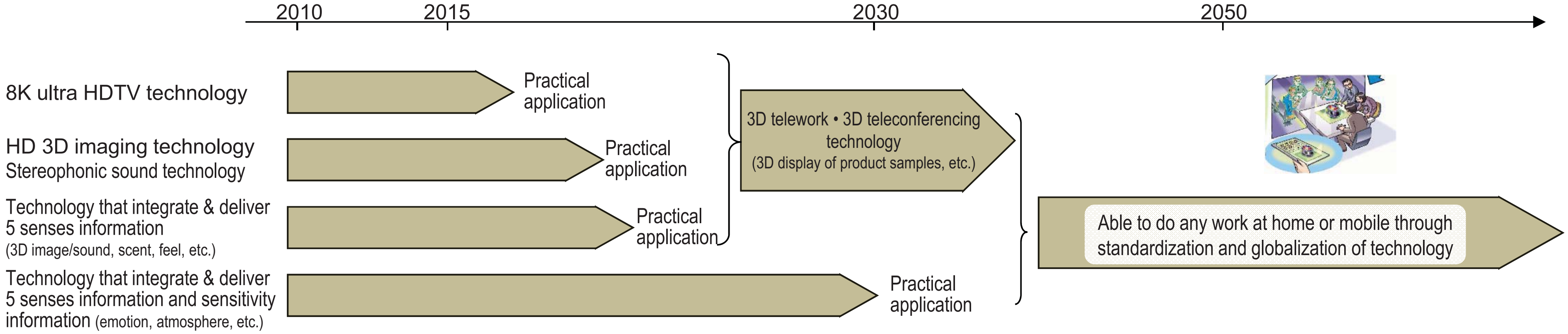
* Estimation based on “Report for the Study Group on the Progress and Environment of Ubiquitous Network Society” (MIC) and taking into account the effects of 3D imaging technology, etc.

Trends and Issues in Technology Development in Japan

○Ministry of Internal Affairs and Communications (MIC) promotes integral R&D on 3D (stereoscopic) imaging technology and ultra reality communication technology, such as “stereophonic sound technology”, “5 senses information (e.g., feel, scent) transmission technology”, and “sensitivity information (e.g., emotion, atmosphere) recognition and transmission technology”.

○Technological tasks remain including device technology to display 3D images, filming/transmission technology to realize 3D image communication and broadcast, and technology to realize ultra reality communication such as stereophonic sound, tactile sense, and scents.

Technology Roadmap



2010 2015 2030 2050

8K ultra HDTV technology → Practical application

HD 3D imaging technology
Stereophonic sound technology → Practical application

Technology that integrate & deliver 5 senses information (3D image/sound, scent, feel, etc.) → Practical application

Technology that integrate & deliver 5 senses information and sensitivity information (emotion, atmosphere, etc.) → Practical application

3D telework • 3D teleconferencing technology (3D display of product samples, etc.)

Able to do any work at home or mobile through standardization and globalization of technology

International Trends

Current state of diffusion

○ In 2010, home appliances such as 3D TV and Blu-Ray3D have been produced, enabling 3D image entertainment at ordinary households. ‘Stereoscopic Television’ has become familiar as home appliances.

Trends in technology development

○ Development of 3D imaging and sound technologies are promoted in many countries. South Korea produced 3D Technology Roadmap, working on development of 3D imaging technology, holography technology, etc.

International competitiveness of Japan

○ Japan’s 3D imaging technology the most advanced in the world.

○ Japan commenced research on other technologies ahead of the world, such as 3D sound technology, 5 senses information transmission technology, and sensitivity information recognition and transmission technology.

○ Global CO_2 emissions reduction can be achieved by promoting suppression of human/object movement and improvement of work efficiency worldwide.

○ Japan’s international competitiveness will be improved through participation in international conferences and joint projects from Japan, essentially eliminating geographic disadvantages of Japan.

21. Innovative Structural Materials

Technology Overview

○ Weight reduction is one of major technological tasks for improving fuel efficiency of transport equipment such as vehicles. To that end, TD for improved strength and ductility of major structural materials such as aluminum, magnesium, titanium, CFRP, and innovative steel plates is needed. TD on dissimilar material joining is required for promoting effective utilization of such materials for various purposes.

○ Development of innovative steel and magnesium materials requires improvement in strength and ductility without using rare metals.

○ CFRP is a thermosetting or thermoplastic carbon fiber/resin composite material.

○ IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of vehicle fuel reduction technology to be ~4.7 billion tons in 2050.

Trends and Issues in Technology Development in Japan

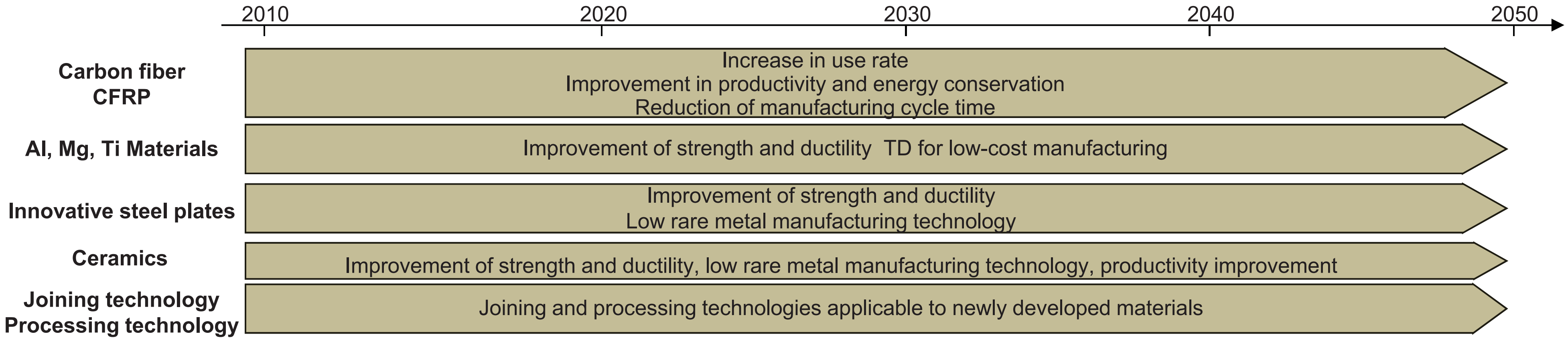
○ Japan is conducting R&D of structural materials through "Innovative TD for Structural Materials" project, "Element Strategy Program", etc.

○ "Innovative TD for Structural Materials" project conducts integral development of Al, Mg, Ti, carbon fiber, thermosetting CFRP, and innovative steel materials with improved strength, processability, corrosion resistance as well as cost competitiveness, and development of joining technologies, aiming at drastic weight reduction of transport equipment such as cars.

○ "Element Strategy Program" conducts TD for improving strength and ductility of materials without using rare elements, through atomic- to micron-scale microstructure control.

○ The tasks are multi-functionalization (e.g., high strength, high ductility) of structural materials and development of joining technologies and shaping technologies without spoiling such functions. 。

Technology Roadmap



(* Related roadmap: 14. Airplanes, ships, railways, (low fuel consumption airplanes (low noise), 16. Airplanes, ships, railways (high-efficiency railway vehicle)

International Trends

Current extent of diffusion

○ Thermosetting CFRP are in use as structural materials for airplanes, contributing to energy saving and CO_2 reduction by reducing fuel consumption by 20%. Thermoplastic CFRP may be introduced in mass produced vehicles in future.

○ High-tensile steel plates are in use for seats and center pillar of cars. Application may expand via development of steel plates with higher strength and ductility.

Trends in technology development

○ US is promoting development of new materials with higher strength and less density than current materials, as part of DOE Vehicle Technologies Program Multi-Year Program Plan (2011-2015). 'Passenger Vehicle Weight Reduction Research' aims at reducing weight of gasoline vehicles by 20% by 2020 and by 50% by 2050, and weight of EV by 26% by 2020 and by 64% by 2050.

○ EU FP7 provides funds to TD for improving manufacturing efficiency and shaping efficiency of carbon fiber. A collaborative research project "SuperLIGHT-CAR" aims at reducing weight of middle-sized vehicles by 30% in future, and conducts TD on various new materials through a joint effort of engineers and researchers from European car manufacturers and research institutions.

International competitiveness of Japan

○ Japanese manufacturers are dominating the global market of carbon fibers.

○ Japanese companies possess advanced technology for innovative steel plates, where competition may accelerate in future for cost reduction and further improvement in strength and ductility.

22. Energy Management System

Technology Overview

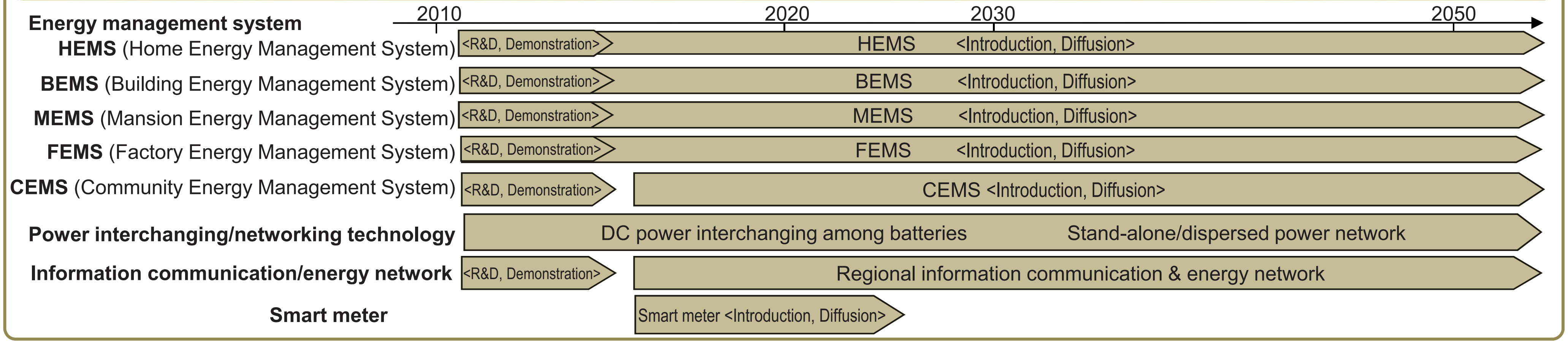
- ○ Energy management system (EMS) is an energy-saving technology that conducts energy monitoring and control of houses, buildings, and even regions, by utilizing IT. EMS is divided into the following categories according to applicable ranges. HEMS (Home EMS), BEMS (Building EMS), MEMS (Mansion* EMS), FEMS (Factory EMS), CEMS (Community EMS)
- ○ As elemental technology, development of communication hardware technology, intra-house/building censor network (all-apparatus mutual communication), micro processing technology, and prediction technology is necessary.
- ○ Regional EMS requires development of HEMS/BEMS/MEMS/FEMS technology, as well as collaboration technology with renewable energies (e.g., regional cogeneration, SPG), energy use optimization and assessment technology (electricity, heat), and heat and electricity storage technology.

* The word “mansion” refers to condominium in Japan.

Trends and Issues in Technology Development in Japan

- ○ METI is conducting R&D of large-scale EMS (HEMS, BEMS, MEMS, FEMS, CEMS) at 4 smart communities (e.g., Toyota, Kitakyushu) and demonstration of demand response, etc. In collaboration with them, MIC is demonstrating communication network technologies.
- ○ MOE is conducting TD and demonstration of stand-alone dispersed low-carbon energy system using DC electricity supply technology etc., and demonstration of CO_2 reduction at homes utilizing the data of HEMS, etc.
- ○ Task for HEMS and BEMS is TD on energy demand analysis/prediction, control system for home appliances, air conditioner and lighting, and energy-saving cooperative control by life activity prediction technology.
- ○ Introduction support projects for HEMS, BEMS and MEMS are conducted. Realization of mutual connection between EMS and communication devices is in consideration, in collaboration with power companies, electrical manufacturers, universities and research institutions. Global diffusion requires improved data transmission, standardization, and cyber security.

Technology Roadmap



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Energy management system

HEMS (Home Energy Management System) <R&D, Demonstration> HEMS <Introduction, Diffusion>

BEMS (Building Energy Management System) <R&D, Demonstration> BEMS <Introduction, Diffusion>

MEMS (Mansion Energy Management System) <R&D, Demonstration> MEMS <Introduction, Diffusion>

FEMS (Factory Energy Management System) <R&D, Demonstration> FEMS <Introduction, Diffusion>

CEMS (Community Energy Management System) <R&D, Demonstration> CEMS <Introduction, Diffusion>

Power interchanging/networking technology DC power interchanging among batteries Stand-alone/dispersed power network

Information communication/energy network <R&D, Demonstration> Regional information communication & energy network

Smart meter Smart meter <Introduction, Diffusion>

International Trends

Current extent of diffusion

- ○ Large-scale demonstrations are being conducted in many places in the world. According to NEDO, 266 projects are in progress in developed countries, and 219 projects in emerging countries. In develop countries smart grid-type and regional redevelopment-type are dominant, while in emerging countries a majority are establishment of smart community for creation of new cities.

Trends in technology development

- ○ US DOE is working on practical application of technology standards related to smart grid, high-speed bidirectional communication system, automated power transmission/distribution systems, etc.
- ○ European Initiative on Smart Cities aims at reducing GH gas emissions by 40% in 2020 compared to 1990, and plans on conducting achievement of zero-emission for new buildings and large-scale refurbishment of existing buildings, advancement of energy supply systems (heat interchanging at town area, ICT, smart meter, smart grid, etc.), advancement of traffic systems (smart public traffic, ITS, traffic demand adjustments, etc.)

International competitiveness of Japan

- ○ Multi-industry collaborations are conducted for diffusion of HEMS. Power companies, electrical manufacturers, universities and research institutions formed a consortium, working on establishment of a common standard ECHONET Light to control multiple devices at the same time. Introduction support products achieved early introduction of HEMS in Japan. Japan is building an international technological advantage in this field.
- ○ For smart meter and micro grid, Japanese electrical manufacturers are conducting business development by utilizing their technological competitiveness. Public-private cooperation as seen in infrastructure (high-speed railway) exports is expected for future global expansion.

23. Energy Efficient Houses/Buildings

Technology Overview

○ CO_2 emissions from civilian houses and business sector account for ~35% of Japan's total CO_2 emissions. Reduction of energy consumption and CO_2 emissions from the said sector need promoting, taking into account activities around the world (e.g., EU). Promotion of TD for improving thermal insulation of houses and buildings as well as improving efficiency and operation of equipment will result in reduction in total energy consumption and CO_2 emissions in Japan.

○ IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of thermal insulation technology for buildings to be ~0.3 billion tons in 2050.

○ Product development (e.g., new technology, new services, new production method) is being promoted in order to reduce the burden on the end consumer, i.e. citizens, through improved energy efficiency and lifetime of houses/buildings.

Trends and Issues in Technology Development in Japan

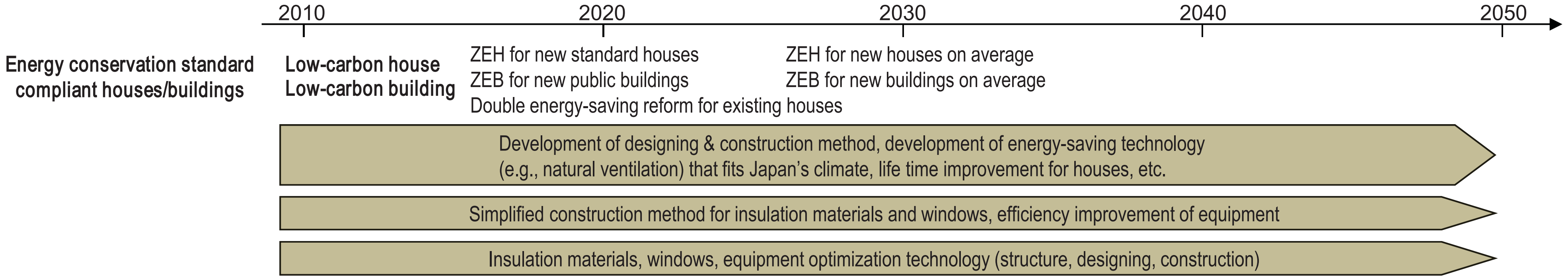
○ Japan aims to develop energy efficient houses/buildings that improve QOL at acceptable cost, through packaging of building materials and equipment (e.g., power generation/storage systems of natural and unused energies, HEMS/BEMS). To that end, ZEH, LCCM, ZEB will be diffused, and development of energy-generating houses/building in future will be considered.

○ Demonstration for introducing materials that suppress heat exchange during ventilation, consideration on high thermal insulation of houses via ultra thermal insulation window sash, and TD on thin thermal insulation interior building materials are conducted. NEDO is developing vacuum thermal insulation materials.

○ TD on production methods and component materials will be conducted for improving the life time of houses/buildings. Long-term energy conservation and CO_2 emissions reduction (LCCM) will be achieved by developing CO_2 emissions reduction technology for the life cycle of construction, operation, waste processing, recycling, etc.

○ Methods to properly assess advanced activities such as energy creation, energy storage, and passive methods will be developed taking into account CASBEE and Energy Conservation Act, and awareness and understanding of the population about environmental performance of houses will be raised.

Technology Roadmap



Energy conservation standard compliant houses/buildings

Low-carbon house
Low-carbon building

ZEH for new standard houses
ZEB for new public buildings
Double energy-saving reform for existing houses

ZEH for new houses on average
ZEB for new buildings on average

Development of designing & construction method, development of energy-saving technology (e.g., natural ventilation) that fits Japan's climate, life time improvement for houses, etc.

Simplified construction method for insulation materials and windows, efficiency improvement of equipment

Insulation materials, windows, equipment optimization technology (structure, designing, construction)

○ Induce market expansion by Energy Conservation Act, Housing Quality Assurance Act, Eco Town Act
○ Tax benefits, funding

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

International Trends

Current extent of diffusion

○ In Germany new houses require acquisition of a certificate detailing energy demands, and they need to be low-energy houses.

○ Aiming at achieving ZEH, the British government has been tightening its energy efficiency requirements adopted in 2006. CO_2 emissions regulated by the requirements are to be reduced by 25% from 2010 and by 44% from 2013, and all houses are to be built to net zero-carbon from 2016 including equipment not covered by the current requirements (e.g., home appliances, kitchenware).

Trends in technology development

○ US adopted the Net-Zero Energy Commercial Buildings Initiative based on the Energy Independence and Security Act of 2007, aiming at development and diffusion of Net Zero Energy technologies, customs and policies. Mainly tightening of regulations and R&D lead by the government will be conducted in order to achieve energy conservation targets for buildings.

International competitiveness of Japan

○ Japan possesses world-class elemental technologies for ZEB and ZEH. National activities are needed to globally expand them.

24. High-Efficiency Industrial Energy Utilization

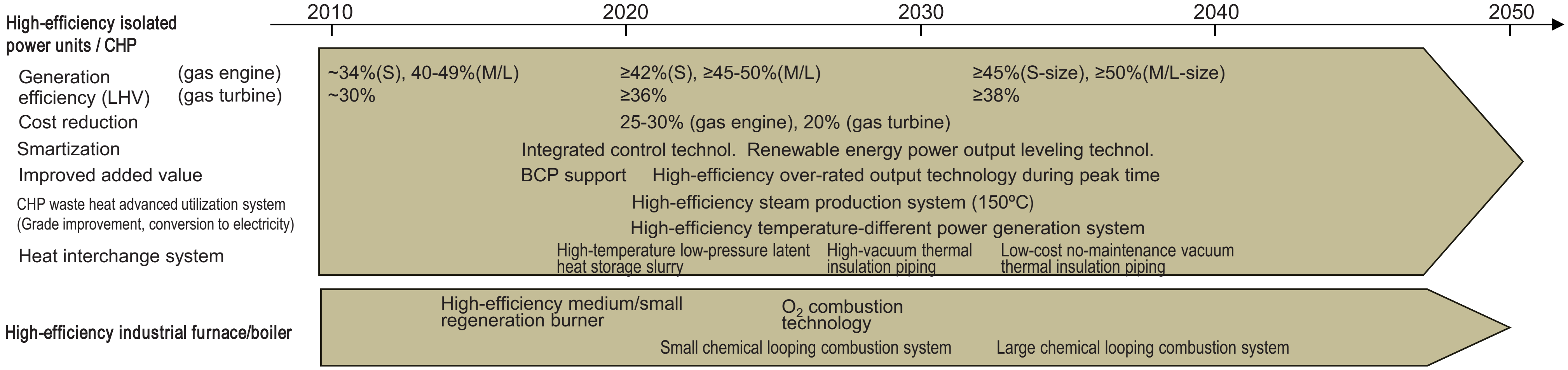
Technology Overview

- ○ The industrial sector uses a large amount of energy. Energy conservation and CO_2 emissions reduction can be achieved through efficiency improvement of isolated power units, industrial furnaces, boilers, etc., that are used in combustion heating processes or dispersed power sources that use fossil fuels.
- ○ Cogeneration (combined heat and power, CHP) utilizes waste heat along with power generated by engine, turbine, fuel cells, etc., built at the demand site, contributing to energy saving and CO_2 reduction.
- ○ CHP also contributes to balancing of electric power supply/demand and power supply in the event of emergency. Its efficiency can be improved by effective heat utilization.
- ○ Fuel consumption during industrial process heating is large. Advancement in efficiency improvement of boiler/burner and fuel conversion will result in significant energy saving and CO_2 reduction.

Trends and Issues in Technology Development in Japan

- ○ METI is assisting development of CHP, including ultra high heat resistant materials and gas turbine intake humidification cooling system for realizing ultra high temperature no-cooling gas turbine, and high efficiency industrial furnace and boilers.
- ○ Cost reduction and efficiency improvement of CHP requires advancement of gas engine combustion control technology and increase of gas turbine inlet temperature.
- ○ Continuing TD is required for effective utilization of waste heat as process heating, grade improvement of electricity, air conditioner, and waste heat (e.g., formation of high temperature high pressure steam, conversion to electricity), heat storage, horizontal heat interchange, and on leveling renewable energy power output fluctuations.
- ○ Practical application of blackout-response CHP technology (e.g., blackout start function) is also desired as one of disaster response technologies.

Technology Roadmap



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High-efficiency isolated power units / CHP

Generation efficiency (LHV) (gas engine): ~34%(S), 40-49%(M/L) → ≥42%(S), ≥45-50%(M/L) → ≥45%(S-size), ≥50%(M/L-size)

Generation efficiency (LHV) (gas turbine): ~30% → ≥36% → ≥38%

Cost reduction: 25-30% (gas engine), 20% (gas turbine)

Smartization: Integrated control technol. Renewable energy power output leveling technol.

Improved added value: BCP support High-efficiency over-rated output technology during peak time

CHP waste heat advanced utilization system (Grade improvement, conversion to electricity): High-efficiency steam production system (150ºC); High-efficiency temperature-different power generation system

Heat interchange system: High-temperature low-pressure latent heat storage slurry; High-vacuum thermal insulation piping; Low-cost no-maintenance vacuum thermal insulation piping

High-efficiency industrial furnace/boiler

High-efficiency medium/small regeneration burner; O_2 combustion technology; Small chemical looping combustion system; Large chemical looping combustion system

International Trends

Current extent of diffusion

- ○ Application of CHP is expanding globally. CHP accounts for 10% of total power generation in OECD countries. CHP plant capacity in US is 82GW, which are applied to more than 3,700 industrial/commercial facilities, covering more than 8% of total generation plant capacity and more than 12% of annual generation. CHP plant capacity in EU was 95GW as of 2012, corresponding to 11% of electricity demand.

Trends in technology development

- ○ US DOE CHP Project targets priority tasks such as maximization of energy efficiency, reduction of pollutant emissions, and optimization of flexibility in fuel use. DOE also works on performance improvement of 20MW+ class advanced industrial gas turbine, aiming at reduction of energy consumption by 1% in US and 150Mt-CO_2 p.a. by 2020 through introduction of 40GW of new economic CHP.
- ○ EU aims at providing 23% of industrial heat source by CHP by 2030, while 5.3% (52GW) will be provided by biomass CHP through its diffusion to industrial use and regional heat supplies. EU also aims at providing 2% (15GW) of industrial heat source by natural gas CHP (excludes fuel cells) by 2030.

International competitiveness of Japan

- ○ Japanese gas engine CHP runs on the highest generation efficiency in the world. Japanese gas turbines and gas engines also possess high competitiveness, achieving total efficiency of 84.3% (generation efficiency 32.8%, heat recovery efficiency 51.5% (LHV)) and 86.3% (48.8%, 37.5%), respectively. Additionally, the energy conservation and CO_2 reduction effects of Japanese industrial burners are at the world's highest level.

25. High-Efficiency Heat Pumps

Technology Overview

○ Air conditioners (AC) and hot water system (HWS) for domestic and business use have improved over the years. Further energy saving may be achieved through improvement of heat pumps, utilization of power electronics, utilization of new coolant, and so on.

○ Unlike AC/HWS via combustion of fossil fuels, active utilization of solar heat through air heat and geothermal heat will achieve efficiencies far exceeding 100%.

○ Applicable to AC, HWS, etc. that account for ~50% of CO_2 emissions from the civilian sector, and highly efficient heat pump technology is expected to drastically reduce CO_2 emissions. Also applicable to AC, process cooling/heating, etc., in the industrial sector.

○ IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of high-efficiency AC to be ~1.1 billion tons in 2050.

Trends and Issues in Technology Development in Japan

○ Development of new coolant, efficiency improvement of heat pumps, etc. are promoted through the NEDO 'Technology Development of High-efficiency Non-fluorinated Air-conditioning Systems', etc.

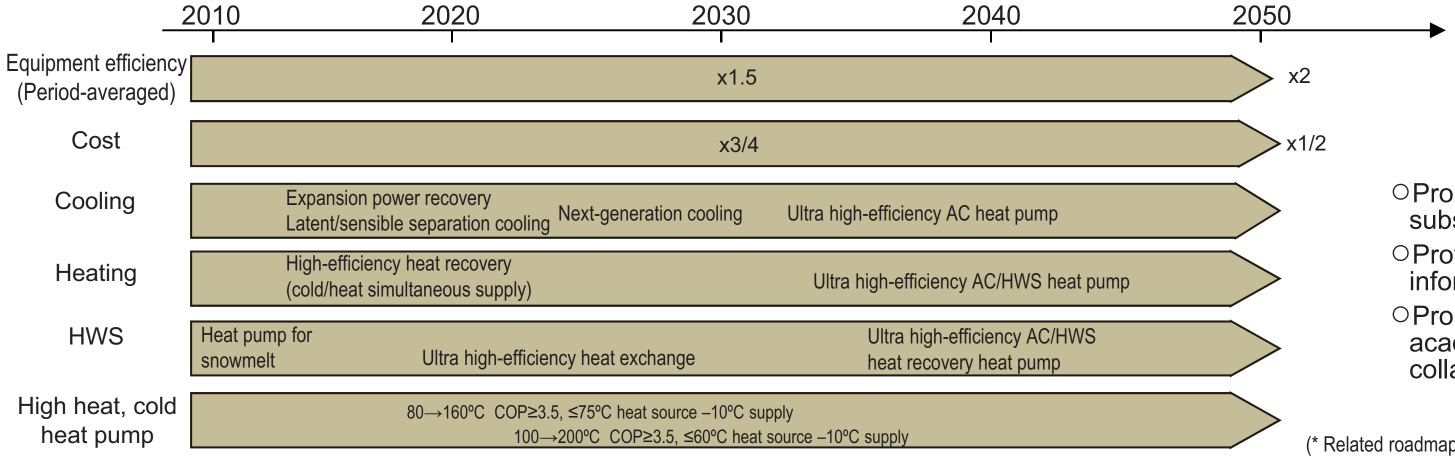
○ The tasks for heat pump technology are cost reduction and efficiency improvement. Cost may be reduced to 3/4 and to 1/2, while efficiency may be increased by 50% and by 100%, by 2030 and by 2050, respectively, compared to the current state, through development of elemental technologies such as efficiency improvement of coolant and heat exchangers.

○ Other technological issues to be overcome include size reduction for improved installation capacity and reduced usage of materials, further adaptation to cost districts for wider applicability (AC, HWS, and snowmelt), and expansion of applicable temperature range. Efficiency improvement for the whole system using unused heat is also promising. Efficiency improvement is also conducted for GHP, etc., that is used for power peak shaving or BCP support.

Technology Roadmap

* Reference

AC	APF6.6
WHS	COP5.1
AC	¥200,000
WHS	¥500,000



2010 2020 2030 2040 2050

Equipment efficiency (Period-averaged): x1.5 → x2

Cost: x3/4 → x1/2

Cooling: Expansion power recovery / Latent/sensible separation cooling → Next-generation cooling → Ultra high-efficiency AC heat pump

Heating: High-efficiency heat recovery (cold/heat simultaneous supply) → Ultra high-efficiency AC/HWS heat pump

HWS: Heat pump for snowmelt → Ultra high-efficiency heat exchange → Ultra high-efficiency AC/HWS heat recovery heat pump

High heat, cold heat pump: 80→160°C COP≥3.5, ≤75°C heat source –10°C supply → 100→200°C COP≥3.5, ≤60°C heat source –10°C supply

○Promote introduction via subsidy and tax benefits

○Provide the people with information

○Promote TD via industry-academia-government collaboration

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

International Trends

Current extent of diffusion

○ Currently the COP of household heat pump AC is 6 or more, which is far greater than 2.2-3.8 for heat pump AC in Europe and US, as valued by the IPCC AR4.

○ High-efficiency heat pumps have already been introduced in Japan.

Trend in technology development

○ US DOE is conducting development of AC/ventilation system optimized to heat exchange, data mining for geothermal heat pump, etc., as part of AC-related research.

○ EU 'Common Vision for Renewable Heating & Cooling 2020-2030-2050' states that all AC demands in EU can be covered by biomass, solar heat, geothermal heat, and air heat by 2050.

○ IEA Technology Roadmaps - Energy-efficient Buildings: Heating and Cooling Equipment aims at reduction of CO_2 originating from buildings by 2Gt by 2050 through improved AC technology. IEA will promote R&D and initial funding of high-efficiency AC heat pump system and components.

International competitiveness of Japan

○ Japanese heat pump AC has achieved relatively high efficiency compared to EU and US. Japanese manufactures providing comprehensive hardware/software services exhibit huge existence in the global market. Recently, Japanese companies started to commercialize high-efficiency large-scale turbo refrigerators.

○ Japanese heat pump HWS technologies are at the world' top level, and their business is globally developing through export and offshore production. Especially, Japan introduced CO2 coolant high-temperature WHS ahead of the world, and 1 million units were introduced within only 6 years.

○ Japanese technology leads the world, represented by the CO_2 coolant heat pump HWS.

26. Environmentally-Aware Iron Manufacturing Process

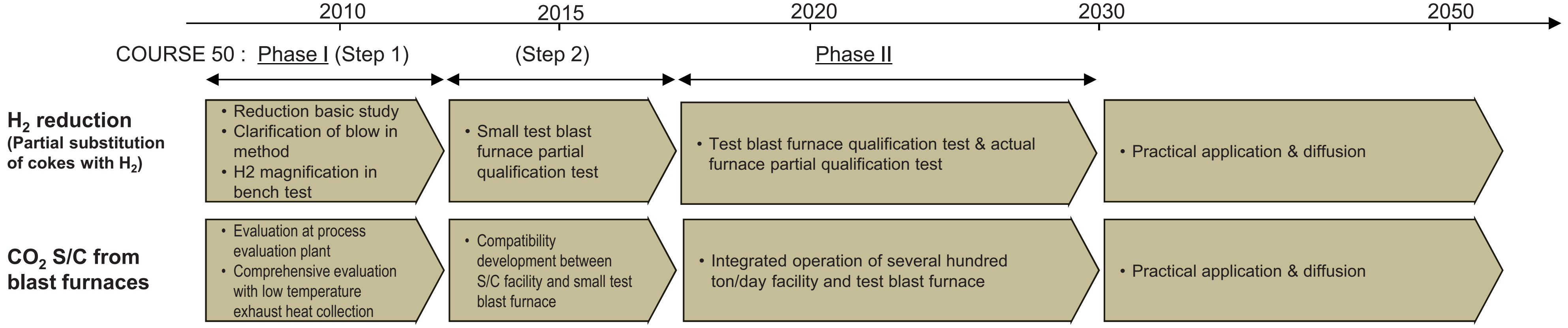
Technology Overview

- ○ About 70% of CO_2 emitted by the iron and steel industry is attributed to the iron manufacturing process using blast furnaces. Therefore, a significant reduction of CO_2 through drastic TD is an urgent task. Japan's current iron manufacturing process has the highest energy efficiency in the world. Further improvement of energy efficiency requires development of innovative groundbreaking technology.
- ○ Specifically, TD will be conducted for reduction of iron ores using both cokes and H_2 that is included (~50%) in the heated gas generated during manufacturing of cokes, new absorbent to separate CO_2 from high-CO_2 blast furnace gas, physical adsorption, new CO_2 separation/capture (S/C) technology utilizing the unused low-temperature waste heat generated at steelworks.
- ○ IEA's ETP 2012 estimates the global CO_2 emission reduction potential of development and diffusion of various innovative iron manufacturing technology to be ~1.6 billion tons in 2050.

Trends and Issues in Technology Development in Japan

- ○ "Environmentally Harmonized Steelmaking Process Technology Development (COURSE 50)", in which all major Japanese steel manufacturers participate, commenced its projects in FY 2008, and conducted elemental TD for H_2-reduction iron manufacturing and CO_2 S/C. (Phase 1 Step 1)
- ○ Future activities include building a small test blast furnace in the scale of 10m^3 and comprehensive evaluation of the laboratory-level results obtained in Step 1, to establish reaction control technology with maximum H_2 reduction effects. For CO_2 S/C, the chemical absorption method will be developed through linked operation with the test furnace and high-performance chemical absorbent, and physical adsorption method will be developed through detailed planning of actual processing, aiming at 'comprehensive development' including acquisition of scale-up data to demonstrative test furnace in phase 2. (Phase 1 Step 2)
- ○ COURSE 50 aims at establishment and practical application of technology that reduces CO_2 emissions from steelworks by 30% by 2030.

Technology Roadmap



2010 2015 2020 2030 2050

COURSE 50 :	Phase I (Step 1)	(Step 2)	Phase II	
H_2 reduction **(Partial substitution of cokes with H_2)**	• Reduction basic study • Clarification of blow in method • H2 magnification in bench test	• Small test blast furnace partial qualification test	• Test blast furnace qualification test & actual furnace partial qualification test	• Practical application & diffusion
CO_2 S/C from blast furnaces	• Evaluation at process evaluation plant • Comprehensive evaluation with low temperature exhaust heat collection	• Compatibility development between S/C facility and small test blast furnace	• Integrated operation of several hundred ton/day facility and test blast furnace	• Practical application & diffusion

(* Related roadmap: CO_2 capture and storage (CCS))

International Trends

Current extent of diffusion

- ○ US DOE is conducting development of a novel iron making process, direct injection process of iron ore into blast furnace, alternative fuels, etc.
- ○ EU Ultra Low Carbon Dioxide Steelmaking Program is conducting activities aiming at reduction of CO_2 by 50%.

Trend in technology development

- ○ EU HORIZON 2050 is to conduct improvement of cokes-free steelmaking, cost reduction and demonstration (includes CCS) of furnace top gas circulation blast furnace, and research on electrolysis methods.
- ○ Australia is conducting TD of heat recovery, etc., from biomass and melted slag.

International competitiveness of Japan

- ○ Japan's steelmaking industry possesses world-class energy efficiency due to its globally preeminent iron making process, which will be further strengthened through promotion of COURSE 50 and broad diffusion of its outcome in Japan.

27. Innovative Manufacturing Process (Other Manufacturing Process)

Technology Overview

○ Japan's manufacturing industry boasts the world's highest energy efficiency. In order to further improve energy efficiency, development of an innovative manufacturing process is required. Specifically;

- Energy-saving petroleum refining process technology
- Radical efficiency improvement technology for nonferrous metals manufacturing process
- Low pressure drop separation membranes that reduce pump power
- Energy-saving ammonia manufacturing technology (catalysis, electrolysis, etc.)
- Energy-saving cement manufacturing process technology etc.

○ IEA's ETP 2012 estimates the global CO2 emission reduction potential of development and diffusion of innovative manufacturing process technologies in 2050 to be ~1.6 billion tons for chemicals manufacturing process and ~1.1 billion tons for cement manufacturing process.

Trends and Issues in Technology Development in Japan

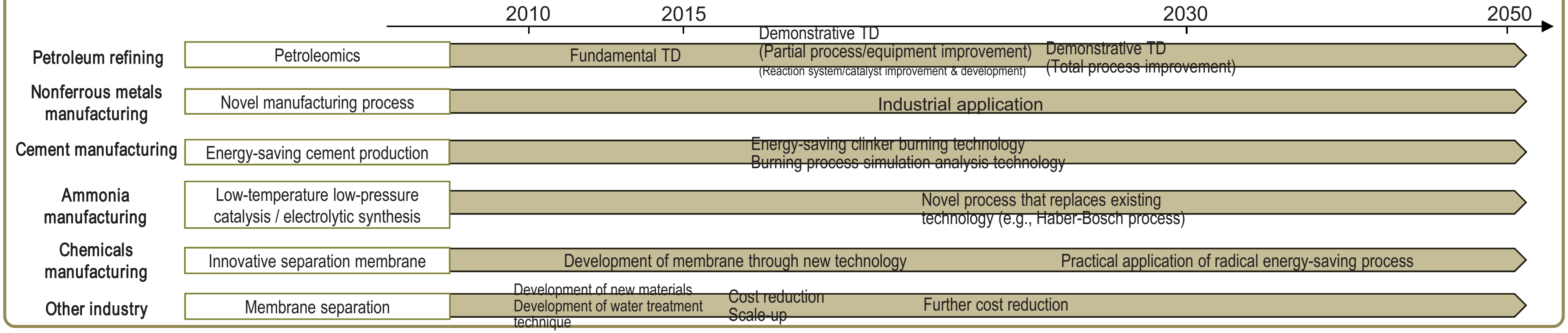
○ Petroleum refining industry is conducting development of "Petroleomics Technology" that consists of petroleum molecular structure analysis technology (petroleum is a highly complicated multi-component system), reaction path simulation technology, etc., in order to establish an innovative refining process.

○ METI's "Fundamental TD of an Innovative Cement Manufacturing Process" focuses on reduction of temperature or time of the clinker burning process that accounts for 80-90% of energy consumption. Tasks include TD for complicated thermal reaction simulation, TD for temperature condition, etc., measurement, and development of clinker burning temperature reduction materials.

○ NEDO "Development of Innovative Separation Membrane Technology" project promotes development of energy-saving RO membranes and NF membranes, and currently in industrialization consideration phase.

○ MEXT is conducting development of novel catalysts for low-energy ammonia production, aiming at practical application in 2030.

Technology Roadmap



2010
2015
2030
2050

Petroleum refining
Petroleomics
Fundamental TD
Demonstrative TD
(Partial process/equipment improvement)
(Reaction system/catalyst improvement & development)
Demonstrative TD
(Total process improvement)

Nonferrous metals manufacturing
Novel manufacturing process
Industrial application

Cement manufacturing
Energy-saving cement production
Energy-saving clinker burning technology
Burning process simulation analysis technology

Ammonia manufacturing
Low-temperature low-pressure catalysis / electrolytic synthesis
Novel process that replaces existing technology (e.g., Haber-Bosch process)

Chemicals manufacturing
Innovative separation membrane
Development of membrane through new technology
Practical application of radical energy-saving process

Other industry
Membrane separation
Development of new materials
Development of water treatment technique
Cost reduction
Scale-up
Further cost reduction

International Trends

Current extent of diffusion

○ EU is assisting TD for individual technology element as part of FP7, aiming at reduction of GH gas emission by 80% by 2050.

○ For the petro chemistry field, construction plans of new/additional petrifaction raw material (ethylene) facilities using cheap natural gas are in progress in North America.

Trends in technology development

○ Assisted by DOE, The US is conducting TD for processing exhaust (contains CO_2) from cement manufacturing facilities. To reduce CO_2 in papermaking process, The US is conducting development of new material membranes, research on reducing steps from 5 to 3 for the black liquor evaporation process, pulp washing technology using steam cycles, etc.

○ EU FP7 assists development of latest technology to produce cement and clean aggregates from construction wastes, new microbial carbonates technology for producing improved strength, economy and environmental cement, green concrete for more sustainable construction business, etc. FP7 also promotes practical application of light-weight multi-functional paper products by utilizing nanocellulose and development of dimethyl ether production technology by gasification of black liquor.

International competitiveness of Japan

○ Japan is conducting comprehensive and systematic R&D of the "Petroleomics Technology" in anticipation of viewing practical application.

○ The base processes of nonferrous metals manufacturing technologies have not been revamped since the invention of the currently used process. Japan is aiming at development of novel manufacturing process with improved productivity.

○ Japan's membrane separation technology leads the world in its technology level.

28. Hydrogen Production/Transport/Storage (Hydrogen Production)

Technology Overview

○ Hydrogen is the secondary energy that can be produced from various energy sources such as fossil fuels, water, and biomass as shown in the table on the right. Hydrogen has a characteristic as a clean energy, where burning it produces water only.

	Element		
Production	Reforming (on-site)	Steam reforming	
		Auto-thermal	
	Reforming (off-site)	Steam reforming	Combination with CCS
		Partial oxidation	
	Water electrolysis	Solid polymer water electrolysis	
		Alkaline water electrolysis	
		High-temp steam electrolysis	
	Renewable energy	Biomass, living form utilization	
		Solar, wind energy utilization	
	Atomic energy	Atomic energy utilization	
Refining	PSA		
	Membrane separation	Alloy/non-alloy membrane	
		Polymer membrane	
	Cryogenic separation		

(Source) NEDO 'Roadmap for Fuel Cell and Hydrogen TD Ver.2'

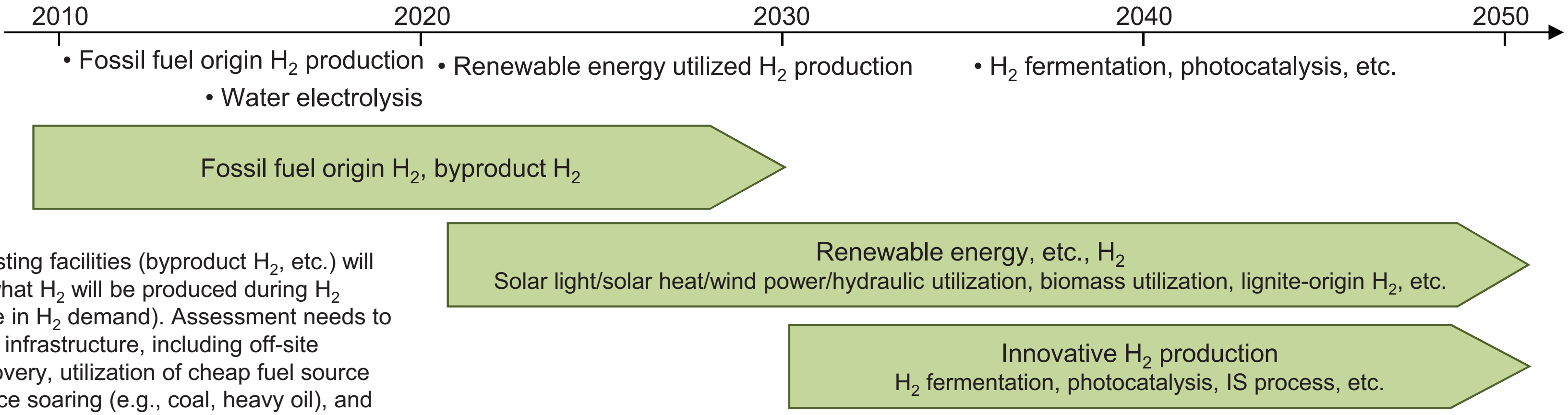
Trends and Issues in Technology Development in Japan

○ NEDO is conducting research on clarification of fundamental properties of Hydrogen under high pressure of in a liquid condition, development of elemental as well as applied technologies for low-cost advanced equipment and systems for Hydrogen production, transport, storage and filling, etc.

○ The tasks for Hydrogen production include development of low-cost production technology and diversification of raw materials. Hydrogen supply requires optimal system along with transport and storage; consideration needs to be made by combining with transport and storage technologies.

○ JAEA is conducting test research on IS process that produces Hydrogen through thermolysis of water.

Technology Roadmap



- Fossil fuel origin H_2 production
- Water electrolysis
- Renewable energy utilized H_2 production
- H_2 fermentation, photocatalysis, etc.

Fossil fuel origin H_2, byproduct H_2

Renewable energy, etc., H_2
Solar light/solar heat/wind power/hydraulic utilization, biomass utilization, lignite-origin H_2, etc.

Innovative H_2 production
H_2 fermentation, photocatalysis, IS process, etc.

For H_2 introduction period, existing facilities (byproduct H_2, etc.) will be utilized. The point is from what H_2 will be produced during H_2 diffusion period (rapid increase in H_2 demand). Assessment needs to be conducted for the whole H_2 infrastructure, including off-site production assuming CO_2 recovery, utilization of cheap fuel source non-susceptive to crude oil price soaring (e.g., coal, heavy oil), and water electrolysis using nighttime power or renewable energy.

(* Related roadmap: 13. Next-generation vehicle (FCV), 29. H_2 production/transport/storage (H_2 transport/storage), 30. Fuel cells)

International Trends

Current extent of diffusion

○ In January 2011, 3 car manufacturers and 10 Hydrogen supply business operators issued a joint statement, indicating that car manufactures will progress development aiming at introduction of mass produced FCV to the domestic market and sales to general users in 2015 focusing on the 4 major cities in Japan.

Trend in technology development

○ The US sets research tasks on biological process such as biocatalysis and biomass processing, Hydrogen production from fossil fuels, electrolysis process using renewable energies etc, thermochemical process such as high temperature/ultra-high temperature water splitting, as well as alternative approaches such as photocatalysis, photoelectrochemical water splitting, and solar methane reforming.

○ EU aims at Hydrogen supply in 2020, which will be more cost competitive than fossil fuel, through development of 100MW-class centralized electrolysis production system, 30% increase of Hydrogen production efficiency and 100% increase in capacity, and realization of dispersed production system using electrolysis and biogas reforming.

International competitiveness of Japan

○ Japan is about to become on of the best in the world in performance of elemental technology that is the core technology of Hydrogen production.

Elemental technology: steam reforming, auto-thermal technology, partial oxidation technology, water hydrolysis.

29. Hydrogen Production/Transport/Storage (Hydrogen Transport/Storage)

Technology Overview

○ A technology to transport and store Hydrogen that is used for FCV or stationary fuel cells.

○ Hydrogen transport methods include compressed Hydrogen transport, liquefied Hydrogen transport, organic hydride transport, transport in a form of ammonia, and transport through pipelines. There is a successful case of transport using compressed water in a steel container.

○ The technology is considered to be useful for when renewable energies are introduced on a large scale.

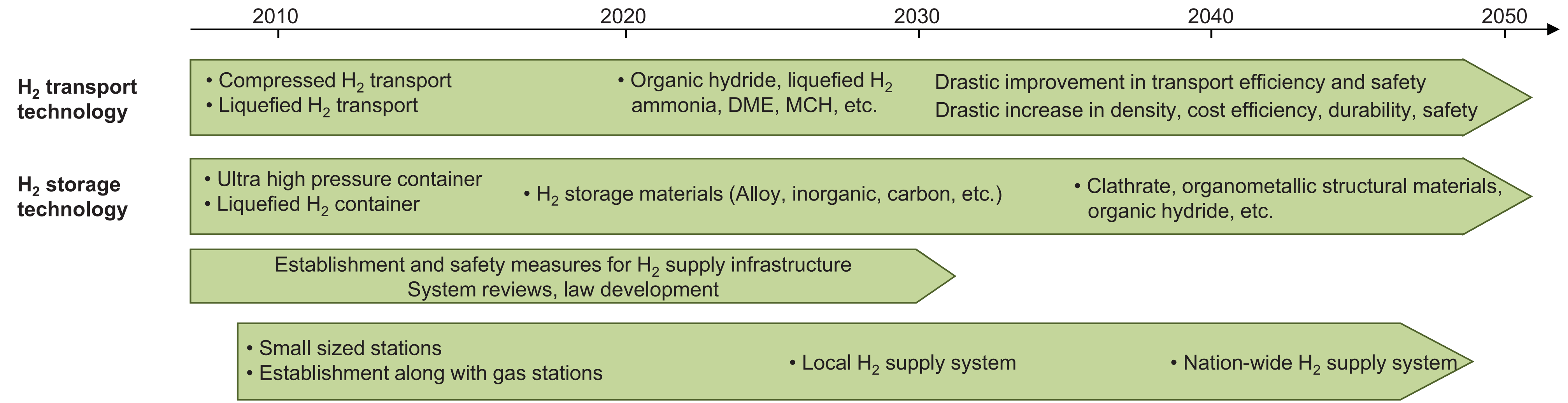
Trends and Issues in Technology Development in Japan

○ NEDO is conducting technical demonstration of FCV and Hydrogen infrastructure with conditions similar to actual use, aiming at commencement of diffusion in 2015. "Technical and Social Demonstration of Regional Hydrogen Infrastructure" commenced, where user convenience, business potential, social receptivity, etc., are evaluated.

○ For organic hydride, a demonstration plant of toluene hydrogenation and dehydrogenation is constructed by the private sector.

○ MOE has conducted applied development of a high-efficiency stand-alone Hydrogen refining and storage system using Hydrogen-occlusion alloys.

Technology Roadmap



H_2 transport technology

- Compressed H_2 transport
- Liquefied H_2 transport
- Organic hydride, liquefied H_2 ammonia, DME, MCH, etc.

Drastic improvement in transport efficiency and safety
Drastic increase in density, cost efficiency, durability, safety

H_2 storage technology

- Ultra high pressure container
- Liquefied H_2 container
- H_2 storage materials (Alloy, inorganic, carbon, etc.)
- Clathrate, organometallic structural materials, organic hydride, etc.

Establishment and safety measures for H_2 supply infrastructure
System reviews, law development

- Small sized stations
- Establishment along with gas stations
- Local H_2 supply system
- Nation-wide H_2 supply system

(* Related roadmap: 13. Next-generation vehicle (FCV), 28. H_2 production/transport/storage (H_2 production), 30. Fuel cells)

International Trends

Current extent of diffusion

○ Hydrogen supply business operators aim for advance establishment of Hydrogen supply infrastructure (about 100 locations) by 2015, in accordance with the prospect of mass produced FCV.

Trend in technology development

○ US suggests gas transport through low-cost pipelines and liquefied transport through pipelines for Hydrogen transport. For Hydrogen storage, high pressure gas storage, absorption materials and carbon materials, Hydrogen-occlusion alloys, and liquid carrier materials and regeneration methods (e.g., organic hydride) are suggested.

○ EU plans demonstration of Hydrogen utilization as power source fuels using large-scale underground storage sites, development of alternative storage methods using solid materials that possess high price competitiveness, demonstration of operability for mixing Hydrogen into natural gas (5%) using existing gas supply networks.

International competitiveness of Japan

○ The performance of Japan's elemental technology required for Hydrogen transport is expected to become world class in future. Economic evaluations on various methods using practical transport routes are required.

30. Fuel Cells

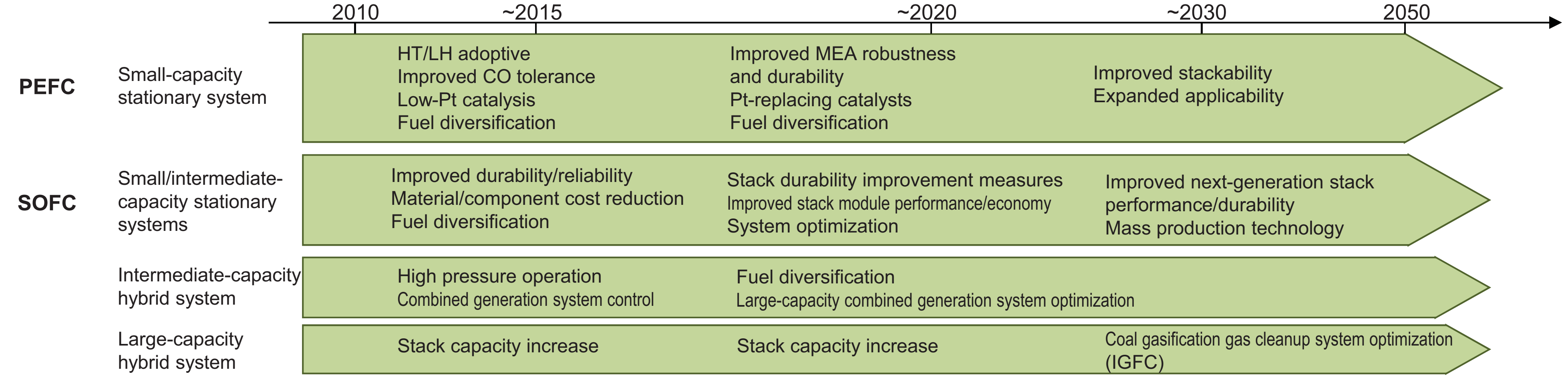
Technology Overview

- ○ Fuel cells directly generate electricity and heat through chemical reaction of Hydrogen and Oxygen, which theoretically has higher generation efficiency than thermal power generation. Additionally, the system itself doesn't have scale-wise restriction; large-scale power generation as well as small-scale power generation at general households are feasible.
- ○ There are currently Polymer Electrolyte Fuel Cell (PEFC) with low operation temperature, Solid Oxide Fuel Cell (SOFC) with high operation temperature and generation efficiency using ceramics, as well as Molten Carbonate Fuel Cell (MCFC) and Phosphoric Acid Fuel Cell (PAFC).

Trends and Issues in Technology Development in Japan

- ○ Both PEFC and SOFC are sold to general public as household systems. Diffusion promotion policies are comprehensively promoted to achieve wider diffusion, such as TD for cost reduction and reliability improvement and international standardization.
- ○ For PEFC, development of low-Pt technology and new catalyst materials to replace Pt catalyst for reducing cost, and TD for improved CO tolerance, improved impurity tolerance, and HT/LH electrolytes are conducted.
- ○ For SOFC, development of quick durability assessment method for achieving both cost reduction and high durability is in progress, and detection of issues obstructing practical application is conducted through demonstration of business-use intermediate-capacity and industrial-use large-capacity systems.

Technology Roadmap



PEFC

Small-capacity stationary system

HT/LH adoptive
Improved CO tolerance
Low-Pt catalysis
Fuel diversification

Improved MEA robustness and durability
Pt-replacing catalysts
Fuel diversification

Improved stackability
Expanded applicability

SOFC

Small/intermediate-capacity stationary systems

Improved durability/reliability
Material/component cost reduction
Fuel diversification

Stack durability improvement measures
Improved stack module performance/economy
System optimization

Improved next-generation stack performance/durability
Mass production technology

Intermediate-capacity hybrid system

High pressure operation
Combined generation system control

Fuel diversification
Large-capacity combined generation system optimization

Large-capacity hybrid system

Stack capacity increase

Stack capacity increase

Coal gasification gas cleanup system optimization (IGFC)

(* Related roadmap: 1. High-efficiency coal-fired power generation, 13. Next-generation vehicle (FCV), 28,29. H_2 production/transport/storage)

International Trends

Current extent of diffusion

- ○ Global market (actual) in 2011 was 49MW for business/industrial use (NA 36.3MW, Asia 11.2MW) and 10.8MW for household use (Japan 10.5MW).

Trends in technology development

- ○ US DOE Hydrogen and Fuel Cells Program works on TD of priority issues such as elucidation of deterioration mechanism. DOE aims at establishing mobile fuel cells of 900Wh/L by 2015, and developing 1-10kW class fuel cells with more then 45% overall efficiency by 2020 using natural gas as fuel.
- ○ EU FP7 is promoting TD on advanced multi-fuel reformers etc. for fuel cell CHP, aiming at commercialization of household-use fuel cells (≤5kW) and 5kW-1MW class CHP units that use H_2, natural gas and biogas.

International competitiveness of Japan

- ○ Japan leads the world in active TD and introduction support of fuel cells. In 2009, household PEFC were sold to general public for the first time in the world. In 2011, household SOFC were also introduced to the market. The cumulative introduction as of the end of FY 2012 reached 37,000 units, far more than in other countries.
- ○ US is ahead of the world in introduction of industrial intermediate-capacity systems. Japanese companies are actively developing them, aiming at catching up with US in several years. Industrial large-capacity systems remain at elemental research level domestically and overseas.

31. High-Performance Electricity Storage

Technology Overview

○ A technology to be utilized for solving issues such as electricity supply/demand imbalance and frequency fluctuations when renewable energies are introduced in a large scale in future. These issues are to be solved by introducing electricity storage systems such as large-scale batteries at renewable energy power generation facilities (e.g., mega solar, wind farm) and power system transformer substations of power companies.

○ High expectation is also placed on its application as peak out measures and peak shift functions, instantaneous blackout measures, as well as disaster measures.

Trends and Issues in Technology Development in Japan

○ METI is conducting development of low-cost long-life batteries for stabilization of the power system. For innovative batteries, a collaborative research system is established by the industry, universities and research institutions, researching various phenomena occurring inside batteries.

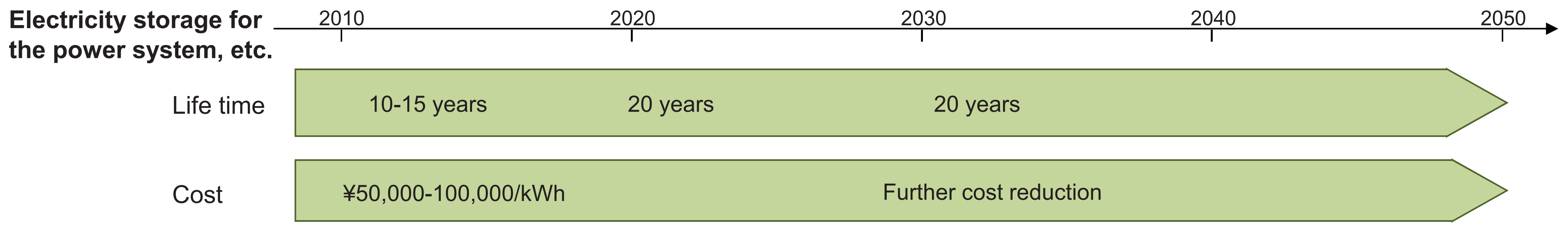
○ METI is also conducting demonstration tests of a world's-largest-scale battery installed in a substation, in order to expand the amount of renewable energies introduced. The target of the product is to acquire technique and knowhow necessary for practical utilization of such batteries in the power system. Furthermore, METI is assisting R&D for reducing cost, aiming at the price of excessive electricity storage batteries to be ¥23,000/kWh by 2020.

○ MEXT is conducting development of post Li-ion batteries, where material evaluation is conducted jointly with METI, aiming at practical application in 2030s.

○ MOE is conducting TD and demonstration of stand-alone dispersed energy systems using DC power supply technologies.

○ Batteries, as electricity storage technology, require energy density increase and cost reduction, as well as further improvement in durability and reliability.

Technology Roadmap



Electricity storage for the power system, etc.

2010 2020 2030 2040 2050

Life time: 10-15 years → 20 years → 20 years

Cost: ¥50,000-100,000/kWh → Further cost reduction

(* Related roadmap: 12. Next-generation vehicle (HV, PHV, EV, clean diesel vehicle, etc.))

International Trends

Current extent of diffusion

○ For stationary electricity storage systems, pumped-storage power generation has been introduced for electric-load leveling purposes. Development has been promoted on electricity storage systems with less locational restrictions and high multi-functionality (e.g., electricity quality improvement function), that allow reduction of power transmission and transformation loss by installing into important nodes. NAS batteries etc. have already been put into practical use.

Trends in technology development

○ Centering on Europe and US, TD and demonstrations are planned for applying batteries as measures against power system instability, etc., on introduction of renewable energies.

International competitiveness of Japan

○ Japanese companies used to lead the world in battery technologies especially for mobile equipment and automotives, but US, Europe, China, South Korea, etc., are expanding their market shares through TD and financial supports.

○ Electricity storage as power system stabilization measures is needed worldwide for expanding introduction of renewable energies in future. Strategic TD of Japan's world-class large battery technologies for practical application to the power system and cost reduction is important.

32. Heat Storage/Insulation Technology

Technology Overview

○ Heat storage, thermal insulation, thermoelectric conversion, etc., for effective utilization of widely dispersed heat resources.

- Heat storage: latent heat storage materials utilizing solid-liquid phase change, etc., are commercialized.
- Heat shielding: heat shielding materials to reflect thermic rays off solar rays, etc.
- Thermal insulation: high-performance thermal insulation materials applicable to high temperature ranges are highly sought after.
- Thermoelectric conversion: technology to utilize thermoelectric materials that directly generate electricity from heat.
- Waste heat recovery power generation (WHRPG): technology to recover unused heat as a form of electricity by utilizing thermal cycles.
- Thermal management: system technology to efficiently control element technologies.

Trends and Issues in Technology Development in Japan

○ METI is promoting R&D of heat storage, heat shielding, thermal insulation, thermoelectric conversion, WHRPG, heat pump, and thermal management technologies in its “R&D of innovative utilization technology of unused heat energy”.

○ MEXT is conducting development of thermal insulation materials, heat shielding technology, thermoelectric conversion materials and systems, etc.

○ Tasks for heat storage materials include improved heat storage density, improved heat conductivity, and cost reduction. Tasks for heat shielding technology include cost reduction. Tasks for thermal insulation technology include development of materials that achieve high strength, low cost and high insulation performance. Tasks for thermoelectric conversion technology include improvement of material performance index. Tasks for WHRPG include development of small-sized WHRPG technology. Tasks for thermal management include efficient management of unused energy utilization technologies.

Technology Roadmap

	2017	2022
Heat storage	Heat storage density: 0.5MJ/kg In –20 to 25ºC, retention time: ≥12h	Heat storage density: 1MJ/kg In –20 to 25ºC, retention time: ≥24h
Heat shielding	Visible light transmittance: 70% Solar radiation heat acquisition: 43%	Near-theoretical limit visible light transmittance: 70% Solar radiation heat acquisition: 40%
Thermal insulation	Compressive strength: ≥10MPa Thermal conductivity: ≤0.25W/m•K	Compressive strength: ≥20MPa Thermal conductivity: ≤0.20W/m•K
Thermoelectric conversion	Performance index: ZT=1 (organic) Performance index: ZT=2 (inorganic)	Performance index: ZT=2 (organic) Performance index: ZT=4 (inorganic)
WHRPG	Power generation efficiency: 14% Power output: 1kW	Power generation efficiency: 14% Power output: 10kW
Thermal management	High-efficiency device development High-accuracy heat generation/conduction simulation	Device efficiency improvement Thermal management technology (vehicle heat loss reduced by 75%)
Renewable heat utilization	Solar heat utilization system cost reduction Geothermal heat utilization system cost reduction	

2010 2017 2022 2030 2050

(* Related roadmap: 5. Solar energy utilization (solar heat utilization), 23. Energy-saving house/building)

International Trends

Current extent of diffusion

○ The issue of unused thermal energy is a global issue: TD for solving the issue is being promoted worldwide.

Trends in technology development

○ US (DOE), Europe (FP7), China, South Korea, etc., have commenced large-scale projects, such as development of applied research on thermal management under industry-academia-government collaboration. For instance, US DOE is actively working on WHRPG under industry-academia-government collaboration as part of “Next-Generation Vehicle R&D Project”, where car manufacturers participate in.

○ DOE is running a thermoelectric refrigeration HVAC project along with the vehicle WHRPG project. A DOE/NSF joint project was institutionalized and basic research on thermoelectric materials and systems are conducted by a collaborative team of universities, national institutions and companies.

International competitiveness of Japan

○ Japan maintains global excellence and leadership in development of novel materials that are essential for all the technologies discussed here.

33. Electricity Transmission by Superconductivity

Technology Overview

○ A cable transmission technology where energy loss during transmission is reduced by superconductivity (SC: a phenomenon where electric resistance of specific materials becomes zero when subjected to low temperatures)

○ Utilization of high-temperature SC (SC critical temperature is higher than the boiling point of liquefied N_2 (–196ºC)) enables reduction of transmission loss.

○ The technology enables effective utilization of electric energies through reduced transmission loss as measures against power demand increase in cities and establishment of power systems in emerging countries in future.

○ SC technology can be applied to not only power cables but also current limiters (CL), transformers, generators, flywheels, superconducting magnetic energy storage (SMES), etc.

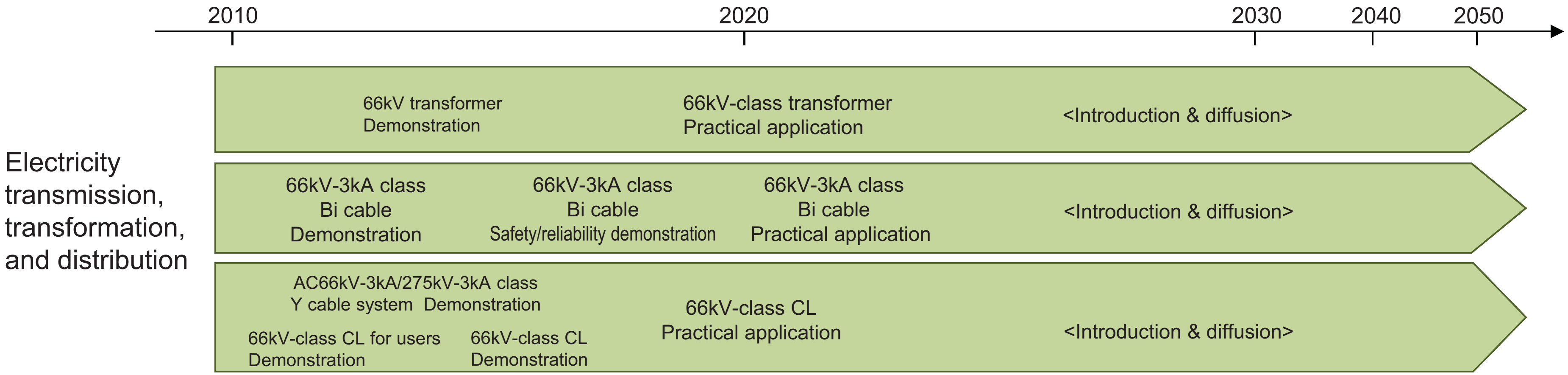
Trends and Issues in Technology Development in Japan

○ TD elements include length increase of wire rods and cables, voltage increase, current increase, loss reduction, development of transformers and electricity storage equipment, and refrigeration technology.

○ NEDO is conducting TD of Y(yttrium) SC electric appliances and demonstration of Bi(bismuth) high temperature SC cables. MLIT is supporting TD of SC cables between transformers and trains in railways.

○ For Y SC electric appliances, wire rods of 300m or more and SC cables of several dozen meters using Y materials have been developed. Bi high temperature SC cables have been also developed for current increase, cost reduction and length increase, aiming at industrial application as early as possible.

Technology Roadmap



2010 2020 2030 2040 2050

Electricity transmission, transformation, and distribution

66kV transformer Demonstration

66kV-class transformer Practical application

<Introduction & diffusion>

66kV-3kA class Bi cable Demonstration

66kV-3kA class Bi cable Safety/reliability demonstration

66kV-3kA class Bi cable Practical application

<Introduction & diffusion>

AC66kV-3kA/275kV-3kA class Y cable system Demonstration

66kV-class CL for users Demonstration

66kV-class CL Demonstration

66kV-class CL Practical application

<Introduction & diffusion>

International Trends

Current extent of diffusion

○ In developed countries, application of SC to underground cables is anticipated as a measure against power demand in cities by reduced transmission loss and large current transmission. In NY State in The US, power transmission using actual cables commenced in July 2006 (Albany Project).

○ In Japan, demonstration of linkage operation to the power system started in late 2012 as part of NEDO project, attracting attentions of overseas power companies.

Trends in technology development

○ NEDO is promoting “TD Project for Yttrium Superconducting Electrical Systems” and “High-Temperature Superconductor Cable Verification Project”. The former project is developing wire rods of 300m or more and SC cables using Y materials.

○ NIMS is conducting research on advanced SC wire rods including development of new wire rod materials and elucidation of SC mechanisms, contributing to less transmission power loss.

International competitiveness of Japan

○ Japan’s SC technologies maintain advantage over Europe and US, especially in Bi wire rods that are called the first generation SC and Y SC cables that are called the second generation SC where global competition is becoming intense lately.

34. Methane etc. Reduction Technology

Technology Overview

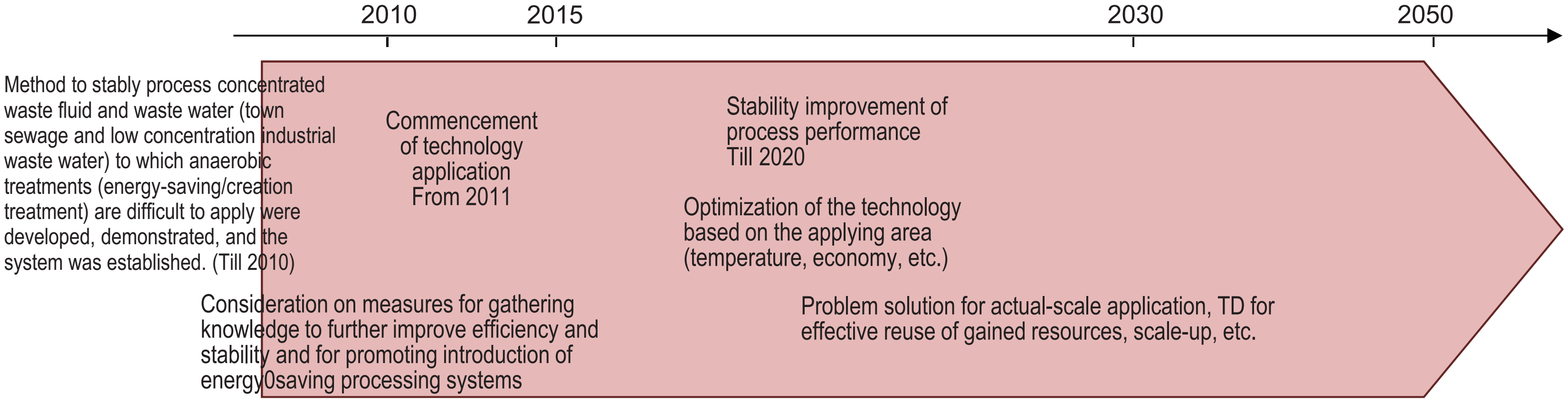
- High-efficiency low-cost processing methods centering on anaerobic treatment (e.g., methane fermentation) with no aeration power and less excess sludge.
- Microorganisms that take charge of anaerobic treatment of waste water will be enriched (optimized) and sustained for achieving treatment time reduction and stability improvement of waste water treatment.
- Methane generated during processing will be recovered and utilized as energy.
- Water quality improvement through a combination with aerobic treatment where no aeration power by using gravity flow.
- These technologies will achieve a significant reduction of GH gas emission.
- The GH gas reduction effects of waste water/fluid process optimization are 8.07Mt-CO_2 p.a. in Japan and 250Mt-CO_2 p.a. in Asia (converted to CO_2, estimate by MOE).

Trends and Issues in Technology Development in Japan

- MAFF is conducting R&D of livestock wastewater treatment technology and feed that reduces methane emissions of ruminant livestock origin. MAFF also promotes development of N_2O reduction technologies in the agricultural field.
- MLIT is conducting demonstration of GH gas emission reduction (e.g., CO_2, N_2O) at sewage treatment plants in its B-DASH project.
- MOE is conducting demonstration of anaerobic treatment, etc.
- Tasks for anaerobic treatment include heating energy reduction (methane fermentation temperature reduction), low-concentration/high-concentration waste water treatment, treatment of non-decomposing components, and fermentation inhibition avoidance; relevant TD is conducted. Cost reduction is also required.
- Development of MBR and UASB-DHS (anaerobic-aerobic) is conducted to reduce electricity consumption during waste water treatment.
- Conversion from CFC and HCFC to HFC is progressing (e.g., coolant for refrigerators and AC). Measures against leakage during use and disposal will be required in future.

Technology Roadmap

Demonstration of Shochu waste fluid processing



Method to stably process concentrated waste fluid and waste water (town sewage and low concentration industrial waste water) to which anaerobic treatments (energy-saving/creation treatment) are difficult to apply were developed, demonstrated, and the system was established. (Till 2010)

Commencement of technology application From 2011

Stability improvement of process performance Till 2020

Optimization of the technology based on the applying area (temperature, economy, etc.)

Consideration on measures for gathering knowledge to further improve efficiency and stability and for promoting introduction of energy0saving processing systems

Problem solution for actual-scale application, TD for effective reuse of gained resources, scale-up, etc.

International Trends

Current state of diffusion

- Methane fermentation facilities are spreading in US and Europe to treat livestock wastewater and sewage. In Europe, a total of ~7,500 methane fermentation (biogas) plants are in operation as of 2012 (includes other than wastewater).
- High-efficiency wastewater treatment is also introduced to Southeast Asia, etc.
- Japan worked on departure from fluorocarbons in refrigerators ahead of the world.

Trends in technology development

- Europe and US continue developing high-efficiency and energy-saving anaerobic aerobic wastewater treatment technologies.

International competitiveness of Japan

- Japan's anaerobic processing technologies and research on microbial control and optimization are the most advanced in the world.
- Processing energy and CO_2 emissions will be further reduced by applying the technology to unapplied areas (e.g., industrial waste water/fluid and town sewage) and improving its efficiency, and secondary effects (carbon neutral) are expected through collection and utilization of generated methane.
- Advanced wastewater treatment technologies including nitrogen treatment need to be introduced to developing countries.

35. Carbon Fixation by Vegetation

Technology Overview

○ Super trees are genetically modified (GM) trees that grow in arid environments where desertification or salt damage has progressed, developed by introducing genes related to environmental stress tolerance.

○ Depending on introduced gene, various characteristic can be added, including salinity tolerance, drought tolerance, acid soil tolerance, growth promotion, ozone tolerance, and high cellulose content.

○ Planting super trees in arid areas in the world will contribute to the fight against global warming as a source of CO_2 absorption.

○ Planting super trees to 5% (2 million km^2) of a 40 million km^2 of desertified area will achieve absorption of 0.5 t-CO_2 p.a. (calculated using the annual absorption value of 2.5t-CO_2/ha·year. Source: Forestry and Forest Products Research Institute research results).

Trends and Issues in Technology Development in Japan

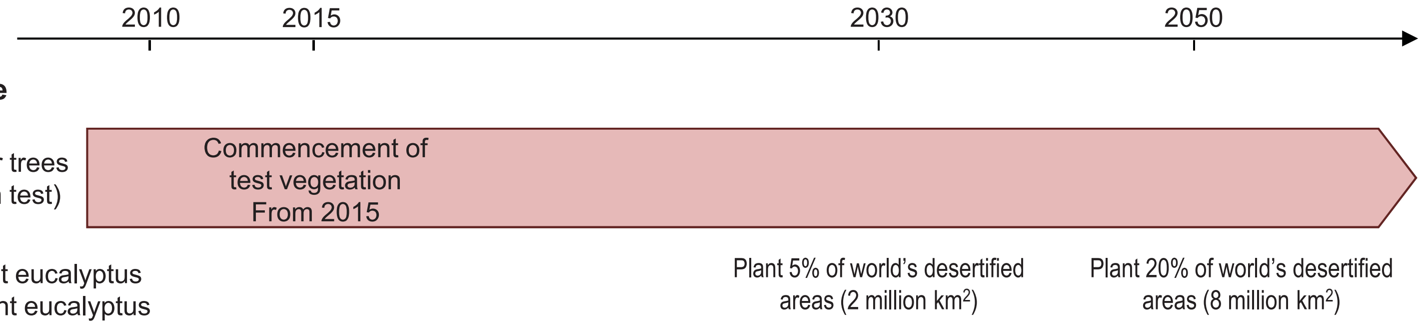
○ MAFF conducts "Fundamental TD for Creation of Super Trees Contributing to Environmental Conservation", promoting development of super trees through genetic modification.

○ MEXT is promoting research on "high-productivity easy-decomposition super trees" as part of the biomass engineering program.

○ METI is promoting technology to extend vegetation to hostile environment areas such as arid areas.

○ Development of super trees require bestowing multiple beneficial properties (e.g., environment stress resistance such as drought tolerance and salinity tolerance, high biomass yielding property) through genetic modification.

Technology Roadmap



2010 2015 2030 2050

Super trees development example

Development of super trees
(e.g., GM, application test)

Commencement of
test vegetation
From 2015

Plant 5% of world's desertified areas (2 million km^2)

Plant 20% of world's desertified areas (8 million km^2)

- Environmentally tolerant
- High in biomass
- Fast growing

- Salinity tolerant eucalyptus
- Drought tolerant eucalyptus
- Acid soil (Al) tolerant eucalyptus
- Growth promoted poplar
- Ozone tolerant poplar
- High-cellulose poplar etc.

International Trends

Current extent of diffusion

○ There is an example of commercial growth of BT poplar in China. Basic research and field growth test of high-productivity trees are promoted in many countries.

Trends in technology development

○ R&D of high-productivity trees are promoted in some countries. More than 100 field tests of GM trees have been conducted in US.

International competitiveness of Japan

○ Development of GM trees specified to environmental tolerance is specific to Japan (US sets priority on biomass yield).

○ Super trees may grow in hostile environment areas that are growing worldwide due to desertification and salt damage.

○ Global desertified areas include arid area 9 million km^2, semiarid area 27.4 million km^2, and salt accumulated area 4 million km^2 (totaling 40 million km^2). Super trees suitable to each area will be developed and globally diffused.

36. Global Warming Adaptation Technology

Technology Overview

○ Field crops with hostile environment tolerance will be developed through utilization of DREB genes (drought and salinity tolerance genes), cold tolerance genes, etc.

○ Stable production of agricultural products will be achieved as a core measure toward global warming.

○ Dependence on new farmland development through deforestation, resulting in preservation of forests as a source of CO_2 absorption.

Trends and Issues in Technology Development in Japan

○ MAFF has conducted production of drought-tolerant rice and wheat through genetic modification and evaluation of their drought stress tolerance in its “DREB Project” .

○ MAFF is promoting development of production stabilization technologies adaptive to the progressing global warming, development of stable livestock growing technology, development of laver breeding technology, and stable agricultural production technology utilizing biodiversity (integrated pest management systemization technology with high biodiversity sustainability), etc., in its “Project for Establishing Recirculating Food Production Adaptive to Climate Change”.

○ MEXT is promoting research on “Innovative Technology and System for Sustainable Water Use”, development of method to downscale global climate change prediction to regional scales, R&D and infrastructure establishment for data & information integration, etc., aiming at contribution to achieving sustainable society adaptive to climate changes, etc.

Technology Roadmap

2010 2015 2030 2050

Development of high-tolerance rice

Normal rice Gene high expression rice

Development of drought- and salt damage-tolerant crops was commenced in collaboration with international agricultural research institutions (2007)

- Produced drought-tolerant GM rice (paddy rice, upland rice) and wheat
- Identified properties other than drought tolerance in greenhouse

Till 2008

- Separate/improve novel tolerance genes, etc.
- Evaluate tolerance/applicability of transformation systems

Till 2017

Develop highly cold-tolerant biomass/feed rice

From 2010

Global diffusion of useful outcome

Planting target (worldwide) 8.1 million ha

Planting target (worldwide) 24.3 million ha

Example of potential adaptive measures

	Food, fiber, forestry	Water resources	Human health	Industry, habitat, society
Drying / drought	Development of new drought tolerant species etc.	Reduction of leakage etc.	Storage of food and preparation of emergency feeding stations etc.	Improvement of water supply system and adjustment of service area, etc.
Increased rainfall/ deluge	Improvement of reclaimed lands and drainage, etc.	Protective measures incl. deluge forecast / warning, etc.	Structural and non-structural measures etc.	Improvement of deluge mitigation infrastructure, etc.
Warming/ heat wave	Development of new heat tolerant species etc.	Water demand management through planning and pricing, etc.	International monitoring system for breakout of diseases, etc.	Assistance program for specifically vulnerable groups etc.
Gale / rainstorm	Development of wind tolerant crops	Planning and practice of coast protection to protect water resources from contaminations	Early warning system, etc.	Preparation against emergencies including early warning system, etc.

* Extract from IPCC WG2 AR4

International Trends

Current extent of diffusion

○ In various places creation of global warming adaptive systems is in progress. NYC produced a city plan adapting to global warming.

○ In developing countries establishment of water infrastructure is in progress, which potentially becomes one of measures against global warming measures.

Trends in technology development

○ IPCC WG2 AR4 evaluated impacts of climate change to water, ecosystem, food, coastal areas, and human health, and proposed adaptive measures for each item.

International competitiveness of Japan

○ Japan’s research related to cold tolerance goes ahead of Europe and US.

○ Japan discovered drought-tolerance induction genes, etc., ahead of the world.

37. Earth Observation • Climate Change Prediction

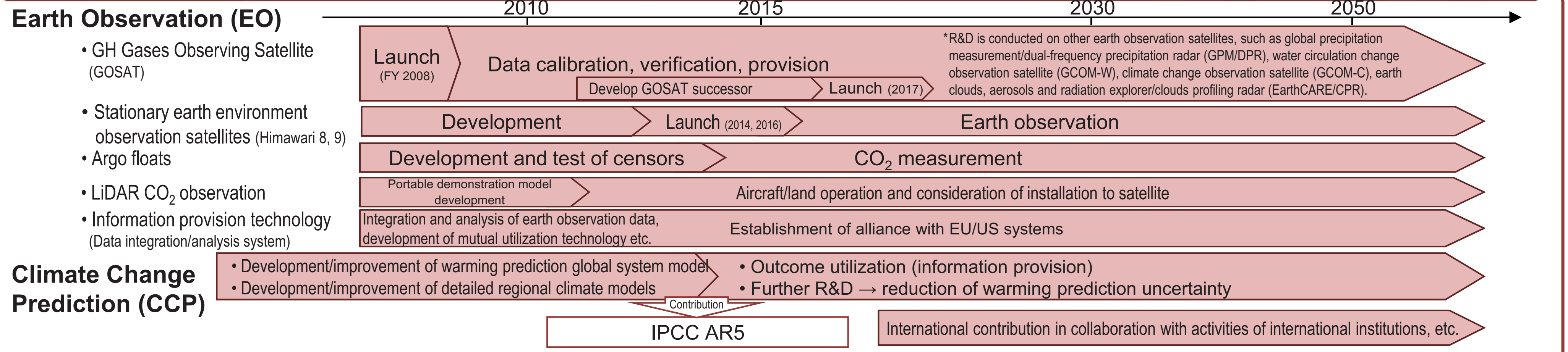
Technology Overview

- ○ Earth observation: In order to assist effective and efficient global warming countermeasures, accurate long-term continuous monitoring of global GH gas concentration distribution and climate change will be conducted using earth observation satellites (e.g., GOSAT), stationary earth environment observation satellites, LiDAR technology for measuring CO_2 concentration in the air, Argo floats for measuring CO_2 concentration in the ocean, etc.
- ○ Climate change prediction: Long-term precise prediction of global warming effects and evaluation of impacts of resultant natural disasters (e.g., aerial CO_2 concentration stabilization scenario, ice sheet melting) are available through advancement of climate change prediction model itself as well as development and introduction of elemental models such as models that take into account interactions of CO_2 absorption and response among the air, land, and ocean, and detailed regional climate models that extract detailed prediction information around Japan.

Trends and Issues in Technology Development in Japan

- ○ Earth observation: MEXT is the main entity contributing to establishment of the Global Earth Observation System of Systems (GEOSS) where various worldwide observation and information systems (e.g., existing and future satellites) are working in collaboration. MOE is conducting development of a succession machine in collaboration with relevant institutions from FY 2012.
- ○ Climate change prediction: MEXT is promoting TD, in “Program for Risk Information on Climate Change (SOUSEI)” etc., aiming at realization of accurate high-resolution climate change prediction by developing prediction models that take account of complex physical and biogeochimical processes in the air, ocean, and land for a broad scale from the global scale to river basin scale. MEXT also aims at creation of predictive base information that contributes to planning of measures against climate change impacts by quantifying uncertainty of prediction experiment results.
- ○ Carbon cycle, nitrogen cycle: Observation and modeling research are conducted for elucidation of carbon cycles. MAFF is conducting climate change measure project research, etc., for nitrogen cycles. However, grasp of actual condition is inadequate; development of monitoring technology is required.

Technology Roadmap



Earth Observation (EO)

- • GH Gases Observing Satellite (GOSAT): Launch (FY 2008) → Data calibration, verification, provision; Develop GOSAT successor → Launch (2017)

*R&D is conducted on other earth observation satellites, such as global precipitation measurement/dual-frequency precipitation radar (GPM/DPR), water circulation change observation satellite (GCOM-W), climate change observation satellite (GCOM-C), earth clouds, aerosols and radiation explorer/clouds profiling radar (EarthCARE/CPR).

- • Stationary earth environment observation satellites (Himawari 8, 9): Development → Launch (2014, 2016) → Earth observation
- • Argo floats: Development and test of censors → CO_2 measurement
- • LiDAR CO_2 observation: Portable demonstration model development → Aircraft/land operation and consideration of installation to satellite
- • Information provision technology (Data integration/analysis system): Integration and analysis of earth observation data, development of mutual utilization technology etc. → Establishment of alliance with EU/US systems

Climate Change Prediction (CCP)

- • Development/improvement of warming prediction global system model
- • Development/improvement of detailed regional climate models
- → • Outcome utilization (information provision)
- • Further R&D → reduction of warming prediction uncertainty

Contribution

IPCC AR5

International contribution in collaboration with activities of international institutions, etc.

International Trends

Current extent of diffusion

- ○ EO: In US, a high resolution remote sensing satellite was developed by a private company and in commercial operation. NASA etc. have launched various remote sensing satellites, medium/low-resolution data such as LANDSAT and EOS are globally distributed for free.
- ○ CCP: In UK, based on Climate Change Act, UK-wide Climate Change Risk Assessment (CCRA) is conducted every 5 years, and National Adaptation Plan is formulated based on CCRA.

Trends in technology development

- ○ EO: National Geospatial-Intelligence Agency is assisting long-term development cost for pictures, strengthening competitiveness of US remote sensing industry (e.g., GeoEye-2). The Afternoon Constellation (A-Train) project is in progress where observation is made by multiple earth environment observation satellites forming a constellation.
- ○ CCP: The prediction models global comparison project was promoted aiming at formulation of IPCC AR5 (to be authorized in order from the end of September 2013).
- ○ Others: As an option of climate risk management, global evaluation research on the effects of Solar Radiation Management and risks other than climate change was commenced from the viewpoint of geo-engineering.

International competitiveness of Japan

- ○ EO: GOSAT can observe CO_2, CH_4 etc.; Japan has the edge.
- ○ CCP: Warming prediction using Japan’s climate models is referred by IPCC AR and known as the most advanced research in the world. The earth simulator has led climate change research. Japan has the edge in realization of high resolution (region/city level) prediction.