Environment Innovation Strategy (Summary)

January 21, 2020

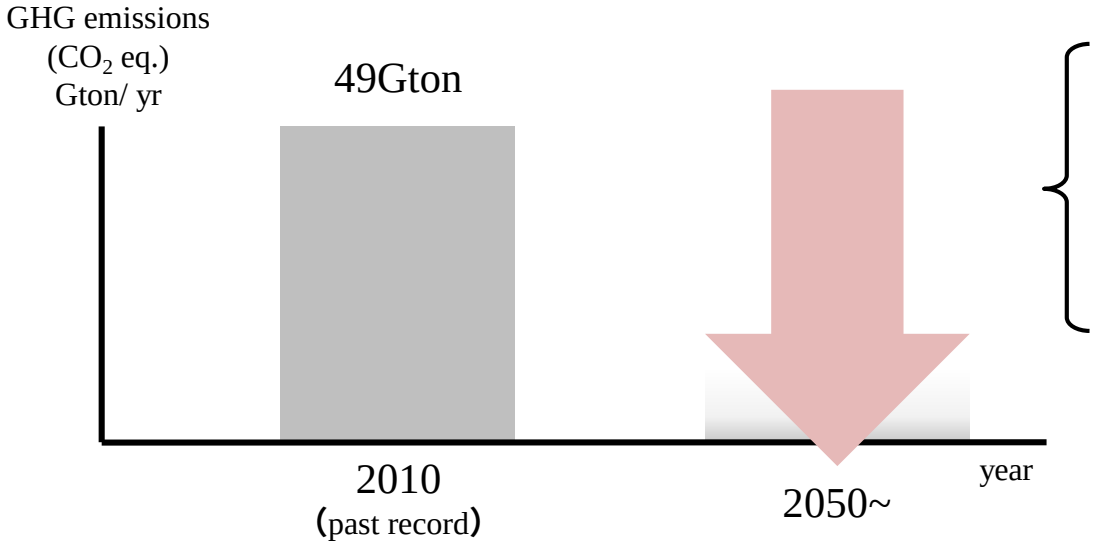
What we aim for with this strategy

○ In the “Long-Term Strategy under the Paris Agreement” (approved by the cabinet in June 2019, hereafter “Long-Term Strategy”), Japan’s government set an ambitious target of a “decarbonized society” as a final goal that should be achieved as early as possible in the last half of the twenty-first century. The government stated the drastic actions required for realizing an 80% reduction of GHG by 2050. Moreover, the government clearly expressed Japan’s contribution to the Paris Agreement including the 1.5-degree goal by sharing Japan's mind and actions in the world.

○ However, a large additional annual cost for reducing GHG emissions, roughly estimated as seven trillion USD, is expected for achieving the 2-degree goal written in the Paris Agreement and further additional cost is needed for the 1.5-degree goal. Therefore, disruptive innovation that enables the early introduction of the new technology with reasonably acceptable cost is absolutely necessary for reducing global GHG emissions. (Japan has contributed through innovation; e.g., one-two hundred fiftieth cost reduction in the photovoltaic cell. See next page.)

○ 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.

※described as “Progressive Environment Innovation Strategy” in the Long-Term Strategy.



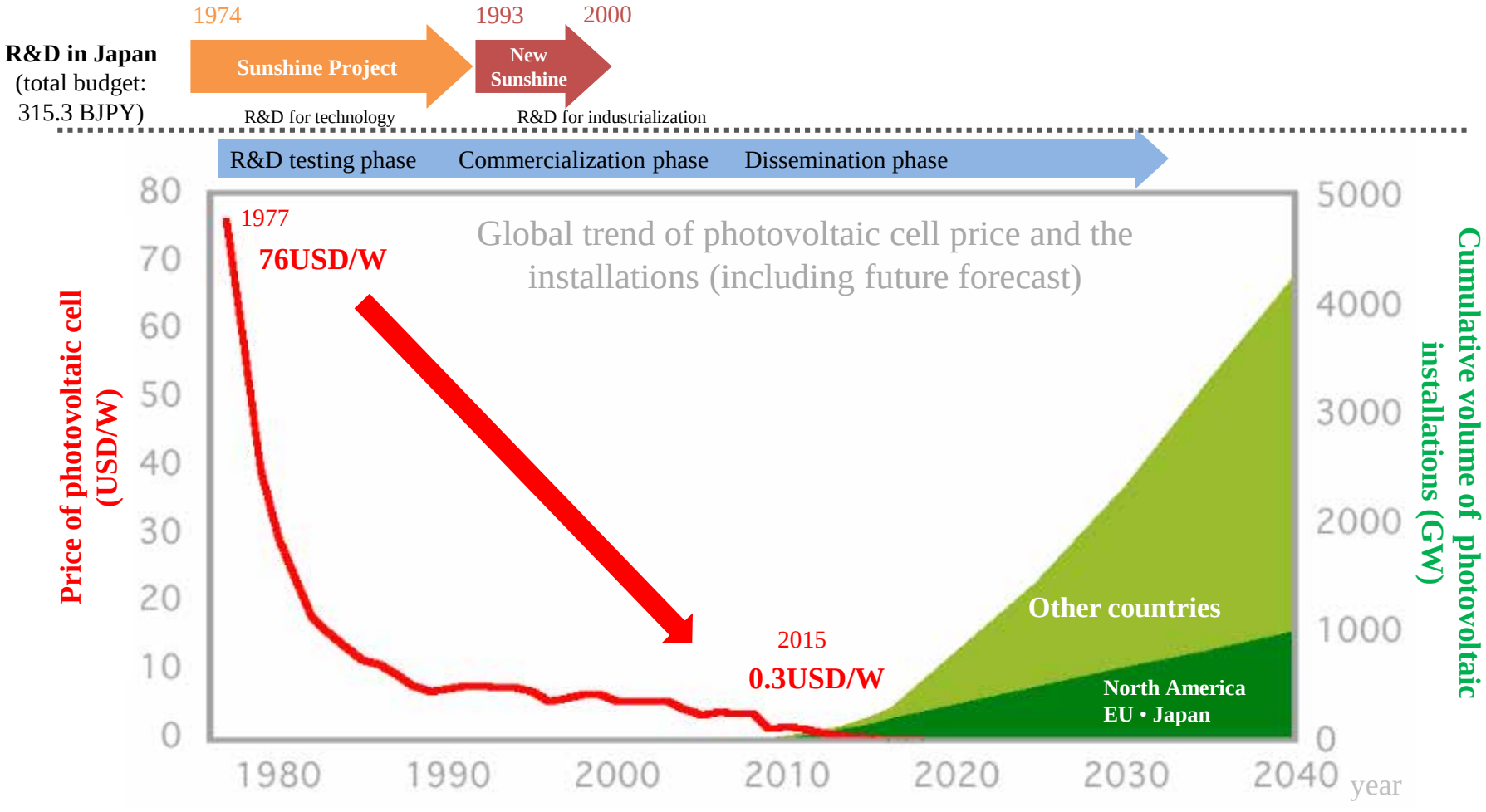
An additional annual cost of 7 trillion USD is needed for GHG reduction by 70% by 2050, which corresponds to the 2-degree goal. 1)

A further additional annual cost is needed for GHG reduction by 100% by 2050, which corresponds to the 1.5-degree goal.

1) A model-based simulation by RITE. The annual additional cost for GHG reduction by 100% is expected to be over ten trillion USD.

(Reference) 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.



Prepared by Ministry of Economy, Trade and Industry (METI) based on CRIEPI report, Bloomberg New Energy Finance &pv.energytrend.com, IEA-World Energy Outlook 2018.

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

Innovation Action Plans

○ 16 important and common technical challenges were extracted from 5 fields; (I) energy transformation, energy demands (II) transportation, (III) industry, (IV) business, household, cross-sectoral and (V) agriculture, forestry and fisheries / absorber. 39 themes having large amount of GHG reduction potential and significantly contributed by Japanese technology were set.

○ Aiming to establish innovative technologies by 2050, which will enable global carbon neutral, (1) concrete cost target of innovation, quantity of global GHG reduction to clarify the social impact, (2) R&D contents, (3) R&D formations, and (4) specific scenarios and actions from basic R&D to practical application and demonstration development are described in the strategy.

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: CO_2-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-NOx hydrogen power generation

4. Next-generation atomic energy and nuclear fusion

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

5. Low-cost CO_2 capture for CCUS and carbon recycling

12) Establishment of low-cost CO_2 capture technology for CCUS and carbon recycling

GHG reductions (CO_2 equivalents, can be counted twice) are estimates to share a common image to be pursued. Assumptions are different.

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 CO_2-free hydrogen). Sophisticated carbon recycling technologies, such as transforming CO_2 into materials and fuels, will be used as much as possible.

7. Independence from fossil fuels (electricity from renewable energy and CO_2-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 CO_2 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 CO_2 and concrete absorbing CO_2

GHG reductions (CO_2 equivalents, can be counted twice) are estimates to share a common image to be pursued. Assumptions are different.

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. CO_2 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 N_2O 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

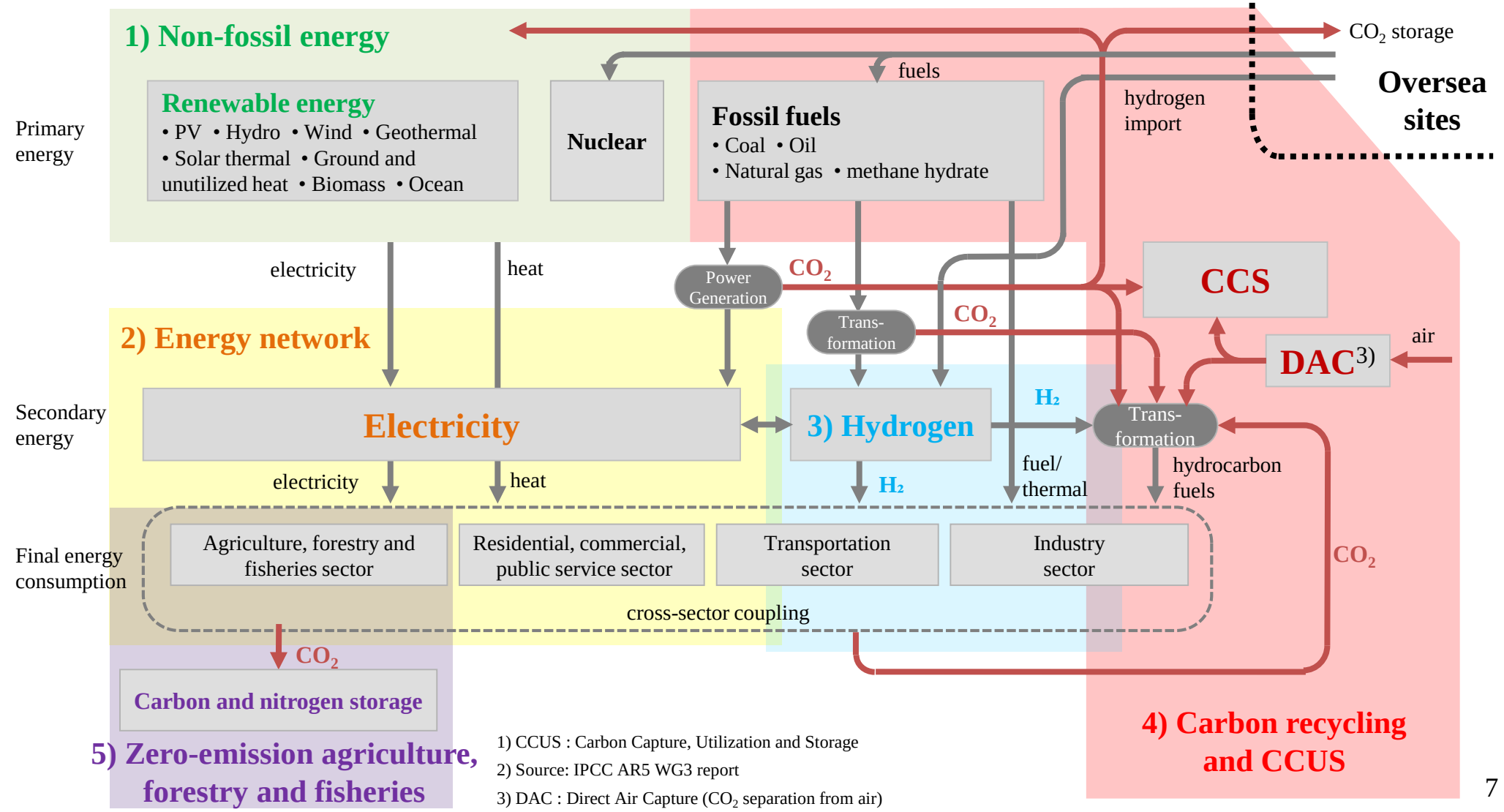
16. Capturing CO_2 in the air

39) Pursuit of DAC (Direct Air Capture) technology

GHG reductions (CO_2 equivalents, can be counted twice) are estimates to share a common image to be pursued. Assumptions are different.

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 CO_2; 5) Agriculture, forestry and fisheries, which account for a quarter of global GHG emissions.



1) CCUS : Carbon Capture, Utilization and Storage
2) Source: IPCC AR5 WG3 report
3) DAC : Direct Air Capture (CO_2 separation from air)

①Non-fossil

Photovoltaics installed anywhere

Efficiency more than twice as high as that of current solar cells

- Target cost: Equal to or less than conventional power sources
- Potential of CO_2 reduction: 7 billion tons/year**

【R&D】

- Solar cells： Establishment of extremely lightweight, highly-efficient (more than 35%), and flexible module manufacturing technologies using new materials (e.g., perovskite) and new structures (e.g., tandem, quantum dot), which enables installation of the solar cells anywhere (e.g., facade of buildings).

【Measures】

- Strengthening international cooperation through Global Zero Emission Research Center (GZR) and RD20.
- Organized enforcement from leading study to practical use.

↑Perovskite-type (lightweight・flexible)

↓For cars

②Energy network

Digital electricity network

Cost equivalent to current electric rate, including energy management cost

- Target cost: Equal to current power source
- Inevitable for regulating the variable renewable energy source***

【R&D】

- Technologies that enables renewable energy as main power source (e.g., VPP, DR*, energy management system as next-generation regulating technology, battery, high-efficiency power electronics technology).

*VPP: Virtual Power Plant, DR: Demand Response

【Measures】

- International cooperation through international conferences such as RD20.
- Collaboration between industry and academia.

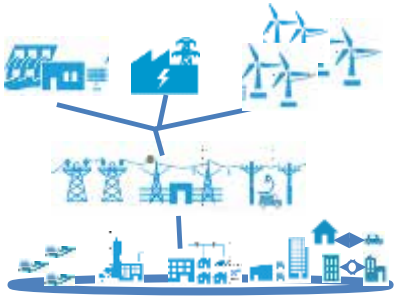


Image for next-generation energy management system

**Potential for reduction of global GHG emissions is estimated by NEDO.

***Since the technology acts as a regulation of the renewable energy, individual GHG reduction potential is not calculated.

③Hydrogen

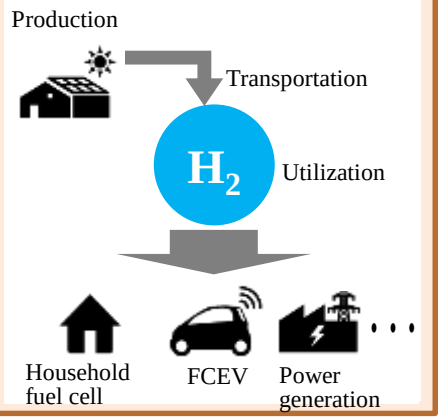
Hydrogen society

Cost equivalent to that of existing energy

- Target cost: 1/10 or less than current production cost
- Potential of CO_2 reduction: 6 billion tons/year*

【R&D】
- Cost reduction to produce CO_2-free hydrogen from renewable energy or fossil fuel with CCUS.
- Transportation and storage of hydrogen (compressed hydrogen, liquefied hydrogen, organic hydride, metal hydride, etc.).
- Establishment of the international supply chain.
- High efficiency fuel cell. Low NOx hydrogen power generation. Utilization of artificial photosynthesis.

【Measures】
- International cooperation through International conferences.
- Collaboration of industry, university, and public institute activated by national R&D projects.



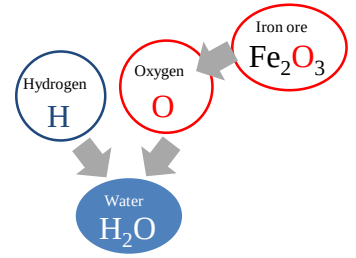
Zero-carbon steelmaking process

Utilization of CO_2-free hydrogen as the reducing agent instead of carbon

- Target cost: Equal to current steel
- Potential of CO_2 reduction: 3.8 billion tons/year*

【R&D】
- Breakthrough technologies for the reduction of iron ore by hydrogen.
- CCUS technology such as CO_2 capture by unused waste-heat.

【Measures】
- Start of feasibility study, and development for practical use by industry.



The reduction of iron ore by hydrogen

④Carbon Recycling, CCUS

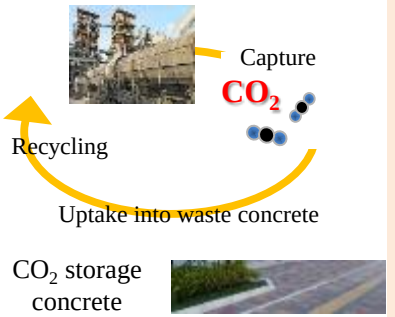
CO_2 uptake using cement and concrete

Utilizing CO_2 emitted during production

- Target cost: Equal to or less than current products
- Potential of CO_2 reduction: 4.3 billion tons/year*

【R&D】
- Capturing of CO_2 from cement burning process. Recycling of CO_2 as cement raw materials and construction materials by uptaking CO_2 into waste cement and concrete.
- CO_2 storage under infrastructure by concrete materials.

【Measures】
- Acceleration of development, including scale-up test, by national R&D projects.



*Potential for reduction of global GHG emissions is estimated by NEDO, etc.

DAC (Direct Air Capture)

Low concentration CO_2 capture from ambient air

- Target cost: Acceptable cost as an industry
- Potential of CO_2 reduction: 8.0 billion tons/year*

【R&D】
- Pursuing technologies for CO_2 capture from ambient air.
- Development of CO_2 fixation technology for the captured CO_2.

【Measures】
- Considering utilization of the Moonshot R&D Program.

Image for DAC

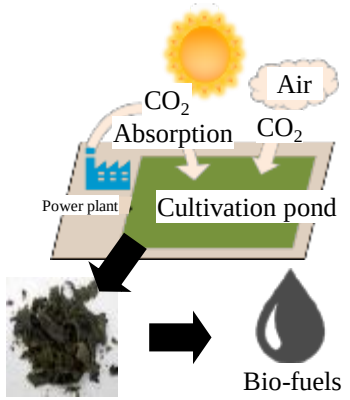
Bio-jet fuel from CO_2

Production of bio-jet fuels and diesel by absorbing CO_2 into Microalgae that grow 1000 times faster than usual

- Target cost: Equal to or less than current jet fuel
- Potential of CO_2 reduction: A part of 2.0 billion tons/year*

【R&D】
- Large-scale demonstration project under various conditions to establish large and constant cultivation systems of Microalgae in the natural environment.
- Establishing a research hub in Hiroshima to conduct the cultivation test using CO_2 from coal-fired power plants. Promoting research to maximize CO_2 absorption efficiency.

【Measures】
- Realizing commercial flights powered by bio-jet fuel in 2030.
- Project operation such as demonstration project in a large-scale cultivation pond.



⑤Zero-emission agriculture, forestry and fisheries

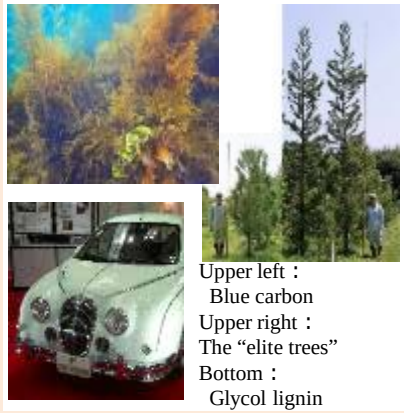
CO_2 absorption and fixation to the farmland, forest, and ocean

Enlarging carbon sinks source by innovative technology

- Target cost: Enabling to continue the business
- Potential of CO_2 reduction: 11.9 billion tons/year*

【R&D】
- Blue carbon such as culture technology of marine algae.
- Biochar application to agricultural soil. Fast-growing trees and the “elite trees”. Wooden high-rise buildings. Low-cost mass production technology of biomass materials such as Glycol lignin.

【Measures】
- Advancement of underlying technology through biotechnology.
- Organized enforcement from leading study to practical use.


Upper left：
Blue carbon
Upper right：
The “elite trees”
Bottom：
Glycol lignin

*Potential for reduction of global GHG emissions is estimated by NEDO, etc.

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.

Basic Research | **Development for application** | **Demonstration** | **Adoption in the Society**

Innovation Action Plans

Acceleration Plans

Green Innovation Strategy Meeting **(appraising existing projects and considering efficient system of promoting R&D)**

Support for young promising researchers (Zero-Emission Creators 500)
(Identifying promising young researchers and supporting joint research with companies)

Feasibility Study Program
(JST[1)], NEDO: identifying innovative technologies and fostering demonstration and implementation)

Utilization of the Moonshot Research and Development Program
(Basic R&D for Innovative technologies for implementation)

1) Japan Science and Technology Agency (JST)

International collaboration at the Global Zero Emission Research Center (GZR)
(Also cooperating with academia-industry-government collaboration of RD20, ICEF, Hydrogen Energy Ministerial Meeting, International Conference on Carbon Recycling, and playing a focal role in the collaboration between universities, public institutions and companies)

Research Center for Basic Energy Sciences ⇄ collaboration through the Zero-Emission Hub Forum

International application
(CEFIA, International standardization)

Zero-Emission Startup Support
(JST, NEDO; Promotion of VC investment for R&D startups)

⇕

Circulating and Ecological Economy
(Social decarbonization, resource circulation)

The Tokyo Bay Zero-emission Innovation Area
(Demonstration site)
Carbon Recycling R&D and Demonstration Base
(R&D for utilizing CO_2 as resources)

Facilitating private investment to innovative technical development
(Promoting green finance through corporate information disclosure in line with the TCFD recommendations and “Zero-Emission Challenge” of promising projects)

Zero-Emission Initiatives (Strengthening international engagement)

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.