

Environment Innovation Strategy

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Chapter 1 Backgrounds, Aims, and Composition

Chapter 2 Innovation Action Plans

Chapter 3 Acceleration Plans

Chapter 4 Zero-Emission Initiatives

Backgrounds

Based on the Long-term Strategy under the Paris Agreement (Cabinet Decision in June 2019; hereinafter referred to as the “Long-term Strategy”) and the Integrated Innovation Strategy 2019, this Environment Innovation Strategy is formulated in order to create innovations in the fields of energy and environment, where Japan has a strength, to realize a feasible level of cost for adoption of such technologies in the society and to apply them globally. This strategy will contribute to significant reduction in Japan’s GHG (Greenhouse Gas) emissions and to the reduction in GHG emissions worldwide as much as possible.

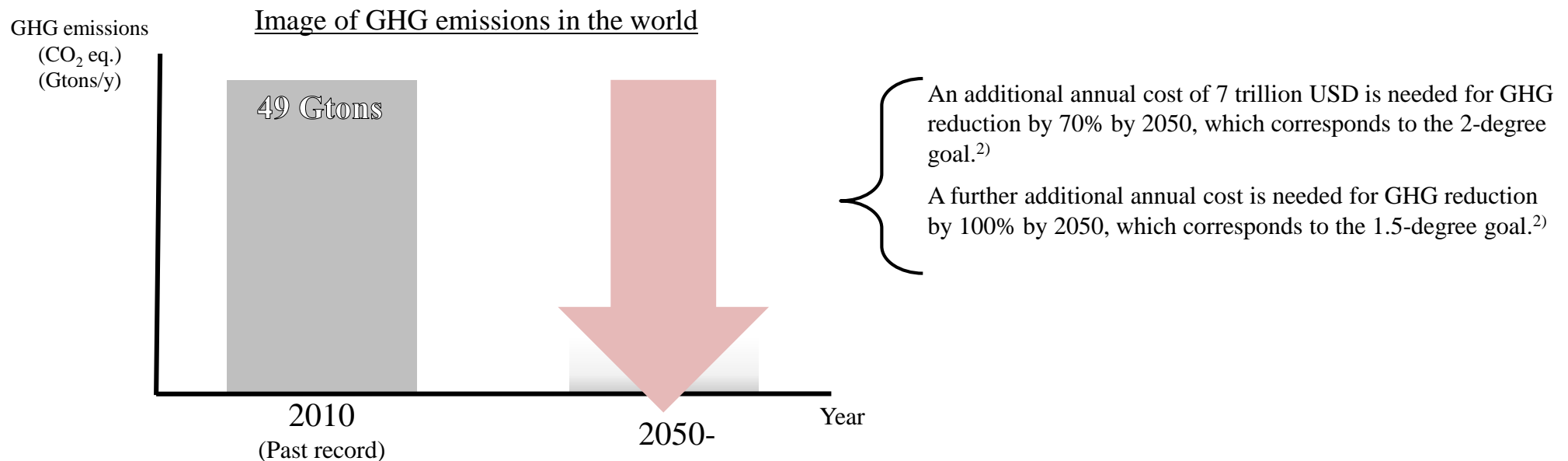
- | In the Long-term Strategy, Japan proclaimed a “decarbonized society” as the ultimate goal, aiming to accomplish it ambitiously as early as possible in the second half of this century, while boldly taking measures towards the reduction of GHG emissions by 80% by 2050. In addition, it is clearly stated that the Government will share the concepts and approaches of this Strategy with the world, and will contribute towards realization of the long-term goal in the Paris Agreement including the pursuit of efforts to limit the global average temperature increase to 1.5°C above the pre-industrial levels. Further, in the Long-term Strategy, Japan proposed a “virtuous cycle of environment and growth” to contribute to the solution of the climate change problem, which is an urgent global challenge, through business-led disruptive innovation, rather than regulations. This concept achieved an international consensus at G20 Osaka Summit and was endorsed by the industry, financial community, and academia at the Green Innovation Summit in 2019.
- | Even for realization of the scenario of 70% less GHG emissions in the whole world in 2050 shown by IPCC¹⁾, which will hold the increase in the global average temperature to below 2°C, there is an estimate that an additional annual cost of 7 trillion USD will be required in the world.²⁾ Further additional cost will be required to achieve the 1.5-degree goal. The most important issue for securing investment necessary to achieve the goals under the Paris Agreement, particularly in emerging countries where much increase in GHG emission is expected, is reducing this cost.

1) The SSP2 scenario in 1.5°C Special Report by the Intergovernmental Panel on Climate Change (IPCC); simulation of 40-70% global GHG reduction by 2050 in relation to achieve the 2-degree goal.

2) Based on an assumption that innovative technologies will be incrementally adopted, starting with those with higher cost performance, so that the cost of global reduction of GHG emissions will be minimized in comparison to the extended use of the current technologies. The cost for 100% reduction will be much larger when compared with that for 70% reduction, and is estimated to be over 10 trillion USD (on a model by the Research Institute of Innovative Technology for the Earth (RITE)).

Backgrounds

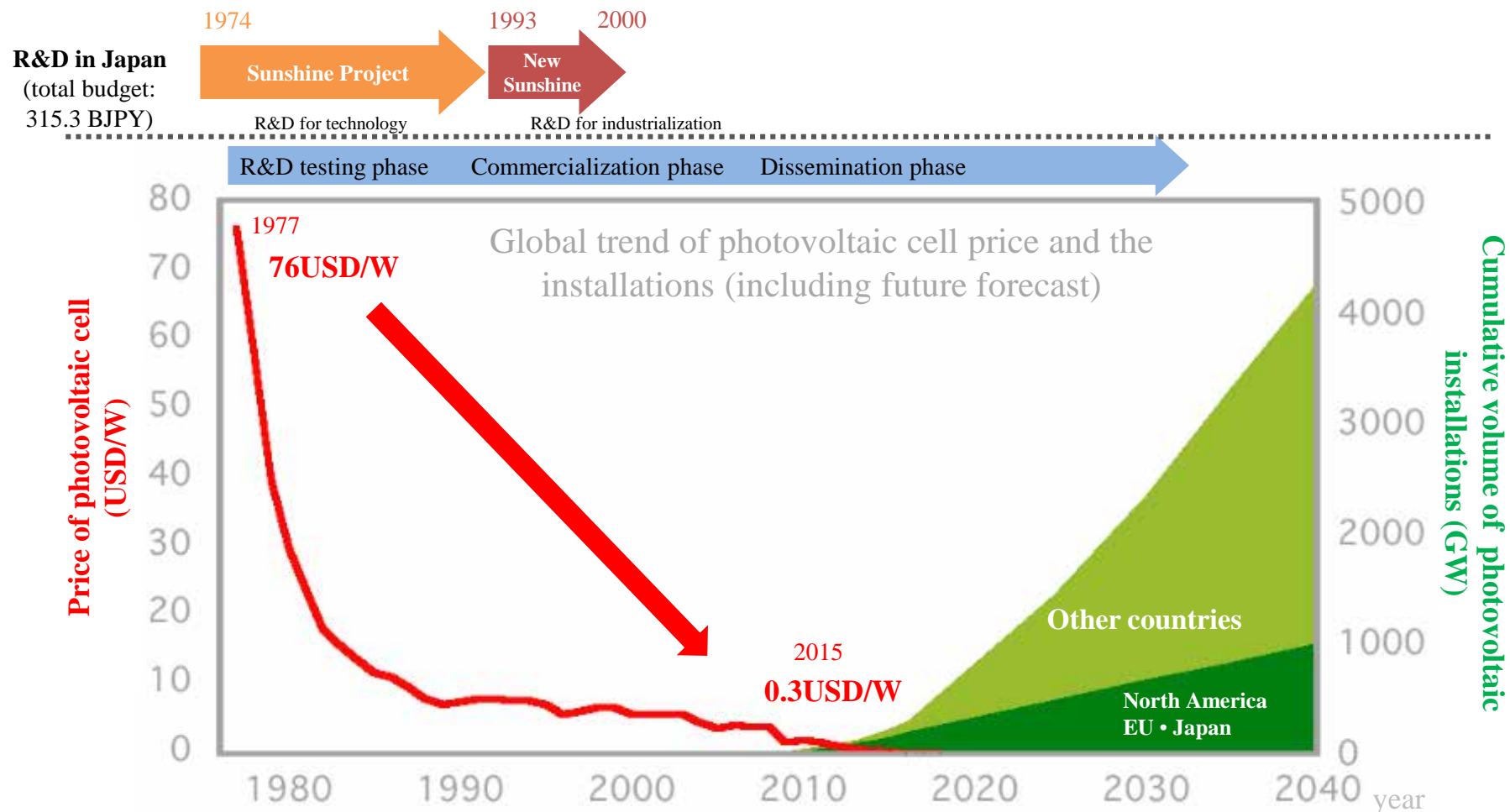
- | Japan has worked on innovation for more than 30 years, including on the Sunshine Project and the New Sunshine Project, and contributed to reducing the cost of solar cell to 1/250th (worth a cost reduction of 17 trillion USD globally (See Reference 1)). Thus, solar cells are introduced to many countries including developing countries, and serve as important means to deal with climate change.
- | Therefore, it is absolutely important for the reduction of global GHG emissions to realize a feasible level of cost for adoption of such technologies in the society as early as possible, based on disruptive innovation.
- | The Environment Innovation Strategy, hereby formulated, based on the Long-term Strategy, consists of:
 - 1) the Innovation Action Plans, which describe 16 technological challenges with cost targets;
 - 2) the Acceleration Plans, which show research frameworks and investment promotion policies;
 - 3) the Zero-Emission Initiatives, which are on collaborative works and outreach activities with global leaders for implementation in the society.This Environment Innovation Strategy aims to establish innovative technologies that enable global carbon neutrality and, further, reduction of the accumulated stock of CO₂ in the earth's atmosphere ("Beyond Zero") by 2050.



²⁾ See page 4.

Reference 1 Progression in photovoltaic installations and price

For more than 30 years, Japan has invested in the research and development (R&D) of photovoltaics, including in the “Sunshine Project” and the “New Sunshine Project”. As a result, the price of the photovoltaic cell has reduced dramatically by more than 1/250th, leading to the global trend of mass installation of photovoltaics. The estimated cost saved in the period from 1977 to 2015 is as large as 17 trillion USD.



Overview: Chapter 2 Innovation Action Plans

- | In order to establish innovative technologies that enable global carbon neutrality, it is necessary to have a set of guiding principles to show the technologies to be developed, their targets, and the systems for such development. In five fields in total (energy supply (I) and demand (transportation (II), industry (III), business, household and other cross-sectoral fields (IV), as well as agriculture, forestry, fisheries and carbon sinks (V)), 16 important and common technological challenges are selected with 39 themes where GHG can be significantly reduced with large potential contribution from Japanese technological strength. Aiming at establishing innovative technologies by 2050, descriptions are provided in each 39 themes on: 1) specific target cost of the innovative technology and amount of reduction in global GHG emission to clarify social impacts, 2) specifics of technology development, 3) systems for development, 4) specific scenarios and actions for the processes from underlying technology phase to demonstration and deployment phases.
- | It is not easy to estimate the global amount of reduction in GHG emission achieved by the specific innovative technology adopted, since there are other varying factors in each country such as policies including support for introduction, trends in private investment and demand, and feasibilities for adopting the technology. In order for those concerned in an out of Japan to gather wisdom toward establishment of the technology, however, there is much value in showing “the global amount of reduction in GHG emission” under certain premises, even if there remain limitations due to uncertainties. Therefore, the Innovation Action Plans in this strategy show the extent of GHG emission reduction estimated by several elements such as the Government strategies, international commitments, reports from international organizations and expected figures in planning. The assumptions and approaches in the estimate differ by technology, and timely re-evaluation based on technological and other developments will better serve the purpose.

Fields	Challenges	Themes
5 fields	16 challenges	39 themes

- | The five fields above are classified by activities causing GHG emissions. On the other hand, when classifying by technology, there are five key sets of technologies as follows:
 - 1) **Non-fossil energy:** In addition to supply of electricity, this set of technology contributes to all the fields through hydrogen and carbon recycling.
 - 2) **Energy network:** It is important for introducing renewable energy to coordinate power network and optimize the supply-demand balance.
 - 3) **Hydrogen:** CO₂-free hydrogen obtained with renewable energy and carbon capture and storage (CCS) will be used in place of fossil resources in the transport and industrial sector.
 - 4) **Carbon recycling and CCUS:** Recycling CO₂ as carbon resources as well as capturing and storing CO₂ from fossil fuels offer a large CO₂ reduction.
 - 5) **Zero-emission agriculture, forestry and fisheries:** Utilization of ecosystem in the agriculture, forestry and fishery fields, which account for one-fourth of global emissions, is expected to produce a large reduction effect.

Overview: Chapter 3 Acceleration Plans

R&D in energy and environment takes a long time to be adopted in the society and involves a high risk in development for cost reduction. To enhance and apply the Innovation Action Plans and achieve early realization of innovative technologies and their adoption in the society, the Government will implement the Acceleration Plans consisting of the following three approaches.

1) Systematic implementation with a chain of command

The Government will establish a Green Innovation Strategy Meeting to command inter-agency initiatives, thereby ensuring that the whole government will make efforts together to realize the Innovation Action Plans. The progress in each project will be thoroughly reviewed at least once every three years and the Innovation Action Plans will be revised based on the latest knowledge. Consideration will be given on advice to various research centers including the Global Zero Emission Research Center (GZR) and introduction of the LCA (Life Cycle Assessment) method to the evaluation on GHG reduction and cost, amongst other issues.

2) Gathering the wisdom of the world

Players working on advanced R&D are not only in Japan. In order to pioneer innovative technologies in the world, the Government will gather the wisdom of the world. The Government will establish the Global Zero Emission Research Center (GZR) , serving as a platform to connect 120,000 researchers in G20 member countries, the Alternative Energy Fundamental Research Center with industry-academia collaboration, and the Carbon Recycling R&D and Demonstration Base to accelerate technology development through collaboration. At the same time, the potential of future technological innovation will be enhanced by providing intensive support to promising young researchers (the Zero-Emission Creators 500), and seeds of technologies will be explored and planted utilizing the Feasibility Study Program and the Moonshot Research and Development Program, so that the potential of future technological innovation is increased. In the Tokyo Bay Zero-emission Innovation Area and the Circulating and Ecological Economy, various researches and demonstrations will be developed taking advantage of integrated industry-academia-government collaboration and regional needs.

3) Promotion of private investment

It is important for such innovative R&D to be applied in the society that the market prioritize the supply of finance to the business with advanced technology or high potential. In order to promote private investment in these fields, the Government will promote publicity on excellent corporate efforts through corporate information disclosures in line with the TCFD (Task Force on Climate-related Financial Disclosures) and an award system, enhanced dialogue between the industry and the financial community, and appropriate assessment and utilization of corporate information by the financial sector. The Government will also facilitate venture capital (VC) investment into R&D startups and support their set-up overseas including institutional arrangements. These measures will bring 30 trillion JPY of public and private investment in R&D in the coming ten years.

Overview: Chapter 4 Zero-Emission Initiatives

Five international meetings listed below will be held every autumn for: 1) sharing the latest information in Japan and the world on innovative technologies covered in the Innovation Action Plans; 2) amplifying opportunities of international co-creation including those enriching the Acceleration Plans and promoting green finance; and 3) continuous efforts to promote utilization of achievements. Further, the Green Innovation Summit, consisting of representatives from the participants of these meetings, will drive the Zero-Emission Initiatives aimed at specific initiatives toward early realization of a carbon-neutral world, conducted by those concerned around the world.

Green Innovation Summit

The Prime Minister invites the leaders of the industry, the financial community and the researchers participating in the meetings below to share Japan's specific initiatives and strengthen international engagement with the world.

RD20 (Research and Development 20 for Clean Energy Technologies)

The RD20 is the international conference of the leaders of research institutes engaged in R&D for clean energy technologies from G20 member countries in order to create disruptive innovation toward significant reduction of CO₂. The RD20 enhances alliance among research institutes in G20 member countries and promotes international joint R&D.

TCFD Summit

The TCFD Summit is the international meeting to promote dialogues among the leaders of global corporations and financial institutions to channel financial flow into companies active on environmental measures, thereby aiming to realize “virtuous cycle of environment and growth”. This summit calls for support and commitment to the TCFD in the world and discuss the future directions of the TCFD.

ICEF (Innovation for Cool Earth Forum)

ICEF provides opportunities to discuss climate action through technological innovation. More than one thousand experts from about seventy countries and regions gather to discuss innovation and finance. ICEF aims to accelerate promotion of innovation.

Hydrogen Energy Ministerial Meeting

Countries, areas and organizations that are highly interested in hydrogen policy participate in this meeting where the direction of policies toward global use and utilization of hydrogen is discussed.

International Conference on Carbon Recycling

The Conference aims to realize carbon recycling by taking stock of innovative efforts in each country, the most recent knowledge and possible international collaboration, as well as facilitating enhanced industry-academia-government network among the participating countries.

Outline of Environment Innovation Strategy

Innovation Action Plans

- Action plans for establishment of the innovative technologies by 2050 -
(16 challenges in 5 fields)

Describing: i) specific target cost and amount of reduction in global GHG emission; ii) specifics of technology development; iii) systems for development; and iv) the processes from basic research to demonstration.

Enhanced by:

Acceleration Plans - 3 approaches for accelerating the “Innovation Action Plans” -

1) Systematic implementation with a chain of command

[Green Innovation Strategy Meeting] Driving plans on an inter-agency and long-term basis from basic research to adoption. Thorough reviews on ongoing projects and revision of the Innovation Action Plans with the latest knowledge.

2) Gathering the wisdom of the world

[Joint zero-emission research bases] Establishment of the Global Zero Emission Research Center (GZR) to connect 120,000 researchers in G20 member countries, the Research Center for Basic Energy Sciences with industry-academia collaboration and the Carbon Recycling R&D and Demonstration Base. The launch of the Tokyo Bay Zero-emission Innovation Area to strengthen industry-academia-government collaboration.

[Zero-Emission Creators 500] Intensive support to young promising researchers.

[Strengthening support to promising technologies] Utilization of the Feasibility Study Program and the Moonshot Research and Development Program, and creation of the Circulating and Ecological Economy.

3) Promotion of private investment

[Promoting green finance] Promotion of disclosure of corporate climate-related information in line with the TCFD recommendations and dialogue between the industry and the financial community.

[Zero-Emission Challenge] Enhancing investors' access to corporate information with an award system and information disclosure of excellent projects

[Zero-Emission Startup Support] Promotion of VC investment for R&D startups.

Zero-Emission Initiatives -messages at international conferences for global collaboration-

Green Innovation Summit, RD20, ICEF, TCFD Summit, Hydrogen Energy Ministerial Meeting, and International Conference on Carbon Recycling

Chapter 1 Backgrounds, Aims, and Composition

Chapter 2 Innovation Action Plans

Chapter 3 Acceleration Plans

Chapter 4 Zero-Emission Initiatives

Innovation Action Plans

16 important and common technological challenges are selected in 5 fields: (I) energy supply and demand ((II) transportation, (III) industry, (IV) business, household and other cross-sectoral fields, (V) agriculture, forestry, fisheries and carbon sinks), and 39 themes where GHG can be significantly reduced with large potential contribution from Japanese technological strength are set.

Aiming to establish innovative technologies to enable global carbon neutrality by 2050, descriptions are provided on: (1) specific target cost of innovative technology and amount of reduction in global GHG emission to clarify the social impact; (2) specifics of technology development; (3) systems for development; and (4) specific scenarios and actions for the processes from underlying technology phase to demonstration and deployment phase.

The challenge for development of a technology in energy and environment fields is to achieve energy transformation and material circulation from natural state, which involve energy loss in the scientific terms, efficiently with the minimum loss of energy and dependency on CO₂ emission sources. Development of such a technology is therefore very difficult. Further, for a technology to be adopted in the society, there are various requisites: discovering, proving and reproducing a phenomenon; developing the technology for particular practical application; developing and integrating peripheral technologies required for practical use; and demonstrating in the society. In addition, unlike the economic theory where an additional value is paid for, it is also a requisite to minimize the cost of adoption so that CO₂ reduction technology will not result in a large additional cost. Therefore, it takes a long time to develop and adopt the technology. Thus, it is necessary to tackle these issues persistently from the medium- and long- term perspectives and with a view on bioeconomy, circular economy and other social innovations. It will also be necessary for the 39 themes covered to be subject to review and rearrangement according to future progress of technology.

I. Energy transformation

GHG reduction: more than 30 billion tons

Renewable energy will be made a main power source by drastic improvement to the efficiency and cost reduction of photovoltaic (PV) systems with innovative materials and structures. At the same time, CCUS and carbon recycling technologies will be introduced to fossil fuel power generation. These measures will lead to decarbonized and affordable energy supply.

1. Renewable energy as a main power source

- 1) Flexible, lightweight, and highly efficient PV systems to reduce constraints on installation
- 2) Supercritical geothermal systems
- 3) Floating offshore wind turbines applicable to harsh environments

2. Resilient electricity network using digital technologies

- 4) Low-cost innovative battery to make renewable energy a main power source
- 5) Energy management system (EMS) with digital technology to reduce the grid cost
- 6) Highly-efficient and low-cost power electronics technology

3. Low-cost hydrogen supply chain

- 7) Production: CO₂-free hydrogen production cost reduced to 1/10
- 8) Storage & transportation: compressed hydrogen, liquefied hydrogen, organic hydride, ammonia, and metal hydride
- 9) Utilization: low-cost hydrogen station and low-NO_x hydrogen power generation

4. Next-generation atomic energy and nuclear fusion

- 10) Atomic energy with excellent safety system
- 11) Nuclear fusion

5. Low-cost CO₂ capture for CCUS and carbon recycling

- 12) Establishment of low-cost CO₂ capture technology for CCUS and carbon recycling

II. Transportation

GHG reduction: more than 11 billion tons

GHG from vehicles, aviation, and shipping will be significantly reduced with various approaches such as electrification and decarbonization of fuels.

6. Green mobility modalities

- 13) Expansion of electrification of vehicles and aviation, including high-performance storage batteries, and significant improvement in environmental performance
- 14) Fuel cell electric vehicles (FCEV) system and establishment of hydrogen-mobility infrastructure including storage system
- 15) Technologies for producing biofuels and synthetic fuels with carbon recycling technologies at a cost comparable with the existing fuels and their utilization

III. Industry

GHG reduction: more than 14 billion tons

Independence from fossil fuel will be achieved with innovative technologies (e.g. zero-carbon steelmaking process with CO₂-free hydrogen). Sophisticated carbon recycling technologies, such as transforming CO₂ into materials and fuels, will be used as much as possible.

7. Independence from fossil fuels (electricity from renewable energy and CO₂-free hydrogen)

- 16) “Zero-carbon steel” with innovative technologies such as hydrogen reduction
- 17) Higher efficiency of metal resource circulation
- 18) Advanced plastic resource circulation

8. Carbon recycling technologies to transform CO₂ to materials and fuels

- 19) Producing plastics by artificial photosynthesis technology
- 20) Fine chemicals with innovative manufacturing process and Carbon Recycling
- 21) Low-cost methanation
- 22) Cement made from CO₂ and concrete absorbing CO₂

IV. Business, household and other cross-sectoral fields

GHG reduction: more than 15 billion tons

Advanced technologies will be widely adopted in the business and household sectors, and the social system and lifestyle will change with advanced information and communication technologies.

9. Implementation of advanced GHG reduction technologies

- 23) Cross-sectoral energy efficiency
- 24) Low-cost stationary fuel cell systems
- 25) Increased use of unutilized and renewable thermal energy
- 26) Low global warming potential (GWP) and non-fluorocarbon refrigerants

10. Transformative urban management using big data, AI, decentralized management technology (smart community)

- 27) Accelerating the application of relevant technologies in the society (Smart City)

11. Energy saving by sharing economy and telework, work style reform and behavior change

- 28) Promoting sharing economy, telework, work style reform and behavior change

12. Developing scientific knowledge for the verification of GHG reduction effects

- 29) Elucidating and improving the forecast of the climate change mechanism, research including observation, reinforcement of information infrastructure

V. Agriculture, forestry, fisheries and carbon sinks

GHG reduction: more than 15 billion tons

Zero-emission in agriculture, forestry and fisheries will be achieved with smart ecosystem, and carbon sinks will be expanded by innovative technologies.

13. CO₂ absorption and fixation in the ocean, farmland, forest with advanced biotechnology

- 30) Genome editing technology and other applied biotechnology
- 31) Raw material changes using biomass
- 32) Carbon sequestration in farmland using biochar
- 33) Wooden high-rise buildings and wood-based bioplastics
- 34) Smart forestry and fast-growing trees
- 35) Blue carbon (carbon sequestration in the marine ecosystems)

14. Reduction of methane and N₂O from agriculture and livestock industry

- 36) Breeding and optimal management for farmland and livestock

15. Smart agriculture, forestry and fisheries

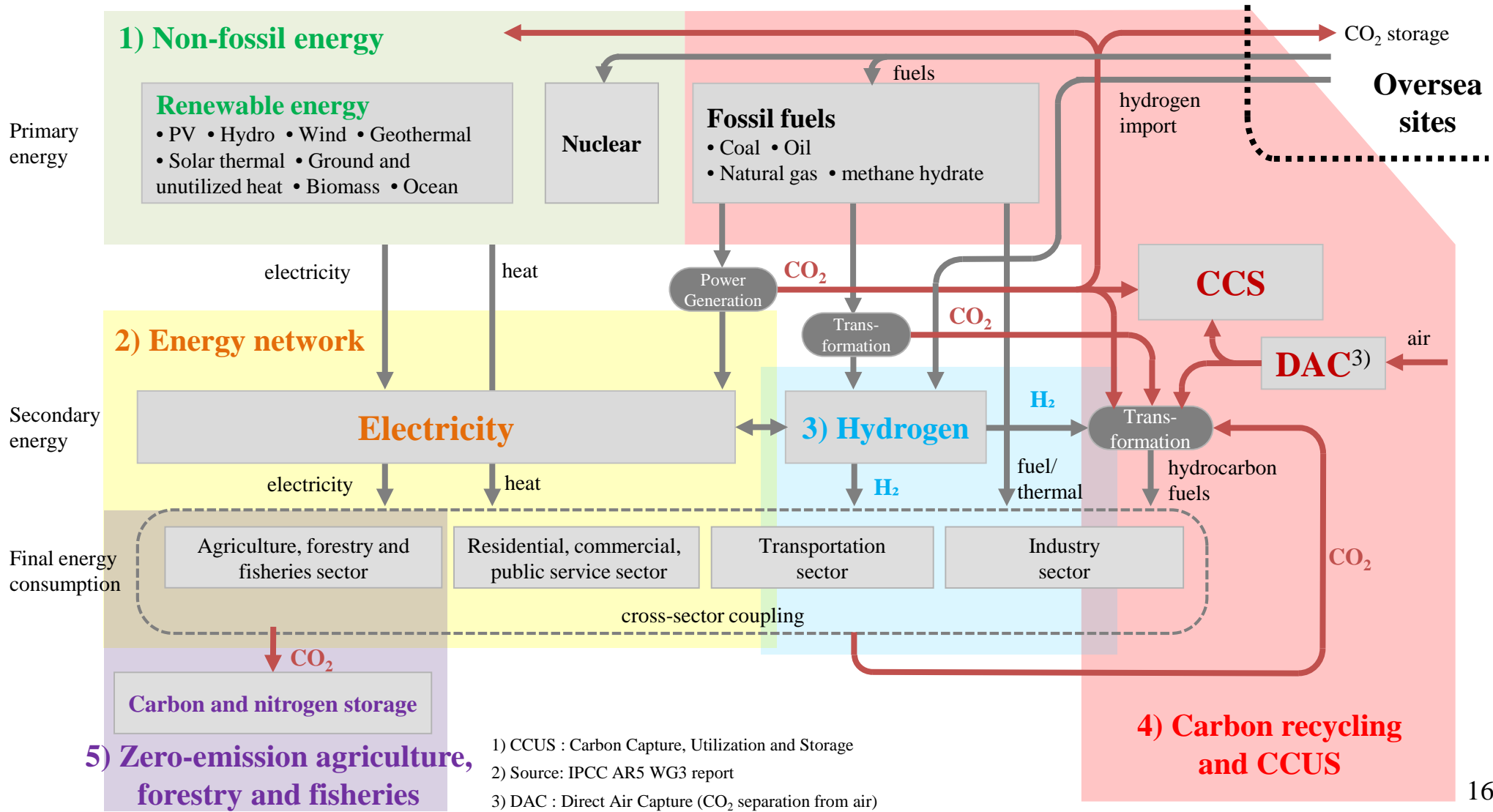
- 37) Building the energy system based on local production for local consumption to suit rural areas
- 38) Reduction of fossil fuels and materials by electrifying agricultural and forestry machines and fishing boats, and by labor optimization

16. Capturing CO₂ in the air

- 39) Pursuit of DAC (Direct Air Capture) technology

Five prioritized technology sets in the Innovation Action Plans

There are five key sets of technologies in the Innovation Action Plans: 1) non-fossil fuel energy that contributes to electricity supply and all the fields with hydrogen and carbon recycling; 2) energy network technologies including storage batteries, integral to a wide use of renewable energy; 3) hydrogen energy, which can be utilized in transport, industry, power generation sectors; 4) carbon recycling and CCUS, which contribute to a significant reduction of CO₂; 5) Agriculture, forestry and fisheries, which account for a quarter of global GHG emissions.



I. Energy transformation

Renewable energy as a main power source

1) Flexible, lightweight, and highly efficient PV systems to reduce constraints on installation

[Target]

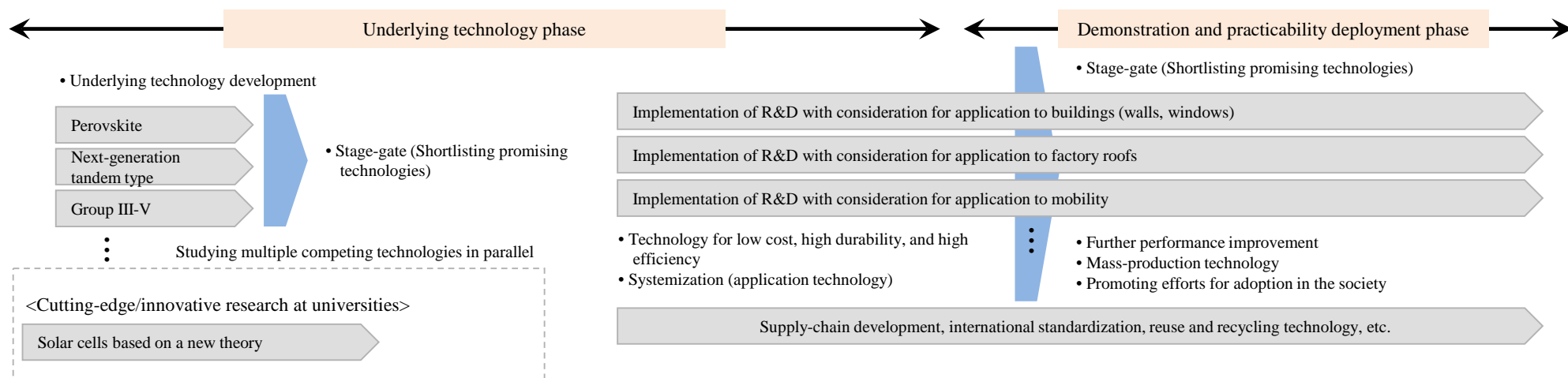
- Innovative photovoltaics technologies to reduce constraints on installation, such as those achieving higher efficiency (over 35%, twice the current level), light weight (1/10 of the current weight) and curved-surface followability, at the cost level of other existing power sources or lower on kWh basis, will be adopted in the society from around 2030 toward the goal of 2050. This will enable installation on walls of buildings, roofs of factories and vehicles, which is difficult with current technologies. While suitable sites for installation of photovoltaic generation systems become increasingly limited, a huge increase in photovoltaic generation systems over a longer term will be possible with such development. The global amount of CO₂ reduction is estimated to be around 7 billion tons.¹⁾

[Technology development]

- Research and development for innovative devices and materials at underlying technology phase, including perovskite materials (of light weight, curved-surface followability and unleaded features), the next-generation tandem module and the group III-V compound will be conducted with industry-government- academia collaboration, aiming for adoption in the society by around 2030. Technology development will not be limited to devices, and the development of the system of PV, including device structure, and installation, will also be considered.

(System for development)

- During the underlying technology phase, works on theory and performance will be mainly conducted by universities and other institutions. In future, the technologies which have come close to adoption with successful cooperation among the industry, Government and academia, as well as with other countries, will move on, subject to short-listing with a Stage-gate process, to a research and development phase conducted by a consortium, driven by commercial entities including panel manufacturers and user industries (such as the construction and automobile industries), in order to facilitate efforts for adoption in the society, including capital investment by the beneficiaries.

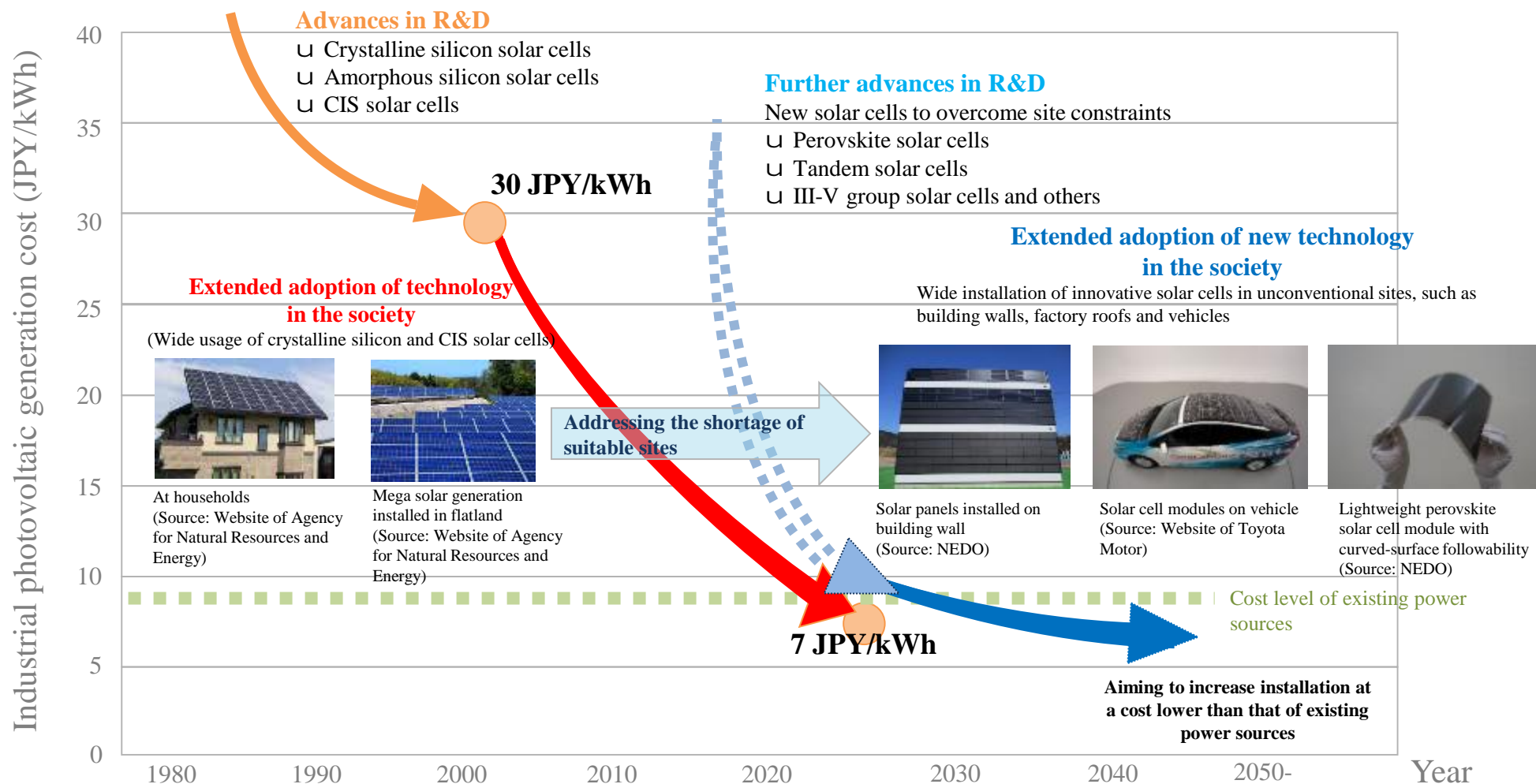


1) Estimated by New Energy and Industrial Technology Development Organization Technology Strategy Center (hereinafter referred to as "NEDO TSC" based on IEA ETP2017 and others.

I. Energy transformation

Reference 2 Cost reduction by innovation -- Example of photovoltaic generation

The cost of photovoltaic generation for conventional use, such as at the household and on the flatland, has steadily declined with the investment in R&D so far. However, as suitable sites for installation become limited, developing innovative solar cells with such characteristics as high efficiency, light weight, and curved-surface followability is required in order to promote further installation of photovoltaic generation systems. At the same time, it is necessary that the level of cost for such innovative solar cells is kept under the level of existing power sources by 2030 and onwards.¹⁾



1) The cost of competing technologies may also change.

I. Energy transformation

Renewable energy as a main power source

2) Supercritical geothermal systems

[Target]

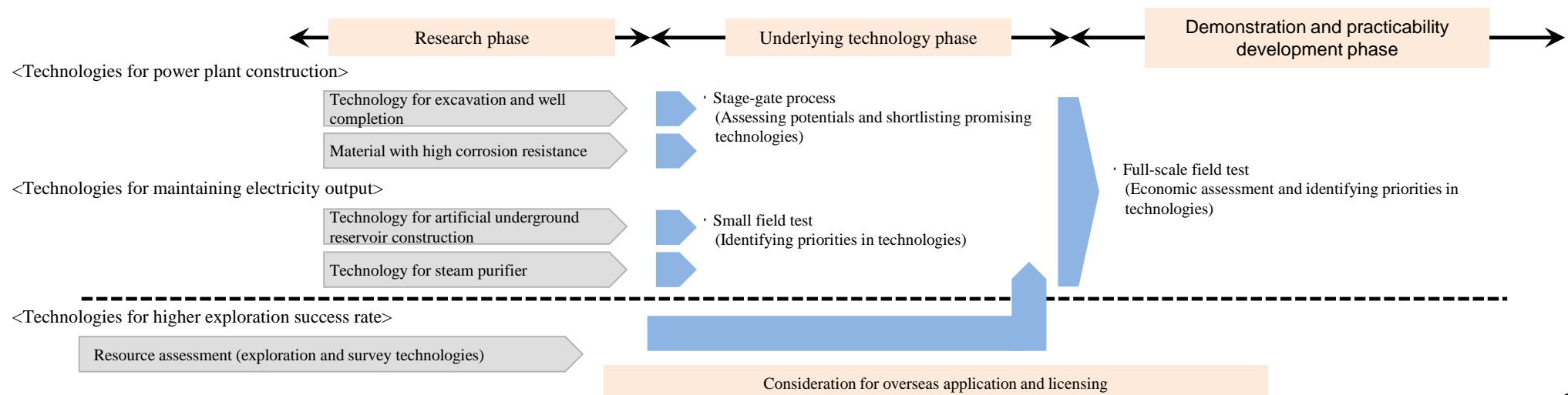
- Geothermal power generation can be a base load power source with constant power generation, unaffected by weather and other natural conditions. In order to promote wider usage of geothermal system, acquisition of energy beyond the level of conventional geothermal system is sought, and technology development for next-generation geothermal power generation, including the use of underground water in supercritical conditions (at very high-temperature and pressure), will be pursued, with a view to reducing the level of cost to that of the existing power sources by 2050. The global amount of CO₂ reduction is estimated to be around 0.7 billion tons.¹⁾

[Technology development]

- Technological challenges will be identified at the research phase on technologies such as: excavation and well completion technology to extract fluid in the supercritical state from the depth of around 5km; materials with high corrosion resistance to enable power generation with acid steam; and construction of artificial underground reservoir and steam purifier to enable constant use of energy. Promising technologies to overcome the challenge will be shortlisted through a Stage-gate process, and proceed to development in the underlying technology phase. In addition to designing the overall power generation system, the Government will lead exploration and survey to assess the underground resources alongside technology development. Efforts will be aimed at making these technologies commercially viable in about 20 years.

(System for development)

- Universities, research institutions and companies in Japan and other countries will collaborate from the phase of underlying technology development with an eye toward future overseas application and licensing. Collaboration with venture firms will also be considered.
- Relevant ministries and agencies, local governments and operators will also work together to identify and overcome non-technical challenges such as consensus building with local residents on selecting sites.



¹⁾ Estimated by NEDO TSC based on IEA ETP2017 and others.

I. Energy transformation

Renewable energy as a main power source

3) Floating offshore wind turbines applicable to harsh environments

[Target]

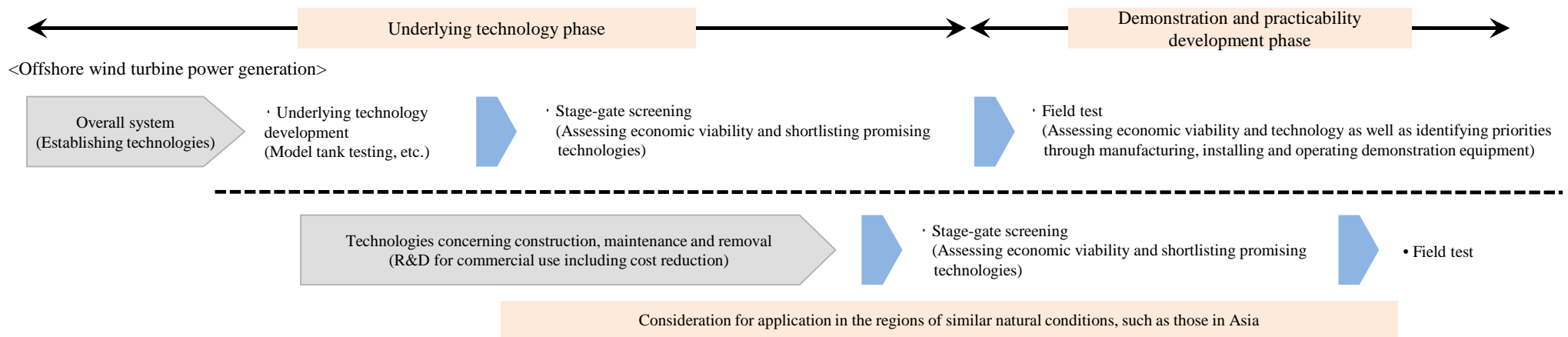
- Advanced floating offshore wind turbine technology applicable to harsh environment will be developed, including through the field test of floats and turbines and the development of low-cost construction and efficient maintenance technologies, aiming to enable installation at a cost lower than that of existing power sources. The global amount of CO₂ reduction is estimated to be around 6.5 billion tons.¹⁾

[Technology development]

- Floating offshore wind power generation is still at demonstration phase around the world, as it is difficult to stabilize the float and the huge turbine amidst the waves. Efforts to lead the world in establishing and using floating offshore wind turbine technology will be made. Furthermore, floating offshore wind power generation applicable to the natural environment of Japanese waters, where many typhoons and thunders are expected and, surrounded by a continental shelf, the seabed is steep and rocks are abound, will be sought. Field tests aimed at commercial use, including research on the cost reduction of power generation will be conducted, and efforts will be made at making floating offshore wind power generation economically viable in the long term.
- Low-cost construction technology to significantly reduce the installation cost of the wind turbine and the base structure, a challenge shared with bottom-fixed offshore wind turbines, will be established. At the same time, the development and demonstration of technologies will be conducted to reduce maintenance cost with sophisticated maintenance technology, including fault prediction, and enhance capacity factor, aiming to achieve a target capacity factor of 97% for the offshore wind turbine in Japan.

(System for development)

- During the underlying technology phase, identification and feasibility assessment will be conducted through collaboration among universities, research institutions and operators. In the demonstration phase, the operators, with a view to adopting the technology in the society, will play a central role in manufacturing the demonstration equipment, verifying design with measured data and properly maintaining the equipment for demonstration operation.



¹⁾ Estimated by NEDO TSC based on IEA ETP2017 and others.

I. Energy transformation

Resilient electricity network using digital technologies

4) Low-cost innovative battery to make renewable energy a main power source

[Target]

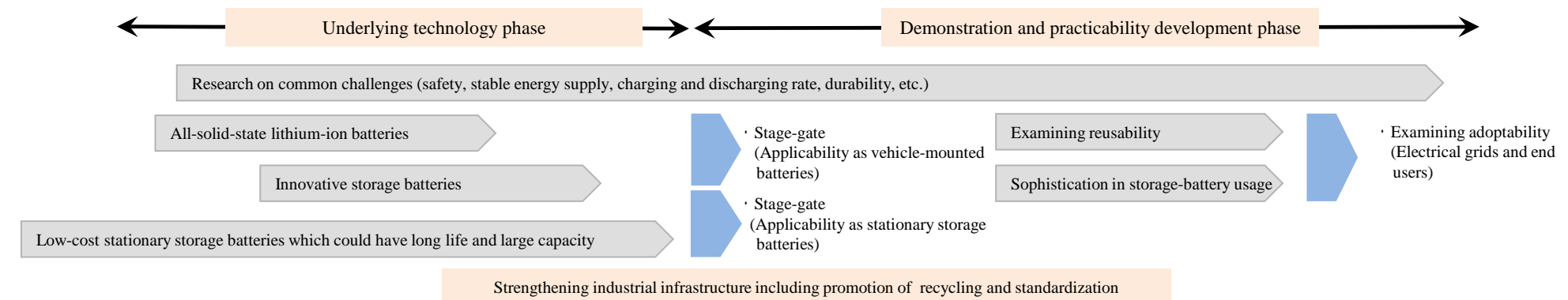
- In order to make renewable energy a main power source in 2050, vehicle-mounted next-generation storage batteries of less than 5,000 JPY/kWh cell cost will be developed, and also made available for stationary electricity storage systems. By using batteries as a means of storage and flexibility for fluctuating renewable energy, the entire system will contribute to the reduction of CO₂ emissions.

[Technology development]

- Technologies to reduce the cost of power storage, based on the technology for vehicle-mounted storage batteries supplied in large quantities to accompany wider use of electric vehicles, will be pursued including through field test. Technologies on deterioration measurement and recycling of storage batteries, including reusing vehicle-mounted storage batteries, will be developed to make the most out of storage batteries.
- In order to improve energy density as well as durability and safety of electrodes, innovative batteries intended to cater for the high-spec requirements of the mobility such as all-solid-state batteries and air batteries, currently being developed as underlying technologies, will be demonstrated for initial adoption as stationary storage batteries. Research aimed at identifying seeds of technology for low-cost stationary storage batteries with long life and large capacity, potentially lower in electricity storage cost than vehicle-mounted batteries will be conducted.
- Energy management technology for distributed energy system including stationary storage batteries will be developed using Internet-of-things (IoT) and other technologies.

(System for development)

- During the underlying technology phase, research and development will be carried out through industry-academia-government collaboration. A consortium based on collaboration with research institutes in Japan and abroad will be formed for development in the demonstration phase.



I. Energy transformation

Resilient electricity network using digital technologies

5) Energy management system (EMS) with digital technology to reduce the grid cost

[Target]

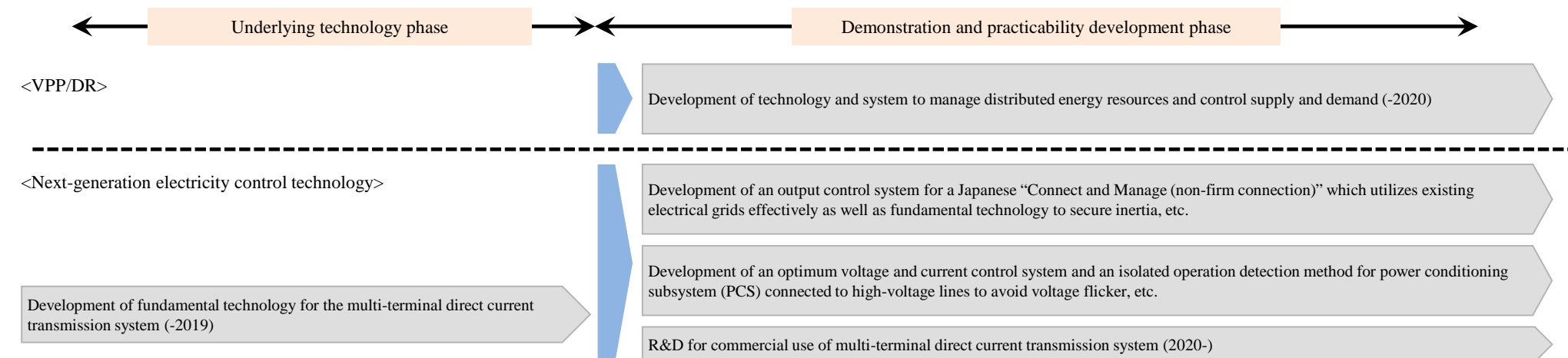
- An energy management system to keep the cost of electrical networks under control will be developed and adopted, in accordance with efforts aimed at minimizing and optimizing the total cost of power generation and grid in making renewable energy a main power source. This will contribute to the comprehensive reduction of CO₂ emissions of the electricity system.

[Technology development]

- Technology for an energy management system which controls energy supply and demand in various voltage classes from transmission lines to distribution lines and suits sector coupling will be developed using virtual power plant (VPP), demand response (DR) and next-generation electricity control technologies.

(System for development)

- VPP/DR
Group control technology for distributed energy resources and storage batteries such as EV and stationary storage batteries will be used for controlling energy supply and demand. A system of collaboration among electricity companies, communication companies and equipment manufactures will be formed to establish such technology.
- Next-generation electricity control technology development
In order to develop a system which enables renewable energy companies to connect to electric power networks smoothly, joint research will be conducted through collaboration of universities, research institutions, electronic manufacturers and electricity transmission and distribution utilities.



I. Energy transformation

Resilient electricity network using digital technologies

6) Highly-efficient and low-cost power electronics technology

[Target]

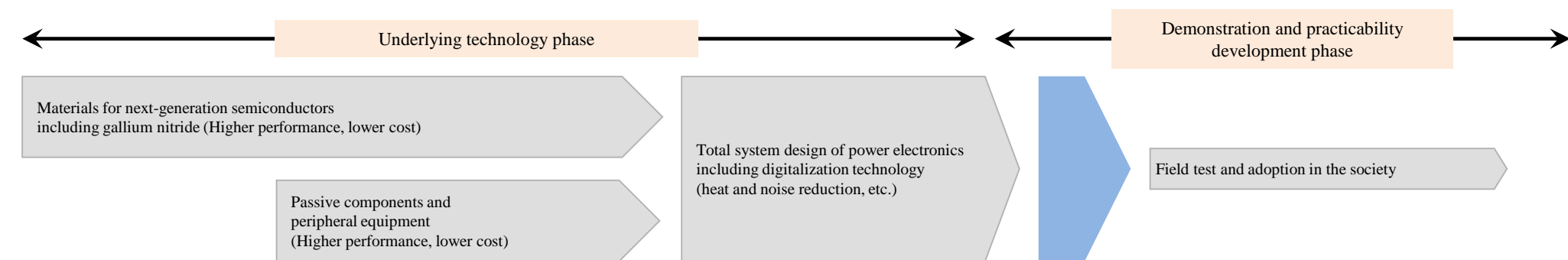
- Research and development for high-performance and low-cost power electronics technologies to slash power loss in conversion at each phase of generation, transmission, distribution and consumption will be conducted for wide usage in the new device by 2050. The global amount of CO₂ reduction is estimated to be around 1.4 billion tons.¹⁾

[Technology development]

- Efforts have been made to develop technologies for new silicon device structure and next-generation power semiconductors using silicon carbide and gallium nitride, for vehicle-mounted devices or industrial usage where a high withstand voltage is required than for existing usage, as well as for communication devices which are required to operate faster. Further development for sophistication and cost reduction of next-generation power semiconductors including those using gallium nitride will be pursued. Silicon carbide is expected to substitute silicon and achieve higher inverter efficiency (by 2% to over 10%), and efforts to facilitate early adoption in the society, including capital investment by the private operators, will be made.
- Furthermore, efforts will be made on a total system design of power electronics including: general-purpose power module including passive components and peripheral equipment; heat and noise reduction; digitalization technology for precise management of energy supply and demand; and mounting equipment.
- Efforts to apply technologies developed for next-generation semiconductors, including those using gallium nitride, to communication devices, lasers and wireless power transfer will continue from the research and development phase to the adoption in the society.

(System for development)

- Higher performance of next-generation semiconductor component, passive components, peripheral equipment and other equipment will be pursued and prototypes will be developed to facilitate commercial use by companies, based on inter-agency collaboration and collaboration among universities in Japan and abroad, research institute and companies.



1) Based on NEDO TSC's calculation of the amount of reduced CO₂ when innovative power electronics technologies have been introduced at a certain percentage to sectors such as transportation and industry

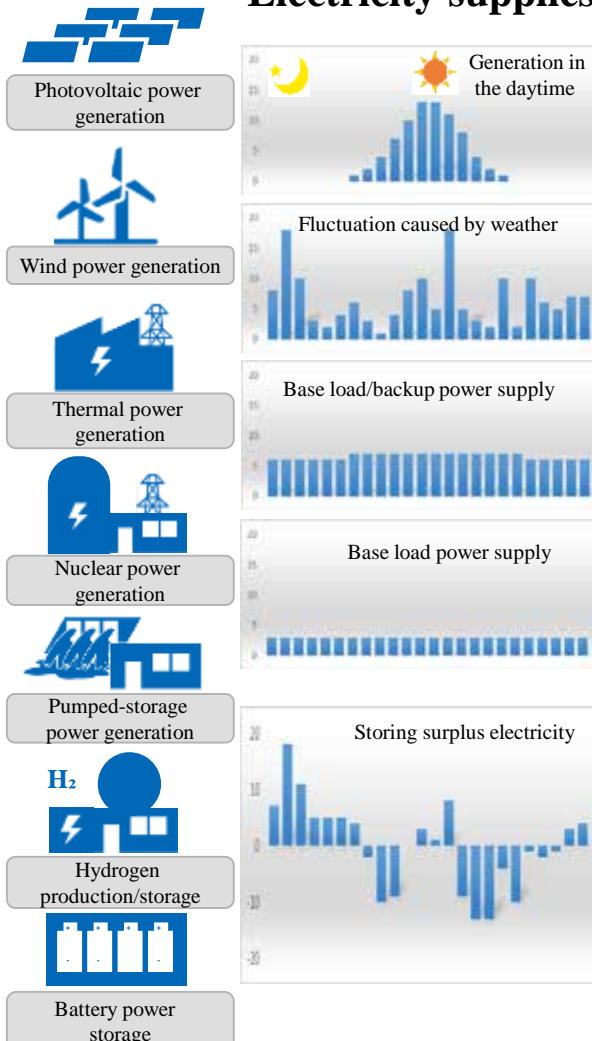
I. Energy transformation

Reference 3

Power network system to realize low-carbon society

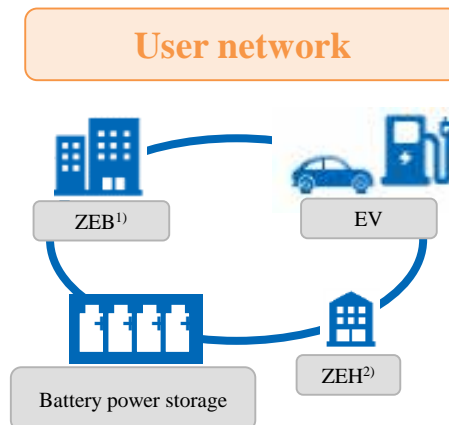
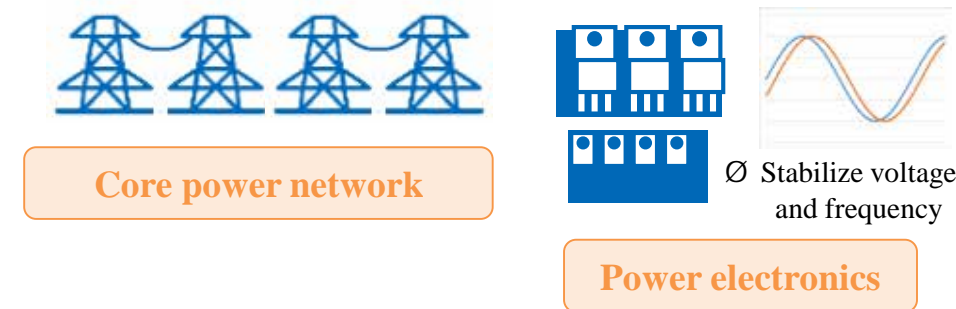
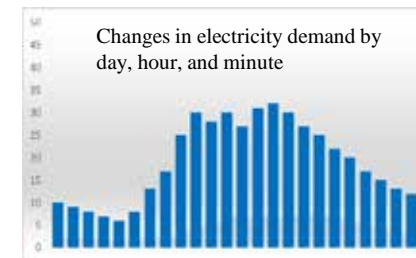
Power electronics technologies to thoroughly reduce power loss in the supply of electricity from non-fossil energies and its transmission as well as at the demand-side are indispensable. Effective use of digital information technology and AI is the key driver to manage the electricity supply and demand at different time scales and under constraints such as low-cost and low-carbon. It is also important to utilize energy storage technology and power electronics technology, which contribute to ensuring flexibility and inertia to maintain the resilience of power network.

Electricity supplies



- Advanced technology to manage electricity supply and demand using AI and IT
- Flexibility and inertia secured with power electronics technology and storage batteries

Electricity users



- Securing flexibility and inertia to enable wider introduction of renewable energy
- Digitalizing electricity supply and demand information and optimizing supply-demand balance through development and introduction of an advanced management system based on information technology

- Advanced electricity supply-demand management system applied in demand side network based on information technology
- Importance of securing flexibility and inertia

1) ZEB: zero-emission building
2) ZEH: zero-emission house

7) Production: CO₂-free hydrogen production cost reduced to 1/10

[Target]

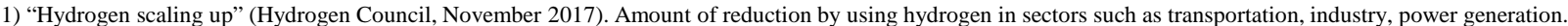
- The cost of CO₂-free hydrogen production will be kept under 1/10 of the current cost, comparable to that of natural gas, and achieve a level equivalent to existing energy sources by around 2050. The global amount of CO₂ reduction from hydrogen production, transportation and storage, as well as usage and power generation, including FCEV and stationary fuel cell (FC), is estimated to be around 6 billion tons.¹⁾

[Technology development]

- Methane decomposition technologies to produce hydrogen, which do not generate CO₂ byproduct and are at underlying technology phase, and technologies to reduce separation and other costs and raise efficiency through energy saving in hydrogen production from natural gas and lignite, which are at practicability development phase, will be developed, including at a national-level project, aiming to establish a commercial supply chain by around 2030.
- Technologies to improve efficiency and durability of equipment in a renewable-energy-based water electrolysis system will be developed, including at a national-level project, aiming for commercial use by around 2032. Underlying technologies for reduced cost and wide usage will also be developed, including at a national-level project and a cutting-edge research program, with a view to enhancing competition and selectiveness based on suitability.
- A regional field test program to cover the comprehensive hydrogen supply chain from production, storage and transportation to usage, will be carried out with a view to reducing cost and promoting usage of the hydrogen supply chain in a regional context.

(System for development)

- A system of collaboration covering universities, equipment manufacturers, plant manufacturers and system operators will be established at technology practicability development phase to improve material properties for actual process and reduce cost in the total cost of the manufacturing process.



I. Energy transformation

Low-cost hydrogen supply chain

8) Storage & transportation: compressed hydrogen, liquefied hydrogen, organic hydride, ammonia, and metal hydride

[Target]

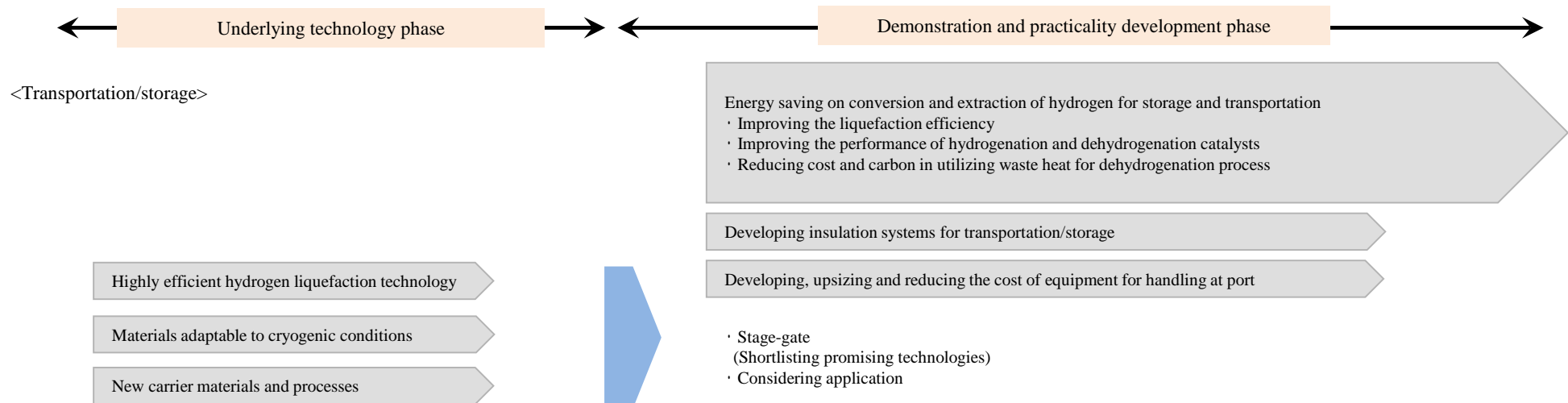
- The cost of hydrogen (at the plant gate) will be reduced, aiming for around 20 JPY/Nm³ toward 2050. The global amount of CO₂ reduction for hydrogen production, transportation and storage, as well as usage and power generation (including FCEV and stationary FC) is estimated to be around 6 billion tons.¹⁾

[Technology development]

- Technologies for hydrogen transportation and storage, such as compressed hydrogen, liquefied hydrogen, organic hydride, ammonia and metal hydride, will be developed, to be used for mobility, hydrogen power generation and industry. New technologies for higher efficiency of transportation and storage, currently at underlying technology phase, will be developed at a national-level project and a cutting-edge research program in a competitive environment with a Stage-gate system. Compressed hydrogen, liquefied hydrogen, organic hydride, ammonia and metal hydride are in the practicability development phase and transportation and storage systems to utilize these technologies competitively and selectively, based on practical suitability, will be developed at a national-level project, aiming to establish a commercial-scale supply chain in around 2030.

(System for development)

- Underlying technology will be developed by collaboration of universities, public research institutions, and companies. Technologies in the demonstration and practicality development phase will be developed in a collaboration where trading companies and distributors, in addition to engineering companies, are involved.



1) Reproduced from page 25.

I. Energy transformation

Low-cost hydrogen supply chain

9) Utilization: low-cost hydrogen station and low-NOx hydrogen power generation

[Target]

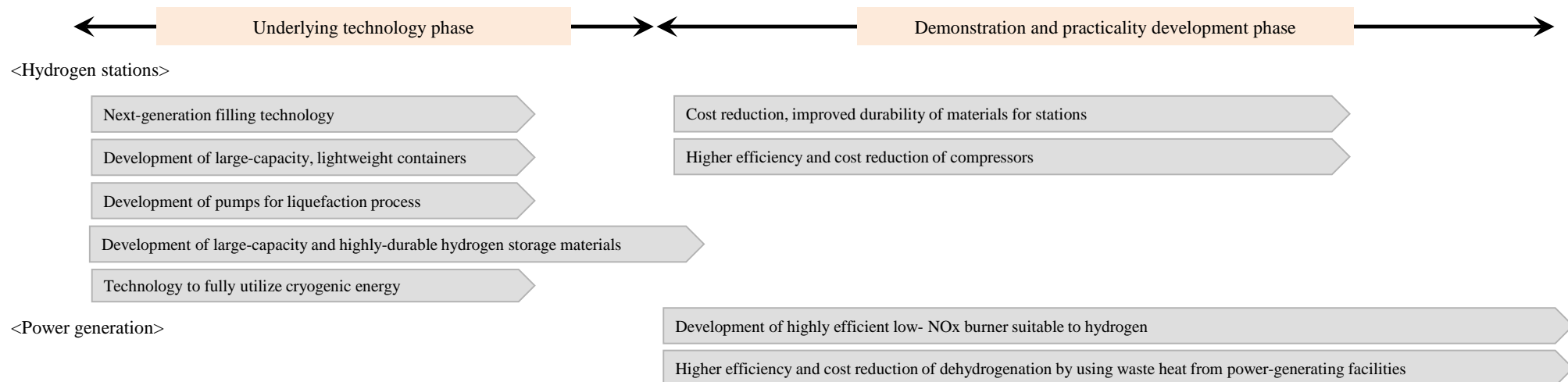
- The maintenance and operation cost for hydrogen stations will be reduced, aiming for commercial viability by the second half of the 2020s. As a long term goal, a basic energy-infrastructure network for fuel cell mobility will be established by around 2050.
- Technologies for hydrogen power generation will be developed and hydrogen cost will be reduced, aiming to enable commercial application in around 2030. The global amount of CO₂ reduction is estimated to be around 6 billion tons.¹⁾

[Technology development]

- Underlying technologies will be steadily developed and regulation will be reviewed in order to reduce the maintenance and operation cost of hydrogen stations.
- Technologies necessary for 100% hydrogen power generation, such as low-NOx hydrogen burner, reducing combustion oscillation and cooling, will be developed if reduced procurement cost makes them feasible. Also, in order to make the entire system commercially viable, issues for upsizing hydrogen-supply equipment will be identified and addressed at the underlying technology phase.

(System for development)

- Hydrogen station operators and equipment manufacturers will collaborate on hydrogen stations. Universities and research institutions as well as turbine manufacturers and power utilities will collaborate on hydrogen power generation.

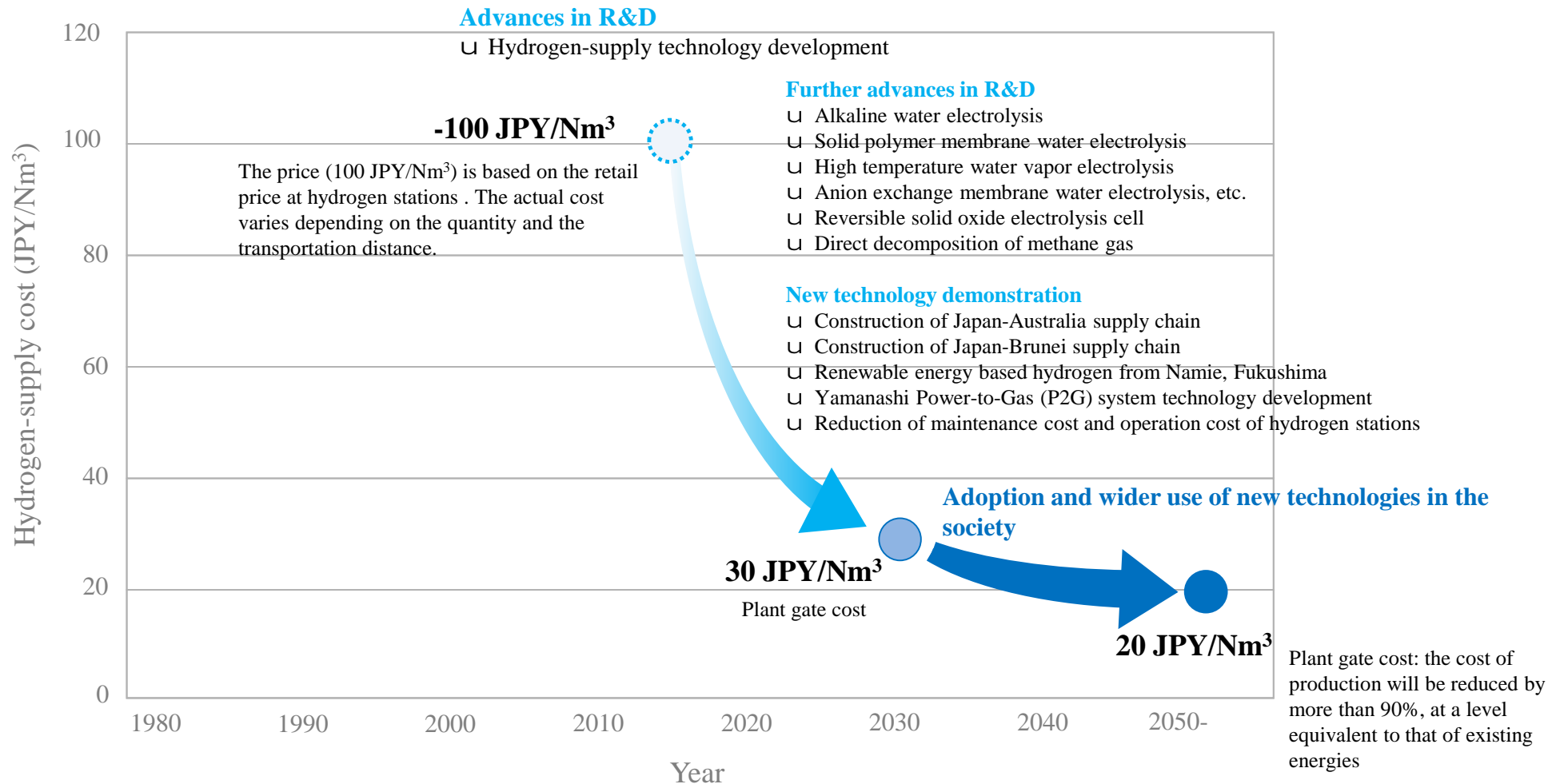


¹⁾ This estimate is a reiteration of that in page 25.

I. Energy transformation

Reference 4 Cost reduction by innovation -- Example of hydrogen supply

The cost of hydrogen has steadily declined thanks to the long-term investment in R&D so far. In the light of past experience and existing innovative technologies, it is aimed that the level of cost of hydrogen will be equivalent to the existing energy sources by around 2050. ^{1), 2)}



1) Assuming that: economies of scale are achieved through steady adoption in the society; renewable energy prices decline substantially, and; a market with balanced supply and demand is created.

2) Change in the costs of competing technologies needs to be taken into account as well.

I. Energy transformation

Next-generation atomic energy and nuclear fusion

10) Atomic energy with excellent safety system

[Target]

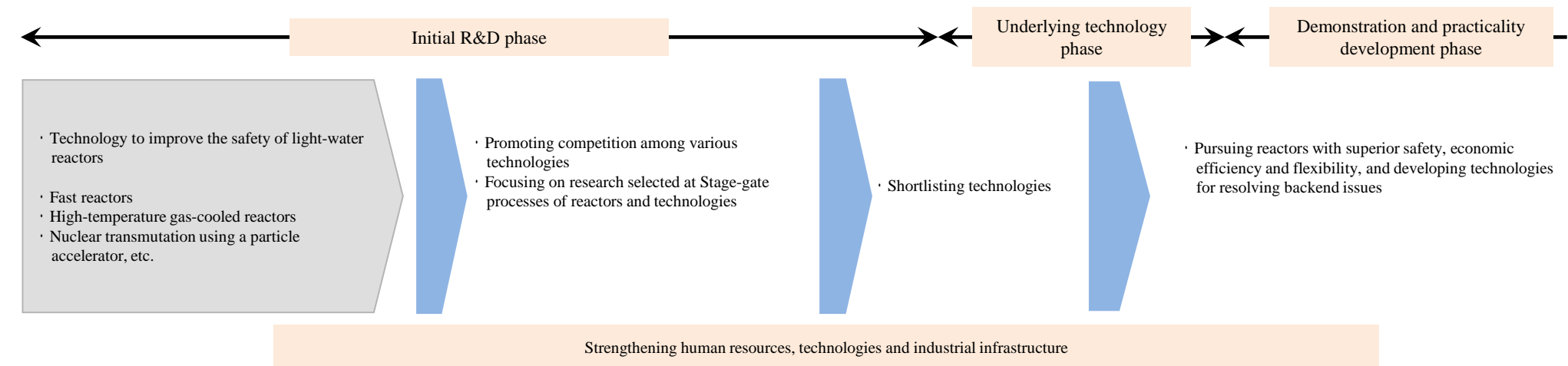
- Firstly, technologies on light-water reactors, such as those contributing to further improvement of safety, will be developed toward 2030. Reactors with superior safety, economic efficiency and flexibility will be sought and technologies for resolving backend issues will be developed toward 2050.

[Technology development]

- In addition to further improvement of safety, reliability and efficiency, innovation in nuclear-related technologies will be facilitated in the light of various social demands including coexistence with renewable energy, hydrogen production and heat usage.
- For the coming five years, competition among various technologies utilizing innovation in the private sector will be promoted. At the following stage, support will be provided according to the maturity of the technology while the scope will be narrowed down.

(System for development)

- The Government will set out a long-term vision of development, considering efforts in the US and Europe. The private sector will utilize their ingenuity and wisdom for competition among various technologies and the selection by the market at home and abroad.
- Inter-agency collaboration will be strengthened for technology and human resources development, private sector engagement in the public research infrastructure and enhanced industrial infrastructure, to promote innovation in nuclear-related technologies by utilizing the private sector's ingenuity.



I. Energy transformation

Next-generation atomic energy and nuclear fusion

11) Nuclear fusion

[Target]

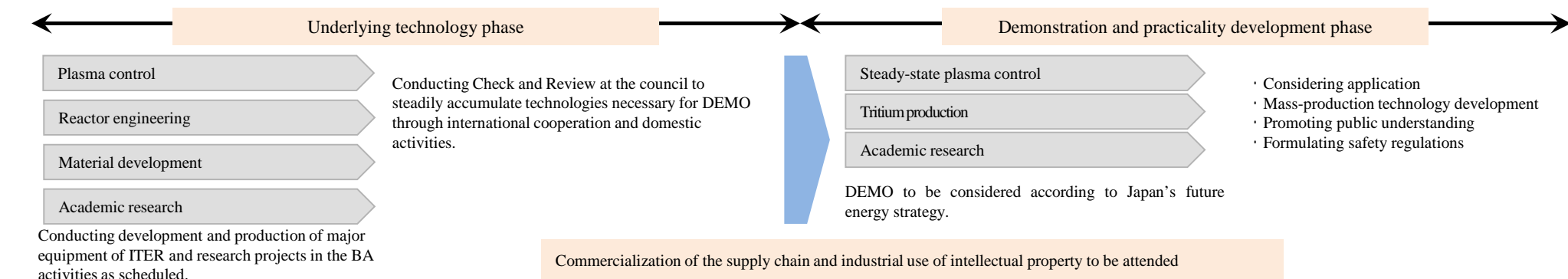
- The International Thermonuclear Experimental Reactor (ITER) project and the Broader Approach (BA) activities will be steadily advanced with a view to commercialization during this century. Based on the progress of the project and activities, a decision on whether to move on to the Demonstration Power Reactor (DEMO) in the 2030s will be made. The global amount of CO₂ reduction is estimated to be around 590 million tons in 2100.¹⁾

[Technology development]

- Equipment manufacturing technologies will be established by developing major equipment such as heating units and remote maintenance devices, of which Japan is in charge in the ITER project. Japanese research community will lead the experiment phase of ITER to accumulate the expertise for the realization of fusion energy.
- An operational scenario of ITER will be developed in the BA activities. At the same time, research and development for generation and control of high pressure plasma with an advanced superconducting tokamak device “JT-60SA” will be conducted in order to verify the safety, reliability and economy of nuclear fusion generation. Also, human resources, the young researchers who will sustain long-term research and development as well as commercialization, will be developed. Furthermore, research and development on technologies to collect lithium from seawater and to produce tritium using lithium will be conducted, to prepare for test facilities including fusion neutron generators and the fuels, which will be used for developing and assessing constructional and other materials with durability against fusion neutrons and low-activation properties.
- Research on the helical method, laser method and other innovative concepts will also be facilitated in order to secure the diversity of technologies.

(System for development)

- An all-Japan team is formed with the National Institute for Quantum and Radiological Science (QST), the Domestic Agency of the ITER Agreement and implementing the BA activities, at its center and joined by universities and the industry. The system will be reviewed as the project moves forward over various phases such as the development of technology infrastructure for DEMO and the transition to DEMO, with strengthened involvement of the industry.



¹⁾ The amount of reduction in 2100 is estimated by the QST based on the data on 2010 as the point of reference: the estimated amount of electricity generated by nuclear fusion generation by country in 2100 is compared to the CO₂ emission factors of the power generation sector of each country in 2010 (IEA, CO₂ emissions from fuel combustion 2018).

I. Energy transformation

Low-cost CO₂ capture for CCUS / carbon recycling

12) Establishment of low-cost CO₂ capture technology for CCUS / carbon recycling

[Target]

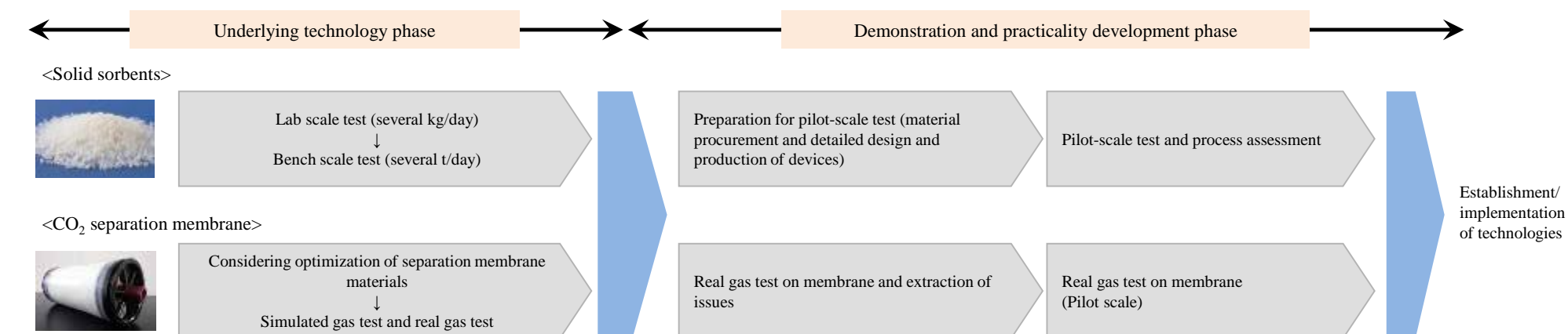
- Technologies will be developed for the cost of CO₂ capture to be 1,000 JPY/t-CO₂ by 2050. Capture capabilities adaptable to various sources of CO₂ emissions will be acquired. The global amount of CO₂ reduction through CCS (including EOR¹⁾ and BECCS²⁾) is estimated to be around 8 billion tons.³⁾

[Technology development]

- Research on CO₂ capture technologies using solid sorbents for post-combustion capture (for gases at atmospheric pressure and low pressure gases) and separation membrane for pre-combustion capture (for high-pressure gases) will be conducted to reduce the cost of CO₂ capture, which accounts for the majority of carbon capture and CO₂ cost.
- Research and development for establishment and application of CO₂ capture technology will be conducted, including on pilot-scale tests.
- Technology to CO₂ capture CO₂ from exhaust gases, avoiding environmental impact, will be established for the adoption of environment-conscious CCS in the society.

(System for development)

- Solid absorbent technology will be particularly sought for CO₂ capture from exhaust gases of coal-fired thermal power stations (at atmospheric pressure; with N₂, CO₂, O₂ and H₂O as main components). Pilot-scale project will be conducted in collaboration with private companies and universities.
- Separation membrane technology will be particularly sought for the integrated coal gasification combined cycle (IGCC). A project to develop technology to capture CO₂ from fuel gases (at high pressure; with H₂, CO₂, CO, H₂O, N₂ as main components) manufactured at coal gasifiers will be implemented.



1) EOR: Enhanced Oil Recovery

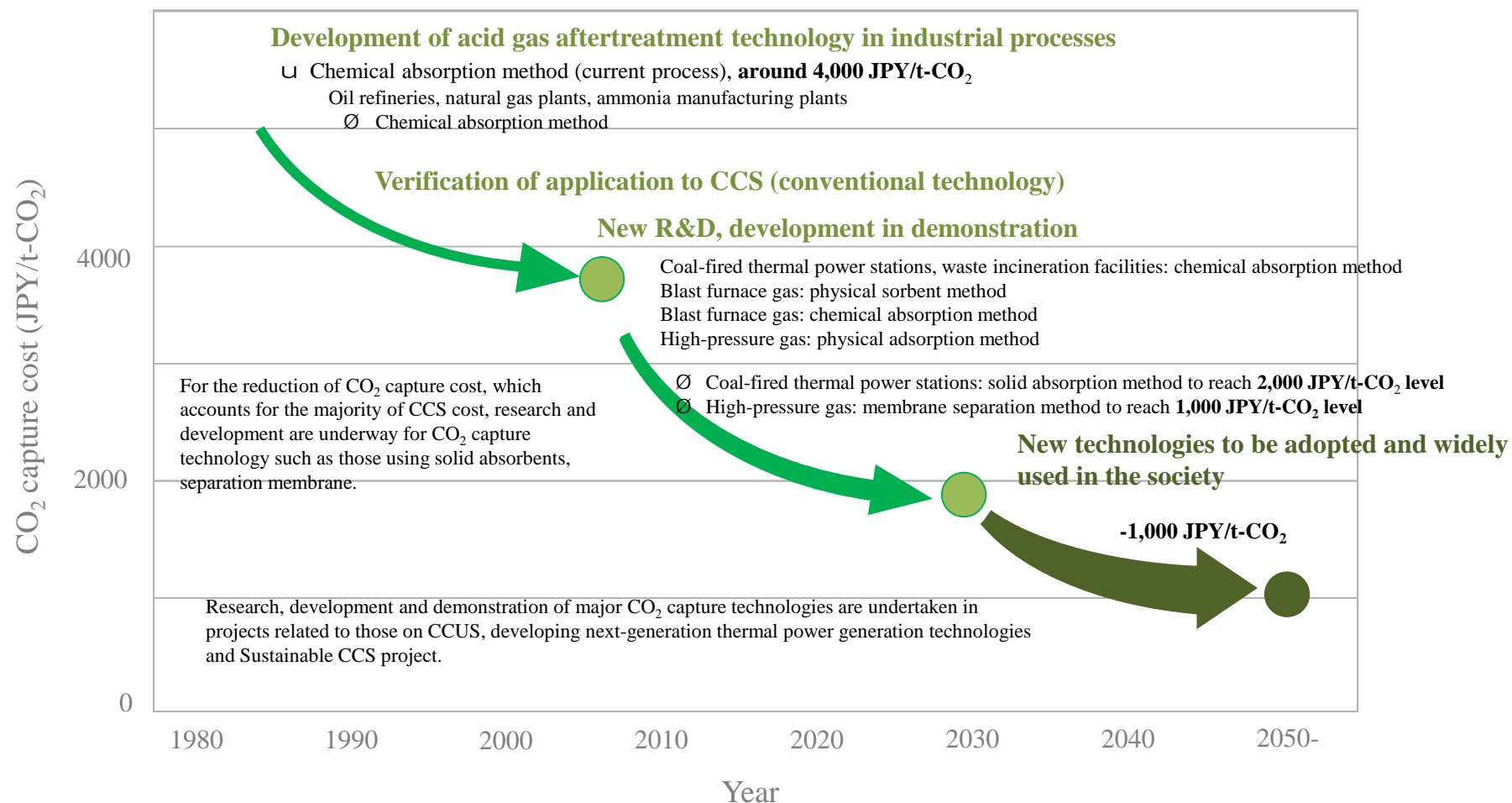
2) BECCS: Bioenergy with Carbon Capture and Storage

3) Estimated by NEDO TSC based on IEA ETP2017 and other data.

I. Energy transformation

Reference 5 Cost reduction by innovation -- Example of CO₂ capture

In the light of past experience and existing innovative technologies, it is aimed that the cost of CO₂ capture to be 1,000 JPY/t-CO₂ by 2050. ^{1) 2)}



1) If the capture cost is reduced from the current level of around 4,000 JPY/t-CO₂, to 1,000 JPY/t-CO₂, and if 5 million tons of CO₂ is captured from coal-fired thermal power stations every year, the cost could be reduced by around 15 billion JPY annually. 2) The chart was drawn based on the Carbon Recycling Roadmap (2019). It is assumed that economies of scale are achieved through steady adoption in the society. Change in the costs of competing technologies needs to be taken into account as well.

II. Transportation

Green mobility modalities

13) Expansion of electrification of vehicles and aviation, including high-performance storage batteries, and significant improvement in environmental performance

[Target]

<Vehicle> As a long-term goal, the highest level of environmental performance in the world will be achieved for globally-supplied Japanese brand cars by 2050. The GHG emissions per vehicle will be reduced by around 80 percent against 2010 levels. Automobile usage innovation, such as autonomous driving and connected technologies, will be pursued, in line with the global effort for zero-emission energy supply, to help achieve the ultimate target of Well-to-Wheel zero-emission. At the same time, a virtuous cycle of transportation projects and higher productivity will be pursued for further reduction in GHG emissions, including by introducing a system supporting eco-friendly driving with connected technologies and facilitating digital technologies and business collaborations. The global amount of CO₂ reduction from electrification and fuel decarbonization is estimated to be approximately 6 billion tons.¹⁾

<Aircraft> In order to achieve the International Air Transport Association (IATA) goal of halving CO₂ in the aviation industry against 2005 levels by 2050, next-generation electric aircraft will be developed and necessary technologies will be established. The global amount of CO₂ reduction from electrification and fuel decarbonization is estimated to be around 2.0 billion tons.²⁾

[Technology development]

<Vehicle> Various technologies including high-performance battery, motor, inverter, such as next-generation power semiconductor, fuel cell, lightweight components at underlying technology stage will be developed and those at practicality development stage will be demonstrated, to realize electrified vehicle, such as battery electric vehicle (BEV), plug-in hybrid electric vehicle (PHEV), hybrid electric vehicle (HEV) and fuel cell electric vehicle (FCEV).

<Aircraft> Core light-weight and high-power technologies required for next-generation electric aircraft, such as motor, battery, power electronics and equipment, will be developed and demonstrated. Development of structure and engine material to achieve light-weight and save fuels will be pursued.

(System for development)

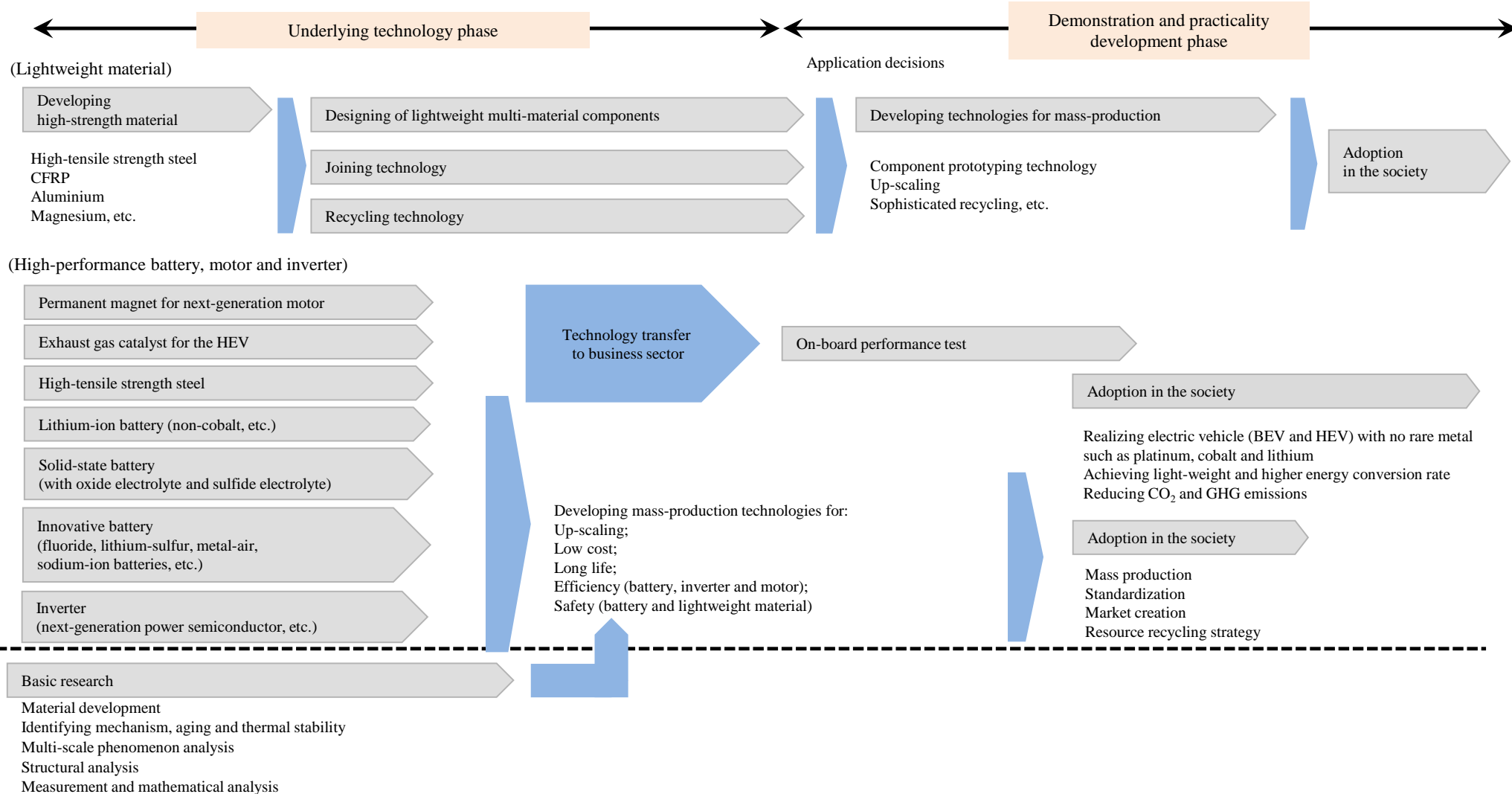
- Basic research for the underlying technologies will continue, while academic and startup expertise will be incorporated to build a network of research institutions within Japan and abroad.
- Furthermore, a center for resolving basic issues in battery properties to create a comprehensive framework covering battery-related activities thoroughly, such as designing, developing electrode and electrolyte, building, assessing and analyzing, for research and development on battery.

As also mentioned in page 35 and page 36, CO₂ reduction in the transportation sector requires a multi-dimensional approach, such as development of electrification and fuel decarbonization technologies, taking into consideration the prospect of future electricity generation mix and infrastructure development.

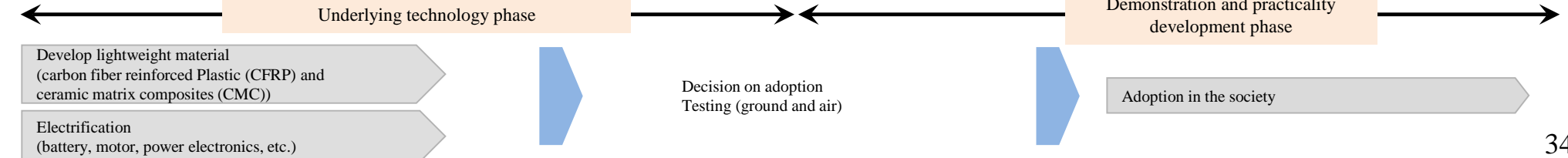
1) A METI estimate, assuming that all actions, including electrification and low-carbon fuels, were taken. 2) A METI estimate, assuming that all the actions in the global aviation sector, including electrification and low-carbon fuels, to clear the long-term IATA goal, were taken.

II. Transportation

<Vehicle>



<Aircraft>



II. Transportation

Green mobility modalities

14) Fuel cell electric vehicles (FCEV) system and establishment of hydrogen-mobility infrastructure including storage system

[Target]

<Vehicle> The price gap between the FCEV running on hydrogen and the hybrid electric vehicle of the same class will be reduced to around 700 thousand JPY by 2025 through joint technological development and promotion for wider use of the FCEV by the Government and the business, with a goal of introducing 800 thousand FCEV by 2030. As a long-term target, globally-supplied Japanese brand cars including the FCEV will achieve the highest level of environmental performance in the world. At the same time, technologies will be developed to realizing fuel cell-based mobility vehicles other than passenger cars.

<Vessel> In order to reduce the total annual GHG emissions by at least 50% by 2050 and phase them out as soon as possible in this century, as set forth in the initial strategy on the reduction of GHG emissions from ships of the International Maritime Organization (IMO), a roadmap towards achieving zero emission of GHG from vessels, including efforts aimed at facilitating the use of hydrogen and other next-generation fuels, such as orientation for safety and environmental rules and internationally regulated incentive system for operators, will be formulated in FY 2019, and efforts will be made to develop commercially viable zero emission vessel by 2030. The use of hydrogen fuel cell vessels will be facilitated, including by setting guidelines for wider use of hydrogen on vessels.

<Others> Technologies for other fuel cell-based mobility will be developed as well.

The total global amount of CO₂ reduction through the FCEV and the hydrogen production, transportation, storage, usage and power generation, including stationary FC, is estimated to be around 6.0 billion tons.¹⁾

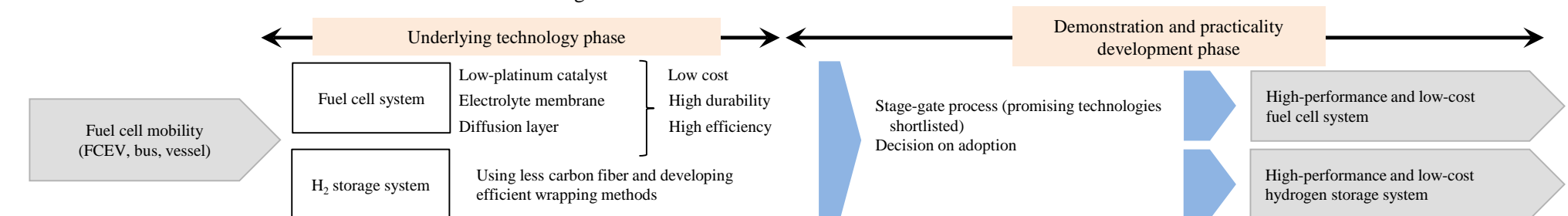
[Technology development]

<Vehicle> In order to improve output density and achieve high-load operation and high durability, to prepare for mass introduction after 2030, underlying technologies such as those on catalyst, electrolyte, membrane-electrode assembly (MEA) and hydrogen storage system (on-board hydrogen tank) will be developed.

<Vessel> Technologies for using next-generation fuels on vessels, based on the roadmap for zero-emission vessels to be formulated in FY 2019, will be developed.

(System for development)

- The Council for a Strategy for Hydrogen and Fuel Cells will continue to facilitate the collaboration among the Government, the academia and the business. At the same time, a multi-layered structure for technological development, with automobile and shipping industries sharing technological information and challenges within their fields of collaboration and universities and research institutions offering their solutions.



1) This estimate is a reiteration of that in page 25.

As also mentioned in page 33 and page 36, CO₂ reduction in the transportation sector requires a multi-dimensional approach, such as development of electrification and fuel decarbonization technologies, taking into consideration the prospect of future electricity generation mix and infrastructure development.

II. Transportation

Green mobility modalities

15) Technologies for producing biofuels and synthetic fuels with carbon recycling technologies at a cost comparable with the existing fuels, and their utilization

[Target]

<Vehicle> The combustion engine vehicles, such as those using gasoline, are expected to have a share of over 80% in 2040, and there is a need for decarbonizing the fuels.¹⁾ Technologies will therefore be developed to synthesize liquid fuels from CO₂ emissions. The goals include establishing manufacturing technology at a demonstration phase at around 2030 and lowering the production cost to the same level as the existing bio-ethanol (200 JPY per liter) or less at around 2040. The total global amount of CO₂ reduction is estimated to be around 6 billion tons.²⁾

<Aircraft> The cost of bio-jet fuels (currently 1,600 JPY per liter for microalgae-based products) will be reduced, aiming for 100-200 JPY per liter by 2030. Emission intensity will also be reduced, aiming for less than half that of the existing jet fuels on LCA basis. Further cost reduction will be pursued to contribute to reducing the CO₂ emission in aviation by 50 percent against that of 2005. The same target as vehicle will be set on synthetic fuels. The total global amount of CO₂ reduction is estimated to be around 2 billion tons.³⁾

<Vessel> In order to reduce the total annual GHG emissions by at least 50% by 2050 and phase them out as soon as possible in this century, as set forth in the initial strategy on the reduction of GHG emissions from ships of IMO, necessary technologies for next-generation fuels will be developed and efforts will be made to develop commercially viable zero emission vessel by 2030. The total global amount of CO₂ reduction is estimated to be around 2.6 billion tons.⁴⁾

[Technology development]

<Vehicle> Synthetic fuels will be developed.

- A comprehensive production process to turn CO₂ into synthetic fuels will be optimized to establish a highly efficient and low-cost reaction process.
- Innovative new technologies and processes will be developed to boost efficiency.

<Aircraft> Biofuels and synthetic fuels will be developed to replace jet fuels.

A. Biofuels

- Large-scale field test will be conducted under various conditions to establish low-cost mass-scale production methods for large-scale cultivation tanks and equipment, including photo-bioreactor (PBR), in natural environment.
- A testing center for using CO₂ retrieved from thermal power stations to experiment with various conditions, such as light, temperature, microalgae species and culture configurations, will be prepared. This center will be used for research into maximizing the absorption of CO₂ emissions from thermal power stations and resolving issues resulting from large-scale field tests.
- Genome editing methods will be developed to establish genetic engineering technologies for efficient and low-cost production of microalgae-based biofuel.

B. Synthetic fuels (the same as for vehicle)

<Vessel> Technologies for using next-generation vessel fuels will be steadily developed.

As also mentioned in page 33 and page 35, CO₂ reduction in the transportation sector requires a multi-dimensional approach, such as development of electrification and fuel decarbonization technologies, taking into consideration the prospect of future electricity generation mix and infrastructure development.

1) Energy Technology Perspectives 2017, IEA

2) This estimate is a reiteration of that in page 33

3) This estimate is a reiteration of that in page 33

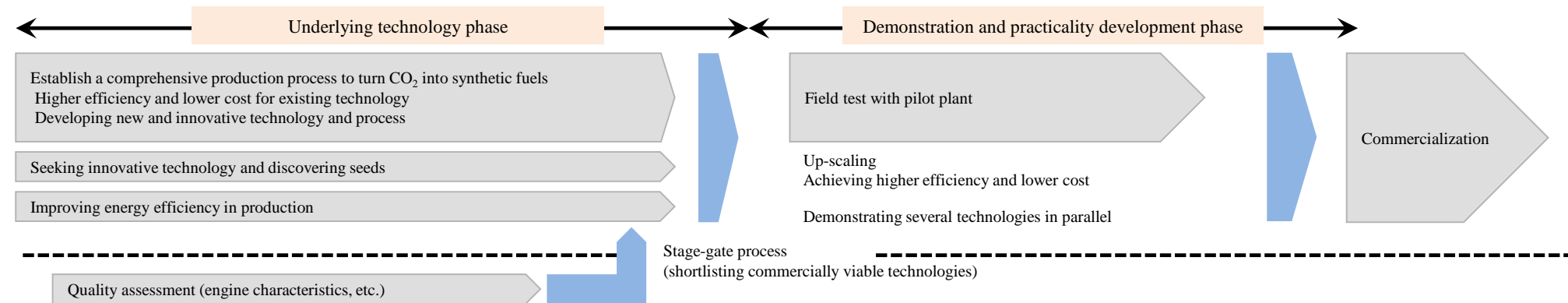
4) An estimate by the Ministry of Land, Infrastructure and Transportation (MLIT), based on the outlook for 2050 in "Third IMO Greenhouse Gas Study 2014" and assuming that the IMO GHG reduction strategy target for CO₂ reduction by 2050 has been met.

II. Transportation

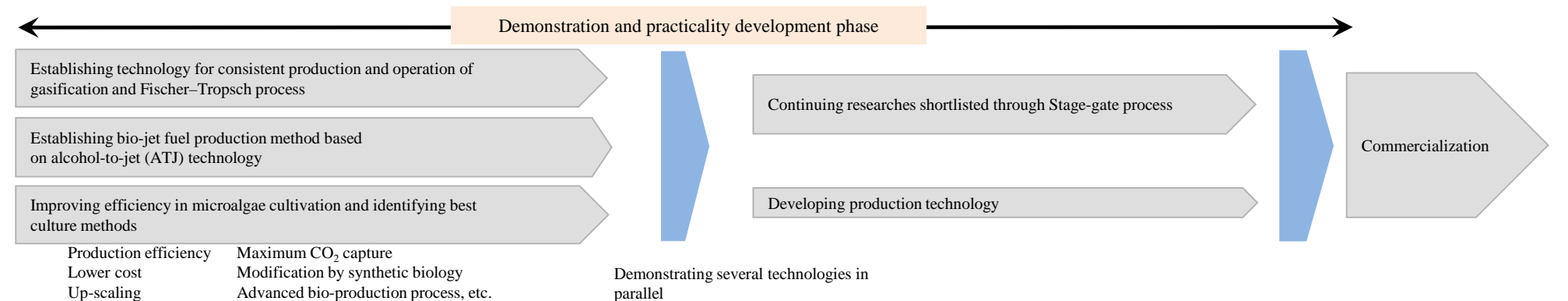
(System for development)

- Optimal technology and process for practical use of synthetic fuels for vehicle and aircraft as well as for vessels will be sought in collaboration with universities, research institutions and companies in Japan and overseas.
- Field test project for practical use of bio-jet fuels will be steadily implemented in collaboration with universities, research institutions and companies in Japan and overseas.

<Vehicle and aircraft (synthetic fuels)>



<Aircraft (biofuels based on carbon recycling technology)>



<Vessel>



Independence from fossil fuels (electricity from renewable energy and CO₂-free hydrogen)

16) “Zero-carbon steel” with innovative technologies such as hydrogen reduction

[Target]

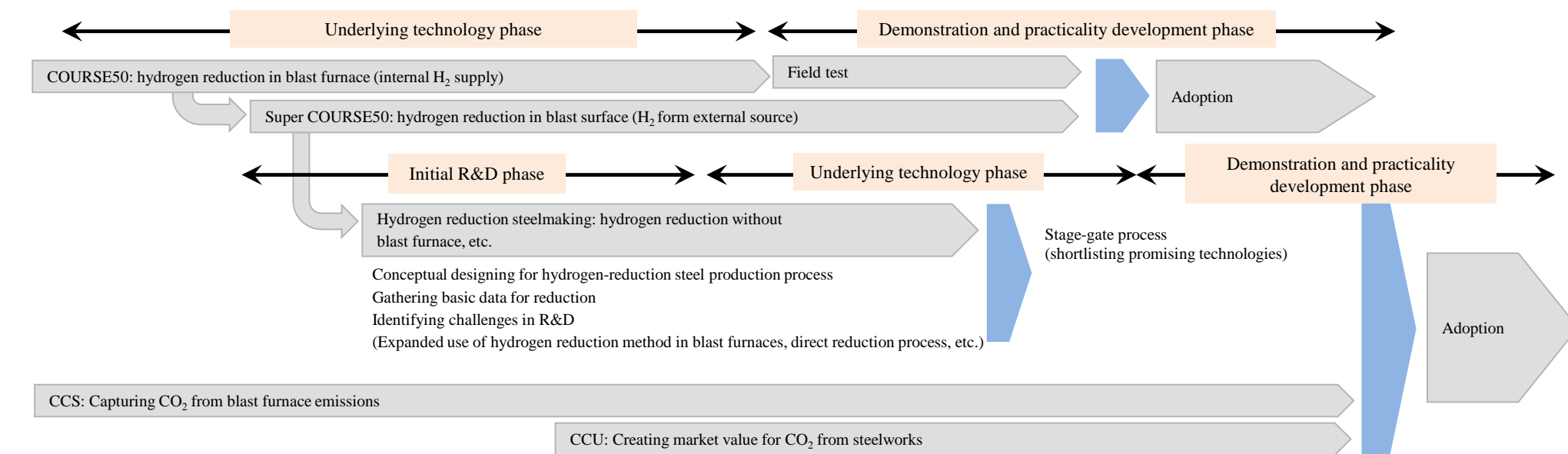
- Super-innovative technologies such as hydrogen reduction steelmaking will be developed to realizing “zero-carbon steel” at the same cost level with traditional blast furnaces as early as possible after 2050. The feasibility will depend on a consistent and massive supply of CO₂-free hydrogen at a cost lower than the 2050 target cost of 20 JPY/Nm³ at the plant gate . The global amount of CO₂ reduction is estimated to be around 3.8 billion tons.¹⁾

[Technology development]

- Realizing “zero-carbon steel” will require long-term research and development, and therefore it is also important to reduce CO₂ emissions and save energy in traditional blast furnaces. COURSE50 and ferro-coke technologies will continue, aiming to become commercially viable at around 2030.
- Super-innovative technologies for realizing “zero-carbon steel” will be considered based on the expertise gained through COURSE50 and development of ferro-coke technologies. To this end, feasibility studies on super-innovative technologies will be carried out to develop technologies and identify issues for adoption on expanding hydrogen reduction in blast furnaces (expanded COURSE50 technologies), hydrogen reduction based on direct reduction process, CCUS, and other technologies. Based on these studies, super-innovative technology to achieve zero-carbon steelmaking will be developed, supported as a national project.

(System for development)

- To correspond to global competition in this field, steel companies in Japan will collaborate to develop technologies.



1) Estimated by NEDO-TSC (including reduction by CCUS).

Independence from fossil fuels (electricity from renewable energy and CO₂-free hydrogen)

17) Higher efficiency of metal resource circulation

[Target]

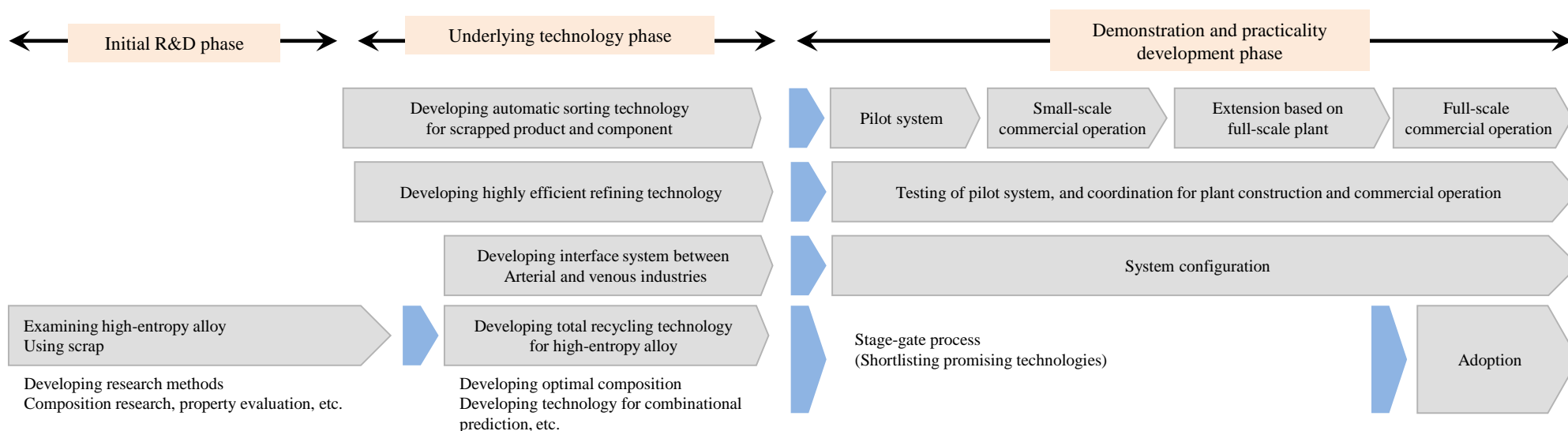
- Metal recycling eliminates the initial refining process from raw materials, and significantly reduce CO₂ emissions. The introduction of automated and autonomous recycling plant, as well as technologies for refining various valuable metals in small quantities, can lower the intermediate processing cost to half and the rare metal refining cost to half to one-thirds, triggering a dramatic growth in metal resource recycling business. High-entropy alloys combining various metals may dispense with the purification steps such as refining and electrolysis required in the traditional recycling process, since the alloys have the potential to be recycled into high-function products with less weight and higher strength compared to traditional products, simply by adjusting metal components in the scraps. As this innovation may ultimately lead to total recycling, the development and adoption of high-entropy alloys will be sought. The global amount of CO₂ reduction is estimated to be 0.12 billion tons.¹⁾

[Technology development]

- Automatic sorting systems based on AI and robotics, highly efficient metal refining methods and other recycling technologies and data interface systems between arterial and venous industries will be developed. Technologies for total recycling including fabrication, using high-entropy alloys in underlying technology phase, will be developed as a national public-private project.

(System for development)

- Technologies will be developed based on collaboration among universities, recycling businesses, alloy producers and final product manufacturers, starting at the underlying technology phase.



1) Estimated by NEDO-TSC.

III. Industry

Independence from fossil fuels (electricity from renewable energy and CO₂-free hydrogen)

18) Advanced plastic resource circulation

[Target]

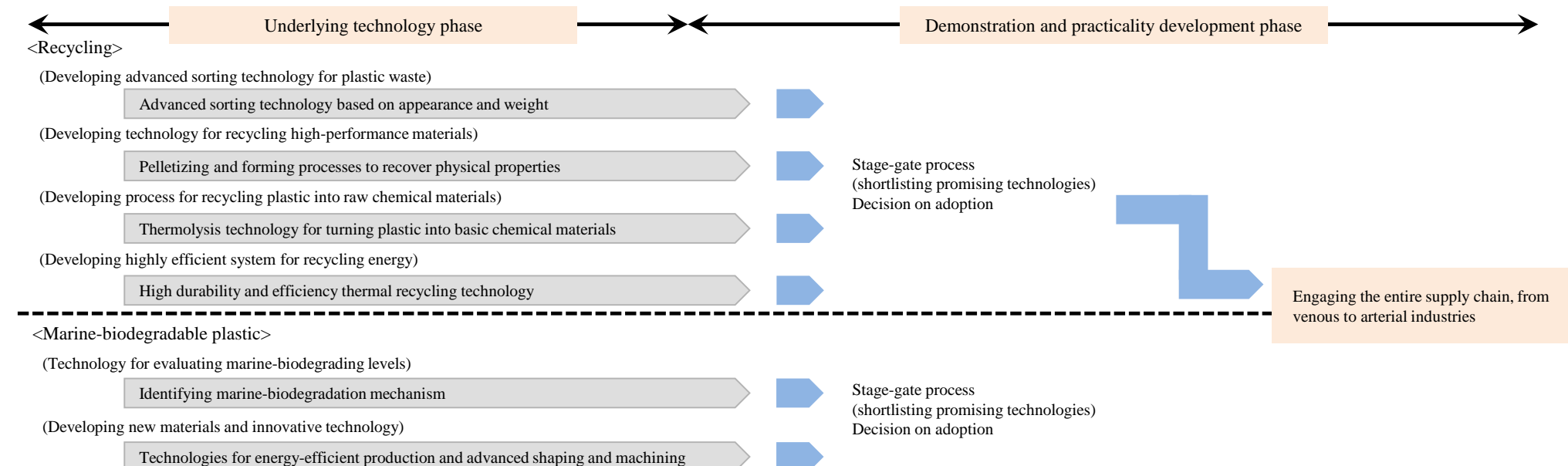
- Technologies on accurate sorting of waste plastic, improving physical properties of recycled materials, turning recycled materials into chemical raw materials through thermolysis and retrieving more energy will be developed. Furthermore, in order to reduce CO₂ emissions, the decomposition mechanism of plant-based and marine-biodegradable plastics will be identified and new materials will be developed alongside advanced plastic-resource recycling. The global amount of CO₂ reduction in 2050 is estimated to be 0.32 billion tons.¹⁾

[Technology development]

- Basic technologies for optimal recycling of retrieved plastic products according to their contamination levels and composite material qualities will be developed. These include technologies from underlying technology phase to practicality development phase, such as accurate sorting, recycling high-performance material, conversion into basic chemicals and highly efficient energy recycling. At the same time, innovative new materials with high potential will be developed through the identification of the decomposition mechanism of marine-biodegradable plastics, and their wide adoption will be facilitated by establishing safety assessment methods and global standards.

(System for development)

- Technologies will be developed by a consortium of plastic resource circulation suppliers such as plastic material and product manufacturers, recycling companies, recycled materials users in agriculture, forestry and fisheries, construction electric machinery and other sectors, universities, and research institutions.



1) Estimated by NEDO-TSC, based on IEA sources, assuming that innovative technologies were sufficiently introduced.

III. Industry

Carbon recycling technologies to transform CO₂ to materials and fuels

19) Producing plastics by artificial photosynthesis technology

[Target]

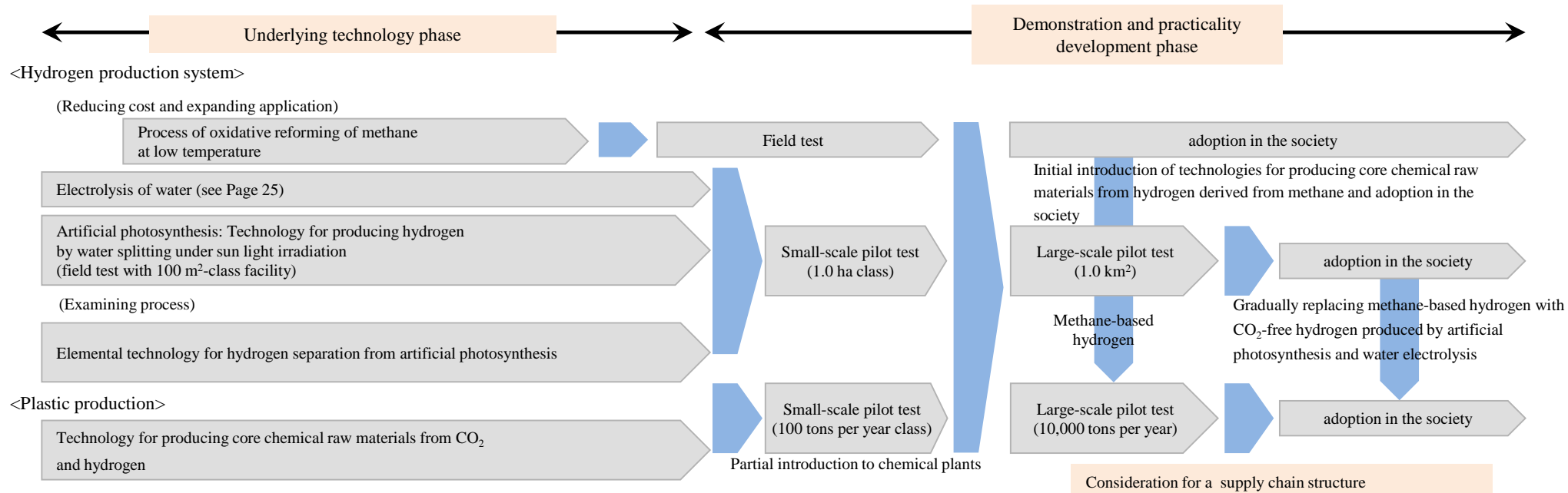
- Efforts will be made to achieve plastics production with artificial photosynthesis at a cost comparable with the core chemical raw materials from fossil fuels, reducing the production cost to less than one tenth, by 2050. The global amount of CO₂ reduction for production of core chemical raw materials is estimated to be 1.5 billion tons.¹⁾

[Technology development]

- Underlying technologies to transform separated and captured CO₂ from the emissions of the industrial processes to core chemical materials, with artificial photosynthesis to produce hydrogen, will be established by 2030. Field tests will be initiated in 2020 using a 100 m² photo catalyst panel for hydrogen production, and a pilot hydrogen production system for methane reforming, aiming at adoption in the society, will be launched from 2021. Artificial photosynthesis and relevant technologies for providing CO₂-free hydrogen are still at underlying technologies phase, and continuous basic research is required. At the same time, a national project under public-private partnership will design materials for more efficient conversion and examine separation and other processes.

(System for development)

- The chemical industry, plant manufacturers, universities and public research institutions will join and establish a system responsive to the supply chain.



1) Estimated by NEDO-TSC, based on IEA "The Future of Petrochemicals".

Carbon recycling technologies to transform CO₂ to materials and fuels

20) Fine chemicals with innovative manufacturing process and carbon recycling

[Target]

- Drastic energy saving and cost reduction will be sought for the production of fine chemicals by innovating the batch method (synthetic process where each reaction is handled separately with relevant materials and heating and cooling as necessary), the current mainstream production technology for fine chemicals, and establishing a continuous precise control technology based on the flow method (synthetic process where raw materials are continuously supplied for a series of consecutive reactions to take place) by 2025.
- A process to utilize carbon recycling technologies for producing fine chemicals based on CO₂ will be established by 2030 and efforts will be made to achieve a cost level equivalent to that of existing technologies. The global amount of CO₂ reduction in 2050 is estimated to be up to 0.1 billion tons.¹⁾
- Bio-production technologies for fine chemicals using CO₂ and carbon-neutral sources of carbon will be developed. The global amount of CO₂ reduction from bio-production and bio-based products is estimated to be about 2.5 billion tons.²⁾

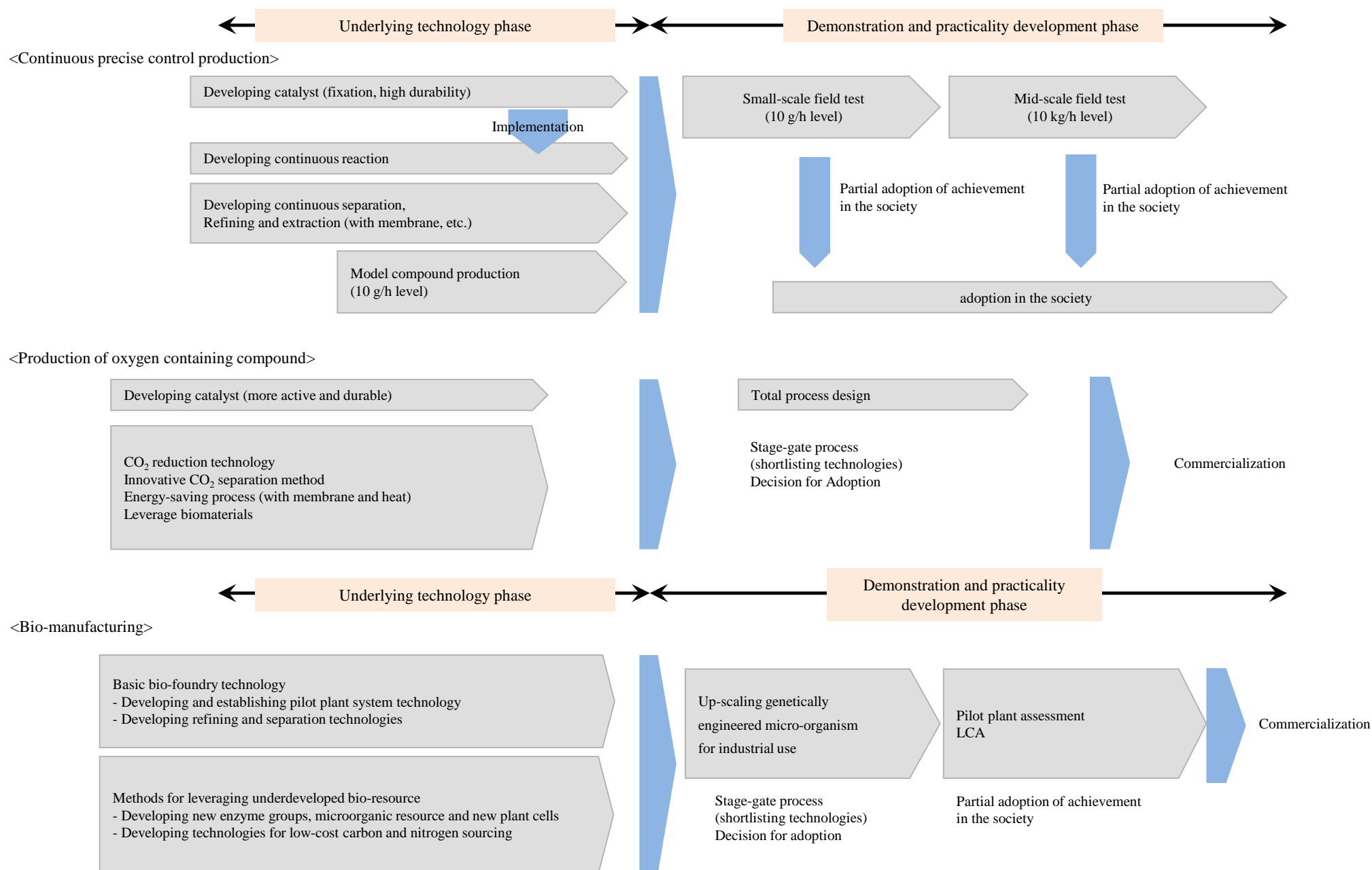
[Technology development]

- Technologies required for continuous precise control technology, including new catalyst free of by-products and underlying technologies, such as energy-saving membrane separation and solvent recycling, will be developed, and technologies for a process with less energy and waste will be established.
- A reaction process that separates, captures and utilizes CO₂ emitted from factories for producing polyester, polyurethane and other oxygen-containing chemical compounds will be established, and catalysts will be developed. A scalable energy-saving process will be developed and field tests will be taken.
- Technologies for finding enzymes and microorganisms that utilize CO₂ and carbon-neutral carbon sources to produce bioplastics, fine chemicals and edible substances will be developed. Bio-foundries will also be established for resolving the scalability issue in the production process.

(System for development)

- The development of catalysts for continuous and precise production technology will continue as a national project with universities, research institutions and chemical production companies in collaboration.
- On carbon recycling technologies, the feasibility of CO₂ separation and capture technologies, currently at underlying technology phase, will be examined according to intended fine chemicals. Designing of scalable entire process will be conducted as a large-scale field test, mainly by chemical manufacturers collaborating with universities and other research institutions, mindful of international applicability.
- On bio-process production technologies, a new national project with universities, research institutions, chemical manufacturers, food companies and plant manufacturers in collaboration, will be launched and implemented, based on the bio-strategy of the Government.

1) Estimated by NEDO-TSC, based on CARBON DIOXIDE UTILIZATION (CO₂U) ICEF ROADMAP 1.0 (ICEF, 2016). 2) Quote from Industrial Biotechnology and Climate Change (OECD), page 7.



Carbon recycling technologies to transform CO₂ to materials and fuels

21) Low-cost methanation

[Target]

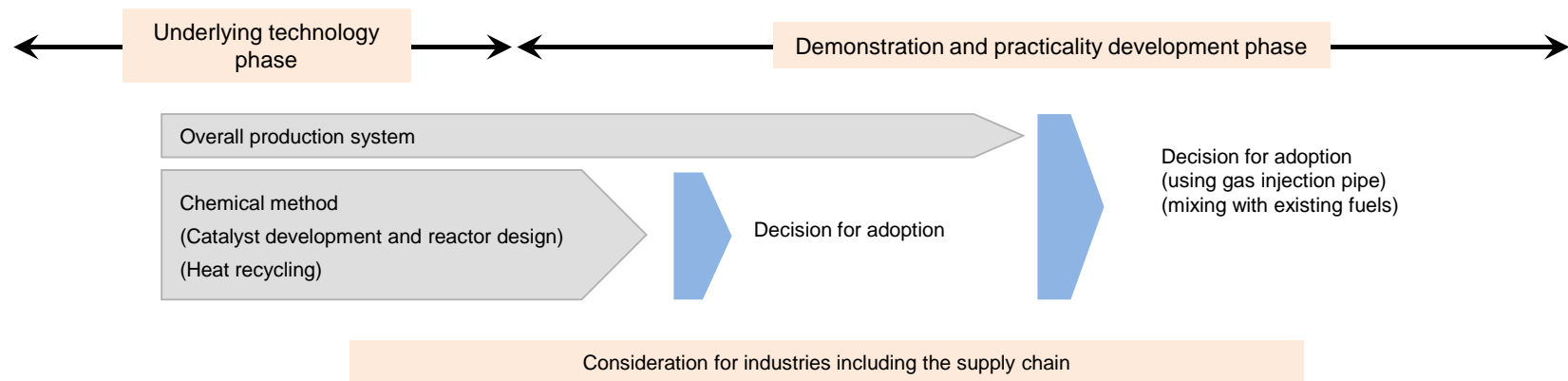
- Efforts will be made to achieve a cost comparable to the existing methane by 2050 (40-50 JPY/Nm³: imported natural gas price). The global amount of CO₂ reduction is estimated to be 1.1 billion tons.¹⁾

[Technology development]

- In order to establish technologies for producing methane fuels at a low cost using renewable energy-based hydrogen and CO₂ retrieved from thermal power plant emissions, a five-year national project for developing durable and innovative catalysts and optimizing the entire production system will be implemented at a test plant in the 1:150 scale of a commercial operation.
- On methane using CO₂ emissions from waste incinerators, a commercial scale (125 Nm³/h) field test will be conducted at the garbage incinerator, and efforts will be made for the full adoption in the society after 2030.

(System for development)

- Mindful of future business operations, in order to develop the catalyst usable in the actual process and achieve the reduction of cost in the overall production process, a system considering the supply chain wherein universities, catalyst manufacturers, plant manufacturers, system operators and gas suppliers whose gas pipelines would be used collaborate, will be built.



¹⁾ Estimated by NEDO-TSC, based on CARBON DIOXIDE UTILIZATION (CO₂U) ICEF ROADMAP 1.0 and assuming that innovative technologies were sufficiently introduced.

Carbon recycling technologies to transform CO₂ to materials and fuels

22) Cement made from CO₂ and concrete absorbing CO₂

[Target]

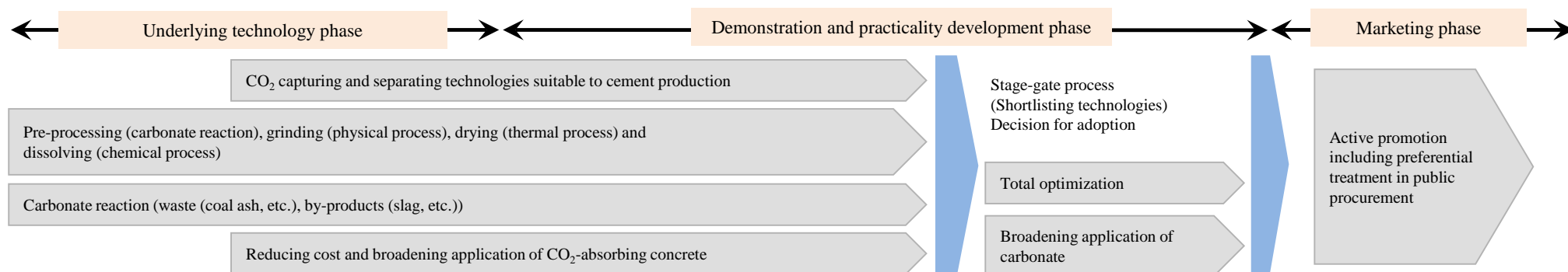
- Efforts will be made to establish a cement production process to recycle CO₂ by capturing the emission during manufacturing process to be fixed as carbonate and subsequently used as raw materials and construction materials, aiming for less cost and better quality compared to the existing cement in 2030 onwards. Similarly, efforts will be made to establish a new production process for wider usage of concrete that absorbs CO₂ during solidification, aiming for the same or less cost and the same or better quality compared to the existing concrete. Once these technologies have been established, the Government will consider promoting their usage, including preferential treatment on public procurement. The global amount of CO₂ reduction by 2050 is estimated to be 4.3 billion tons.¹⁾
- CO₂ reduction in the field of paper and pulp will also be sought, including by energy saving in the recycling and production of paper resource and fuel conversion to biomass fuels.

[Technology development]

- On cement production process, technologies in underlying technology phase as well as demonstration and practicality development phase will be developed for adoption in the society in around 2030. These include: technology to capture CO₂ emitted during manufacturing process to be fixed as carbonate with waste and fresh concrete and subsequently used as materials to substitute limestone, and; technology to fix CO₂ as carbonate to be recycled as construction materials, such as roadbed materials. In 2020, a pilot project aiming for a CO₂ reduction of 10 tons per day, 500 times larger than the current capacity, will be launched.
- Underlying technologies will be developed, and field tests and technical feasibility study for wide usage will be conducted, on the application of special admixture that reacts with CO₂ and solidifies to become CO₂-absorbing concrete to reinforced concrete products and large concrete structures.

(System for development)

- Mindful of future business development, technologies will be developed as a national project with cement manufactures playing a key role in the collaboration with universities and research institutions that possess the technology to capture CO₂.
- A national project will also be implemented on CO₂-absorbing concrete, mindful of future business development and with major construction companies playing a key role.



¹⁾ Estimated by NEDO-TSC.

IV. Business, household and other cross-sectoral fields

Implementation of advanced GHG reduction technologies

23) Cross-sectoral energy efficiency

[Target]

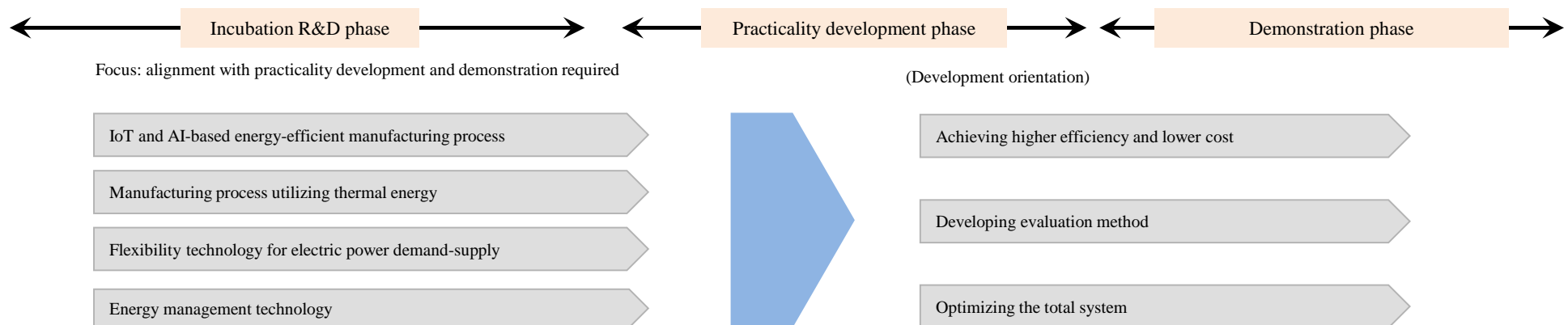
- The development of innovative technologies to achieve cross-sectoral and significant energy-efficiency will be facilitated, aiming at a reduction of CO₂ emissions by 0.026 billion tons¹⁾ in Japan in 2030. Wider usage of these technologies and development of new seed technologies will be continuously supported for the adoption of further energy-efficient technologies in the society toward 2050. The global amount of CO₂ reduction is estimated to be 3.3 billion tons.²⁾

[Technology development]

- The development of innovative energy-efficient technologies, such as 10 key technologies³⁾ in Energy Efficiency Technology Strategy 2016⁴⁾, including energy-efficient manufacturing process with IoT, and AI and manufacturing process with effective utilization of thermal energy, will be facilitated with a view of commercialization.
- Specifically, a wide range of promising topics will be gathered from the public and support will be provided for technologies in implementation and demonstration phase to develop toward commercial application. The development of innovative technologies to be pursued with collaborating and cooperating manufacturers to resolve sector-wide and cross-sectoral issues as well as a unified assessment method for the technologies will also be supported.

(System for development)

- In addition to individual and collective efforts of companies, a system for collaboration with public research institutions and universities will be established.



1) The target figure for the project for promoting the development of innovative energy-efficient technologies. 2) Estimated by METI, based on a global energy consumption forecast for 2050. 3) Revised in 2019: i. Highly efficient power supply; ii. Effective utilization of renewable energy; iii. Highly efficient heat supply; iv. Effective utilization of thermal energy; v. Energy-efficient manufacturing process; vi. net zero energy buildings (ZEB), net zero energy house (ZEH), and Life-cycle carbon-minus (LCCM) Houses; vii. Energy-saving information equipment and system; viii. Next-generation vehicle; ix. ITS/Smart logistics, and; x. Cross-sectoral application, with focus on technologies closer to introduction. 4) The Agency for Natural Resources and Energy and NEDO.

Implementation of advanced GHG reduction technologies

24) Low-cost stationary fuel cell systems

[Target]

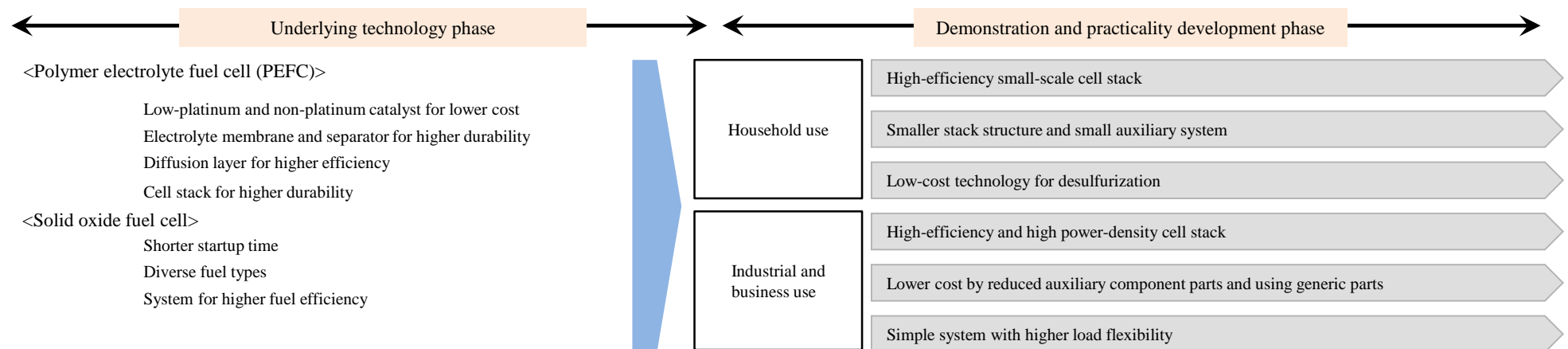
- Household fuel cells market will be sustainable by around 2020. Further improvement for the fuel cell users will be sought, and the current investment payback period of 10 years will be reduced to 5 years. Efforts will be made to establish a new energy system based on fuel cells to be sustainable and widely used by around 2050.
- Catalyst and auxiliary equipment for fuel cells for industrial and business use, aiming for the cost of 500,000 JPY per 1.0 kW for low-voltage appliance and 300,000 JPY for high-voltage appliance by 2025, thereby realizing a grid-parity¹⁾ including heat recycling.
- Efforts will be made for the next-generation fuel cells for industrial and business use to aim for a power generation efficiency better than that of the latest gas-turbine combined cycle system, at 64 percent²⁾.
- The global amount of CO₂ reduction with stationary FC, hydrogen generation, transportation and storage, as well as usage, including FCEV, and power generation is estimated to be around 6.0 billion tons.³⁾

[Technology development]

- The development of underlying technologies for drastic improvement will be conducted as a national project. At the same time, in order to shorten the investment payback period, the efficiency of cell stacks will be improved to enable downsizing of household fuel cells, and stack structure and auxiliary component design will be revised. On fuel cells for business and industrial use, efforts to reduce cost, such as developing technologies to improve efficiency and output density of fuel stacks, reducing parts of auxiliary component and substituting parts with generic ones, will be made.

(System for development)

- Underlying technologies will be developed through collaboration among universities, public research institutions and companies. Demonstration and practicality development will be led by the private sector, with equipment companies and gas utilities working together.



1) Grid parity: point where the cost becomes the same as existing power price. 2) Sending-end lower heating value (LHV) efficiency. 3) This estimate is a reiteration of that in page 25.

Implementation of advanced GHG reduction technologies

25) Increased use of unutilized and renewable thermal energy

[Target]

<Unutilized thermal energy> Technologies will be developed to reduce, reuse and recycle unutilized thermal energy that amounts to almost 60 percent of primary energy. Efforts will be made to enable sustainable adoption and wide usage of unutilized thermal energy, with lower initial cost for the equipment.

<Renewable thermal energy> Efforts will be made to make renewable thermal energy more affordable than existing technologies of air conditioning and hot water supply by 2030.

The global amount of CO₂ reduction in 2050 is estimated to be around 4.2 billion tons.¹⁾

[Technology development]

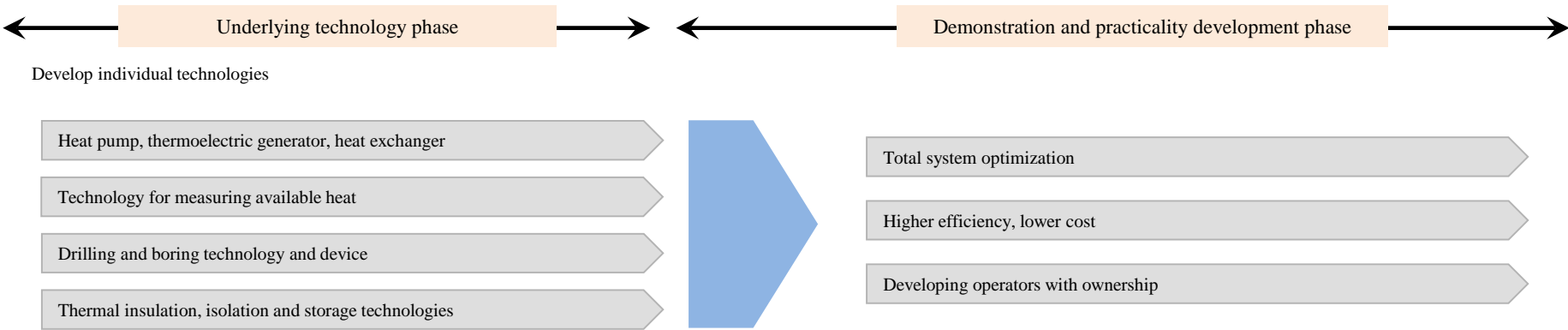
<Unutilized thermal energy> Technologies will be developed to reduce, reuse and recycle unutilized thermal energy wasted in the factory, such as those generated in the heating process.

<Renewable thermal energy> Technologies will be developed to reduce the cost of geothermal energy, solar heat, cryo-energy and other renewable thermal energy sources.

(System for development)

<Unutilized thermal energy> Development will be conducted through collaboration among research institutions, universities and companies. International framework, such as RD20, will also be utilized.

<Renewable thermal energy> In order to facilitate sustainable and wider use of renewable thermal energy, a consortium of companies involved in the thermal system will be established, and technologies for reducing installation cost and operation cost will be developed in collaboration with universities and research institutions.



1) Estimated by NEDO-TSC, assuming that innovative technologies for leveraging heat are introduced at a certain level.

IV. Business, household and other cross-sectoral fields

Implementation of advanced GHG reduction technologies

26) Low global warming potential (GWP) and non-fluorocarbon refrigerants

[Target]

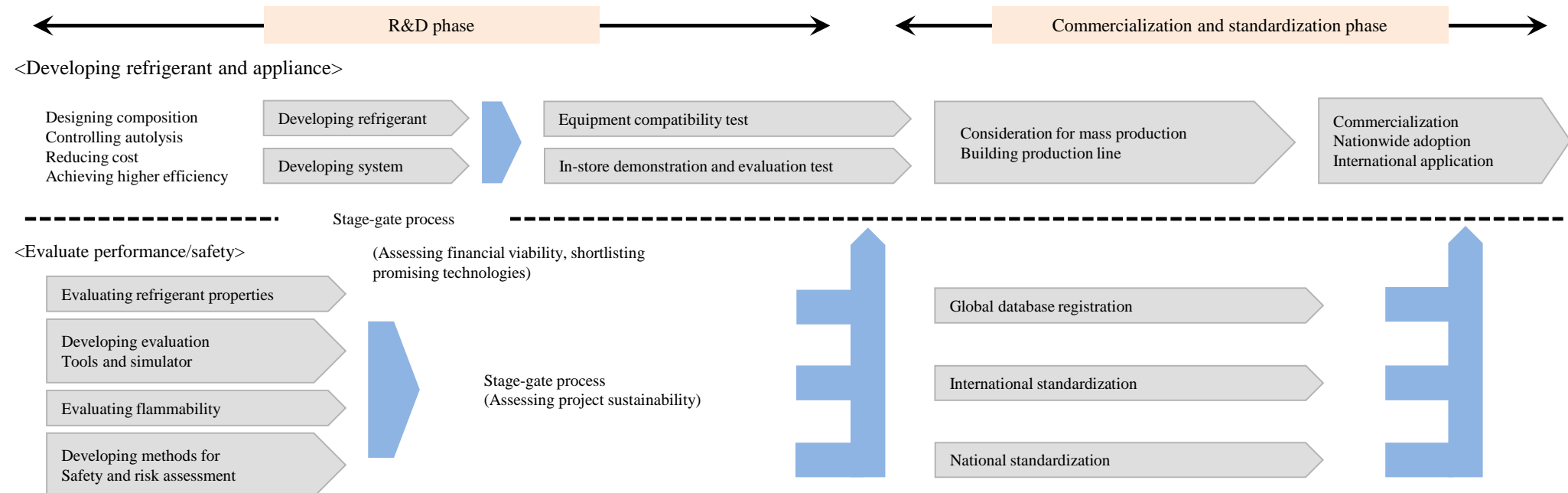
- Low-GWP and non-fluorocarbon refrigerant as well as relevant appliances will be developed and their costs will be reduced to the level comparable to the existing products, in order to reduce the usage of hydrofluorocarbon (HFC), a GHG and the substance regulated under the Kigali Amendment to the Montreal Protocol. The global amount of GHG reduction (CO₂ equivalent) by 2050 is estimated to be 2.7 billion tons.¹⁾

[Technology development]

- In order to facilitate transition to low-GWP and non-fluorocarbon refrigerant, the refrigerant will be developed; air conditioning appliances with sustained energy efficiency developed; research and development on establishment of safety and risk assessment method conducted, and; assessment established to lead the world.

(System for development)

- Taking into account overseas production and regulation, the development of refrigerant and appliance will be developed, led by air-conditioning manufacturers and refrigerant manufacturers. A industry-academia-government collaboration will be established for developing safety and risk assessment method on refrigerant and appliance. Their efforts will be incorporated in the standards in Japan and abroad, and their wider use will be supported, including through the framework of the Act on Rational Use and Proper Management of Fluorocarbons.



1) Estimated by NEDO-TSC

Transformative urban management using big data, AI, decentralized management technology (smart community)

27) Accelerating the application of relevant technologies in the society (Smart City)

[Target]

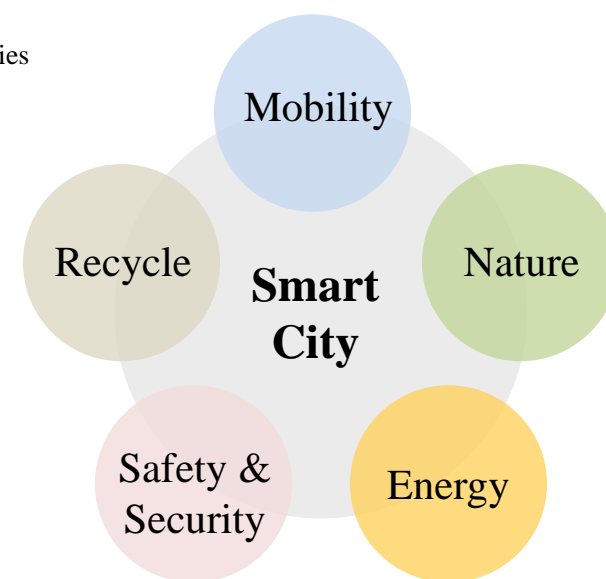
- A common architecture which ensures data connectivity between cities and sectors and system extendibility will be established, and the development of IT systems in each region (“City OS”) will be developed.
- Each region will make use of the latest IoT and AI technologies to each area to improve urban management as well as energy efficiency and to optimize mobility.

[Technology development]

- A shared Smart City Architecture, on which area-specific IT system (City OS) will be developed, will be established and maintained, contributing to regional level functionality, data and interface.
- Power consumption peaks will be lowered by optimally balancing distributed power sources such as PV cells and batteries with the grid system of the electricity utilities, and also by sharing power between city districts.
- Aerial data of the energy supply and demand of facilities, weather and human traffic information will be utilized for improved prediction for power-sharing needs.
- Efforts will be made to achieve transition from individually-driven mobility to public transportation, bicycles and walking with the introduction of MaaS and smart planning method based on real-time demand of mobility.
- The use of various tools supporting urban management, such as AI search technologies operating across various databases, technologies for managing information flow, AI technologies for supporting decision-making and documentation and city management console based on real-time mapping, will be facilitated.
- By taking lead in setting a global standard for “smart urban infrastructure” for Smart Cities, an environment conducive to the advantages of Japanese urban infrastructure will be developed, to prepare for contribution to and involvement in urban development throughout the world.

(System for development)

- The Smart City public-private collaboration platform, jointly administered by the Cabinet Office, the Ministry of Internal Affairs and Communications, METI and MLIT will identify technical and systemic challenges towards implementing Smart City and provide support for addressing these challenges.
- Space for bicycle traffic will be secured and the use of cycle trains and share-cycles will be promoted based on the Act for Promoting the Use of Bicycles. Furthermore, prefectures and municipalities are encouraged to formulate local plans for promoting bicycle usage and support will be provided for their implementation.



Energy saving by sharing economy and telework, work style reform and behavior change

28) Promoting sharing economy, telework, work style reform and behavior modification

[Target]

- Awareness will be raised and actions will be taken at the levels of individuals, families and communities, based on the concept or “sustainable coexistence”. Efforts will be made toward achieving feasible, carbon-neutral, resilient and comfortable neighborhood and way of life in communities and companies by 2050. The global amount of GHG reduction by 2050 is estimated to be 4.9 billion tons.¹⁾
- (1) Achieving both “creation of decarbonized market” and “quality-oriented economy” for sustainable growth
- (2) “Regional revitalization” with renewable energy business based on natural resources and compact cities
- (3) National vision of significant contribution to climate change security and improved energy security
- As the change in the lifestyle, a shift from owning to sharing things, takes place, it is expected that less obligatory human movement, such as commuting and business trips, will be observed with IoT developing and remote work increasing, and that paper-less working environment will lead to work-style reforms and saving energy. Car-sharing and shared rides may drastically reduce CO₂ by improving car utilization and calculating the best routes. Eco-friendly behavior change at the levels of individuals, companies and communities will be appreciated, and economically rational transactions on environmental values of renewable energy will increase.



[Technology development]

- Efforts will be made to improve the convenience of sharing and network environment with IT. Nudging and other insights from behavioral science, as well as block-chain technology, will be applied to the field of environment to lower the cost and improve the efficiency of eco-friendly behavior and transactions on environmental values of renewable energy and to increase the participation in the market.

(System for development)

- An industry-academia-government collaboration will establish a social system to appreciate values of sustainable co-existence, such as future CO₂ reduction and resilience, applicable from underlying technologies phase. This will accelerate technological development and their wide-ranging applications. Cross-sectoral collaboration will be sought with sector-coupling.

¹⁾ Estimated by NEDO-TSC, based on the expected effect of innovative Japanese technologies applied globally.

Developing scientific knowledge for the verification of GHG reduction effects

29) Elucidating the climate change mechanism, improving the climate change projection, advancing research including observation, reinforcement of information infrastructure

[Target]

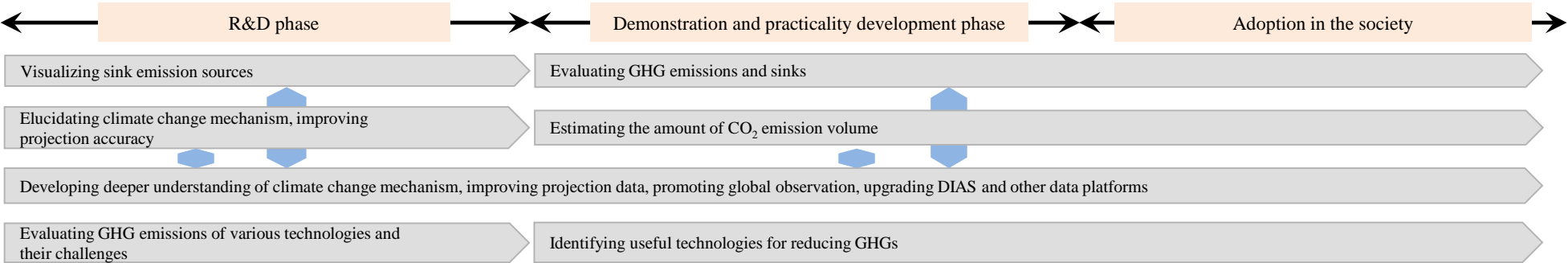
- The scientific insights for evaluating GHG reduction effects and identifying effective technologies in Japan and abroad will be enhanced by: elucidating the climate change mechanism; improving the climate change projection; advancing research including observation; reinforcing information infrastructure, and; estimating the GHG emissions from different technologies as well as identifying their challenges. These will contribute to the evaluation of GHG reduction effect in Japan and the identification of effective technologies, by accurately estimating the CO₂ emission reduction, which is the basis of actions for addressing global warming such as cost estimates, and accurately evaluating GHG emissions for global stock-taking. Furthermore, observation and projection data will contribute to managing renewable energy and climate change risks.

[Technology development]

- (1) More accurate estimate of CO₂ emissions will be sought by improving modelling and simulation technologies, elucidating the climate change mechanism and reducing uncertainties. At the same time, higher accuracy for climate change projection will be expedited by improving temporal and spatial resolutions, based on actual needs.
- (2) The observation network of satellites, aircrafts, vessels and stations will be established and strengthened in collaboration with international frameworks, and the technology to visualize data in quasi-real-time and integrate them with advanced analytic system will be developed for global stocktaking and other uses. The impact of decarbonization efforts, as well as the amount of emission and sink, will be amassed worldwide to evaluate the potential of negative emission.
- (3) Using the international frameworks such as the Group on Earth Observations (GEO), observation and monitoring will be conducted continuously to contribute to assessing the amount of GHG emission and sink and managing renewable energy. GHG observation data and projection will be further utilized by the Data Integration and Analysis System (DIAS).
- (4) Technologies useful for GHG reduction will be identified with the estimates of GHG emissions and their challenges, and a roadmap to a decarbonized society will be proposed.

(System for development)

- Universities and research institutions in Japan and abroad will collaborate to conduct research and reinforce infrastructure, making the most of international frameworks and information platforms.



V. Agriculture, forestry, fisheries and carbon sinks

CO₂ absorption and fixation in the ocean, farmland, forest with advanced biotechnology

30) Genome editing technology and other applied biotechnology

[Target]

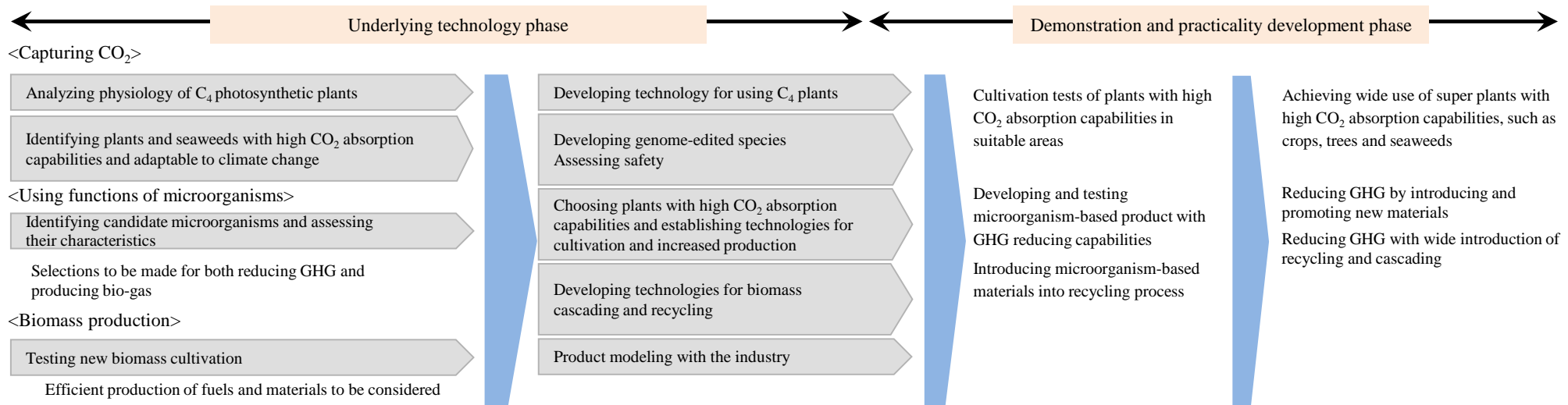
- Efforts will be made to realize a consistent production of plants and seaweeds with enhanced CO₂ absorption capability (super plants) as well as microorganisms and plants with enhanced energy production and reduced GHG by 2050. Technologies will be developed for creating species adaptable to climate change and introducing them at commercially viable cost levels. The global amount of CO₂ reduction is estimated to be 4.0 billion tons.¹⁾

[Technology development]

- Technologies will be developed for using C₄ photosynthesis plants adapted to dry lands or infertile soils, and will be made available globally.
- Technologies will be developed to facilitate the use of plants and seaweeds with high CO₂ and N₂ fixation capabilities, microorganism that reduce methane from soil and plants resilient to climate change.
- Relevant technologies to assess and ensure safety will be also developed, such as that contains genetically engineered plants and microorganisms.

(System for development)

- National institutions, universities and companies will establish a joint development system, involving companies from the underlying technology phase, engaging startups at the demonstration phase and aiming for large-scale fields tests and commercial adoption abroad.



1) Estimated by the Ministry of Agriculture, Forestry and Fisheries (MAFF), assuming that dry areas with poor farming qualities are made available for cultivation.

V. Agriculture, forestry, fisheries and carbon sinks

CO₂ absorption and fixation in the ocean, farmland, forest with advanced biotechnology

31) Raw material changes using biomass

[Target]

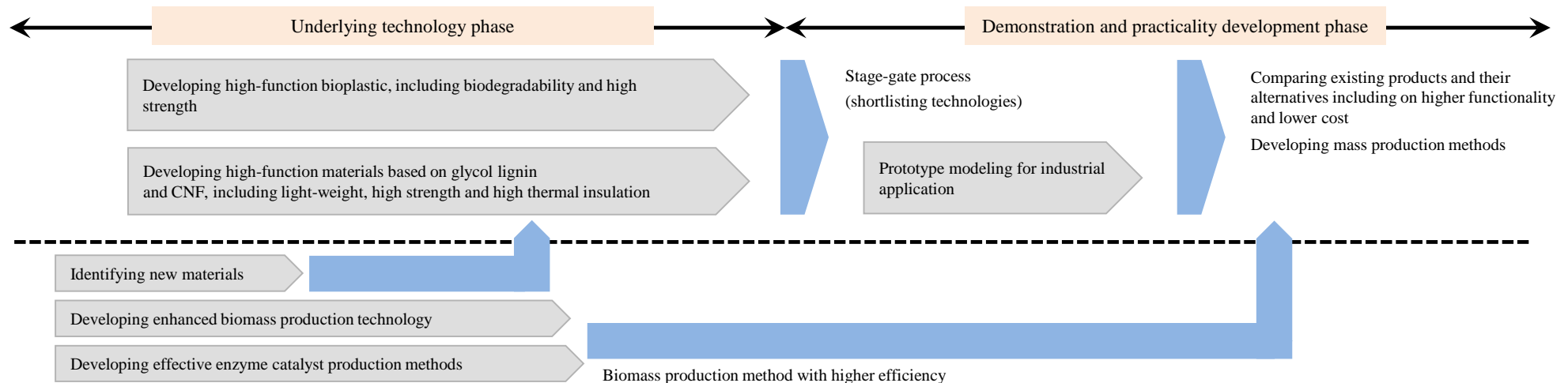
- Technologies will be developed to utilize biomass resources such as micro algae and plants absorbing CO₂ by photosynthesis, garbage and sewage to produce products using plastics, cellulose nanofiber (CNF) and other high-function materials. Efforts will be made to adopt these technologies in the society at a commercially viable cost. The global amount of CO₂ reduction is estimated to be 0.67 billion tons.¹⁾

[Technology development]

- Innovative and disruptive seeds of technologies on various approaches to the materials at the underlying technologies phase will be developed for high-function biomass products based on non-edible biomass resource (in approximately 5 years).
- Technologies for enhanced and efficient production and breeding enzymes and catalysts will also be developed as an indispensable component for mass production of the material.
- Technologies will be developed for low-cost and mass production of glycol lignin and CNF.

(System for development)

- At the underlying technology phase, universities, research institutes and companies in Japan and abroad will collaborate to pursue higher performance; the involvement of companies will increase according to the phase and joint research with material and component manufacturers and end-product manufacturers. The implication for the supply chain and the industry on future business development will be considered throughout, from the underlying technology phase.



¹⁾ Estimated by NEDO-TSC, based on the Ellen Macarthur Foundation sources.

V. Agriculture, forestry, fisheries and carbon sinks

CO₂ absorption and fixation in the ocean, farmland, forest with advanced biotechnology

32) Carbon sequestration in farmland using biochar

[Target]

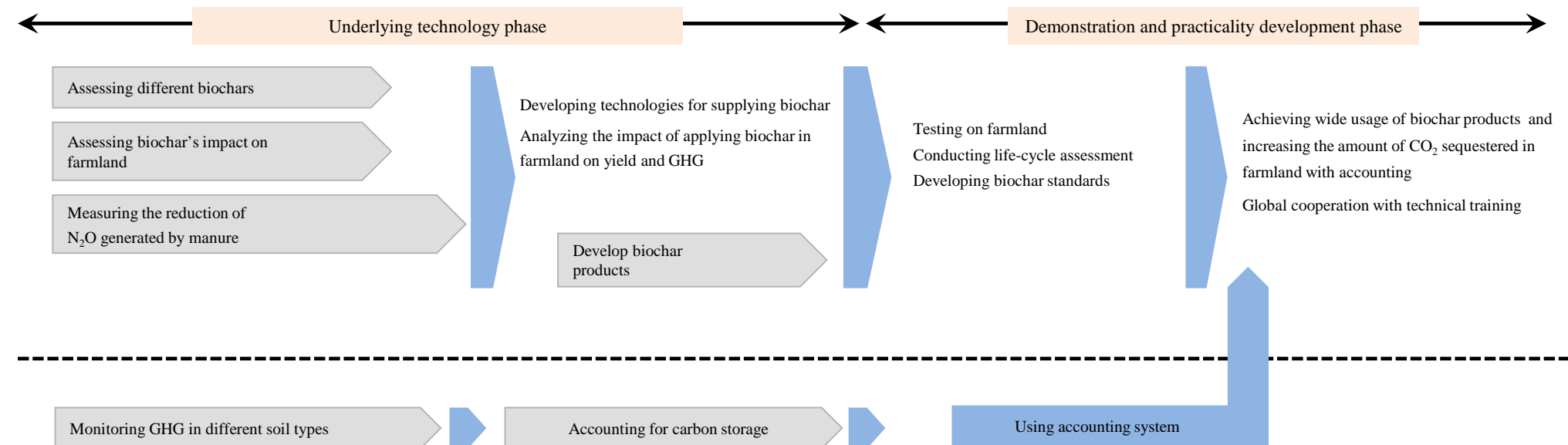
- Technologies for sequestering organic carbon from atmospheric CO₂ and applying it in farmland soil using biochar will be developed by 2050, together with a method for calculating the amount of fixed carbon. Efforts will be made to avail such technologies at commercially viable costs. The global amount of CO₂ sequestration is estimated to be 2.2 billion tons.¹⁾

[Technology development]

- Research and development will be conducted for calculating the amount of biochar as a new sink and assessing its impact, in order to turn farmland into CO₂ sink.
- A system to account for carbon sequestered in farmland will be developed.
- As technologies are developed, the total cost of the system, including the introduction of biochar into the scope, will be reduced, based on farmland field test results.

(System for development)

- A collaborative structure of various research institutions, universities, and companies will be established, led by public research institutions.



¹⁾ Estimated by the MAFF, assuming that all the world's agricultural waste are turned to biochar and used on farmland.

CO₂ absorption and fixation in the ocean, farmland, forest with advanced biotechnology

33) Wooden high-rise buildings and wood-based biomass materials

[Target]

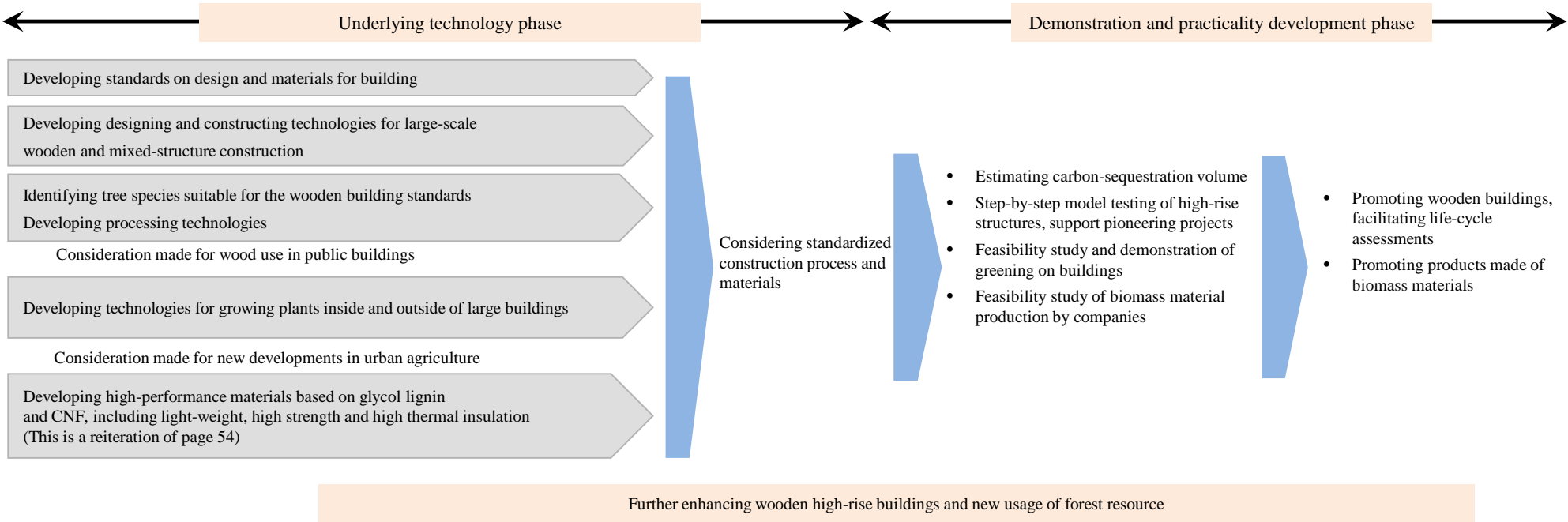
- Designing and constructing technologies for buildings using wood and biomass materials replacing high energy-consuming material and low-cost production technologies for biomass materials will be developed to establish a “carbon-recycling society” that makes full use of biomass resource by 2050. The global amount of CO₂ absorption is estimated to be 0.35 billion tons.¹⁾

[Technology development]

- Wooden high-rise and other buildings will be made available with development in wooden construction materials to increase wood usage in urban areas and designing and constructing technologies for large-scale wooden and mixed structure.
- A cascading system, in which biomass resources are repeatedly used in multiple stages, will be developed with material conversion and cost saving technologies, such as glycol lignin and CNF.

(System for development)

- A collaborative structure for various research institutions, universities and companies, led by public research institutions, will be established.



1) Estimated by the METI, based on Japan’s share of GDP against the entire world.

CO₂ absorption and fixation in the ocean, farmland, forest with advanced biotechnology

34) Smart forestry and fast-growing trees

[Target]

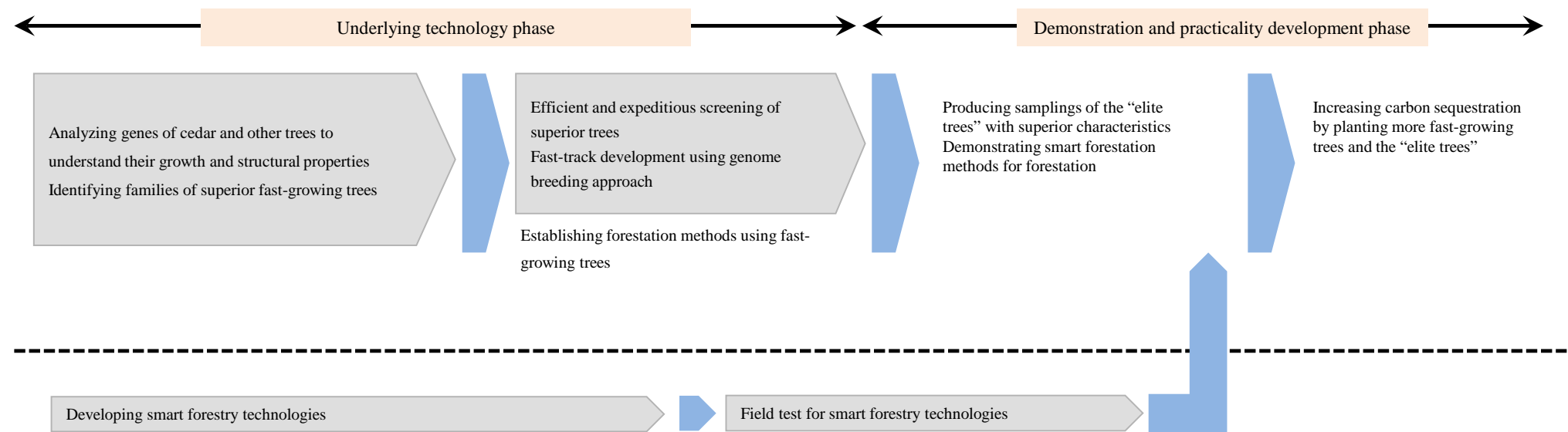
- Technologies for wide adoption of fast-growing tree species to sequester carbon from atmospheric CO₂ into forests will be developed at a cost level comparable to existing technology by 2050. The global amount of CO₂ absorption is estimated to be 3.8 billion tons.¹⁾

[Technology development]

- The species of fast-growing trees and the “elite trees” (superior plus trees) will be developed, by efficiently and expeditiously identifying suitable trees for improved breeding method, and field tests will be carried out to develop forestation method using these trees.

(System for development)

- A collaborative system of various research institutions, universities and companies will be established, led by public research institutions.



1) The Emissions Gap Report 2015 by the United Nations Environment Programme (UNEP).

V. Agriculture, forestry, fisheries and carbon sinks

CO₂ absorption and fixation in the ocean, farmland, forest with advanced biotechnology

35) Blue carbon (carbon sequestration in the marine ecosystems)

[Target]

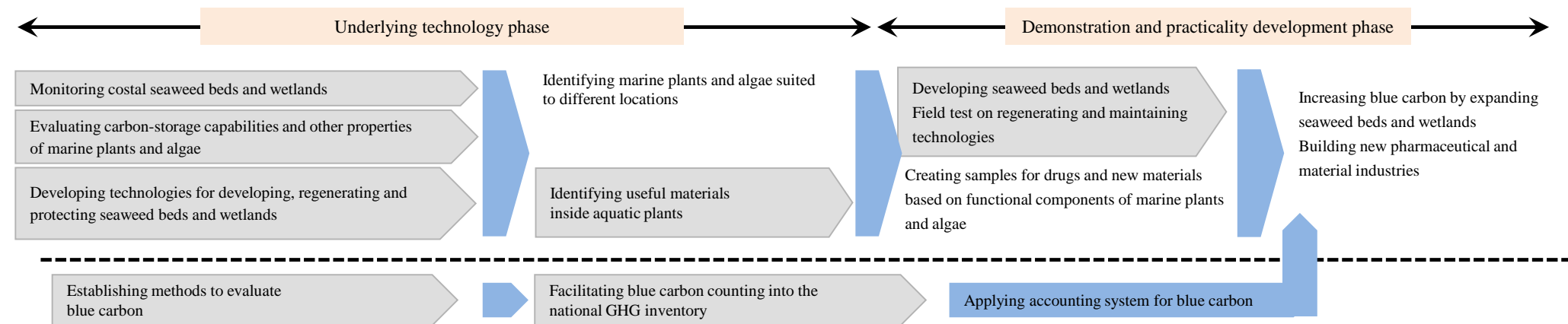
- Technologies for sequestering carbon from atmospheric CO₂ in oceans, including seaweed beds and wetlands, in the form of organic substance (blue carbon) will be established by 2050, at a cost level comparable to the existing technology. The global amount of CO₂ absorption is estimated to be more than 0.9 billion tons.¹⁾

[Technology development]

- Marine plants and algae that efficiently capture CO₂ in sea water will be identified and advanced farming technology will be developed, utilizing biotechnology.
- A national project led by the private sector will be conducted to develop technologies for using marine plants and algae as new materials.
- Methods to estimate the amount of CO₂ captured in seaweed beds and wetlands will be developed.
- Technologies for developing, regenerating and maintaining seaweed beds and wetlands will be developed and tested.

(System for development)

- A collaborative system of universities, manufactures and other companies will be established for advanced farming technologies and new materials, involving startups and in view of large-scale field tests and business development in Japan and abroad.
- The development of seaweed beds and wetlands will be conducted by local authorities and private companies, in collaboration with NPOs and fishery cooperatives.
- Academic experts and government authorities will consider methods for estimating the amount of CO₂ captured.
- Technologies for developing, regenerating and maintaining seaweed beds and wetlands will be developed and tested by private companies.



¹⁾ Estimated by the METI, based on *Blue Carbon* (published by Chijin Shokan).

V. Agriculture, forestry, fisheries and carbon sinks

Reduction of methane and N₂O from agriculture and livestock industry

36) Breeding and optimal management for farmland and livestock

[Target]

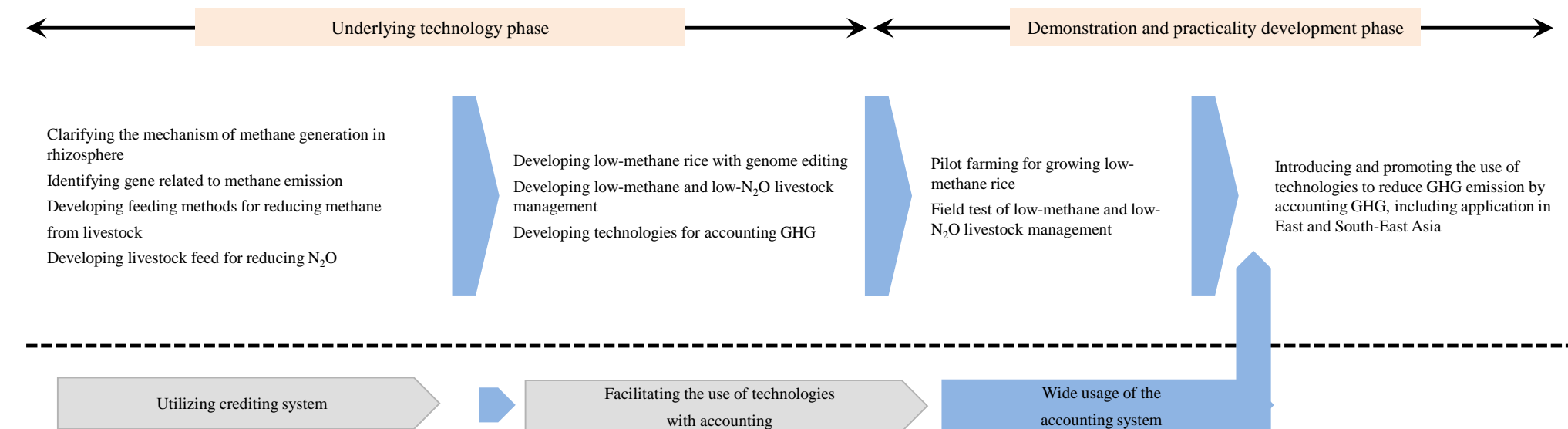
- Materials and management technologies for reducing methane and N₂O emissions from farmland and livestock at a cost level comparable to the existing production method will be developed by 2050. The global amount of GHG reduction (CO₂-equivalent) is estimated to be 1.7 billion tons.¹⁾

[Technology development]

- Rice species and livestock breeds with less methane will be developed, together with materials that reduce N₂O emissions from farmland soil and livestock waste.
- Management technologies for farmland and livestock to reduce methane and N₂O emissions will be developed.
- A system for accounting methane and N₂O reduction will be developed.

(System for development)

- A collaborative system of research institutions in Japan and abroad, local authorities and companies including livestock feed manufacturers will be established, in view of the world-wide contribution and business opportunities abroad.



¹⁾ Estimated by the Ministry of Agriculture, Forestry and Fisheries (MAFF), based on the IPCC AR5 Working Group 3 Report and assuming that the global methane and N₂O emissions from agriculture are reduced pro rata.

Smart agriculture, forestry and fisheries

37) Building the energy system based on local production for local consumption to suit rural areas

[Target]

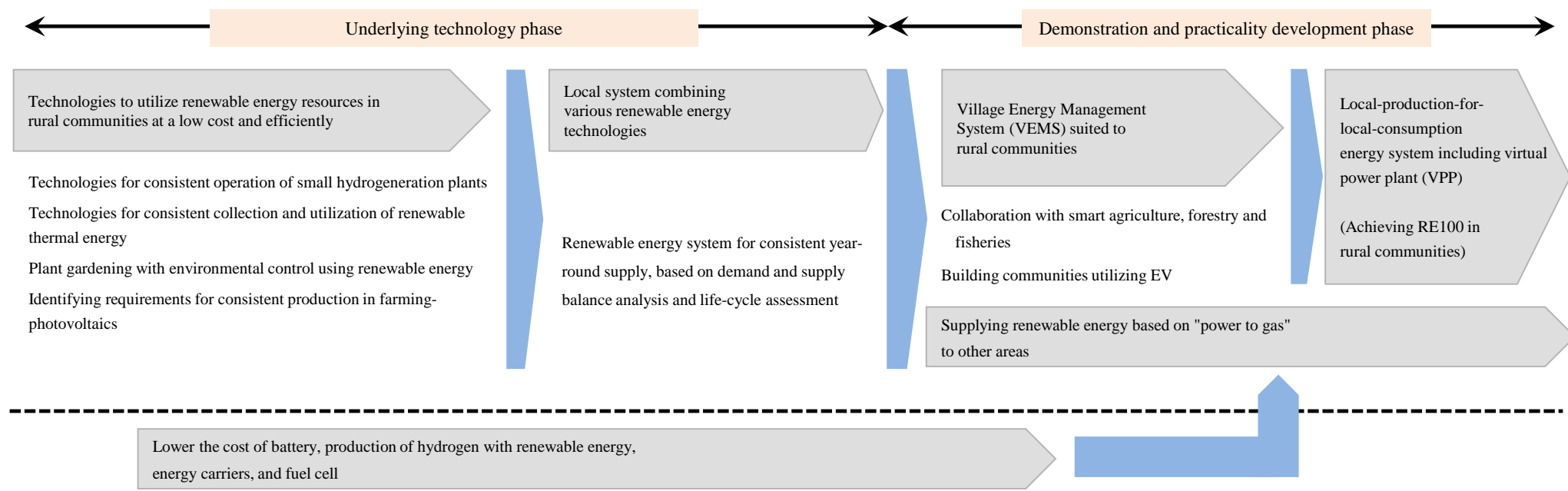
- An energy system based on local production for local consumption with competitive renewable energy generation and stable supply to agriculture, forestry and fisheries, fully utilizing rich resources in rural communities, will be made available (achieving RE100 in rural communities) by 2050. Efforts to supply energy beyond the communities will also be sought. The global amount of CO₂ reduction is estimated to be 1.0 billion tons.¹⁾

[Technology development]

- A collaboration of industry-academia-government will be formed to develop technologies for low-cost and efficient utilization of renewable energy resources in rural communities, establishing a sustainable local-production-for-local-consumption energy system suited to rural communities by combining various renewable sources and a system to efficiently and stably supply renewable energy beyond the communities.

(System for development)

- A collaborative system of research institutions, universities and companies will be established with cooperation of the local authorities in rural communities and based on various field tests.



V. Agriculture, forestry, fisheries and carbon sinks

Smart agriculture, forestry and fisheries

38) Reduction of fossil fuels and materials by electrifying agricultural and forestry machines and fishing boats, and by labor optimization

[Target]

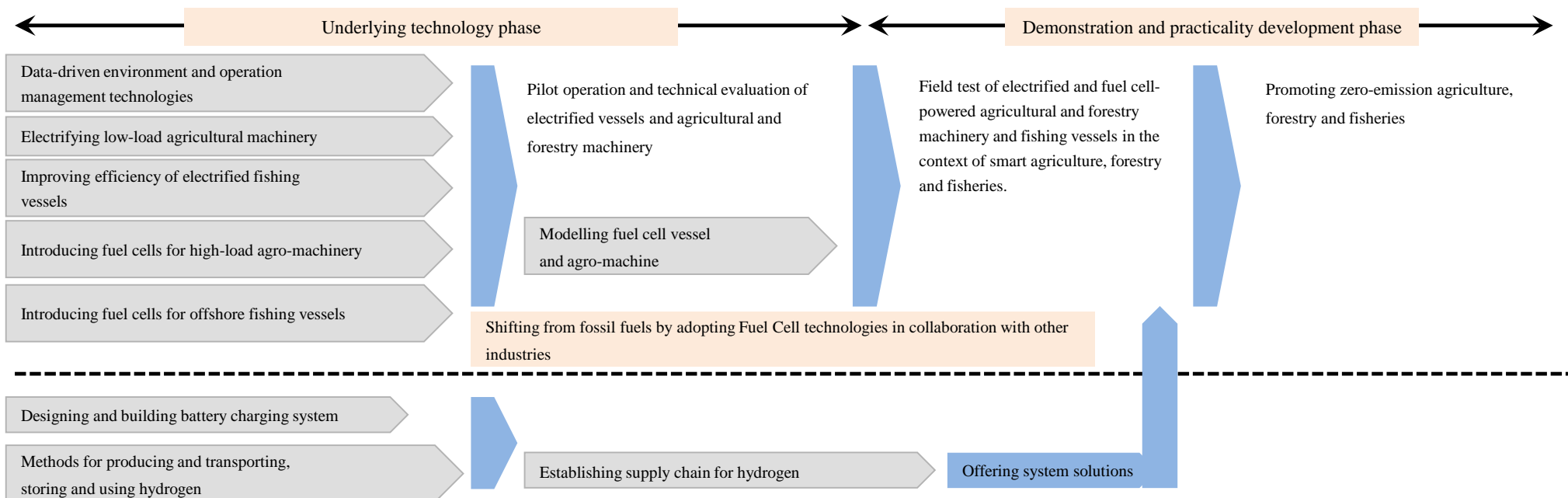
- Technologies to achieve smart agriculture, forestry and fisheries, using electricity and fuel cells for agricultural and forestry machinery and fishing vessels at a cost level feasible for adoption in the society, will be developed. Efforts will be made to move as close as possible toward zero GHG emission from production process by 2050. The global amount of CO₂ reduction is estimated to be 0.6 billion tons.¹⁾

[Technology development]

- Technologies will be developed to reduce fuels and materials by precise management of gardening facilities and streamlining and optimizing operations by smart technologies.
- A collaboration of industry-academia-government will be formed to develop technologies for using electricity and fuel cells for agricultural and forestry machinery and fishing vessels.

(System for development)

- A collaborative system of universities, manufacturers and other companies, involving startups and in view of large-scale field tests and business development in Japan and abroad.



1) Estimated by MAFF, based on the IPCC AR5 Working Group 3 Report, and assuming that all the global CO₂ emissions from agriculture are converted to renewable energy.

Capturing CO₂ in the air

39) Pursuit of DAC (Direct Air Capture) technology

[Target]

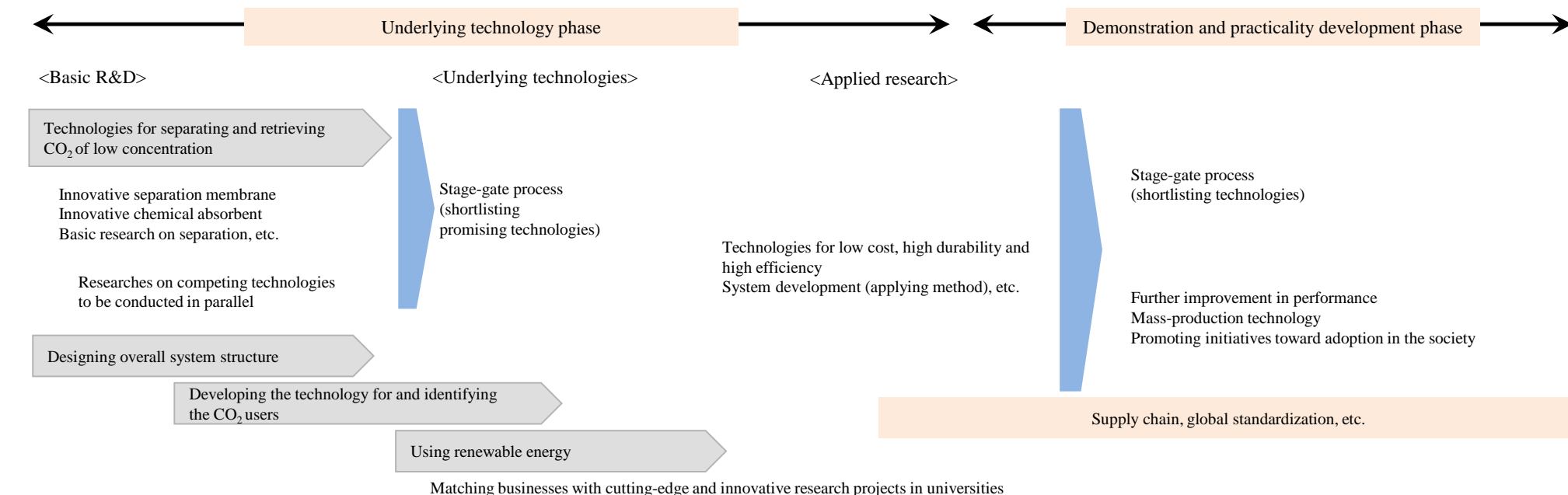
- Inevitable emission of CO₂ into the atmosphere will be separated and captured, to be utilized and fixated. Technologies to achieve a negative emission at an affordable cost, including by using renewable energy for separating and utilizing CO₂, will be developed by 2050. The global amount of CO₂ absorption is estimated to be 8.0 billion tons.¹⁾

[Technology development]

- Technologies to capture and separate low-concentration CO₂ in the atmosphere (400-500 ppm) will be developed. Innovative separation membranes and chemical absorbents, as well as methods, will be developed. The system to utilize CO₂ will also be developed.
- A system that combines renewable energy to achieve an overall negative emissions will be pursued.

(System for development)

- In order to cover seeds in an unprecedented scale, contributions from the public will be invited and the stage gate will be introduced from the basic research and development phase and the underlying technologies phase. Technologies developed to sufficient degree will be developed through industry-academia partnerships in view of the overall system and business opportunities.



¹⁾ This estimate is a reiteration of that in p31.

Chapter 1 Backgrounds, Aims, and Composition

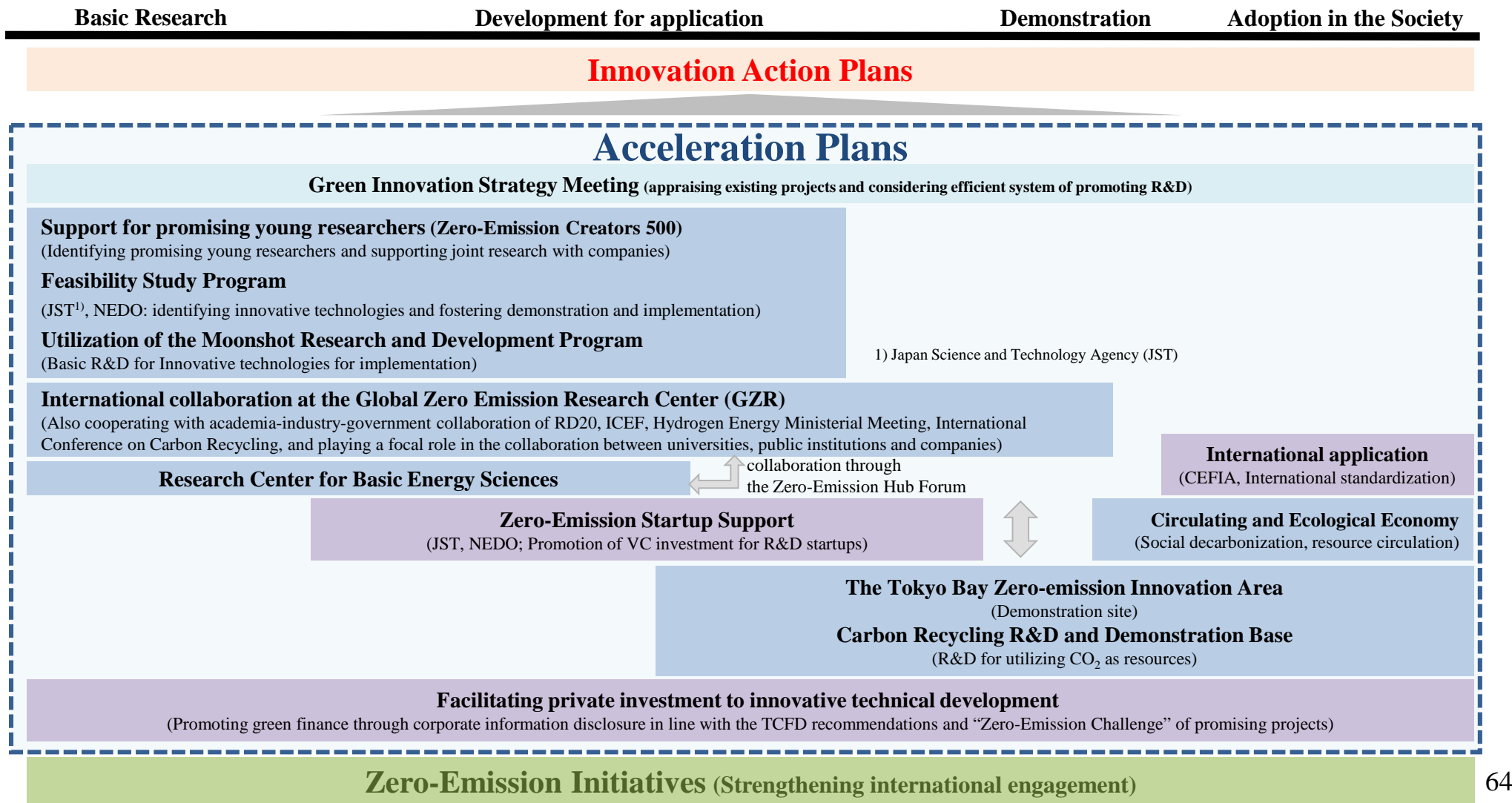
Chapter 2 Innovation Action Plans

Chapter 3 Acceleration Plans

Chapter 4 Zero-Emission Initiatives

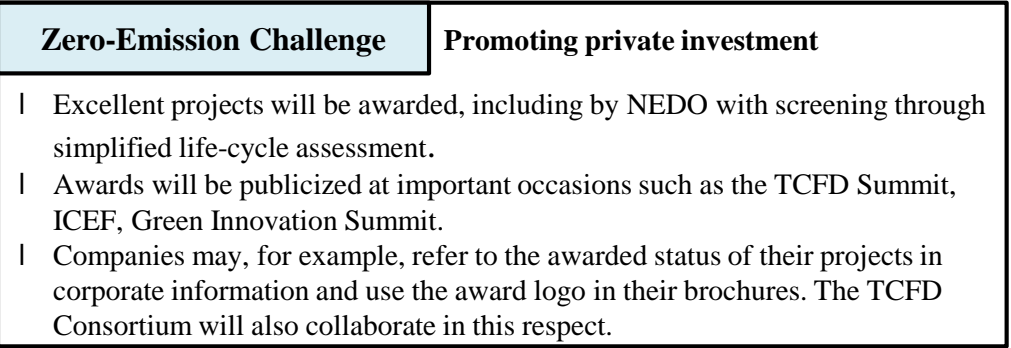
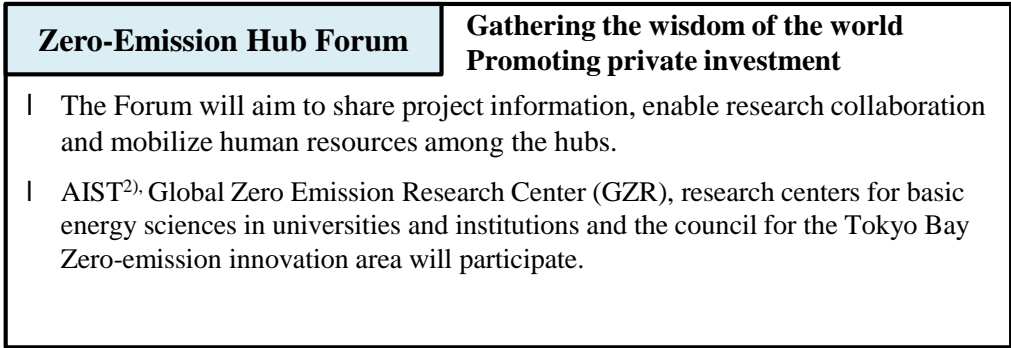
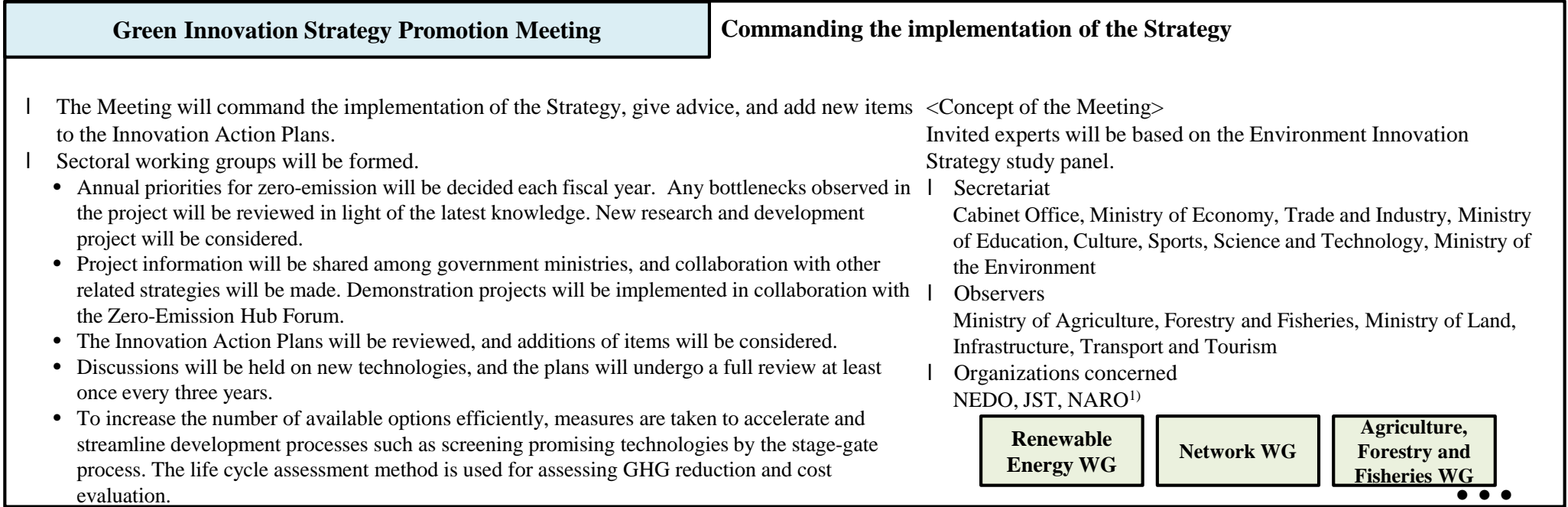
Acceleration Plans

In order to robustly enhance and apply the Innovation Action Plans, the Government will form and implement the Acceleration Plans, and: (1) systematically make efforts together with an inter-agency chain of command; (2) gather a wide range of wisdom not only in Japan but also of the world, and; (3) promote private investments in the light of the increase in ESG investments. The Acceleration Plans will be reviewed periodically, taking into account the progress in the Innovation Action Plans.



Green Innovation Strategy Meeting

- | A Green Innovation Strategy Meeting will be established to command the inter-agency initiatives to substantially implement the Environment Innovation Strategy. The Meeting will appraise the thorough progress of the relevant research and development projects in the long run, from basic technology to its application, overcoming sectionalism.



1) National Agriculture and Food Research Organization 2) National Institute of Advanced Industrial Science and Technology (hereinafter referred to as “AIST”)

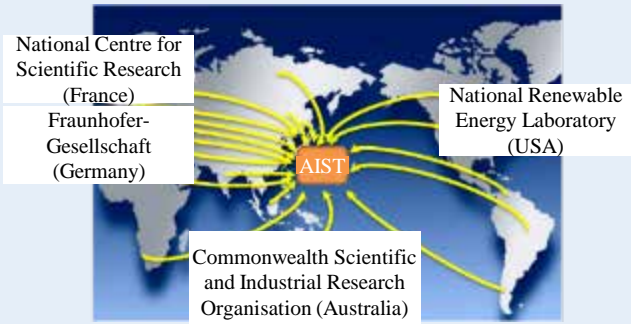
Creation of the Global Zero Emission Research Center (GZR)

- | The Global Zero Emission Research Center (GZR) is created for international joint studies with research institutes abroad in areas such as hydrogen, carbon recycling and energy devices. Project information amassed from all over the world, including through RD20, will be assessed, and a platform for disclosing information to researchers, businesses and investors will be established.
- | A Zero-Emission Hub Forum will be set up with the aim of establishing innovative technologies that enable a carbon-neutral world by 2050. The Forum will share information on the progress of ongoing projects at each research hub, enable research collaboration between hubs and mobilize human resources under the Innovation Action Plans of the Environment Innovation Strategy.

A Zero-Emission Hub Forum

(Secretariat: AIST Global Zero Emission Research Center (GZR))

AIST Global Zero Emission Research Center (GZR)



International joint research and development; publicizing technical information from home and abroad

Universities, national research institutes, etc.

Next-generation energy research hubs

Fundamental research platform for industries and academia

Private entities

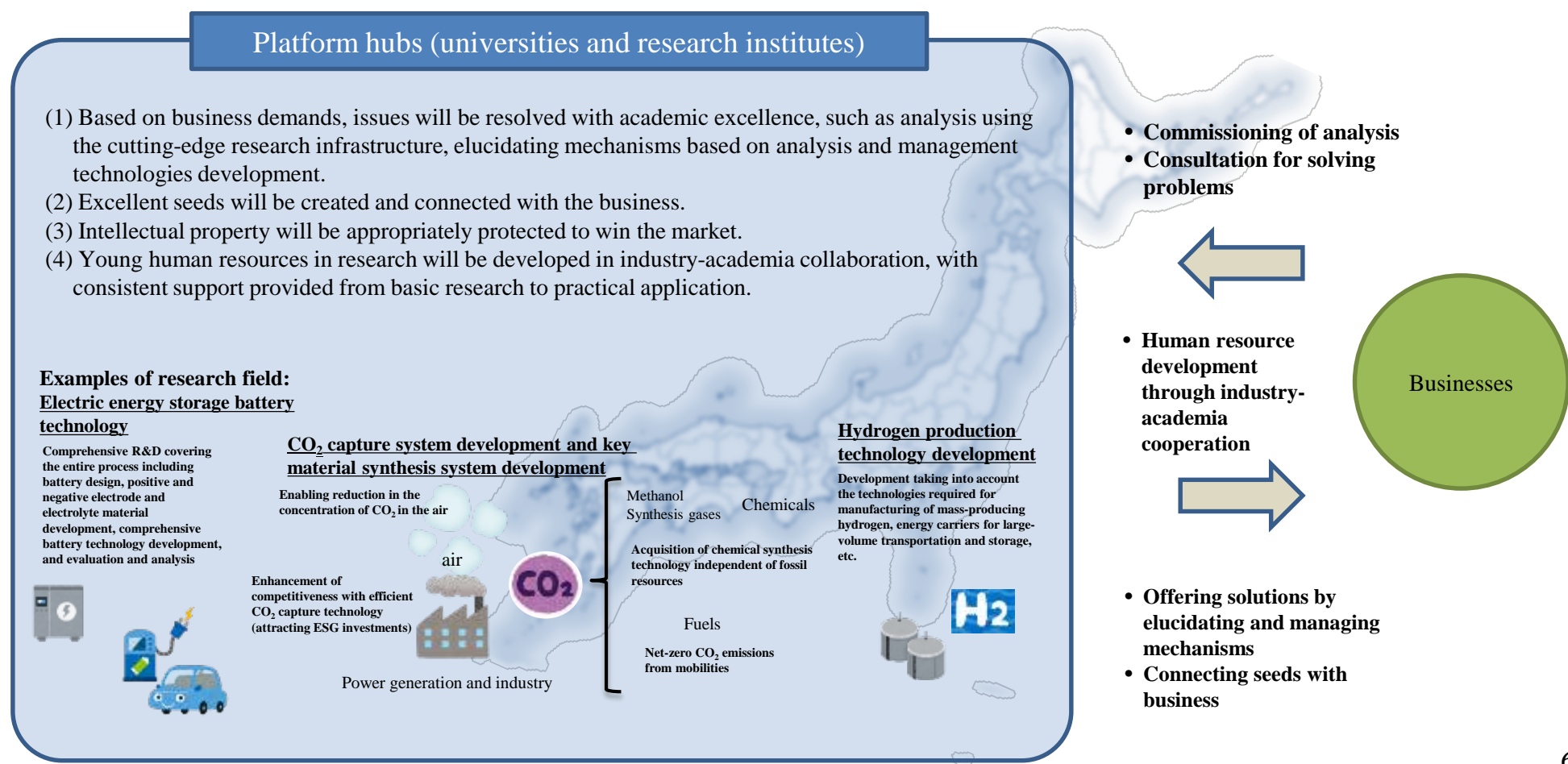
The Tokyo Bay Zero-emission Innovation Area

Carbon Recycling R&D and Demonstration Base

Demonstration site for energy-related companies located in the Tokyo Bay area

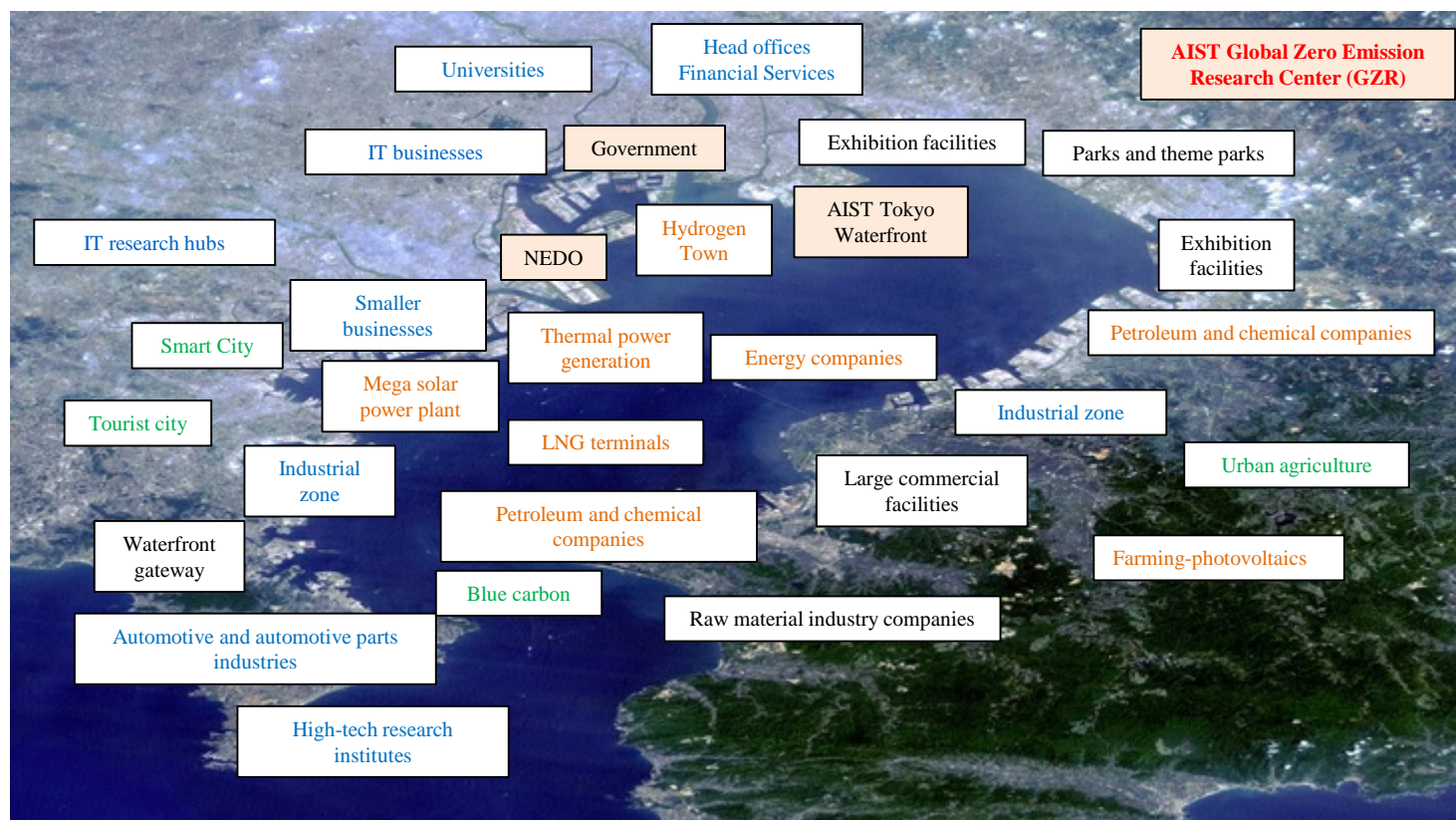
Creation of next-generation energy research hubs

- | Next-generation energy research hubs will be set up universities and research institutions with global competence in the areas of energy and environment, taking advantage of the strengths of academia and serving as a platform to solve business challenges, create seeds and connect them with business, in order to develop and apply innovative technologies through industry-academia collaboration.
- | Institutional systems for basic and fundamental research and development will be strengthened to accelerate research and development on next-generation energy technologies, including electric energy storage batteries, that contribute to solving global environmental problems, disaster prevention and global competitiveness.



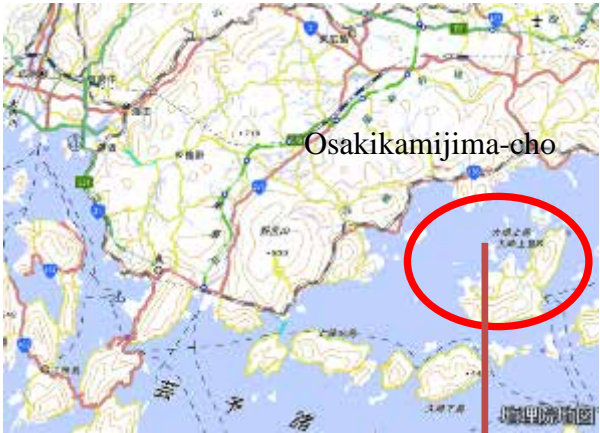
Launch of the Tokyo Bay Zero-emission Innovation Area scheme

- | The Tokyo Bay waterfront area hosts various head offices, research facilities and factories of environment-related and other companies, as well as research institutes and government offices. The collaboration of these entities in research, development, demonstration and business activities will create innovation for zero-emission, make it available to the world and transform the Tokyo Bay area to the most advanced innovation area in the world (a zero-emission version of Silicon Valley).
- | An industry-academia-government council will be set up to plan and implement joint research, development and demonstration projects, such as those in hydrogen, CCUS and energy management, and to conduct publicity activities, including messages at international conferences such as ICEF and RD20.



Creation of Carbon Recycling R&D and Demonstration Base

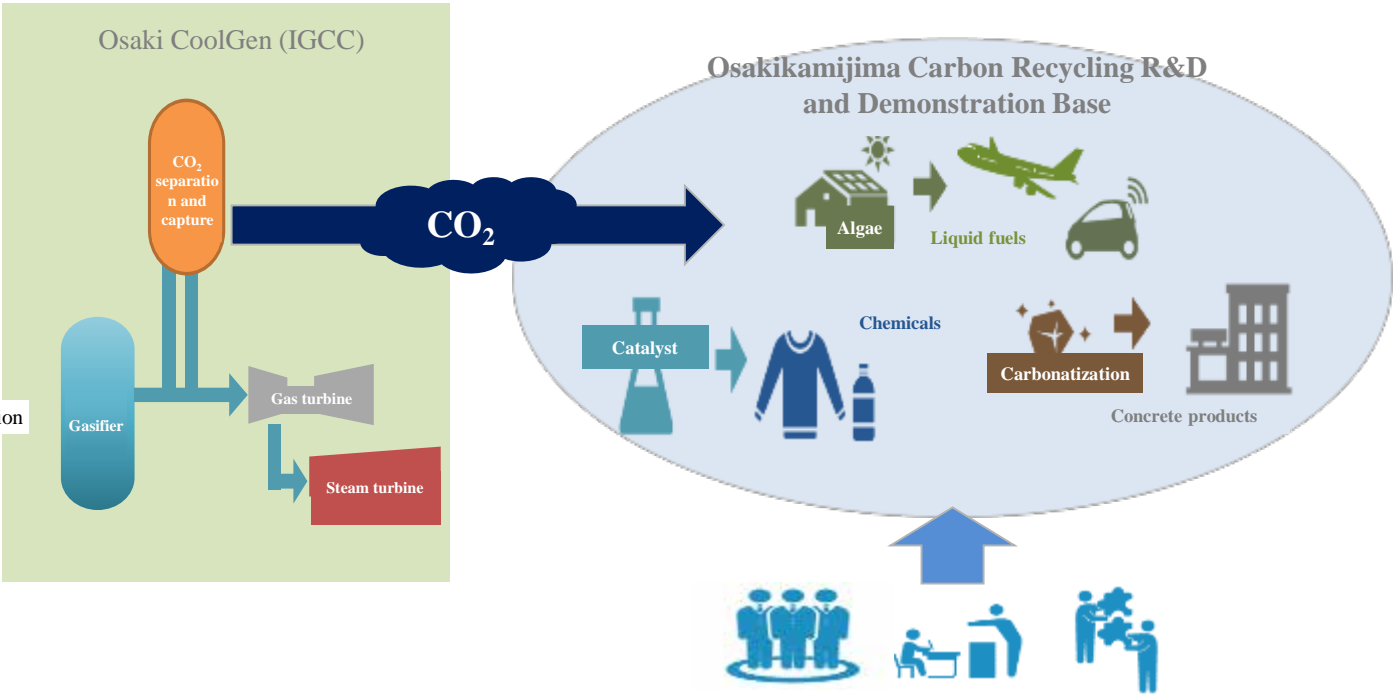
- | A demonstration project is implemented at an integrated coal gasification combined cycle facility, burning coal gasification gas, and capturing CO₂ in Osakikamijima, Hiroshima Prefecture.
- | This facility will prepare for demonstration environment for carbon recycling research, aiming for effective use of CO₂ as a resource.
- | Various carbon recycling technologies such as biofuels, chemicals and carbonates will be show cased and shared with the rest of the world at exposition and other opportunities.



General view of Osaki CoolGen

Carbon Recycling R&D and Demonstration Base at Osakikamijima

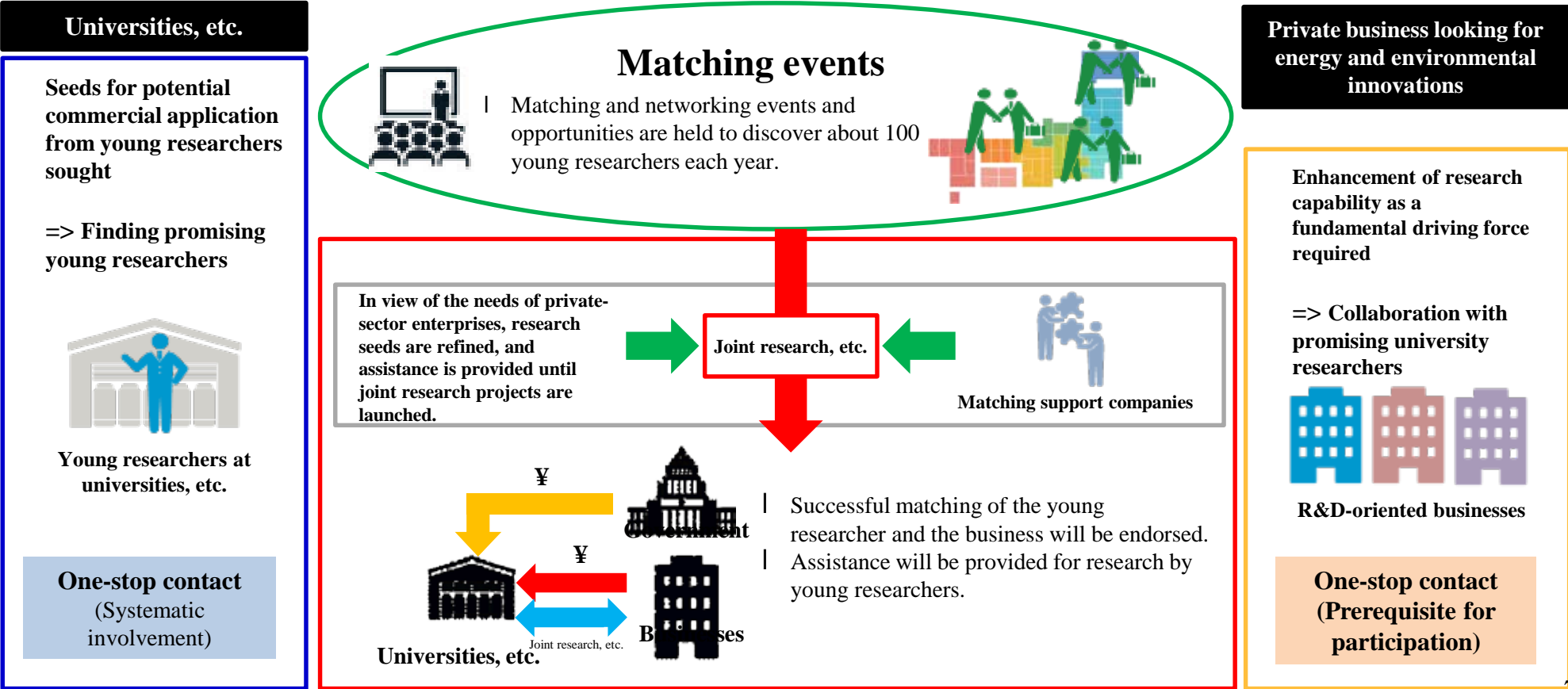
Researchers involved in areas such as algal biotechnology, catalysis, carbonation gather to participate in R&D and demonstration projects in an intensive and interdisciplinary manner, accelerating R&D.



Researchers, engineers, scholars, etc.

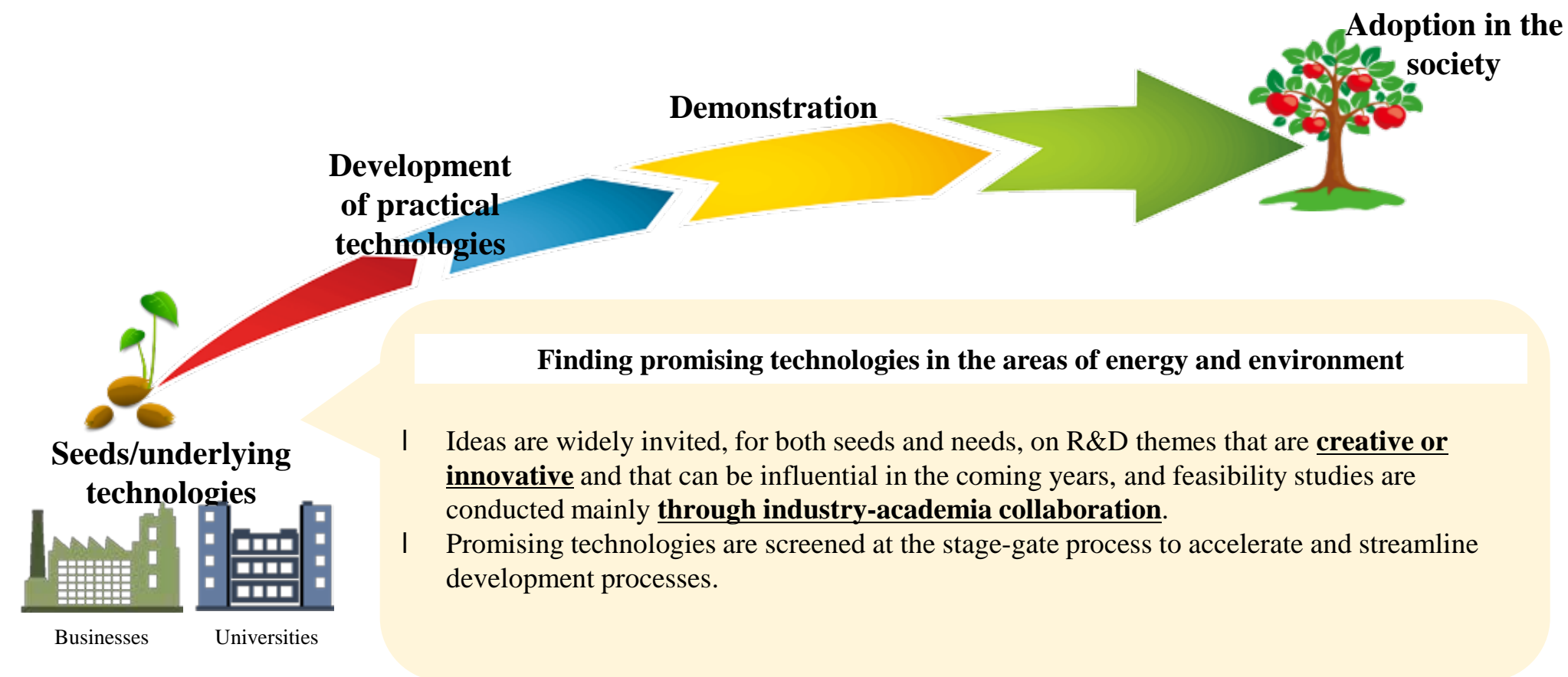
Zero-Emission Creators 500: Intensive support for young researchers

- | In many cases, research and development activities in the areas of energy and environment do not produce short-term profits, which makes it difficult for businesses to be engaged.
- | It is therefore important to collect information on the needs in the business sector, so as to find unnoticed researchers and seeds that could contribute to zero-emission, and to facilitate their matching with the business.
- | With government assistance, an institutional system for matching promising young university and other researchers in the areas of energy and environment to R&D activities of businesses will be established, identifying 500 promising young researchers in five years.



Assistance by feasibility studies in the areas of energy and environment

- | The development of innovative technologies and systems is necessary to solve problems in the areas of energy and environment in the longer terms. Private companies are not very active, however, in the R&D for longer terms.
- | To solve this problem, innovative and disruptive technologies that are risky to develop but can have a great impact on the society will be identified, and feasibility studies will be conducted.
- | The results of feasibility studies will be utilized to test the seeds and identify commercial opportunities, aiming for adoption in the society.



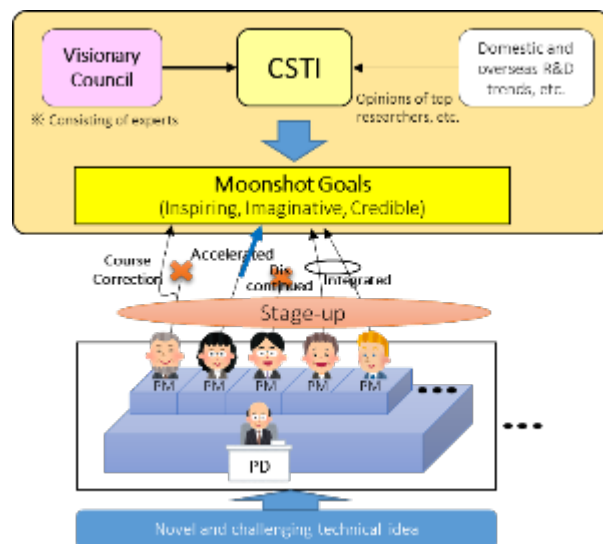
(2) Gathering the wisdom of the world

Utilization of Moonshot Research and Development Program

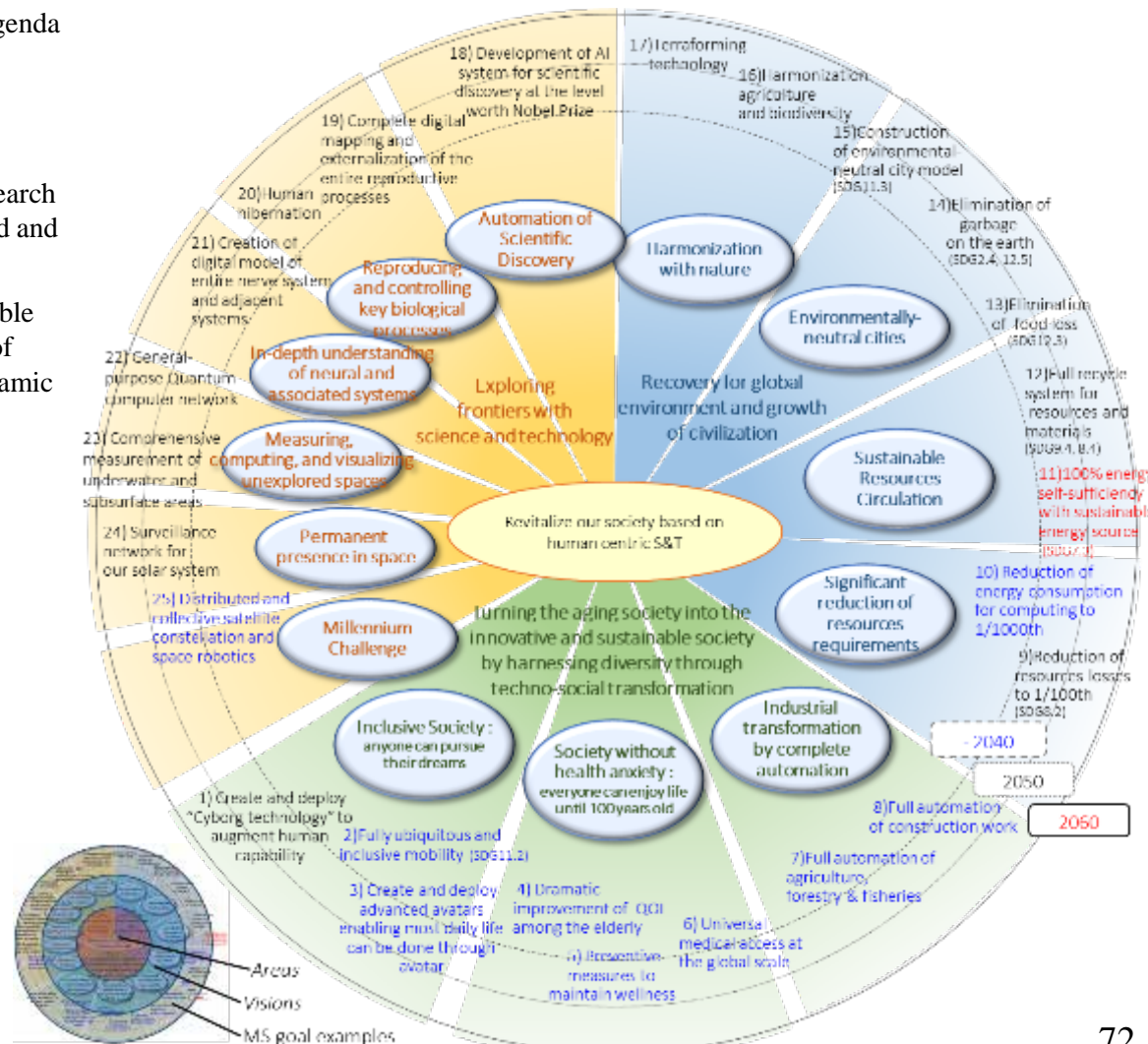
- The CSTI will present visions of future society (moonshot target) on the social agenda which are difficult but can bring profound impact, and invite innovative research ideas (programs) for attaining the target from domestic and overseas researchers.

[Key points]

- The government will set ambitious goals and concepts for the social agenda which are difficult but can bring profound impact.
- Top researchers leading cutting-edge research will head the team of international researchers.
- Challenging research and development building on Japanese basic research capacity will be promoted. Innovative R&D activities will be identified and facilitated with an approach of accepting failures.
- A most advanced system to support cutting-edge research, with a flexible structure for organization and activities in the light of overall context of relevant R&D initiatives and in line with the updated situations of dynamic R&D activities in the world will be established.

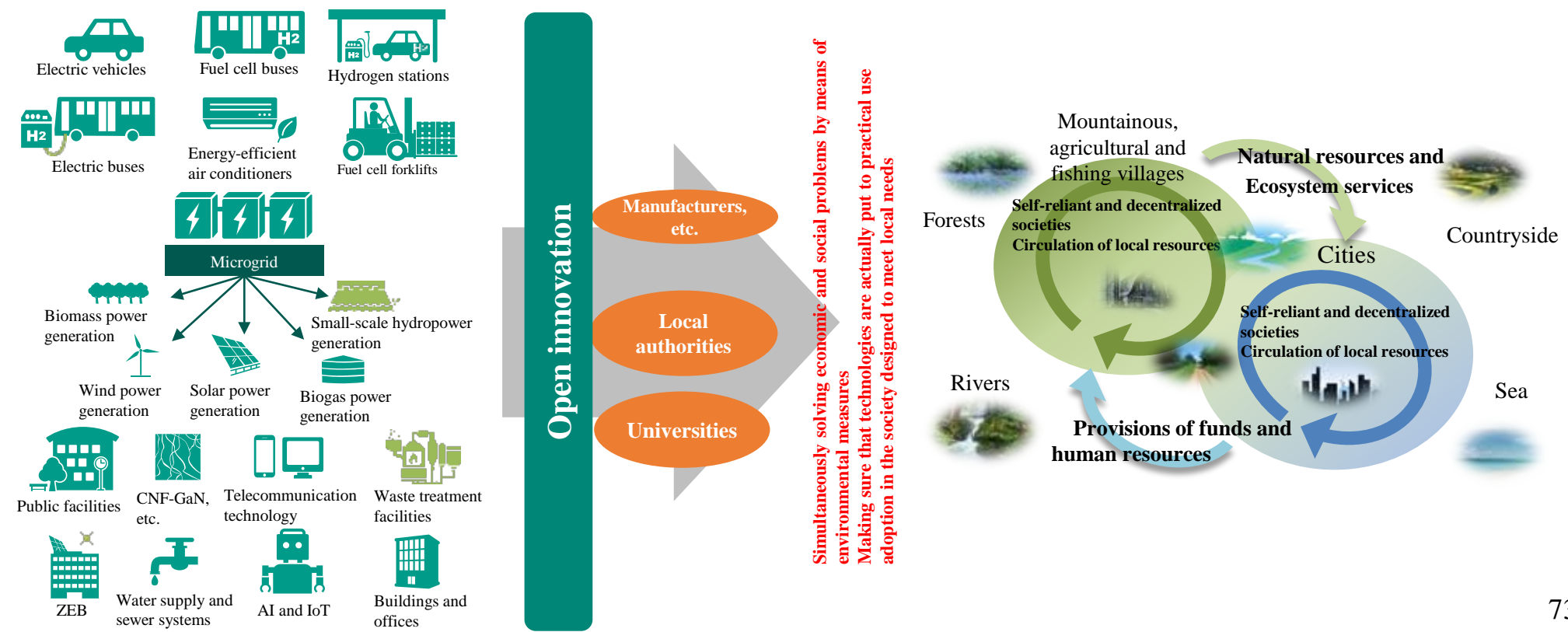


[Future visions and 25 MS goal examples]



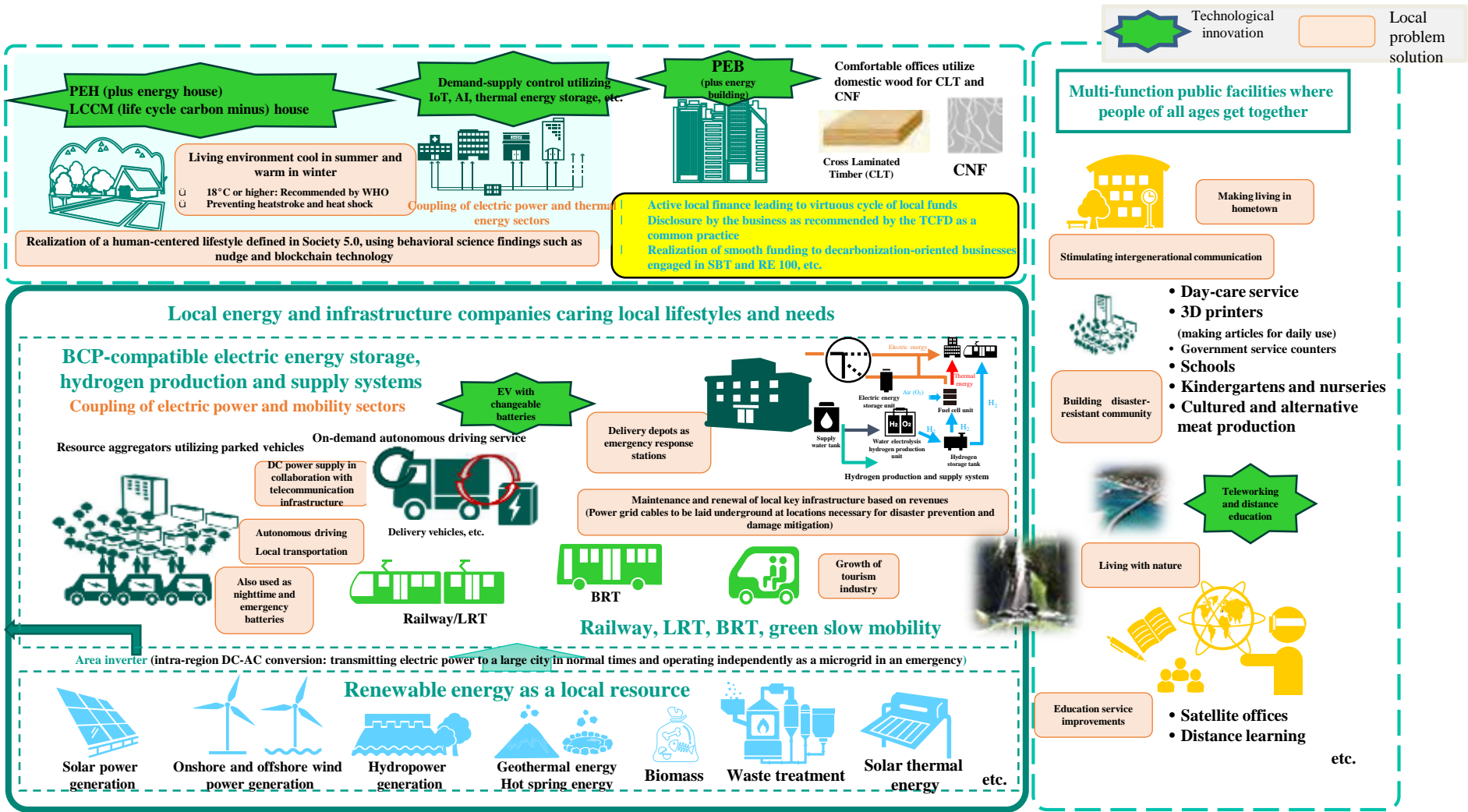
Creation of a Circular and Ecological Economy

- | A number of local authorities including Tokyo, Yokohama and Kyoto have announced their intentions to achieve decarbonization by 2050. Decarbonization and efforts against climate change have thus become increasingly active at the regional level. Building on this momentum, Circular and Ecological Economies will be created throughout the country, catering for regional needs and comprehensively solving environmental, economic and social problems through a series of innovations achieved by diverse stakeholders (in the locality and the business).
- | Technologies that can be used in the event of a disaster as well as in ordinary times, developed through open innovation processes, will be applied in the field and used as local business resources for sustainability.
- | In order to solve a locality-specific problem, it is necessary to systematically combine technologies and address it efficiently, rather than depending on a single technology. Various technologies will be combined and applied in the society, addressing diverse local needs, not limited to environmental needs.



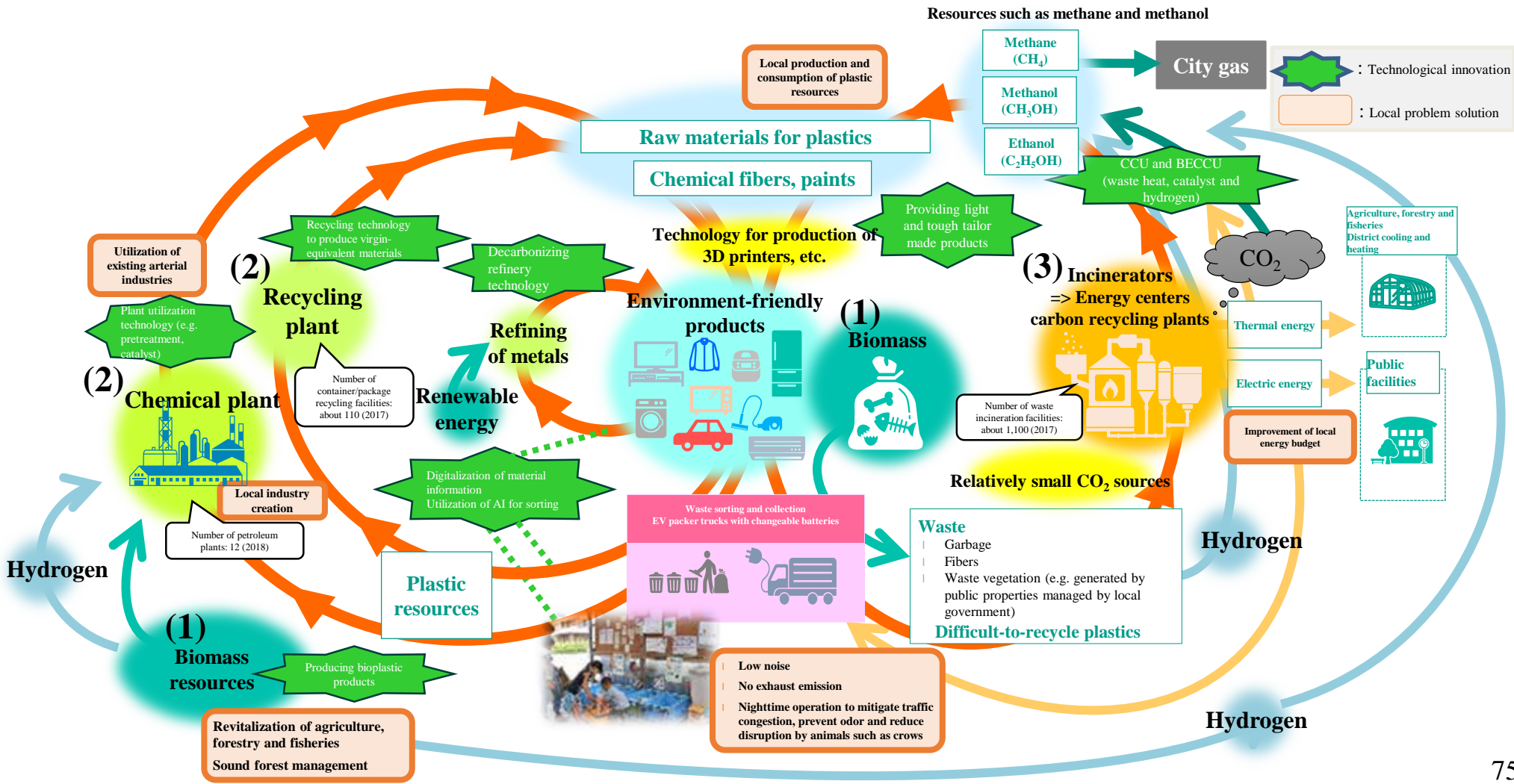
Reference 6 Decarbonization Lifestyle Innovation

In the civilian and transport sectors, maximum use is made of renewable energy as a local resource to establish a vision of a bright society and human-centered lifestyles for which each community aims, mainly through the efforts of decarbonization-oriented businesses and local banking institutions, in order to realize disaster-resistant, carbon-neutral lifestyles and community. Local energy and infrastructure companies conceptualize locally adapted carbon-neutral community management and life centered around decarbonization-oriented businesses and local banking institutions.



Reference 7 Recycling Innovation

The recycling innovation achieves transition from fossil fuel-derived resources to locally available resources, such as biomass, and combines innovative material recycling and chemical recycling technologies to realize local recycling of plastic resources. Furthermore, waste incinerators will be used as energy centers and carbon recycling plants to achieve net negative emission goals. Ultimate decarbonization and resource recycling solutions addressing diverse community needs to achieve the recycling of plastic and other resources will be established.



(3) Increase in Private Investment

Promoting Green Finance

In order to facilitate private investment in Japanese businesses addressing and creating green innovation, three key measures listed below are taken for promoting green finance to drive the “virtuous cycle of environment and growth”.

(1) Dissemination of information on climate change actions by the business

- Promoting effective information disclosure by the business through improving the TCFD Guidance and Scenario Analysis Guide and appraising and publicizing good business practices.

Actions of the business:

- Disclosing climate-related information in line with the TCFD recommendations
- Participating in environmental initiatives such as SBT and RE100
- Disseminating information on contribution to CO₂ reduction through value chain

Main policy measures:

- Zero-Emission Challenge
- Revising TCFD Guidance and Scenario Analysis Guide
- Providing assistance in setting goals and creating a business network
- Disseminating the Guideline for Quantifying GHG Emission Reduction Contribution, etc.

(2) Proactive funding for climate change actions

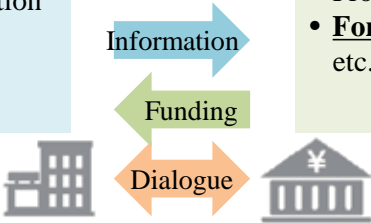
Measures such as promoting the use of the Green Investment Guidance and adopting green bond and green loan guidelines will be taken to encourage appropriate appraisal and use of corporate information by financial institutions, in order to promote green finance.

Actions of financial institutions:

- Green investment using ESG indices
- Issuance of green bonds
- Green loan and local ESG finance

Main policy measures:

- Promoting the use of the Green Investment Guidance and facilitating the business transition toward low-carbon society
- Improving the Green Bond Guidelines and providing subsidies for issuance
- Promoting ESG Regional finance
- Formulating green loan guidelines, providing subsidies for financing, etc.



(3) Dialogue between the industry and the financial community, and platforms

Creating opportunities for dialogue between the industry and the financial community to promote investment in the business tackling climate change.

International opportunities:

- Green Innovation Summit (including the TCFD Summit)
- TCFD Consortium, etc.

Opportunities in Japan:

- ESG Finance High-Level Panel
- ESG Dialogue Platform
- Green Bond Issuance Promotion Platform, etc.

Reference 8 Efforts on promoting green finance

Dissemination by businesses of information on climate change actions by businesses

1. Zero-Emission Challenge

In order for private funding to be effectively and efficiently provided to promising research and development projects with significant GHG reduction potentials, a system to evaluate the technical and economic aspects of the projects contributing to tackle global warming and a platform to provide information of excellent projects will be established.

2. Improving the TCFD Guidance and Scenario Analysis Guide

The TCFD Guidance formulated in December 2018 and the Scenario Analysis Guide adopted in March 2019 will be improved to encourage the business to appropriately disclose climate-related information such as management strategies and efforts on climate change to investors.

3. Providing assistance in setting goals and creating a business network

Assistance will be provided to the business, including smaller companies, for goal setting, reduction efforts and dissemination of information concerning initiatives such as the SBT and RE100. A business network will be organized for companies working for decarbonization and energy related companies supporting such efforts.

4. Disseminating the Guideline for Quantifying GHG Emission Reduction Contribution

This guideline was formulated in March 2018 describing the basic concept of quantification to enable companies serving for the overall reduction of CO₂ emissions to measure their contribution along the global value chain of products and services, thereby publicizing environmental value of their products and services. Proactive disclosure of information will be encouraged, including in the TCFD Guidance.

Proactive funding for climate change actions

1. Promoting the use of Green Investment Guidance and facilitating smooth businesses transition

Based on the Green Investment Guidance of October 2019, measures will be taken to: encourage engagement to enhance the corporate value; identify and evaluate risks and opportunities associated with climate change; create systems for promoting innovation toward decarbonization and facilitating appropriate fund flows. Measures will also be taken to prepare for an environment that facilitates smooth business transition to low-carbon society.

2. Improving the Green Bond Guidelines and providing subsidies for issuance

The Green Bond Guidelines will be revised to keep up with the international green bond principles and market trends. Subsidies and other forms of assistance will be provided to those who facilitate the issuance of green bonds, such as provision of external review, to help the green bond market grow.

3. Promoting local ESG finance

Based on "the ESG Regional Finance: Learning from Examples" of March 2019, ESG Regional Finance will be promoted to enhance the corporate values of smaller companies in the locality in the longer term, thereby contributing to sustainable growth of that locality. The measures will include: assistance in formulating project viability evaluation taking ESG into account; interest subsidies for local ESG financing, and; ESG regional finance seminars across Japan.

4. Adopting Green Loan and Sustainability-linked Loan Guidelines and providing subsidies for financing

In view of the international green loan principles and the sustainability-linked loan principles and ongoing efforts of the financing institutions in Japan, guidelines for green loans and sustainability linked-loans¹⁾ will be formulated. Subsidies and other forms of assistance will be provided to those who facilitate the green loans associated with environmental innovation, such as provision of external review, to promote green loans.

1) A loan intended to encourage the borrower to work for an ambitious sustainability performance target

Dialogues between the industry and the financial Community and platforms

1. Green Innovation Summit, including the TCFD Summit

The leaders of the industry, the financial community and the researchers are invited to three international conferences proposed by the Prime Minister, namely, ICEF, RD20 and the TCFD Summit, to express commitment for accelerating innovation through green finance. The TCFD Summit sends the message highlighting the importance of opportunity assessment and engagement, and, with the second round scheduled in Autumn 2020, is leading the world in this respect.

2. TCFD Consortium

This consortium, the organization led by Japanese TCFD supporters in the private sector, coordinates dialogue between the industry and the financial community. The consortium will also update the TCFD Guidance and promote the use of the Green Investment Guidance in financial institutions.

3. ESG Finance High-Level Panel

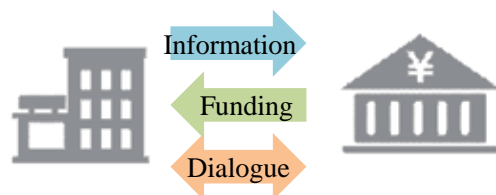
Based on the recommendations of the Roundtable on the ESG Finance published in July 2018, the ESG Finance High-Level Panel was set up in February 2019 for the Government and business sectors to collaborate and seek ways to raise awareness and strengthen efforts on ESG finance. Efforts based on the recommendations will also be periodically reviewed at this Panel.

4. Green bond issuance promotion platform and green finance portal

This platform will register and publicize green bond issuance supporters, share information on actual issuance, and analyze and offer information on trends in Japan and abroad. A green finance portal will be set up to disseminate information on various policy measures associated with ESG finance.

5. ESG Dialogue Platform

As a basic infrastructure for dialogue concerning environmental information and business value evaluation, a platform integrating the database and the opportunities for dialogue will be developed. The platform will start with ESG-related information sharing, with an aim to incrementally cover analysis and dialogue.



Zero-Emission Challenge

- | In order for private funding to be effectively and efficiently provided to promising research and development projects with significant GHG reduction potentials, the technical value and contribution of projects under the Innovation Action Plan will be objectively examined and projects of excellence will be awarded.
- | In collaboration with the “Challenge Zero” (Innovation Challenges Towards a Net Zero Carbon Society) of Japan Business Federation (Keidanren) and the TCFD Consortium, an information platform for investors in the world will be established utilizing information disclosed by the business.

Zero-Emission Challenge

- | Awarding excellent projects (Zero-Emission Project Award)
- | A database of relevant information made available on the Web
- | The business and relevant entities entitled to refer to the awarded status of their projects in corporate information and use the award logo, for example, in their brochures; the TCFD Consortium to collaborate in this respect.

- Implementing organizations:

 - Organizations such as NEDO jointly conduct project evaluation.
- Eligible projects:

 - Projects implemented by organizations such as NEDO and R&D projects carried out by private companies, etc.



Dissemination of information



Access

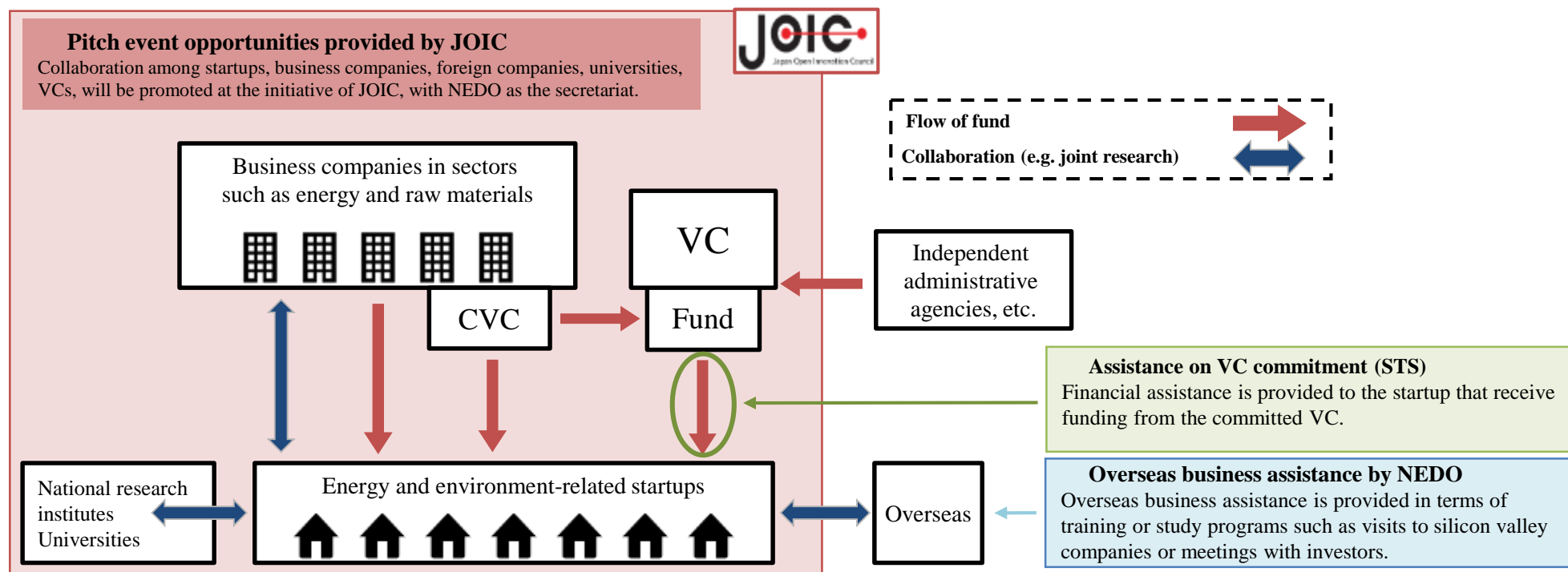
Challenge Zero of Keidanren

- Participating entities will declare their challenge in one of the categories listed below and announce their specific actions.
- | Innovation of net-zero carbon technology (including transition technology)
 - | Active application and promotion of usage of net-zero carbon technology
 - | Active investment or financing to the company working on the challenges mentioned above

- | A database of information on efforts based on the Innovation Action Plans will be created, to be made available without difficulties to investors.
- | Information on the awarded projects and companies of excellence will be shown to the rest of the world at events such as the Green Innovation Summit.

Strengthening assistance to zero-emission startups

- Zero-emission related technology development requires a large initial investment because of the need to acquire expensive equipment. Furthermore, zero-emission related research and development often involve time-consuming demonstration needed to obtain long-term operation data, and it is difficult to predict market growth. For these reasons, those who start a business and those who provide funding, including venture capitals (VCs), are limited in number. The fact that those who own technological seeds do not necessarily have knowledge about project operationalization is another challenge.
- The scope of assistance for technology development and demonstration by the startup business will accordingly be expanded to include wider zero-emission related fields such as energy management and electric energy storage batteries, contingent on the cooperation of VCs or other entities with expertise on operationalization, in order to increase related investments by VCs and other entities.
- Assistance will be augmented, for example: the matching function of the Japan Open Innovation Council (JOIC) for the business ecosystem will be strengthened, and; information disclosure will be promoted, in collaboration with the TCFD Consortium, so that investment in zero-emission startups will be appropriately evaluated by the financial institutions and investors.



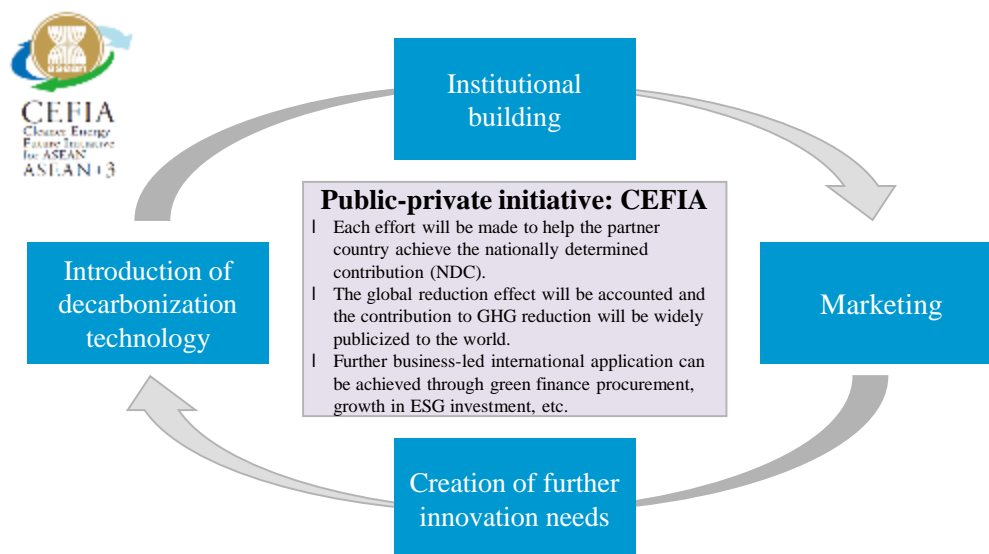
Promotion of International Business

- | In order for zero-emission technology to be widely used in any country, including developing countries, it is necessary to formulate policies, establish institutional systems and set international standards while achieving cost reduction.
- | In all phases of business, from the phase of R&D to growing business, policy formulation, institutional building and international standardization will be offered at multilateral and other frameworks, to promote the wider use of innovations.

Utilization of CEFIA

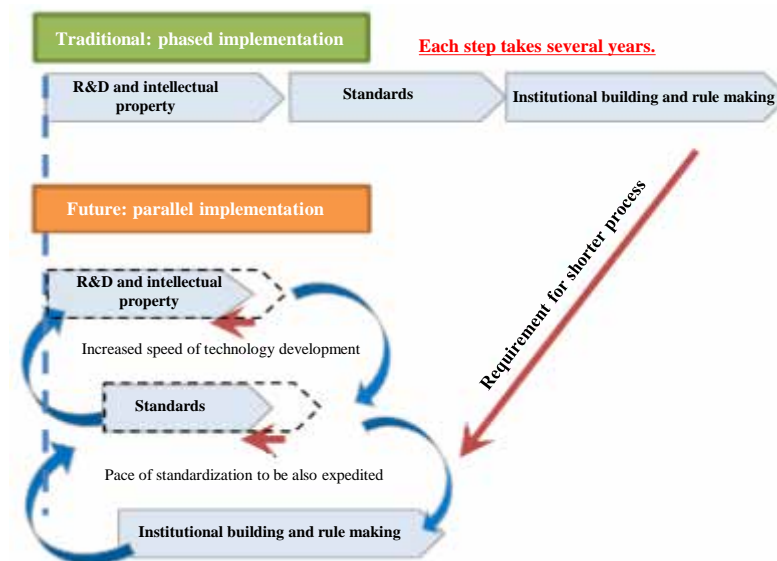
(Cleaner Energy Future Initiative for ASEAN)

CEFIA, the new framework for public-private collaboration for promoting decarbonization technology, can be used for policy formulation and institutional building. The introduction of advanced technology, will be coupled with policy formulation and institutional building as a package, and information on successful cases will be shared as best practices. By setting up a virtuous cycle of marketing, international application of innovation will be led by the business.



International standardization

From the initial stage of research and development, studies will be conducted systematically on institutional building and standardization for promoting the technology. International standardization will promote the wider use of the results obtained and lead to growth in the business.



Chapter 1 Backgrounds, Aims, and Composition

Chapter 2 Innovation Action Plans

Chapter 3 Acceleration Plans

Chapter 4 **Zero-Emission Initiatives**

Zero-Emission Initiatives

The leaders of the industry, finance and academia from around the world gather in Japan annually and take concrete actions to address climate change.

At the Green Innovation Summit and 5 international conferences, continuous efforts will be made to: i) share the latest information on innovative technologies; ii) offer the opportunity of collaboration and to promote the green finance, and; iii) accelerate applying the outcomes.

Innovation Action Plans

Acceleration Plans

Zero-Emission Initiatives

Green Innovation Summit

Led by the Prime Minister, the leaders of the industry, finance and academia gather to share Japan's concrete initiatives with the world. International engagement will be strengthened.

Hydrogen Energy Ministerial Meeting	International Conference on Carbon Recycling	RD20	TCFD Summit	ICEF
Countries, regions, and institutions with a strong interest in global hydrogen utilization discuss the direction of policies.	In order to realize carbon recycling, innovative initiatives and latest knowledge of each country, as well as the chance of collaboration will be shared. The network of the industry, academia and government in participating countries will be strengthened.	R&D activities and experiences will be shared among the leaders of research institutes in the field of clean energy technology from G20 member countries, in order to create disruptive innovations for significant reduction of CO ₂	The global leaders of companies and finance discuss ways forward to attract funds to companies keen on environmental measures, thereby realizing a virtuous cycle of environment and growth.	More than 1,000 experts from about 70 countries and regions gather to discuss measures to address climate change with technological innovation.

Green Innovation Summit

- | Led by the Prime Minister, the leaders of the industry, financial community and researchers gather to share Japan’s concrete initiatives with the world and international engagement will be strengthened.
- | The participants will show the commitments on ways forward to accelerate disruptive innovation to achieve a decarbonized society, and realize a virtuous cycle of environment and growth agreed at the G20 Osaka Summit.

Overview of the 2019 Meeting

1. Date and venue

Date: Wednesday, October 9, 2019
Venue: Prime Minister’s Office

2. Attendees (20 at the summit, about 300 at the reception)

- Prime Minister; Minister of Economy, Trade and Industry; Minister of Education, Culture, Sports, Science and Technology, and; Minister of the Environment

[TCFD Summit]

- Mr. Peter Bakker, President and CEO, WBCSD
- Dr. Mark Carney, Governor of the Bank of England
- Mr. MIZUNO Hiromichi, PRI Board member; Executive Managing Director and Chief Investment Officer, GPIF

[ICEF]

- Mr. TANAKA Nobuo, Chair, ICEF Steering Committee; Chairman, The Sasakawa Peace Foundation; Former Executive Director, International Energy Agency (IEA)
- Mr. David Sandalow, ICEF Steering Committee member; Inaugural Fellow, Center on Global Energy Policy, Columbia University; Co-Director, Energy and Environment Concentration, School of International and Public Affairs, Columbia University

[RD20]

- Dr. CHUBACHI Ryoji, Chair, RD20; President, AIST
- Dr. Reimund Neugebauer, President, Fraunhofer-Gesellschaft

3. Outline of results

The Prime Minister announced the following:

- | In order to draw upon the collective wisdom of the world, Global Zero Emission Research Center (GZR) will be set up in Japan as an organization that links together research institutions in the world.
- | The Environment Innovation Strategy will be formulated with the aim of promoting public-private R&D investments amounting to 30 trillion JPY in 10 years in the field of environment and energy.
- | The Green Investment Guidance has been formulated as guidelines for the evaluation of information disclosed by the business working to address climate change.

[Program]

Chair: Minister of Economy, Trade and Industry

1. Handing of the recommendation and photo-taking session
2. Greetings from Mr. Bakker, Co-organizer, and greetings from the Prime Minister
3. Speeches of session representatives
4. Closing remarks by the Prime Minister

Hydrogen Energy Ministerial Meeting

- | The first Hydrogen Energy Ministerial Meeting was held in Japan in 2018 as a platform on which to promote hydrogen utilization on a global scale and strengthen international collaboration. The Tokyo Statement was announced at the meeting to indicate the direction of measures to be taken in the coming years.
- | Countries, regions and organizations with deep interest in hydrogen-related policy measures participate to discuss the direction of measures to be taken for the global-scale utilization of hydrogen.

Overview of the 2019 Meeting

1. Date and venue

Date: Wednesday, September 25, 2019

Venue: Tokyo (Hotel New Otani)

2. Attendees (more than 600 attendees from 35 countries, regions and organizations)

- Minister of Economy, Trade and Industry
- Dr. Fatih Birol, Executive Director, IEA
- Mr. Matthew Canavan, Minister for Resources and Northern Australia
- Dr. Dato Mat Suny, Minister of Energy, Manpower and Industry, Brunei
- Dr. Mohammed bin Hamad Al Rumhi, Minister of Oil and Gas, Oman
- Mr. Omar Ayub Khan, Federal Minister for Energy, Pakistan
- Mr. Tran Tuan Anh, Minister of Industry and Trade, Viet Nam
- Mr. Alfonso Cusi, Secretary of the Department of Energy, the Philippines
- Dr. Elahi Chowdhury, Adviser to the Prime Minister of Bangladesh

3. Outline of results

- | Specific actions to be taken to implement the Tokyo Statement were clarified, and the Global Action Agenda was adopted and shared as a guideline associated with hydrogen and fuel cell batteries in each country.

[Program]

- | Morning: Discussion among the ministers of the participating countries on specifics of international collaboration
- | Afternoon: Speeches by international organizations and the international business
 - ↳ Cross-sectoral workshop: Potential of hydrogen in energy transition
 - ↳ Mobility workshop: Expanding scope of hydrogen utilization
 - ↳ Supply chain workshop: Hydrogen production and supply chain in the world for utilizing hydrogen
 - ↳ Sector integration workshop

[Points of Global Action Agenda (Chair's statement)]

- | Shared understanding of global goals (e.g. setting up ten thousand hydrogen stations and installing ten million fuel cell systems in ten years: "Ten, Ten, Ten")
- | Efforts to realize mass production and mass consumption of hydrogen (e.g. establishing supply chains, developing technologies and deregulation)

International Conference on Carbon Recycling

- | The first International Conference on Carbon Recycling was held in 2019 to coordinate the industry-academia-government efforts in different countries in order to realize carbon recycling.
- | The purpose is to ascertain each country’s innovative efforts, the latest findings and the possibility of international collaboration and strengthen the international networking of the industry, academia and government.

Overview of the 2019 Meeting

1. Date and venue

Date: Wednesday, September 25, 2019
Venue: Tokyo (Hotel New Otani)

2. Attendees (more than 450 persons from 20 countries and organizations)

- Minister of Economy, Trade and Industry
- Dr. Fatih Birol, Executive Director, IEA
- Mr. Matthew Canavan, Minister for Resources and Northern Australia
- Dr. Dato Mat Suny, Minister of Energy, Manpower and Industry, Brunei
- Mr. Omar Ayub Khan, Federal Minister for Energy, Pakistan
- Mr. Tran Tuan Anh, Minister of Industry and Trade, Viet Nam
- Mr. Alfonso Cusi, Secretary of the Department of Energy, Philippines
- Prof. NISHIMURA Hidetoshi, President, ERIA
- Prof. G.K. Surya Prakash, Director, Loker Hydrocarbon Research Institute, University of Southern California
- Ing. Peter Van Os, Project Manager, The Netherlands Organization for Applied Scientific Research (TNO)
- Mr. KITAMURA Masayoshi, Vice Chairperson, Carbon Recycling Fund Institute

3. Outline of results

- | This conference was held as the first international conference for discussing carbon recycling to ascertain the latest findings about carbon recycling in the world and the possibility of international collaboration. At the conference, the Minister of Economy, Trade and Industry announced the Carbon Recycling 3C Initiative consisting of the promotion of mutual exchange (Caravan), the establishment of R&D and demonstration base (Center of Research) and the promotion of international joint research (Collaboration).
- | In the coming years, opportunities will be pursued for putting carbon recycling technology to practical use in international projects to achieve the goal of global decarbonization, and measures will be taken to raise international awareness and establish international rules. Efforts will also be made to work jointly with other countries such as Australia, the United States and Saudi Arabia, and international cooperation will continue as a step toward advancing innovations and to prepare for the second and subsequent international conferences.
- | As Japan’s first international collaboration project, the Memorandum of Cooperation was signed with Australia. The Carbon Recycling Working Group sessions involving the participation of government representatives of the two countries and, if necessary, industrial leaders will be held to discuss the possibility of joint projects.

RD20

- | RD20 is the international conference of the leaders of G20 research institutes in the field of clean energy technology for the creation of disruptive innovations for massive reduction of CO₂ emissions.
- | By continuing this conference, alliance among G20 research institutes will be strengthened, and international joint research projects will be developed, creating for a cycle of innovation.

Overview of the 2019 Conference

1. Date and venue

Date: Friday, October 11, 2019

Venue: Tokyo (Hotel New Otani)

2. Attendees (about 300 experts)

- Minister of Economy, Trade and Industry (video message)
- Parliamentary Vice-Minister for the Environment, Parliamentary Vice-Minister for Education, Culture, Sports, Science and Technology

[Attendees from G20 research institutes]

- Mr. Iain Stewart, President, National Research Council Canada (Canada)
- Dr. Larry Marshall, Chief Executive, Commonwealth Scientific and Industrial Research Organization (Australia)
- Prof. Antoine Petit, President, French National Centre for Scientific Research (France)
- Dr. William Tumas, Associate Laboratory Director, National Renewable Energy Laboratory (USA)
- Dr. Hammam Riza, Head, Agency for the Assessment and Application of Technology (Indonesia)

3. Outline of results

- | A summary of the opinions expressed by the representatives of G20 research institutes was presented as “RD20 Chair Summary.”
- | Research and development activities in the field of clean energy technology of G20 countries were summarized as the report titled “RD20 Now & Future.”
- | Bilateral research collaborations between AIST and following G20 research institutes were announced.
 - ⊔ Fraunhofer-Gesellschaft (Germany): Letter of Intent focusing on hydrogen research
 - ⊔ National Renewable Energy Laboratory (USA): Renewed Memorandum of Understanding with newly added collaboration in the field of hydrogen research
 - ⊔ Joint Research Centre (EU): Collaborative research arrangement concerning energy storage technology
 - ⊔ French National Centre for Scientific Research (France): Collaborative research arrangement concerning thermoelectric technology
 - ⊔ French Alternative Energies and Atomic Energy Commission (France): Collaborative research arrangement concerning photovoltaic power generation technology
 - ⊔ National Research Council Canada (Canada): Memorandum of Understanding for research collaborations including the field of clean energy technology

TCFD Summit

- | The TCFD Summit is the international meeting aiming to promote dialogues among the world leaders of the business and financial institutions in the world for the funds to be attracted to companies keen on environmental measures, thereby realizing a virtuous cycle of environment and growth.
- | The TCFD Summit purpose calls for the world to endorse and commit to the TCFD and discuss the future of the TCFD.

Overview of the 2019 Meeting

1. Date and venue

Date: Tuesday, October 8, 2019

Venue: Tokyo (The Capital Hotel Tokyu)

2. Attendees (more than 350 persons from many countries)

- Minister of Economy, Trade and Industry
- Prof. ITO Kunio, Chair of TCFD Consortium; Professor, Ph.D. Graduate School of Business Administration, Hitotsubashi University

[Industry]

- Mr. Peter Bakker, President and CEO, WBCSD
- Mr. SHINDO Kosei, Representative Director and Chairman, Nippon Steel Corporation; Vice Chairman, Japan Business Federation (Keidanren)
- Mr. TOKURA Masakazu, Chairman of the Board, Sumitomo Chemical Company
- Mr. Charles O. Holliday, Chairman, Royal Dutch Shell plc.

[Financial community]

- Mr. MIZUNO Hiromichi, PRI Board member; Executive Managing Director and Chief Investment Officer, GPIF
- Mr. Mark Carney, Governor of the Bank of England; Former Chair of FSB
- Ms. Mary Schapiro, Advisor, TCFD Secretariat; Former Chair of SEC

[ESG Indexes Companies, International Organization etc.]

- Mr. Baer Pettit, President of MSCI Inc.
- Mr. Waqas Samad, CEO, FTSE Russell
- Mr. Martin Skancke, Chair, PRI Board

3. Outline of results

[Themes]

- | “From Divestment to Engagement”
- | “How to Develop Opportunity Assessment?”
- | “Disclosure in Asia: Challenges and Opportunities”

[TCFD Summit summary (excerpt)]

- | The Green Investment Guidance is a useful tool for promoting dialogues between businesses and investors.
- | Deeper understandings concerning evaluations of not only business risks but also opportunities associated with climate change should be gained.
- | Divestment as a strategy has its limitations. Constructive engagement is more effective.
- | It is important to adopt a pragmatic approach to support a smooth transition towards a low-carbon society for supporting continued economic development in Asia.
- | A global-scale virtuous cycle of environment and growth should be accelerated by supports from a wide range of stakeholders in the world.
- | The next summit will be held again in Tokyo in 2020. The TCFD Consortium is expected to support the diffusion of best practices.
- | TCFD plays an important role in promoting the transition to low-carbon economy. It is therefore important that the work of the TCFD should continue.

ICEF

- | The Government of Japan has annually hosted a global conference called “Innovation for Cool Earth Forum (ICEF)” since 2014, launched by Prime Minister ABE Shinzo.
- | ICEF provides opportunities to raise awareness and promote discussion on the latest trend of climate action through innovation of energy and environmental technologies as well as to expand the international network of leading figures of the industry, academia and government.

Overview of the 2019 Meeting

1. Date and venue

Date: October 9 (Wed.) and 10 (Thur.), 2019

Venue: Tokyo (Hotel Chinzanso Tokyo)

2. Attendees (more than 1,000 participants from about 70 countries and regions)

- Minister of Economy, Trade and Industry (video letter)
- Parliamentary Vice-Ministers for Foreign Affairs, Parliamentary Vice-Minister of Education, Culture, Sports, Science and Technology, Parliamentary Vice-Minister of the Environment

[Financial community]

- Mr. MIZUNO Hiromichi, Director, PRI; Executive Managing Director and CIF, GPIF
- Mr. Mark Carney, Governor of the Bank of England
- Ms. Mary L. Schapiro, Vice Chair for Global Public Policy, Bloomberg L.P.

[Hydrogen related]

- Mr. FUKAZAWA Kazuhiro, Executive Vice President, Toyota Motor Corporation
- Mr. ISHIZUKA Hiroaki, Chairman, NEDO
- Mr. Marcel Galjee, Director, Energy & New Business, Nouryon

[Decarbonization in industry]

- Ms. Annette Stube, Head of Sustainability, A.P. Moller-Maersk
- Dr. KOBAYASHI Yoshimitsu, Chairperson, Carbon Recycling Fund Institute

3. Outline of Results

| ICEF 2019 Statement from the Steering Committee

A set of principles and recommendations from the ICEF Steering Committee was announced at the closing session of ICEF 2019.

⌋ The following three key actions should be carried out with unprecedented urgency:

- (1) Inspiring investment in technology, products, and services for green growth
- (2) Involving the industry and consumers in accelerating technologies and innovation for decarbonization
- (3) Internationalizing cooperative efforts for deploying innovation outcomes

| Top 10 Innovations

“Top 10 Innovations” was held to select the most notable recent innovative developments in energy and environment. ICEF 2019 Top 10 innovations were selected through votes by the ICEF 2019 participants.

| Roadmap on Industrial Heat Decarbonization

A draft of the Roadmap was presented and discussed at the side event during the ICEF 2019. After revisions to reflect the comments, the final version was presented at a side event of COP25.