STI for SDGs Roadmap
(Tentative)

Mar 25, 2020

Cabinet Office, Government of Japan

Japan's SDGs achievement status

According to the "Sustainable Development Goals Report 2019"*, Japan's SDGs achievement status and outlook are ranked 15th out of 162 countries, and although Goal 4 (Quality education) and Goal 9 (Industry, Innovation and Infrastructure) are highly rated, Goal 5 (Gender Equality), Goal 12 (Responsible consumption and production), Goal 13 (Climate Action) received low rating.

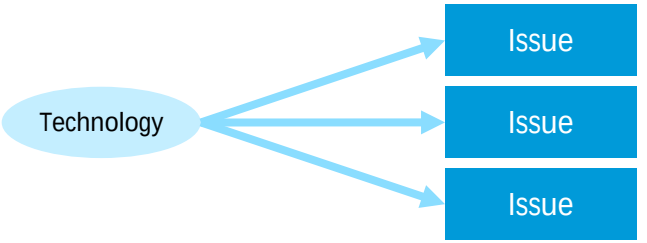
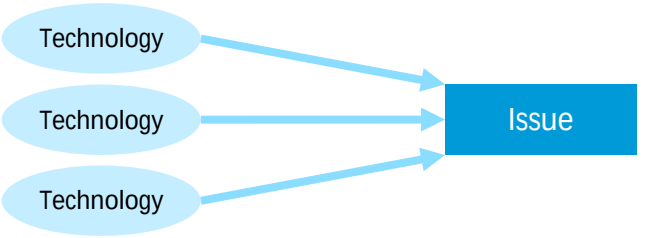
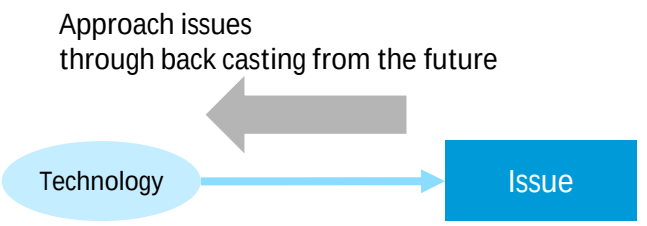
In order to achieve the SDGs in 2030, STI for SDGs Roadmaps should be developed, as shown in the SDGs implementation Guiding Principles (Revised at 2019 year end) to promote initiatives utilizing Science and Technology Innovation.

Evaluation	Goal	Trend
SDG achieved	Goal 4 "QUALITY EDUCATION"	↑
	Goal 9 "INDUSTRY, INNOVATION AND INFRUSTRUCTURE"	↑
Challenges remain	Goal 1 "NO POVERTY"	↗
	Goal 3 "GOOD HEALTH AND WELL-BEING"	↗
	Goal 6 "CLEAN WATER AND SANITATION"	↑
	Goal 8 "DECENT WORK AND ECONOMIC GROWTH"	↑
	Goal 16 "PEACE, JUSTICE AND STRONG INSTITUTIONS"	↗
Significant challenges	Goal 2 "ZERO HUNGER"	↗
	Goal 7 "AFFORDABLE AND CLEAN ENERGY"	↗
	Goal 10 "REDUCED INEQUALITIES"	↓
	Goal 11 "SUSTAINABLE CITITES AND COMMUNITIES"	••
	Goal 14 "LIFE BELOW WATER"	→
	Goal 15 "LIFE ON LAND"	↗
Major challenges	Goal 5 "GENDER EQUALITY"	→
	Goal 12 "REPONSIBLE CONSUMPTION AND PRODUCTION"	••
	Goal 13 "CLIMATE ACTION"	→
	Goal 17 "PARTNERSHIPS FOR THE GOALS"	↗

↓ Decreasing → Stagnating ↗ Moderately Improving ↑ On track or maintaining SDG achievement •• Information unavailable

*Source : Bertelsmann Stiftung "Sustainable Development Report 2019"

Approach for realizing SDGs utilizing STI

Approach	Explanation	Image
1 **Address challenges in various service areas with specific technologies**	With STI's core advanced technologies (such digital technologies), we will work on solving social issues in various service areas around us.	
2 **Address specific challenges by utilizing various technologies**	We will work on solving major issues (environmental issues, climate change, etc.) that need to be addressed and cooperated in the international community with various technologies.	
3 **Address challenges by back casting from the desired future outcome**	In order to realize the SDGs, instead of trying to solve problems from existing technologies and their combinations, we aim to solve difficult problems by back casting from the future of the future and take on challenging ideas and ideas. Promote effective research and development.	

Development of Roadmap according to Approaches

Approach	Strategies and Plans	Roadmaps	Associated SDGs
Approach 1 Address challenges in various service areas with specific technologies	**"AI Strategy 2019"** (June 2019)	Roadmap Ex.1 Social Implementation of AI in Health, Medical Care and Long-term Care fields	
		Roadmap Ex.2 Establish next-generation AI-incorporated transportation, in order to develop a smart city which can be deployed globally	
Approach 2 Address specific challenges by utilizing various technologies	**"Environment Innovation Strategy"** (January 2020)	Roadmap Ex.3 Flexible, lightweight, and highly efficient PV systems to reduce constraints on installation	
		Roadmap Ex.4 "Zero-carbon steel" with innovative technologies such as hydrogen reduction	
Approach 3 Address challenges by back casting from the desired future outcome	**"Moonshot Goal 5"** (2020)	Roadmap Ex.5 By making fully utilizing biological functions of nature, create sustainable food supply industry with no food wastage on a global scale	

*This document summarizes existing strategies, plans, etc. and illustrates them as a roadmap, and does not show the priority areas and priorities that Japan is working on.

AI Strategy 2019

The objective of this strategy is to contribute to solving global issues through the realization of Society 5.0, and to present an environment improvement and measures to utilize AI in the future in order to overcome Japan's own social issues. Formulate an integrated policy package, including educational reform, R & D, social implementation, etc., surrounding AI, to contribute to the world and overcome challenges, and further enhance Japan's industrial competitiveness.

<Overview>

Basic Concept

- Adopt the three principles of "**Dignity**", "**Diversity & Inclusion**" and "**Sustainability**" to realized Society 5.0 and contribute to the SDGs
- Set four strategic targets (Human Resources, Deployment to Real-World, Technologies for Inclusion, Internal Cooperation) that implement the three principles
- Identify initiatives related for "**Building a foundation for the future**" "**Infrastructure for industry and society**" "**ELSI**" to achieve the Strategic Objectives.

Strategic Objective I:
Human Resources
Become a country that nurtures and attracts talents that are most suitable for the AI era in Japan, and establish a mechanism to achieve sustainability

Strategic Objective II:
Deployment to Real-World
Promote AI in real-world industries and secure the position as the world's leader

Principles (Society to realize)
I Dignity
I Diversity & Inclusion
I Sustainability

Strategic Objective III:
Technologies for Inclusion
Establish a series of technical systems to realize the philosophy and implement a mechanism for operation

Strategic Objective IV:
International Cooperation
Building an international AI research, education and social infrastructure network

Identify initiatives

Creation of foundation for the future		Creation of foundation for industry and society			ELSI
Education Reform	Innovation Environment	Social Change	Data Platform	AI Era Digital Government Small and Medium Sized Enterprises and Venture Companies	AI Principles

*Source: Cabinet Office, "AI Strategy 2019"

Development of Roadmaps: Approach 1

AI Strategy 2019

To achieve our strategic targets, we will identify each **targets** and **initiatives** for each of the following three fields: "**Building a foundation for the future**", "**Infrastructure for industry and society**", and "**ELSI**" (Educational Reform, Innovation Environment, Social Change, Data Platform, support for digital and government small-medium and startup companies, AI Principles)

<Targets and Initiatives>

		Detailed Main Objects	Detailed Main Initiatives
Building a foundation for the future	**Educational Reform**	l For the citizens to learn the basics of "mathematic, data science, and AI", which are equivalent of "reading, writing and abacus" in the digital society, and to have these talents excelling in various fields/industry	• Literacy: Deploy ICT Experts for each High School, provision of one PC/tablet for each student • Applied foundation: Double Majors (AI X Specialized fields) • Expert: Global opportunities for young researcher, AI schools for Project Based Learning • Official Certification to excellent education programs
	Innovation Environment	l Research Promotion System that brings together knowledge from around the world l AI technology which Japan can take leadership l Build a AI Research and Development model that is tailored to Japan	• Improve the support for emergent research by researchers from various areas • Establishment of next-generation AI platform technology which could lead the world • Revision of AI core center, establishment of AI research and development network
Infrastructure for industry and society	**Social Change**	l Application to the service structure of the real-world industry l Establishment of Inclusion technology l Promote standardization and implement system architecture which promotes real-world implementation of R&D results	• Health, Healthcare & Nursing care service: World's leading Medical AI Hub, data infrastructure development • Agriculture: On-site implementation of smart agriculture technology, growth industrialization • National resilience: establishment of infrastructure data platform • Transportation and Logistics: Realization of AI terminal, construction of logistics-related data infrastructure • Regional Revitalization: Building an universal architecture for Smart Cities
	Data Platform	l Build next-generation AI data platform through international collaboration	• Data Platform: Full-scale operation and cooperation of data platform • Trust: Development of a trust data distribution platform
	Digital Government **Support for Small and Medium Sized Enterprise and Venture Companies**	l Reduce costs of public services and local government and improve operational efficiency l Improve productivity of mid-sized companies utilizing AI	• Standardization of AI services that can be used safely by local government • Consideration of measures to support medium-sized companies
ELSI	**AI Principles**	l Dissemination of social principles and establishment of international corporation system	• Establishing social principles of human-centric AI, building a multilateral framework

Roadmap Ex.1

Roadmap Ex.2

*Source: Cabinet Office "AI Strategy 2019"

Roadmap Ex.1

Social Implementation of AI in Health, Medical Care and Long-term Care fields

Background	• Japan's facing social issues, such as being the first country to face the full-blown effects of a declining birthrate and an aging population along with the resulting rapid increase in social security costs; decline in the workforce and shortage of healthcare and long-term care workers
Mid-Long Term Goals	• Achieve better health for the public, improved levels of medical and long-term care, and an improved working environment for health-related workers while simultaneously reducing the burden on taxpayers
Specific Goals	1. Provision of a data infrastructure for utilization of AI in the health, medical care and long-term care fields 2. Promotion of AI technology development and reducing the burden on healthcare workers through AI utilization for medical treatment 3. Promotion of the introduction of AI / IoT technology to the field of prevention and long-term care, and reducing the burden on care workers by using AI / IoT for long-term care 4. Formation of the world's leading medical AI market and medical AI hub 5. Education using AI in training facilities and training centers for medical professionals, and recurrent education for healthcare workers
Related measures (Reference material)	• Cabinet Office "AI Strategy 2019"

Development of Roadmaps: Approach 1

Roadmap Ex.1

Social Implementation of AI in Health, Medical Care and Long-term Care fields

AI

Specific Objectives	Action 2020	Action 2025	Action 2030	Main Objective
1 Provision of a data infrastructure for utilization of AI in the health, medical care and long-term care fields	• Trend survey of AI development and utilization in foreign countries • Operation of a system for the smooth and fair use of anonymously processed medical information • Cross-disciplinary information infrastructure design, accumulation of various data and establishment of an AI data • infrastructure • Creation of a system for collecting data linked to region, in data obtained from daily life • Building a framework to provide data and annotation and other infrastructure to partners	• Exploring data infrastructure for sustainable AI development to support image diagnosis		Maintaining an environment in which people feel assured that they can receive the most advanced and effective treatments as wells as high quality long-term care regardless of location, reducing the burden on medical care and long-term care providers Related SDGs
2 Promotion of AI technology development and reducing the burden on healthcare workers through AI utilization for medical treatment	• Investigation into an AI application to drug discovery, toxicity evaluation, etc. • Investigation into utilization of AI in drug development other than mentioned above and medical practice	• Utilizing AI in construction of a framework for drug discovery target • Utilizing AI in development and evaluation of image diagnosis support equipment, and infrastructure development for social implementation • Utilizing AI for development of medical devices and telemedicine services and evaluation of them, and development of infrastructure for social implementation • Utilizing AI for Development of early detection and diagnosis technology for diseases		
3 Promotion of the introduction of AI / IoT technology to the field of prevention and long-term care, and reducing the burden on care workers by using AI / IoT for long-term care	• Starting examination of the provision of health maintenance/promotion services by the private sector • Development and introduction of a consultation system that introduces AI/IoT to long-term care facilities • Implementation of prevention and long-term care field verification projects, and building a support system for AI start-up businesses	• Realization and national expansion of an AI system that supports high-quality long-term care services • Review of the system side and operation side for the utilization of technology established • Promotion of AI/IoT data utilization on personal information controllability		

Roadmap Ex.1

Social Implementation of AI in Health, Medical Care and Long-term Care fields

Specific Objectives	Action 2020	Action 2030	Main Objective
AI 4 Formation of the world's leading medical AI market and medical AI hub	• Preparation of a progress schedule chart for the promotion of AI development based on the roadblock cancellation process schedule selected at the "Consortium for Accelerating Development of AI in the field of Health and Medical Care" of the Ministry of Health, Labor and Welfare and an overview compiled in the consortium • Strengthening collaborative research such as AI development between companies (include foreign capital) and public institutions (such as public hospitals, universities, national research institutions) • Systematization of inclusion technology in the medical and long-term care fields • Based on the needs of each country under such initiatives as the Asia Health and Wellbeing Initiative, strengthening efforts including the following examples for cooperation with overseas (in particular, ASEAN member states and India) regarding data infrastructure, AI medical care, etc. Ø Providing high-grade medical care to workers/ exchange students/ travelers coming from abroad and workers/ exchange students/ travelers going overseas (in cooperation with a series of measures already implemented, especially to aim to put into practice by focusing on the AI medical field where data accumulation is important) Ø Promoting the use of medical AI and data in government and certain institutions and expanding it to other institutions Ø Partnering with overseas medical institutions such as those in Asia in areas where AI implementation is proceeding such as Diagnostic imaging, cancer genome analysis, etc. and enabling access to a larger amount of data while promoting overseas expansion of AI medical system		Maintaining an environment in which people feel assured that they can receive the most advanced and effective treatments as wells as high quality long-term care regardless of location, reducing the burden on medical care and long-term care providers Related SDGs 
5 Education using AI in training facilities and training centers for medical professionals, and recurrent education for healthcare workers	• Examination of educational content using AI in training facilities and training centers for medical professionals • Examination of healthcare workers training that can develop and utilize AI • Establishment of a framework for AI education programs for adults for healthcare workers		

Roadmap Ex.2

Establish next-generation AI-incorporated transportation, in order to develop a smart city which can be deployed globally

Background	• In tandem with the expected aging of society, further increases in the ratio of traffic accidents involving the elderly are expected • There are fears that the issue of securing methods of mobility will become increasingly important, as further population decrease and depopulation will lead to less demand for public transit and not enough drivers, making it difficult to continue the local public transit network • A lack of truck drivers is already an issue in the logistics sector. With the increasing demand in logistics due to the growth of e-commerce, the lack of workers in logistics is a pressing concern as there is also currently a reliance on elderly drivers
Major opportunities	• Activate and sustain public transportation services by securing and enriching mobility methods to regional and tourist destinations
Stakeholders	• Japan Cabinet Office • Japan Ministry of Internal Affairs and Communications • Japan Ministry of Land, Infrastructure, Transport and Tourism (MLIT) • Local public entities • Transportation businesses • Local businesses
Related measures (Reference material)	• Cabinet Office: AI Strategy 2019 • MLIT: Pushing Forward Regional Model Design for Japanese MaaS Development! The First Year of MaaS! 19 Businesses Selected as Leading Model Businesses • Cabinet Office: Public-Private ITS Initiative and Roadmap 2019

Development of Roadmaps: Approach 1

Roadmap Ex.2

Establish next-generation AI-incorporated transportation, in order to develop a smart city which can be deployed globally

Technologies	Major opportunities	Action 2020	Action 2025	Action 2030	Vision
AI 1 AI-based on-demand transportation 2 MaaS data sharing infrastructure 3 Autonomous driving	Activate and maintain public transportation services by securing and enriching mobility methods to regional and tourist destinations	• Prove the practicality of and disseminate AI-based on-demand transportation that uses AI to optimize vehicle allocation • Develop, prove the practicality of, and disseminate data infrastructure that collects and uses data from MaaS app users and transportation operators • Prove the practicality of and disseminate autonomous driving services based on 1. private cars 2. logistics services and 3. mobility services 1. Private cars ØAdvanced safe driving support system ØAutonomous driving on normal roads (Lv 2) ØAutonomous driving on highways (Lv 2 → 3 → 4) 2. Logistics services ØAutonomously driving trucks on highways (Lv 4) ØTrucks driving in fleets on highways (Lv 2+) ØUnmanned autonomous delivery service in limited areas 3. Mobility services ØAutonomously driving buses on highways (Lv 2+) ØUnmanned autonomous mobility service in limited areas (Lv 4)	(Policy not set)	Incorporate cutting-edge technology and public/private data in urban planning to optimize urban management1 and solve urban/regional issues Applicable SDGs

*1 How citizens live, managing urban activities and infrastructure, advancing usage, increasing efficiency, optimizing facilities, creating infrastructures for sharing data, etc.

Environment Innovation Strategy

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.

<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 promising young 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

Development of Roadmaps: Approach 2

Fields	Challenges	Themes
5 fields	16 challenges	39 themes

Environment Innovation Strategy

Fields	Challenges	Themes
Ⅰ. Energy transformation 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 production. These measures will lead to decarbonized and affordable energy supply.	1. Renewable energy as a main power source	①Flexible, lightweight, and highly efficient PV systems to reduce constraints on installation (Roadmap Ex.3) ②**Supercritical geothermal systems** ③**Floating offshore wind turbines applicable to harsh environments** 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**
	2. Resilient electricity network using digital technologies	
	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 CO2 capture for CCUS and carbon recycling	⑫**Establishment of low-cost CO_2 capture technology for CCUS and carbon recycling**
Ⅱ. Transportation 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 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 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** (Roadmap Ex.4) ⑰**Higher efficiency of metal resource circulation** ⑱**Advanced plastic resource circulation** ⑲**Producing plastics by artificial photosynthesis technology** ⑳**Fine chemicals with innovative manufacturing process and Carbon Recycling**
	8. Carbon recycling technologies to transform CO_2 to materials and fuels	㉑**Low-cost methanation** ㉒**Cement made from CO_2 and concrete absorbing CO_2**

*Source: Integrated Innovation Strategy Promotion Council "Environment Innovation Strategy"

Development of Roadmaps: Approach 2

Environment Innovation Strategy

Fields	Challenges	Themes
5 fields	16 challenges	39 themes

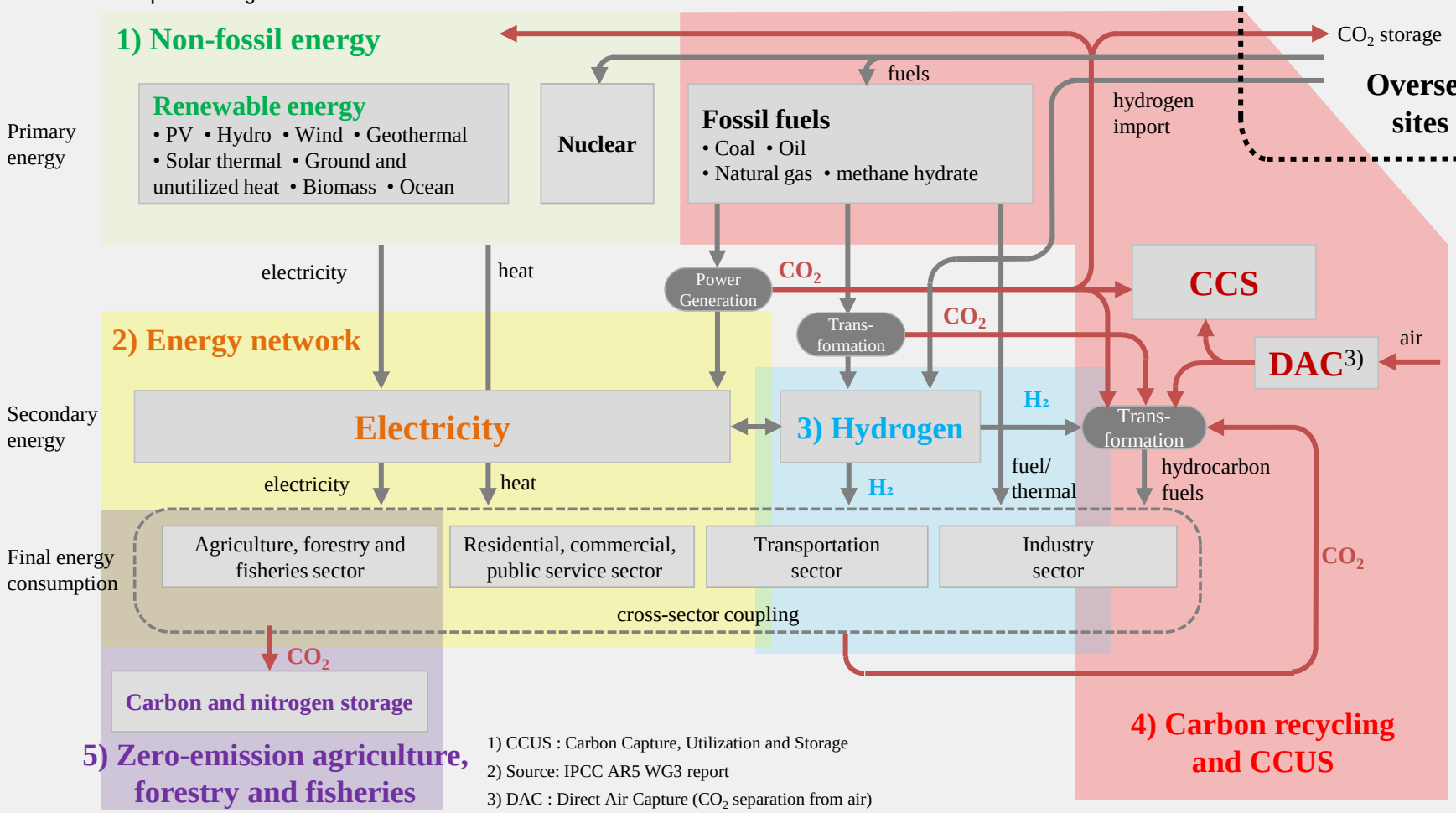
Fields	Challenges	Themes
Ⅳ. Business, household and other cross-sectoral fields Advanced technologies will be widely adopted in the business and household sectors, and the social system and lifestyle will change with advanced information and communication technologies.	9. Implementation of advanced GHG 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 modification**
	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 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 biomass materials** ㉞**Smart forestry and fast-growing trees** ㉟**Blue carbon (carbon sequestration in the marine ecosystems)** ㊱**Breeding and optimal management for farmland and livestock**
	14. Reduction of methane and N2O from agriculture and livestock industry	
	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**

*Source: Integrated Innovation Strategy Promotion Council "Environment Innovation Strategy"

Environment Innovation Strategy

<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)

*Source: Integrated Innovation Strategy Promotion Council "Environment Innovation Strategy"

Roadmap Ex.3

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 CO_2 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.
Related measures (Reference material)	• Integrated Innovation Strategy Promotion Council ”Environment Innovation Strategy"

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.

Roadmap Ex.3

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

Technologies / Action		Vision
Underlying technology phase	**Demonstration and practicability deployment phase**	Renewable energy will be made a main power source by drastic improvement of 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.

- Underlying technology development
  - Perovskite
  - Next-generation tandem type
  - Group III-V
  - ⋮ Studying multiple competing technologies in parallel
- Stage-gate (Shortlisting promising technologies)
- Stage-gate (Shortlisting promising technologies)
- Implementation of R&D with consideration for application to buildings (walls, windows)
- Implementation of R&D with consideration for application to factory roofs
- Implementation of R&D with consideration for application to mobility
  - Technology for low cost, high durability, and high efficiency
  - Systemization (application technology)
- ⋮
  - Further performance improvement
  - Mass-production technology
  - Promoting efforts for adoption in the society
- ⟨ Cutting-edge/innovative research at universities ⟩
  - Solar cells base on a new theory
- Supply-chain development, international standardization, reuse and recycling technology, etc.

Applicable SDGs

Roadmap Ex.4

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

Target	• Super-innovative technologies such as hydrogen reduction steelmaking will be developed to produce “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 CO_2-free hydrogen at a cost lower than the 2050 target cost of 20 JPY/Nm^3 at the plant gate . The global amount of CO_2 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 CO_2 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.
Related measures (Reference material)	• Integrated Innovation Strategy Promotion Council ”Environment Innovation Strategy"

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

Roadmap Ex.4

"Zero-carbon steel" with innovative technologies such as hydrogen reduction

Technologies / Action

Underlying technology phase

Demonstration and practicality development phase

COURSE50: hydrogen reduction in blast furnace (internal H_2 supply)

Field test

Super COURSE50: hydrogen reduction in blast surface (H_2 form external source)

Adoption

Initial R&D phase

Underlying technology phase

Demonstration and practicality development phase

Hydrogen reduction steelmaking: hydrogen reduction without blast furnace, etc.

Conceptual designing for hydrogen-reduction steel production process
Gathering basic data for reduction
Identifying challenges in R&D
(Expanded use of hydrogen reduction method in blast furnaces, direct reduction process, etc.)

・Stage-Gate process (shortlisting promising technologies)

Adoption

CCS: Capturing CO_2 from blast furnace emissions

CCU: Creating market value for CO_2 from steelworks

Vision

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.

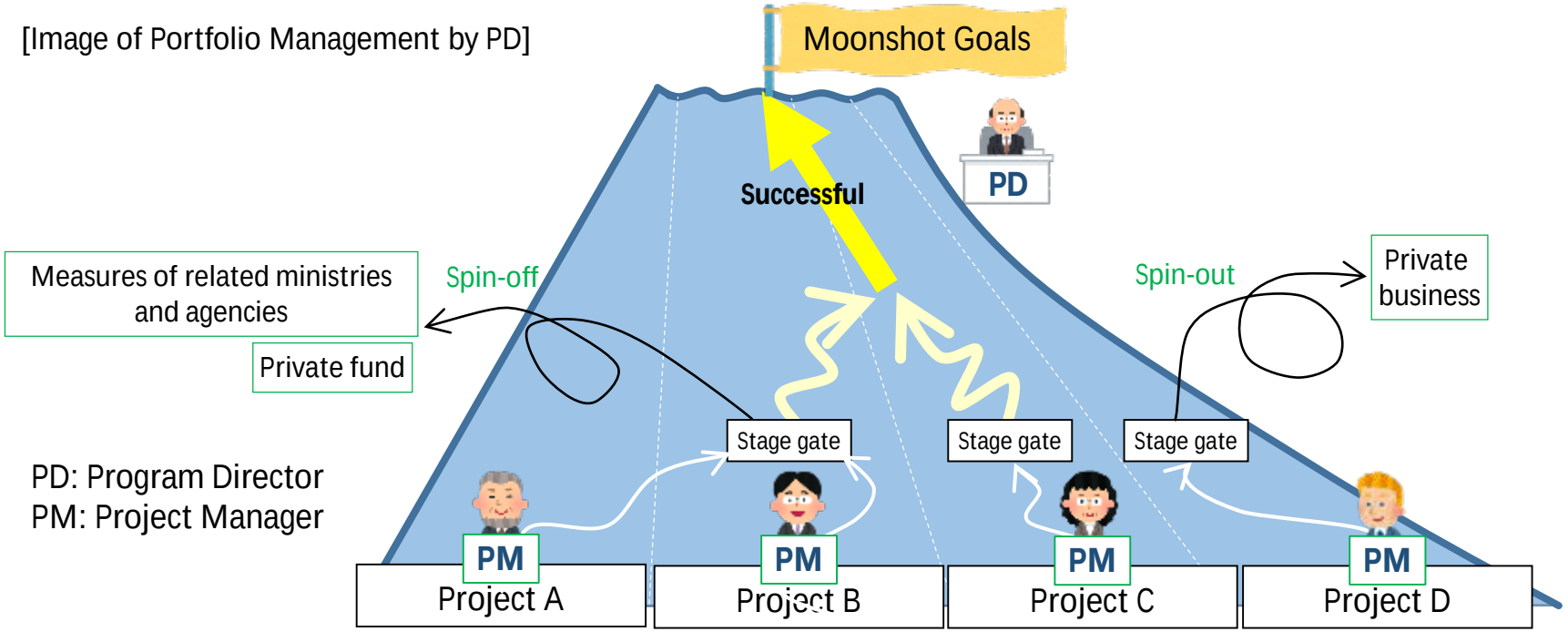
Applicable SDGs

Moonshot Research and Development Program

Point of the Moonshot Research and Development Program

(1) The government sets ambitious goals and concepts for societal issues that are difficult to tackle but will have profound impact once resolved.
(2) Opens call for domestic and foreign top-class researchers as PM*1s under the direction of the PD*2 who oversees multiple projects. *1 Project Manager, *2 Program Director
(3) Builds a portfolio overlooking the program and promotes challenging R&D without fear of failure.
(4) Reviews a portfolio flexibly by stage-gates and actively encourages utilization of the R&D results. Establishes the most advanced research support system by utilizing a data management infrastructure.
(5) 100 billion yen was appropriated in the supplementary budget for FY2018, and a fund was created. 15 billion yen was appropriated in the supplementary budget for FY2019. Supports the program up to 10 years.

[Image of Portfolio Management by PD]



*Source: Cabinet Office, "Overview of Moonshot Research and Development Program"

Moonshot Research and Development Program

Goals

To realize "Human Well-being", six Moonshot goals (MS goals) were decided in the area of society, environment, and economics. **(Council for Science, Technology and Innovation. Jan.23, 2020)**

Society

Turning the aging society into the innovative and sustainable society by harnessing diversity through techno-social transformation

Environment

Recovery for global environment and growth of civilization

Economics

Exploring frontiers with science and technology

6 MS goals to be achieved by 2050

- Goal1: Realization of a society in which human beings can be free from limitations of body, brain, space, and time by 2050.
- Goal2: Realization of ultra-early disease prediction and intervention by 2050.
- Goal3: Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.
- Goal4: Realization of sustainable resource circulation to recover the global environment by 2050.
- Goal5: Creation of the industry that enables sustainable global food supply by exploiting unused biological resources by 2050. — Roadmap Ex.5
- Goal6: Realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security by 2050.

"Moonshot for Human Well-being"

*Source: Cabinet Office, "Overview of Moonshot Research and Development Program"

Development of Roadmaps: Approach 3

Roadmap Ex.5

By making fully utilizing biological functions of nature, create sustainable food supply industry with no food wastage on a global scale

Background	• We have been using a variety of technologies to supply food as the world's population has grown, but have also caused various problems such as soil degradation and polluting of river and groundwater. In the future, to increase food production and preserve the global environment at the same time, we must develop fully sustainable food production system that fully utilizes biological function of nature • In addition, a large amount of food is wasted mainly in developed countries, and obesity and lifestyle-related diseases has become a growing societal issue. The challenge is to develop and globally apply a solution that eliminates waste of food and promotes rational consumption behavior for health and the environment
Major opportunities	• Achieve both food supply expansion and environmental protection • Reduce food loss to zero
Principal entity	• Japan National Agriculture and Food Research Organization
Related measures (Reference material)	• Goal 5 of the Moonshot Goals (Decided at the meeting of the Council for Science, Technology and Innovation on January 23, 2020)

Development of Roadmaps: Approach 3

Roadmap Ex.5

By making fully utilizing biological functions of nature, create sustainable food supply industry with no food wastage on a global scale

Major opportunities	Technologies	Action 2030	Action 2050	Vision
Achieve both food supply expansion and environmental protection	1 Food production system	• Develop and prove the practicality of a full-cycle food production system using biological functions to their full potential Example research and development projects Ø Discover the mechanisms that could make plants resilient against poor growing conditions Ø Develop plant strains and other organisms with desirable functions by building their DNA from scratch Ø Develop technologies to make maximum use of nutrients and reduce production of greenhouse gases through complete control over soil microbes Ø Develop technologies that completely control plant diseases and pests without damaging the ecosystem Ø Develop an organic cycle using plants or seaweed developed to absorb large amounts of CO_2	• Develop a full-cycle food production system	By making full use of untapped biological functions, we hope to create a globally sustainable food supply and production that creates no waste by 2050 Applicable SDGs
		• Engage in discussions on ethical, legal and social implications	• Disseminate globally	
Achieve zero food loss	2 Food consumption system	• Develop and prove the practicality of a prototype method for encouraging logical food consumption that takes into account health and the environment Example research and development projects Ø Develop a system that can virtually match and supply many types of food demands instantly Ø Develop ultra-long lasting food preservation technologies using biological functions to their full potential Ø Develop technologies to effectively convert/reuse food, giving attention to the environment or health, such as developing a 3D printer cooking system that reuses excess crops or home food waste as cartridges for the system Ø Develop technologies to convert food and green waste into food or farm feed by fully utilizing the biological functions	• Develop a method for encouraging logical food consumption	
		• Engage in discussions on ethical, legal and social implications	• Disseminate globally	

*This proposal was prepared based on the R&D concept, further details will be provided in the future under the guidance of the program director