

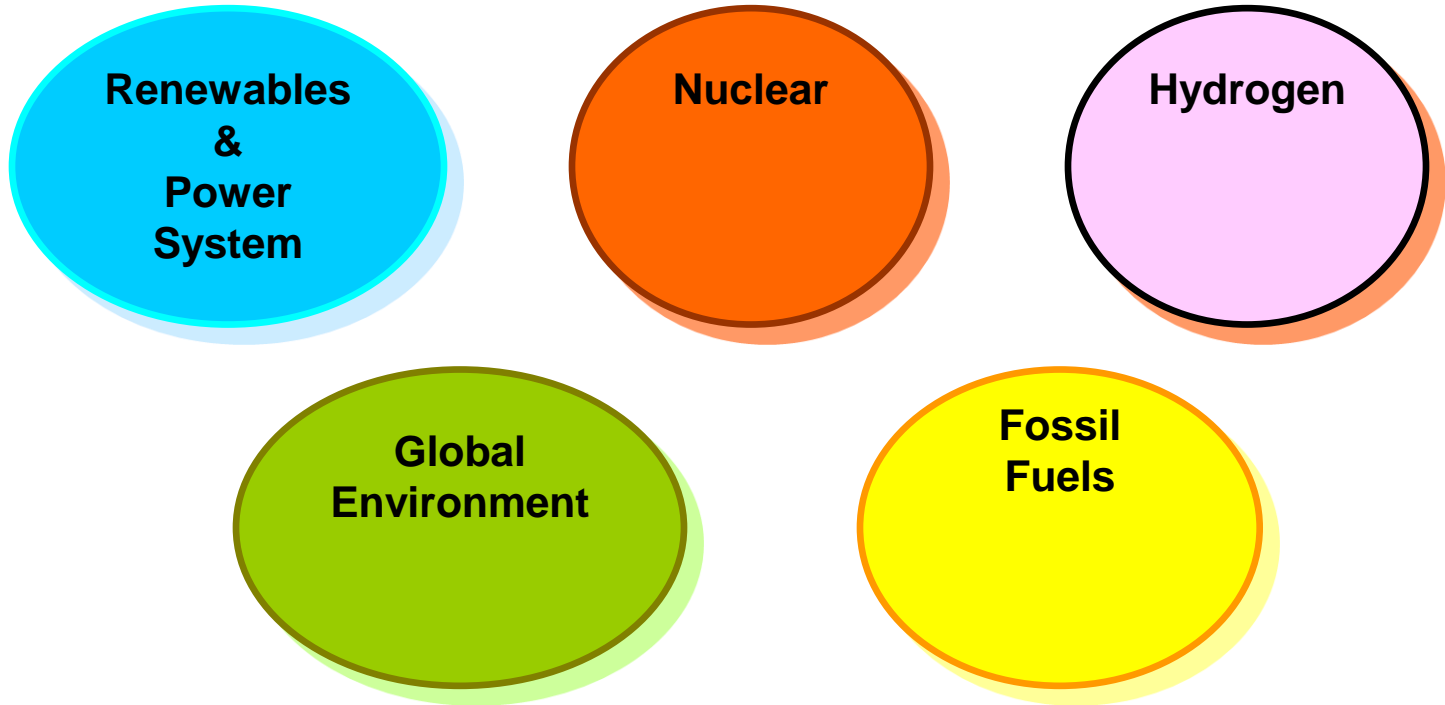
R&D Investment in Japan's New Energy and Climate Technology Strategy

Workshop on
Modeling and Analyses in R&D Priority-setting and Innovation
Experts' Group on R&D Priority-setting and Evaluation (EGRD)
IEA Committee on Energy Research and Technology (CERT)
IEA, Paris, France
April 23-24, 2014

Atsushi Kurosawa
Institute of Applied Energy (IAE), JAPAN

IAE overview

- Since 1978
- Non-profit organization
- Expertise - energy technology assessment
- Energy areas
- Visit <http://www.iae.or.jp> for further information



Energy and Environment System Analysis Tools in IAE

GRAPE : Global

15 regions

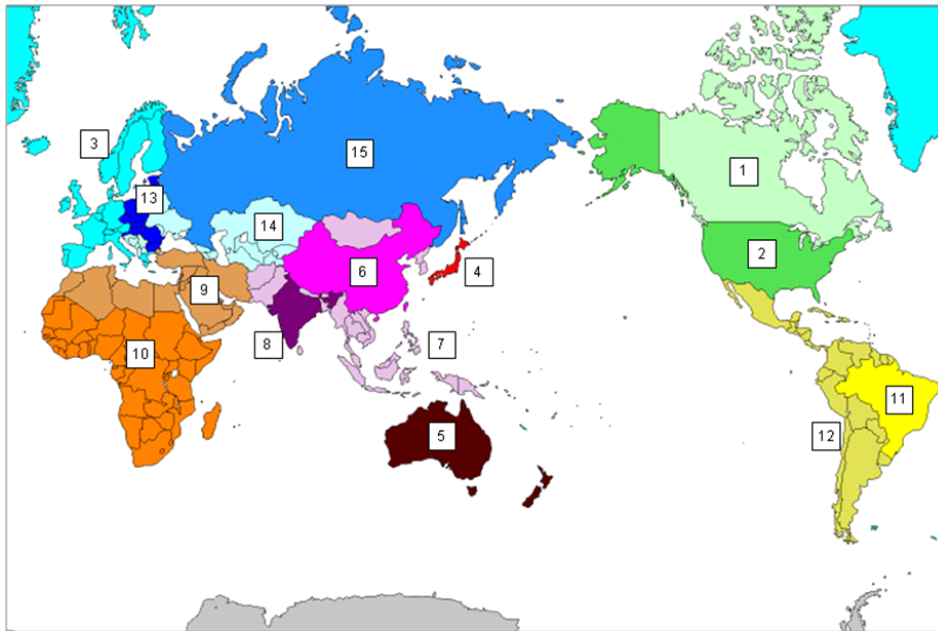
2000 to 2100, Optimization model

Utility maximization

Integrated Assessment Model

Macroeconomy , Landuse&Ag, Energy

Climate, Impacts



TIMES-Japan : Japan

One region

1990 to 2050, Optimization model

Discounted sum of energy system cost

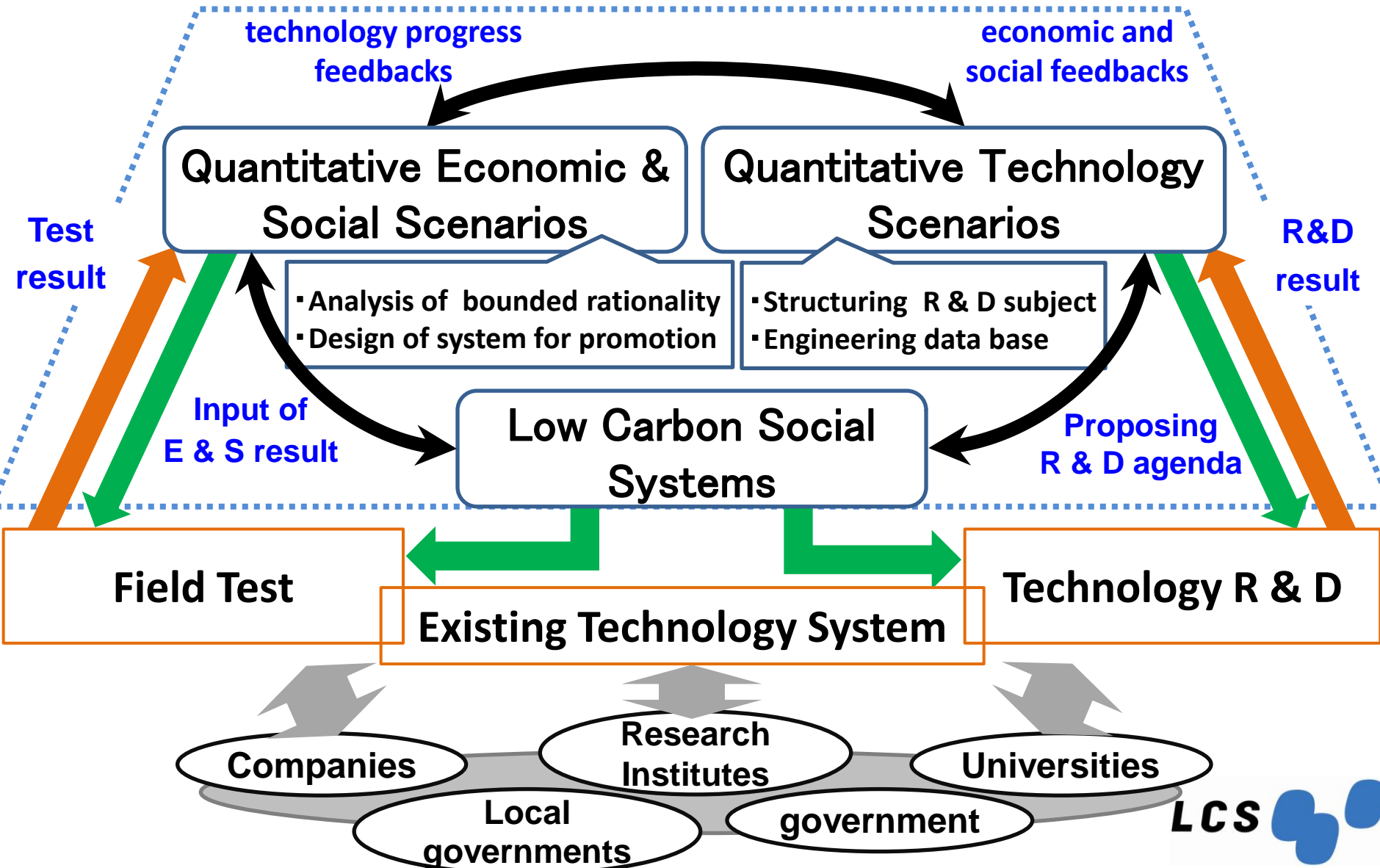
Energy System Analysis model

Energy technology in detail



Towards low carbon society

Center for Low Carbon Society Strategy / Japan Science and Technology Agency (LCS/JST)



Outline

- 1. New Basic Energy Plan**
- 2. What is Innovation?**
- 3. New Low Carbon Technology Plan**
- 4. Summaries**

New Basic Energy Plan

- ❑ Japanese Cabinet made a decision to define revised 'Basic Energy Plan' on April 11, 2014, as results of long political and public debate after Great East Japan Disaster of March 11, 2011.
- ❑ Official English translation will be available soon.
- ❑ Contents and Keywords
 - Agenda of Japanese energy supply and demand
Energy import, Population decrease, Innovation opportunity, global GHGs emission increase
 - Fundamental policy
Energy Security, Economic Efficiency, Environment & Safety (3E+S)
Flexible supply and demand structure
Primary and secondary energy supply structure
 - Sector policy
Energy and mineral resources, Energy conservation and smart use, Renewable energy, Restructuring nuclear policy, Efficient and stable fossil fuel use, Energy market reform, Robust supply network, New secondary energy structure, Market integration, International Cooperation
 - Strategic technology development
Energy technology roadmap
 - Public involvement

What is Innovation?

- ❑ One important keyword of the workshop is 'innovation'. We need common recognition of innovation for deep discussion.
- ❑ Our definition of innovative technology in the past may help the discussions.(extraction from 'cool earth innovative energy technology program, METI, 2008)

http://www.iae.or.jp/research/project/Cool_Earth08_e/CoolEarth_RM.pdf

- Technologies expected to deliver **substantial reductions in carbon dioxide emissions in the world by 2050**.
 - Technologies that can be commercialized by 2030 considering the period required for the diffusion of the technology
 - Technologies that can be commercialized after 2030 if the period required for diffusion is short.
- Innovative technologies expected to deliver a **substantial performance improvement, cost reduction, expansion in diffusion** and so forth through one of the following methods:
 - **Material** innovation including the utilization of new principles and the new utilization of existing materials (e.g. PV cells with new structures or materials, an alternative catalyst to platinum in fuel cells, etc.)
 - Innovation in **production processes** (e.g. Innovative iron and steel process using hydrogen as the reducing agent, etc.)
 - **Demonstration of systems** based on established elemental technologies (e.g. Carbon dioxide capture and storage technology)
- Technologies that Japan can lead.

New Low Carbon Technology Plan

- Initiative of Council for science and technology policy, Cabinet office
- 2013 version revision policy
 - Identifying innovative technologies that should be developed in the short- to medium-term and medium to long-term
 - Challenges and roadmap for promoting technology development
 - Policy measures required for international promotion and dissemination of innovative technologies
 - Seeking to promote the development of Japan's prominent environmental technologies and contribute to achieving the goal of halving global greenhouse gas emissions
- For detail, please visit the website.

http://www8.cao.go.jp/cstp/english/doc/new_low_carbon_tec_plan/

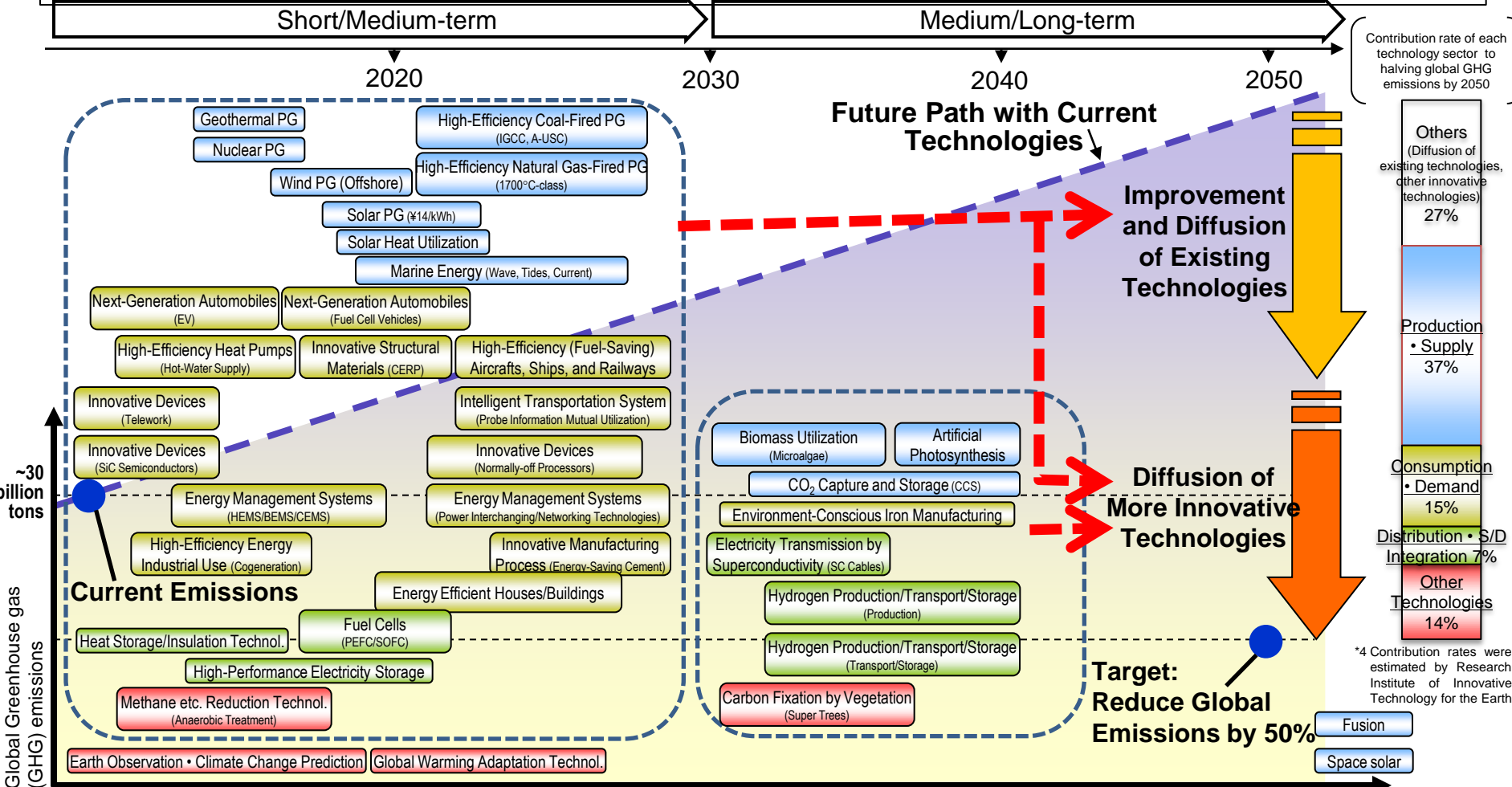
New Low Carbon Technology Plan

□ Key messages

- To achieve both economic development and significant reductions in GHGs emissions, it is essential to develop and disseminate **innovative technologies**. As part of the global effort to find solutions to this challenge, Japan, home to the world's top-level technologies, to take international leadership in the development and dissemination of innovative technologies.
- **37 technology area**
 - energy supply, energy demand, distribution & integration, others
- **R&D promotion**
 - enhancing collaboration among industry, academia and government
 - policy tools
(e.g. regulatory reforms, taxation, standard, venture business)
 - government initiative of high-risk and high return innovative
- Innovative technology **global diffusion** measures
 - finance, standard

Global Contribution of Japan's Environmental and Energy Technologies

Japan will continue to develop advanced environmental and energy technologies in the short/medium-term to medium/long-term, and will contribute to halving global greenhouse gas emissions by 2050 through global diffusion of such technologies. It is necessary to promote developing more innovative technologies over a medium-to-long-term, due to difficulties in achieving this emission reduction target by improvement and diffusion of existing technologies.



*1 The horizontal position of environmental and energy technologies indicates approximate time of practical diffusion based on the roadmap of each technology.
 *2 "Future path with current technologies" indicates approximate transition of global GHG emissions assuming no change in efficiencies for existing technologies (e.g., generating efficiency of coal-fired generation)
 *3 The downward arrows for "Improvement and diffusion of existing technologies" and "Diffusion of innovative technologies" indicate both contributions are required to reduce global GHG emissions; they do not specify the amount of reduction by each contribution.

Legend

- Production • Supply
- Consumption • Demand
- Distribution • S/D Integration
- Other Technologies

*1 Center of bars indicates approximate time of practical diffusion.
 *2 Parentheses show technology examples. Refer to the full text for details.

Target Technologies

Global GH Gas Reduction Effect (2050)	A: 1 billion ton or more, B: 0.3-1 billion ton, C: Less than 0.3 billion ton
Global Market Size	A: 3 trillion yen or more, B: 0.3-3 trillion yen, C: Less than 0.3 trillion yen
Maturity Phase	Basic research, Applied research, Demonstration, Diffusion

Sector	Category	Subcategory	Global GH Gas Reduction Effect (2050)	Global Market Size	Maturity Phase
Production • Supply	Thermal Power Generation	1. High-Efficiency Coal-Fired Power Generation	A	A	Demonstration
		2. High-Efficiency Natural Gas-Fired Power Generation	A *1	A	Demonstration
	Utilization of Renewable Energies	3. Wind Power Generation	A	A	Demonstration-Diffusion
		4. Solar Energy Utilization (Solar Light)	A	A	Basic Research-Diffusion
		5. Solar Energy Utilization (Solar Heat)	A	A	Basic Research-Diffusion
		6. Marine Energy (Wave, Tides, Current)	B	B	Demonstration
		7. Geothermal Power Generation	B	A	Basic Research-Diffusion
		8. Biomass Utilization	A	A	Basic Research-Diffusion
	Nuclear Power	9. Nuclear Power Generation	A	A	Basic Research-Demonstration
	CO ₂ Capture, Use, Storage (CCUS)	10. CO ₂ Capture and Storage (CCS)	A	A	Demonstration
		11. Artificial Photosynthesis	*2	*2	Basic Research-Demonstration
Consumption • Demand	Transportation	12. Next-Generation Automobiles (HV, PHV, EV, Clean Diesel, etc.)	A	A	Diffusion
		13. Next-Generation Automobiles (Fuel Cell Vehicles)	B	A	Demonstration-Diffusion
		14. Aircrafts, Ships, Railways (Aircrafts)	B *3	A	Applied Research-Diffusion
		15. Aircrafts, Ships, Railways (Ships)	B *3	A	Applied Research-Diffusion
		16. Aircrafts, Ships, Railways (Railways)	C	A	Applied Research-Diffusion
		17. Intelligent Transportation System	*2	*2	Demonstration-Diffusion
		Devices	18. Innovative Devices (Information System, Lighting, Display)	A *4	A
	19. Innovative Devices (Power Electronics)		*2	C	Demonstration
	20. Innovative Devices (Telework)		*2	C	Applied Research-Diffusion
	Materials	21. Innovative Structural Materials	A *5	A	Applied Research-Diffusion
	Energy Utilization Technology	22. Energy Management System	A	A	Applied Research-Diffusion
		23. Energy Efficient Houses/Buildings	A *6	A	Applied Research-Diffusion
		24. High-Efficiency Energy Industrial Use	B *7	A	Applied research-Diffusion
		25. High-Efficiency Heat Pumps	B *8	A	Applied Research-Diffusion
	Production Process	26. Environment-Conscious Iron Manufacturing Process	*2	*2	Applied Research-Demonstration
		27. Innovative Manufacturing Process	A *9	A *9	Applied Research
	Distribution • Supply/Demand Unification	Energy Conversion, Storage, Transport	28. Hydrogen Production, Transport, Storage (Production)	*10	C
29. Hydrogen Production, Transport, Storage (Transport/Storage)			*10	C	Demonstration
30. Fuel Cells			B	B	Demonstration-Diffusion
31. High-Performance Electricity Storage			*10	B	Applied Research-Diffusion
32. Heat Storage/Insulation Technology			C *11	B	Applied Research-Diffusion
33. Electricity Transmission by Superconductivity			C	B	Demonstration
Other Technologies	34. Carbon Fixation by Vegetation	A	A	Demonstration-Diffusion	
	35. Other GH Gas (e.g., Methane) Reduction Technology	C	A	Demonstration	
	36. Global Warming Adaptation Technology	*2	A	Basic Research-Diffusion	
	37. Earth Observation • Climate Change Prediction	*2	*2	Basic Research-Diffusion	

(Note) The present table shows evaluation based on estimates using conditions and scenarios specific to individual technologies. Reduction effects cannot be simply added up because their overlaps among technologies are not eliminated.

(References) The following materials were referred to in compilation of the present table.

• IEA, Energy Technology Perspectives (ETP) 2012 (2012); IEA, Energy Technology Perspectives (ETP) 2010 (2010); Council for Science and Technology Policy, Innovative Strategy for Energy and the Environment (2008); 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)

37 Technologies

- GHG mitigation
- Market
- Maturity

- Relative potential contribution to global GHG mitigation and Potential global market size

Large
Medium
Small
Not Evaluated

- Maturity of technology

Basic Research–Demonstration
Basic Research–Diffusion
Applied Research
Applied Research–Diffusion
Demonstration
Demonstration–Diffusion
Diffusion

Technology Categories	GHG reduction potential in 2050	Global Market	Maturity Phase
1. High-Efficiency Coal-Fired Power Generation	Large	Large	Demonstration
2. High-Efficiency Natural Gas-Fired Power Generation	Large	Large	Demonstration
3. Wind Power Generation	Large	Large	Applied Research–Diffusion
4. Solar Energy Utilization (Solar Light)	Large	Large	Applied Research–Diffusion
5. Solar Energy Utilization (Solar Heat)	Large	Large	Applied Research–Diffusion
6. Marine Energy (Wave, Tides, Current)	Medium	Medium	Demonstration
7. Geothermal Power Generation	Medium	Large	Applied Research–Diffusion
8. Biomass Utilization	Large	Large	Applied Research–Diffusion
9. Nuclear Power Generation	Large	Large	Basic Research–Diffusion
10. CO ₂ Capture and Storage (CCS)	Large	Large	Demonstration
11. Artificial Photosynthesis	Not Evaluated	Not Evaluated	Basic Research–Diffusion
12. Next-Generation Automobiles (HV, PHV, EV, Clean Diesel, etc.)	Large	Large	Applied Research–Diffusion
13. Next-Generation Automobiles (Fuel Cell Vehicles)	Large	Large	Applied Research–Diffusion
14. Aircrafts, Ships, Railways (Aircrafts)	Medium	Large	Applied Research–Diffusion
15. Aircrafts, Ships, Railways (Ships)	Medium	Large	Applied Research–Diffusion
16. Aircrafts, Ships, Railways (Railways)	Small	Large	Applied Research–Diffusion
17. Intelligent Transportation System	Not Evaluated	Not Evaluated	Applied Research–Diffusion
18. Innovative Devices (Information System, Lighting, Display)	Large	Large	Applied Research–Diffusion
19. Innovative Devices (Power Electronics)	Not Evaluated	Small	Demonstration
20. Innovative Devices (Telework)	Not Evaluated	Small	Applied Research–Diffusion
21. Innovative Structural Materials	Large	Large	Applied Research–Diffusion
22. Energy Management System	Large	Large	Applied Research–Diffusion
23. Energy Efficient Houses/Buildings	Large	Large	Applied Research–Diffusion
24. High-Efficiency Energy Industrial Use	Medium	Large	Applied Research–Diffusion
25. High-Efficiency Heat Pumps	Medium	Large	Applied Research–Diffusion
26. Environment-Conscious Iron Manufacturing Process	Not Evaluated	Not Evaluated	Applied Research–Diffusion
27. Innovative Manufacturing Process	Large	Large	Demonstration
28. Hydrogen Production, Transport, Storage (Production)	Not Evaluated	Small	Demonstration
29. Hydrogen Production, Transport, Storage (Transport/Storage)	Not Evaluated	Small	Demonstration
30. Fuel Cells	Medium	Medium	Applied Research–Diffusion
31. High-Performance Electricity Storage	Not Evaluated	Medium	Applied Research–Diffusion
32. Heat Storage/Insulation Technology	Small	Medium	Applied Research–Diffusion
33. Electricity Transmission by Superconductivity	Not Evaluated	Medium	Demonstration
34. Carbon Fixation by Vegetation	Large	Large	Applied Research–Diffusion
35. Other GHG (e.g., Methane) Reduction Technology	Small	Large	Demonstration
36. Global Warming Adaptation Technology	Not Evaluated	Large	Applied Research–Diffusion
37. Earth Observation • Climate Change Prediction	Not Evaluated	Large	Applied Research–Diffusion

Source : modified format using new low carbon plan webpage data

1. High-Efficiency Coal-Fired Power Generation

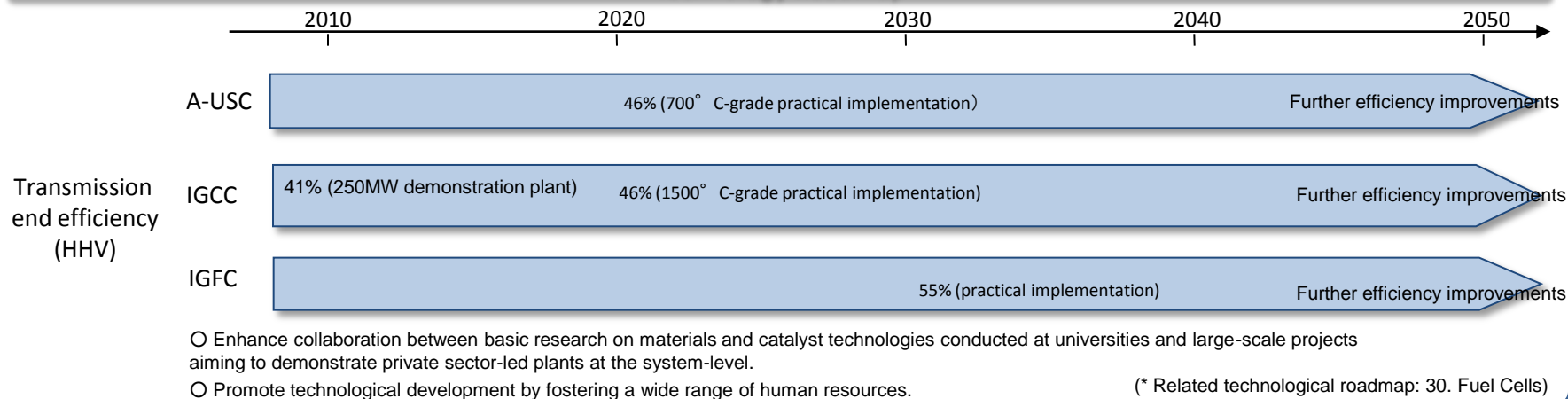
Outline of Technology

- High-efficiency coal-fired thermal power generation technologies, including technologies at the research stage, include the following: ultra-supercritical (USC) power generation, which requires high-temperature high-pressure steam conditions for coal dust-fired power generation; advanced ultra-supercritical (A-USC) power generation; the integrated coal gasification combined cycle (IGCC), where power is generated after converting coal to gas; and the integrated coal gasification fuel cell combined cycle (IGFC), which combines IGCC with fuel cells.
- If CCS can be commercialized and introduced in the future, CO₂ emissions can be reduced to almost zero.
- Estimates show that if coal-fired thermal power technology which has already been commercialized in Japan (USC) were to be introduced at coal-fired thermal power generation plants overseas in the United States, China and India, energy-origin CO₂ emissions could be reduced by 1.5 billion t.

Trends and Challenges in Japan's Technology Development

- Technological development support has been provided for A-USC since fiscal 2008. The main challenges are the development of large-capacity boiler-turbine systems for power industry use and high-temperature valves. The development of materials that can withstand high-temperature steam of more than 700° C is another challenge.
- Regarding IGCC, demonstration tests have been carried out in Fukushima Prefecture for air-blown IGCC, and the remaining challenges include the development of high-efficiency gas turbines and combustor technology.
- Regarding IGFC, demonstration tests to improve the reliability of the overall oxygen-blown IGCC system - a key technology - are currently underway at Chugoku Electric Power Co.'s Osaki Power Station. Future tasks include compatibility evaluation of gasified coal gas with fuel cells.
- It is important that technology development is conducted with a view to improving the efficiency of power generation, utilizing various coal types and reducing power generation costs.

Technology Roadmap



International Trends

Level of dissemination

○ The majority of the world's coal-fired thermal power stations are concentrated in the United States, China and India, and many of these plants have a low power generation efficiency of less than 35%. USC has already become very common in Japan, and its introduction has recently begun at large-scale coal-fired thermal power stations in China. In India, SC has been introduced at some coal-fired thermal power stations but conventional low-efficiency models remain prevalent.

Technology development trends

○ Europe is conducting various elemental tests using steam at 700° C under the AD700 project led by power companies and manufacturers. Its clean coal policy involves promoting a funding support program for 1) carbon capture and storage (CCS) and 2) integrated coal gasification combined

cycle (IGCC) and 3) promoting the engagement of EU companies in the joint development of USC (ultra-supercritical) and A-USC (advanced ultra-supercritical). Commercial use of CCS is targeted for beyond 2020 and field tests for A-USC will be completed in 2016.

○ In the US, the Clean Coal Power Initiative (CCPI) and the Clean Coal Technology Demonstration Program aim to achieve coal-fired thermal power generation with zero or close to zero emissions in the future.

Japan's International Competitiveness

○ The average generation efficiency of coal-fired thermal power generation facilities in Japan is currently around 41% (generation end, HHV), which compared to a 30-39% range in other countries, is the highest level in the world.

12. Next-Generation Automobiles (HVs/ PHVs/ EVs/ clean diesel etc.)

Outline of Technology

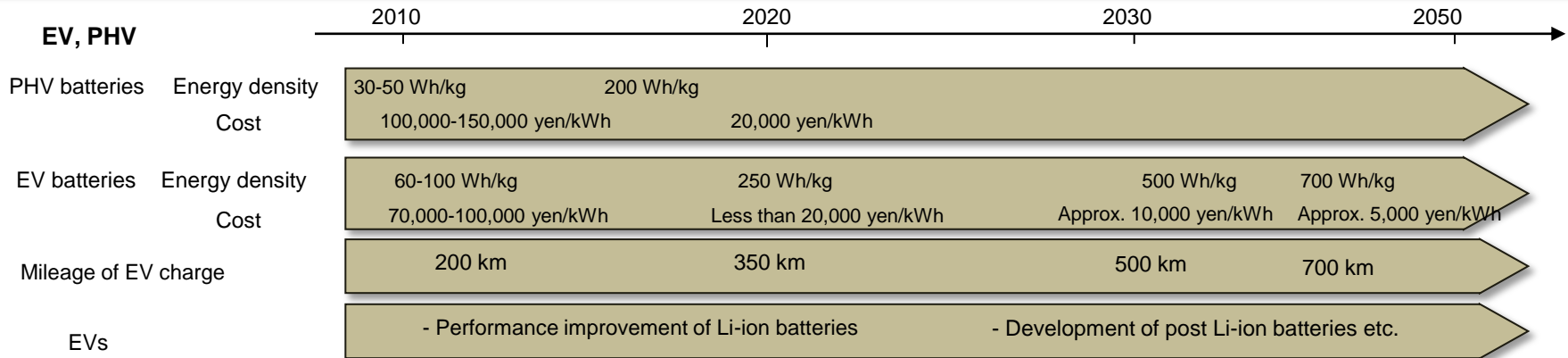
- Hybrid vehicles (HVs) are vehicles that use an internal combustion engine and a motor as power sources. Plug-in hybrid vehicles (PHVs) operate on a combination of a motor charged at home and an internal combustion engine. Electric vehicles (EVs) run solely on a motor powered by electricity stored in batteries instead of an internal combustion engine.
- HVs can reduce CO₂ emissions to approximately half or a third, and EVs, by approximately a quarter, compared to gasoline vehicles. EVs, in particular, can make major reductions in CO₂ emissions from power generation and running by using electricity with a high rate of renewable energy contribution.
- According to the IEA's Energy Technology Perspectives 2012 (ETP2102), estimates reveal that the development and dissemination of next-generation vehicle technology (PHV/ EV) will potentially lead to CO₂ emission reductions by approximately 1.7 billion tons globally by 2050.

*1 "JHFC General Efficiency Review Results" Report

Trends and Challenges in Japan's Technological Development

- The Ministry of Economy, Trade and Industry (METI) is conducting technological development for further performance improvements in Li-ion batteries with the aim of diffusing EVs and PHVs; conducting research and development on innovative batteries for the full-scale development of electric vehicles with travelling performance comparable to gasoline vehicles; and developing common evaluation methods for materials that importantly contribute to improving the performance of batteries.
- Japan is also engaged in projects to develop innovative high-performance magnets which do not rely on rare earth, soft magnetic materials with low energy loss, and high-efficiency motors that harness the high performance of the novel magnets / new soft-magnetic materials.
- The Ministry of Education, Culture, Sports, Science and Technology (MEXT) is developing post-Li-ion batteries, the assessment of which is being conducted in partnership with METI, with the goal of practical application in the 2030s.

Technology Roadmap



(* Related technology roadmaps: 31. High-Performance Power Storage)

International Trends

Level of dissemination

○ Total global HV/PHV/EV sales in 2011 are estimated to have been approximately 2.5 million vehicles, most of which were manufactured in the US and Japan. Sales of mass-produced EVs and PHVs have only recently started and consequently the number of EVs and PHVs on the market remains limited but are expected to increase. The development of charging infrastructure being crucial to the diffusion of EVs and PHVs, it is underway in many countries, including Japan.

○ Clean diesel vehicles have already been widely introduced in the EU, where approximately half of sold new cars are clean diesel vehicles.

Technology development trends

○ The US has supported the technology development – for example, the development and demonstration of Li-ion batteries, the development of vehicle simulation software, the cost reduction and durability improvement of fuel cells, the establishment of H₂ production technologies - through grants from the American Recovery and

Reinvestment Act (ARRA) and Department of Energy (DOE). In his 2013 State of the Union Address, President Obama declared that the US would increase the number of next-generation vehicles to 1 million by 2015 and that he would establish a new technology development fund to promote research and development.

○ The EU has allocated a 1-billion-euro research and development fund for vehicle technology, including EVs and internal combustion engines through its Seventh Framework Programme (FP7). It also aims to commercialize innovative electric vehicles by 2025 under the its Green Car Initiative.

Japan's International Competitiveness

○ Japan has played a leading role in the introduction and dissemination of HVs and Japanese manufacturers enjoy an overwhelming market share. Japanese companies also possess technological advantages in terms of EVs and PHVs, for which Japan was the first to launch sales of mass-produced vehicles.

13. Next-Generation Automobiles (fuel cell motor vehicles)

Outline of Technology

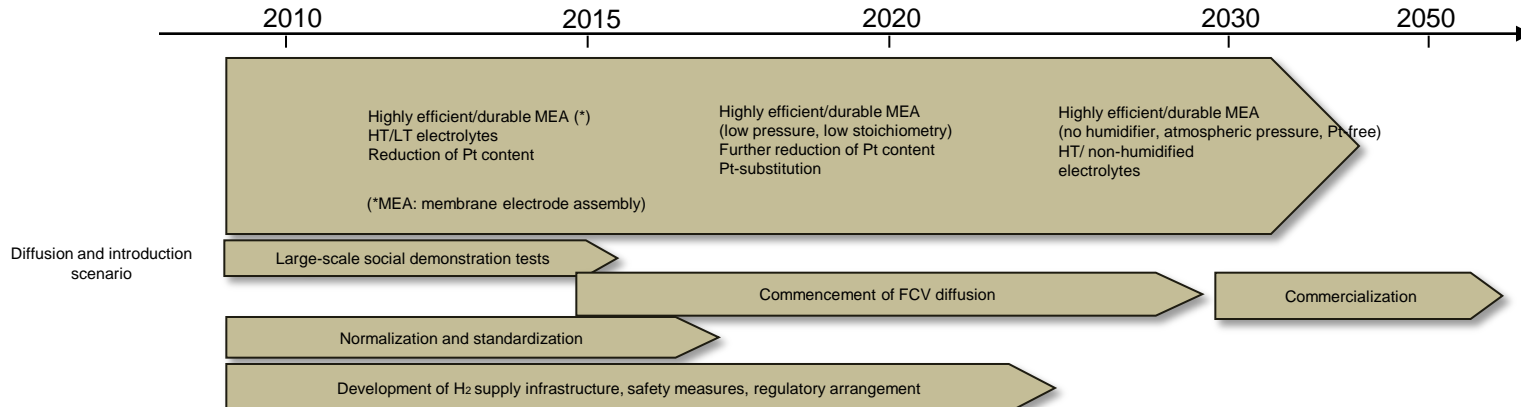
- Fuel cell vehicles (FCVs) run on electricity generated in the reaction of H₂ (fuel) and O₂ in the air.
- FCVs may reduce CO₂ emissions to around one-third compared to emissions from conventional gasoline cars ^{*1}. CO₂ emissions during H₂ production can be significantly reduced by using electricity with a high percentage of nuclear and renewable energy contribution
- Challenges include developing high-performance fuel cells, high-volume hydrogen storage technology and the establishment of H₂ supply infrastructure.
- According to the IEA's Energy Technology Perspectives 2012 (ETP2012), estimates reveal that developing and disseminating FCV can potentially reduce CO₂ emissions by approximately 700 million tons globally by 2050.

**1 "JHFC General Efficiency Review Results" Report*

Trends and Challenges in Japan's Technology Development

- Sales of mass-produced vehicles have yet to start, but some rental cars and demonstrative buses have been introduced in some areas. In 2011, leading Japanese car manufacturers and oil and gas companies announced a joint statement declaring that they would promote the development of vehicles and hydrogen refilling infrastructure in order to enable the dissemination of mass-produced FCVs from 2015.
- The Ministry of the Environment will develop a zero-CO₂-emissions system that combines small-scale solar hydrogen stations and fuel cells, and fuel cell buses for operation on major routes.
- In order to reduce costs related to polymer electrolyte membrane fuel cells, the fundamental technology and power source for FCVs, the development of technologies for high temperature/low-humidified (HT/LH) electrolytes, the reduction of platinum content and platinum-substitute catalysts is essential.

Technology Roadmap



(* Related technology roadmaps: 28, 29: Hydrogen Production, Transportation and Storage; 30: Fuel Cells)

International Trends

Level of dissemination

Sales of mass-produced vehicles have yet to be launched even at the international level.

Technology development trends

The US is conducting research and development under the DOE Hydrogen and Fuel Cells Program, with an aim to fabricate thin film electrolytes for fuel cells, improve the performance of catalysts and improve fuel cell stacks. In his 2013 State of the Union Address, President Obama declared that the US would increase the number of next-generation vehicles to 1 million by 2015 and that he would establish a new technology development fund to promote research and development.

Under the Joint Programme on Fuel Cells and Hydrogen, the EU will support the large-scale demonstration testing of vehicles and refilling facilities, the development of bipolar plates, the development of auxiliary equipment for refilling facilities, the quality assurance of hydrogen, etc. totaling 68.5 million euro (FY2013).

Japan's International Competitiveness

With the sales of mass-produced vehicles yet to be launched, domestic manufacturers have been promoting the development of FCVs with a view to major diffusion. In recent years, joint development based on international technological cooperation has also been observed.

25. High-Efficiency Heat Pumps

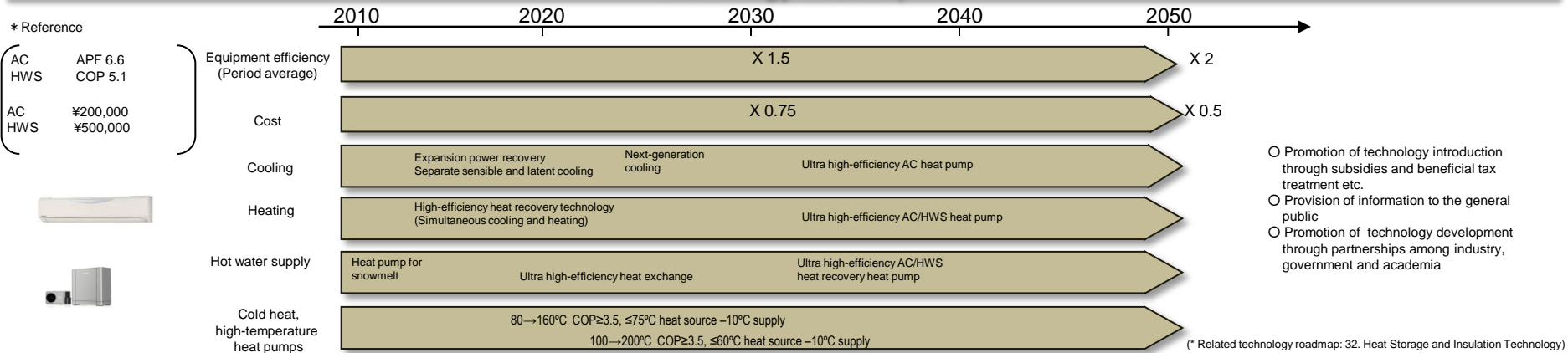
Outline of Technology

- The efficiency of air conditioners (AC) and hot water systems (HWS) for residential and commercial use has improved over the years, but further energy savings can be expected from improvements made in heat pumps and the utilization of power electronics and new coolants.
- Unlike AC and HWS that are fossil fuel combustion-oriented, the active use of solar heat via air-heat and geothermal heat will achieve efficiencies far exceeding 100%.
- This can be applied to AC and HWS, which collectively account for approximately half of the CO₂ emissions from the residential and commercial sector. Greater emission reductions are expected as a result of significant improvements in the efficiency of heat pump technology. The technology is also applicable in the industrial sector for AC, process cooling and heating.
- According to the IEA's Energy Technology Perspectives 2012, estimates have revealed that the development and dissemination of high-efficiency AC will potentially reduce global CO₂ emissions by 1.1 billion t by 2050

Trends and Challenges in Japan's Technology Development

- Technological development, including developing new coolants and improving heat pump efficiency is promoted under projects such as NEDO's "Technology Development of High-Efficiency Non-fluorinated Air-conditioning Systems," etc.
- Challenges faced by heat pump technology include cost reduction and efficiency improvement. The development of elemental technologies such as improved efficiency in coolants and heat exchangers promise to reduce costs by one-fourths and increase efficiency by 1.5 times from current levels by 2030 and to halve costs and improve efficiency by twofold by 2050.
- Other technological challenges include size reduction for better installability and saving the amount of materials used, further adaptation to cold regions (heating, hot water supply and snowmelt) for wider application, expansions in the applicable temperature range. Initiatives are required to overcome these challenges. The utilization of unharnessed heat is another promising way to achieve improved efficiency. Higher efficiency is also being sought in GHP, which can be used as a way of achieving power peak shaving and BCP support.

Technology Roadmap



International Trends

Level of dissemination

- Even at current levels, Japanese household heat pump AC have a COP of 6 or higher, which is much more efficient than the typical European or American level of 2.2-3.8. This was noted in the IPCC Fourth Assessment Report.
- Japan has been a leader in the introduction of high-efficiency heat pumps.

Technology development trends

- The US Department of Energy (DOE) is developing AC/ventilation systems optimized for heat exchange and data mining for geothermal heat pumps, as part of its AC-related research and the development of .
- EU's "Common Vision for Renewable Heating and Cooling 2020-2030-2050" states that the EU will be able to cover all AC demand in the EU using biomass, solar heat, geothermal heat and air heat by 2050.
- The IEA's "Technology Roadmaps: Energy-Efficient Buildings: Heating and Cooling Equipment" sets out the goal of reducing CO₂ emissions originating in buildings by 2Gt by 2050 using improved AC technology. The IEA will promote research and development on

high-efficiency AC heat pump systems and components and reduction of initial costs.

International competitiveness of Japan

- Japanese heat pump AC has achieved an extremely high level of efficiency compared to the EU and US. Japanese manufacturers providing comprehensive software/hardware services have exhibited a strong presence in the global market. Recently, Japanese companies have started to commercialize high-efficiency large-scale turbo refrigerators.
- Japan's heat pump HWS technologies are globally top level. Japan was a pioneer in the practical application of CO₂ coolant high-temperature HWS and 1 million units were introduced in only 6 years. Japan's business is globally developing through exports and offshore production
- The first country to succeed in developing CO₂ coolant heat pump hot water heaters, Japan leads the world in this technology.

26. Environmentally-Aware Iron Manufacturing Process

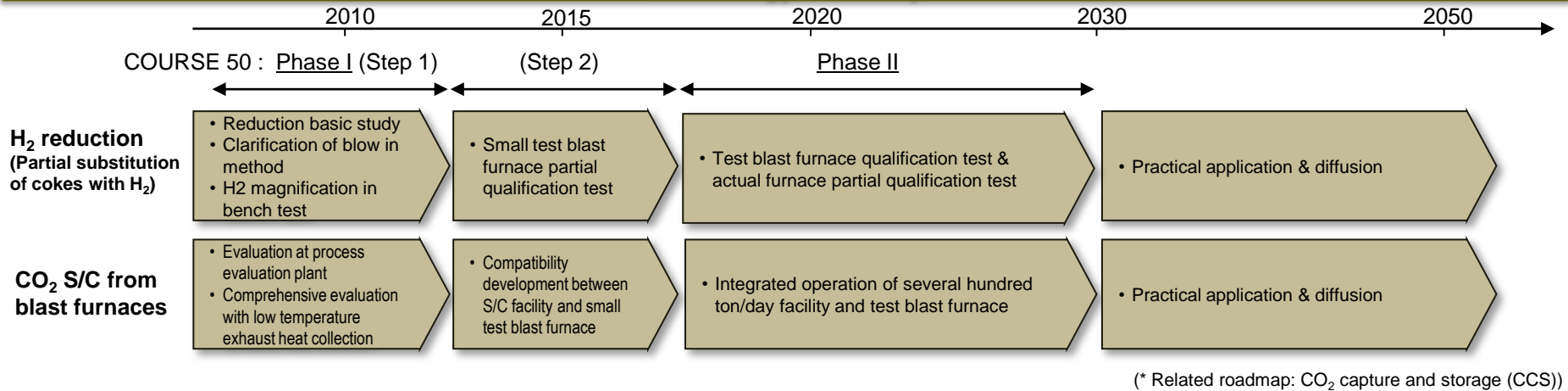
Technology Overview

- About 70% of CO₂ emitted by the iron and steel industry is attributed to the iron manufacturing process using blast furnaces. Therefore, a significant reduction of CO₂ 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 H₂ that is included (~50%) in the heated gas generated during manufacturing of cokes, new absorbent to separate CO₂ from high-CO₂ blast furnace gas, physical adsorption, new CO₂ separation/capture (S/C) technology utilizing the unused low-temperature waste heat generated at steelworks.
- IEA's ETP 2012 estimates the global CO₂ 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 H₂-reduction iron manufacturing and CO₂ S/C. (Phase 1 Step 1)
- Future activities include building a small test blast furnace in the scale of 10m³ and comprehensive evaluation of the laboratory-level results obtained in Step 1, to establish reaction control technology with maximum H₂ reduction effects. For CO₂ 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 CO₂ emissions from steelworks by 30% by 2030.

Technology Roadmap



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 CO₂ 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.

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

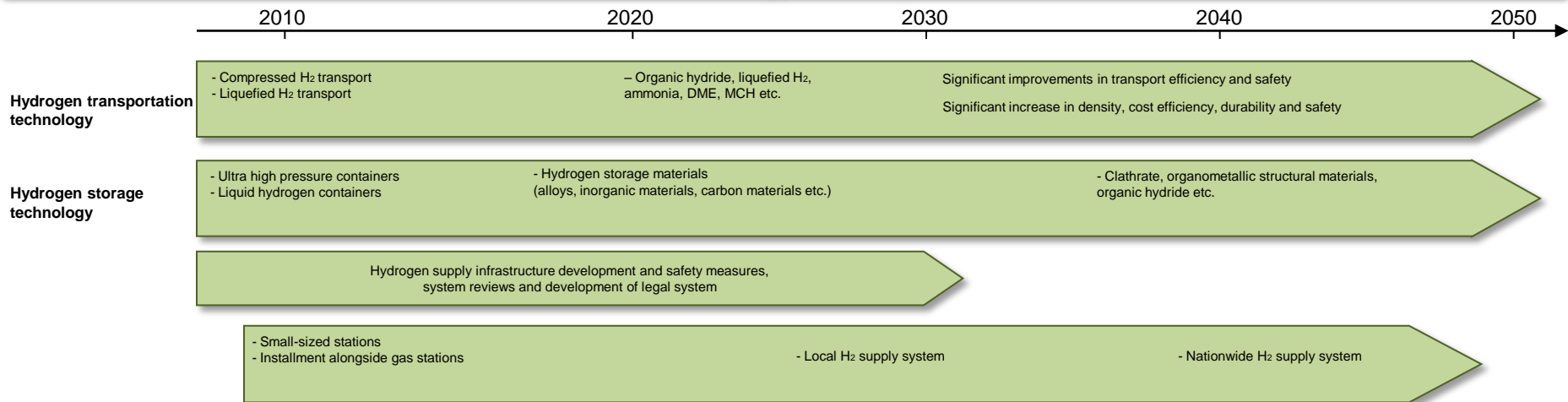
Outline of Technology

- Technology used to transport and store H₂ for use in fuel cell vehicles and stationary fuel cells
- Methods for transporting hydrogen include compressed hydrogen transportation, liquid hydrogen transportation, organic hydride transportation, transportation of hydrogen in the form of ammonia, and pipeline transportation.
- The technology is expected to be useful in the event that a large volume of renewable energy is introduced.

Trends and Challenges in Japan's Technology Development

- NEDO has carried out technology demonstrations for FCV/ hydrogen supply infrastructure in conditions close to real use with a view to beginning dissemination in 2015, as well as launching a "Technological and social demonstration of regional hydrogen supply infrastructure" to verify user-friendliness, commercial viability and social acceptance.
- In organic hydride, a test plant has been constructed at a private sector base for the hydrogenation and dehydrogenation of toluene.
- The Ministry of the Environment has developed the practical application of independent high-efficiency hydrogen treatment and storage systems using hydrogen storage alloys.

Technology Roadmap



(* Related technology roadmaps: 13. Next-Generation Automobiles (Fuel Cell Vehicles); 28. Hydrogen Production, Transport and Storage (Production); 30. Fuel Cells)

International Trends

Level of dissemination

OH₂ suppliers have indicated that they seek advance establishment of H₂ supply infrastructure in approximately 100 locations by 2015 to meet the expected number of mass-produced FCVs.

Technology development trends

○ In the US, solutions for H₂ transport includes low-cost pipelines for gas transport and pipelines for liquefied transport. H₂ storage solutions include high pressure gas storage, absorption materials and carbon materials, H₂-occlusion alloys..

○ E.U. plans to demonstrate H₂ as power source fuels using large-scale underground storage sites, develop alternative storage methods using cost-competitive solid materials, demonstrate the feasibility of mixing H₂ into existing natural gas supply networks (5%).

Japan's International Competitiveness

○ The performance level of Japan's elemental technologies, which are required for H₂ transport are expected to reach global standards. Economic assessments need to be conducted in specific transport routes in order to identify the most beneficial method.

30. Fuel Cells

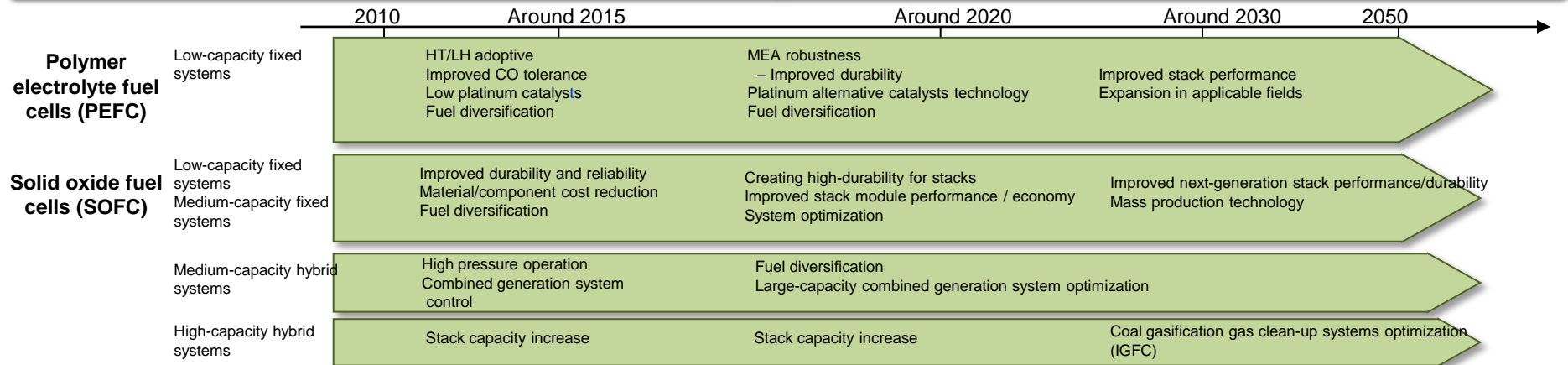
Outline of Technology

- Fuel cells directly generate electricity and heat through the chemical reaction of H₂ and O₂. This theoretically results in higher generation efficiency than thermal power generation because electrical energy is directly acquired from chemical energy. Moreover, under little impact from the system size, it bears the advantage of being feasible not only for large-scale power generation but also for small-sized power generation devices installed in general households.
- Fuel cells include polymer electrolyte fuel cells (PEFC), which use a polymer membrane as the electrolyte and operate at low temperatures, and solid oxide fuel cells (SOFC), with a ceramic electrolyte and high operating temperature, and therefore high generation efficiency. Other types of fuel cells include molten carbonate fuel cells (MCFC) and phosphoric acid fuel cells (PAFC).

Trends and Challenges in Japan's Technology Development

- Both PEFC and SOFC are commercially available in household systems. Diffusion initiatives, including technology development with a view to reducing costs and improving reliability as well as international standardization are being comprehensively promoted.
- In terms of PEFC, the development of low-Pt technology and new catalyst materials to replace Pt catalyst in order to reduce cost is underway, as well as technology development for improved CO tolerance, improved impurity tolerance and HT/LH electrolytes.
- In terms of SOFC, the development of quick durability assessment methods for achieving both cost reduction and high durability is in progress and the identification of issues obstructing practical application is conducted through demonstrations using medium-capacity systems for commercial use and high-capacity systems for industrial use.

Technology Roadmap



(* Related technology roadmaps: 1. High-Efficiency Coal-Fired Power Generation; 13. Next-Generation Automobiles (Fuel Cell Vehicles); 28, 29. Hydrogen Production, Transport and Storage)

International Trends

Level of dissemination

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

Technology development trends

○Under its Hydrogen and Fuel Cells Program, the US DOE conducts research and development regarding priority issues, such as researching deterioration mechanisms. The DOE aims to establish mobile fuel cell technology with energy density of 900Wh/L by 2015, and 1-10kW class fuel cells with a combined efficiency of more than 45% by 2020.

○Under its Seventh Framework Program (FP7), the EU conducts research and development on advanced multi-fuel reformers etc. for fuel cell CHP with a view to the commercialization of fuel cells for household use (≤5kW) and 5kW-1MW class CHP units that use H₂, natural gas and biogas.

Japan's International Competitiveness

○Japan leads the world in the proactive technical development and the introduction support of fuel cells. In 2009, Japan was the first country in the world to make PEFC for household use commercially available. In 2011, it also introduced SOFC for household use into the market. Cumulative installation marked 37,000 units at the end of 2012, exceeding all other countries

○The US has taken the lead in terms of medium-capacity systems for industrial use. Japanese companies have become more activated in an attempt to catch within a few years. High-capacity systems remain at elemental research levels both domestically and overseas.

Enhancing measures for the Japanese Government's promotion of technology development

The Japanese Government will promote technology development on a timely basis in the short and long term and encourage dissemination through domestic institutional reforms.

- Perspectives for policies aimed at technology development

- (1) A strategy in line with the maturity and timing of practical application of the technology

Formulate technology development strategies to fit short-term and medium-term timeframes based on the roadmap for practical application of the technology through 2050.

- (2) Far-sighted strategies based on future market anticipations

Anticipating future markets, promote technology development based on clearly defined needs in the country of application and promote the combination and systemization of multiple technologies

- Policies for domestic dissemination

- (1) Product and technology policies

Encourage investment promotion measures (including tax-related measure), regulatory methods (e.g. Top-Runner System) and purchasing incentives for low-carbon products (e.g. carbon footprint system).

- (2) Cross-sectional system/social system innovation

Promote efficient environmental assessment methods and a rational review of security regulations.

- Enhancement of policies aimed at the sound promotion of research and development

Japan should promote regulatory reforms to encourage innovation, the use of a research and development tax system, and the pursuit of high-risk, high-return transformative research.

International Promotion

The dissemination of innovative technology is essential to halving greenhouse gas emissions. Therefore, the introduction of mechanisms to evaluate environmentally outstanding technology is encouraged.

- Measures for overseas promotion and dissemination of innovative technology

- (1) Bilateral credit systems (JCM: Joint Credit Mechanism)

Promoting systems in which the volume of reduced and absorbed greenhouse gases resulting from the dissemination of low-carbon technology is regularly assessed and recognized as credit.

- (2) Formation of a market that has a preference for technology featuring high environmental energy performance

Providing support for the establishment of a system that can appropriately assess energy-saving performance and a framework for implementation to ensure the sound assessment of outstanding technologies and products.

- (3) Support measures to encourage international development

Reducing tariffs for environmental goods based on the APEC List of Environmental Goods

- (4) Promotion of multilateral international cooperation in relation to energy

Enhancing measures implemented under the Clean Energy Ministerial (CEM) Meeting, the International Partnership for Energy Efficiency Cooperation (IPEEC) and the Global Superior Energy Performance Partnership (GSEP).

- (5) Employment of LCA (Life Cycle Assessment) methods

Utilizing LCA methods in order to promote reductions in greenhouse gas emissions from a product's entire life cycle and help "visualize" its total contribution to reductions.

- Partnerships in R&D with other countries and international institutions

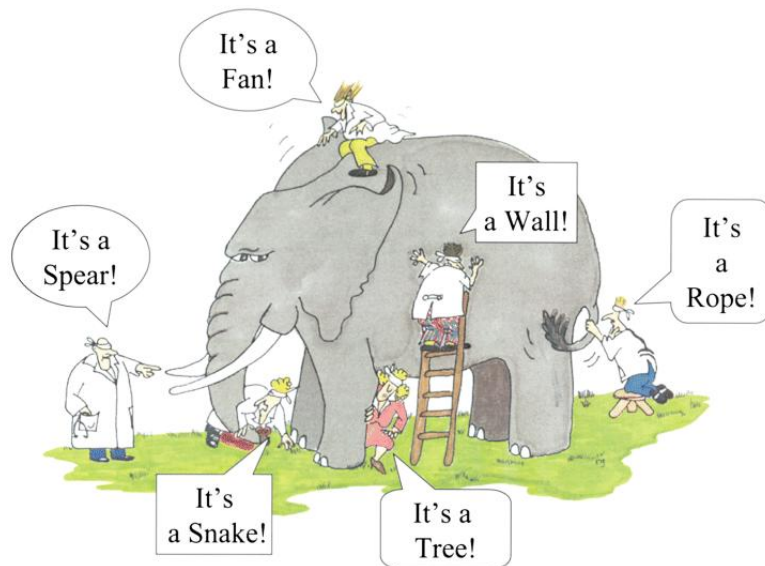
Making active contributions to IEA projects and other projects, reinforcing bilateral energy collaborations, and using the Conference of the Parties (COP) to raise awareness at a global level.

Summaries

□ Concept of innovation is different by stakeholder

- our definition?

- **Basic Scientists** - Invention = innovation
- **Industries** - First commercial product in the market
- **Policymakers** - Commitment to R&D through policy tools
Potential Innovation research,
Innovation diffusion
- **Consumers** - lifestyle change, market share



**No, it's
innovation.**

Summaries

□ R&D priority is different by ... cannot be generalized?

- Time horizon
- Socioeconomic condition
- Technology area and technology readiness level
- National energy resource potential, etc.

□ Role of models

- Useful to check consistency among energy technology roadmaps
- However, it is still our challenge to show R&D impacts of cost reduction, performance improvement, and other technological estimate in the long run.

Innovation Cool Earth Forum (ICEF)

In October 2013, Prime Minister Shinzo Abe announced that the Government of Japan will host an annual global conference, the Innovation for Cool Earth Forum (ICEF).



Innovation for Cool Earth Forum

1. Objectives

World-leading researchers, business persons, and policy makers meet and discuss every year,

- How to promote Innovation in the area of Energy and Environment Technologies
- How to disseminate these technologies to address Climate Change
- How to enhance the cooperation among Academia, Business, and Government

2. Organization

Host: NEDO, New Energy and Industrial Technology Development Organization
(Japanese public research and development management organization)
The Government of Japan

3. Date/Venue for 2014

Date : October 7th, 2014 : Opening Reception

October 8th, 2014 : Plenary Session, Concurrent Session

Venue : Hotel Chinzanso Tokyo, Japan