Research and Development of Hydrogen Technology ICEF

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New Energy and Industrial Technology Development Organization (NEDO)
Technology Strategy Center
Energy System and Hydrogen Unit
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"Hydrogen Strategy around the World"

- **"Basic Hydrogen Strategy" has been firstly established by Japan in 2017**
- France & Korea followed and in 2020 EU & Germany established hydrogen strategy. China schedules to open the industrialization planning of hydrogen

EU

July 2020 Hydrogen strategy established
Hydrogen produced by renewable energy would be promoted strongly
"European clean hydrogen alliance" established
- **Electrolysis 40GW by2030**

European Committee has much interests in investment for preventing global warming.(Economy recovery plan)（May 2020）。
Promoting Horizon Europe

Japan

"Basic Hydrogen Strategy" has been firstly established in 2017

Germany

Hydrogen strategy established June 2020
9 billion Euro for commercialization and industrialization of hydrogen technology
- **Electrolysis 5GW by 2030**
  10GW by 2040年

China

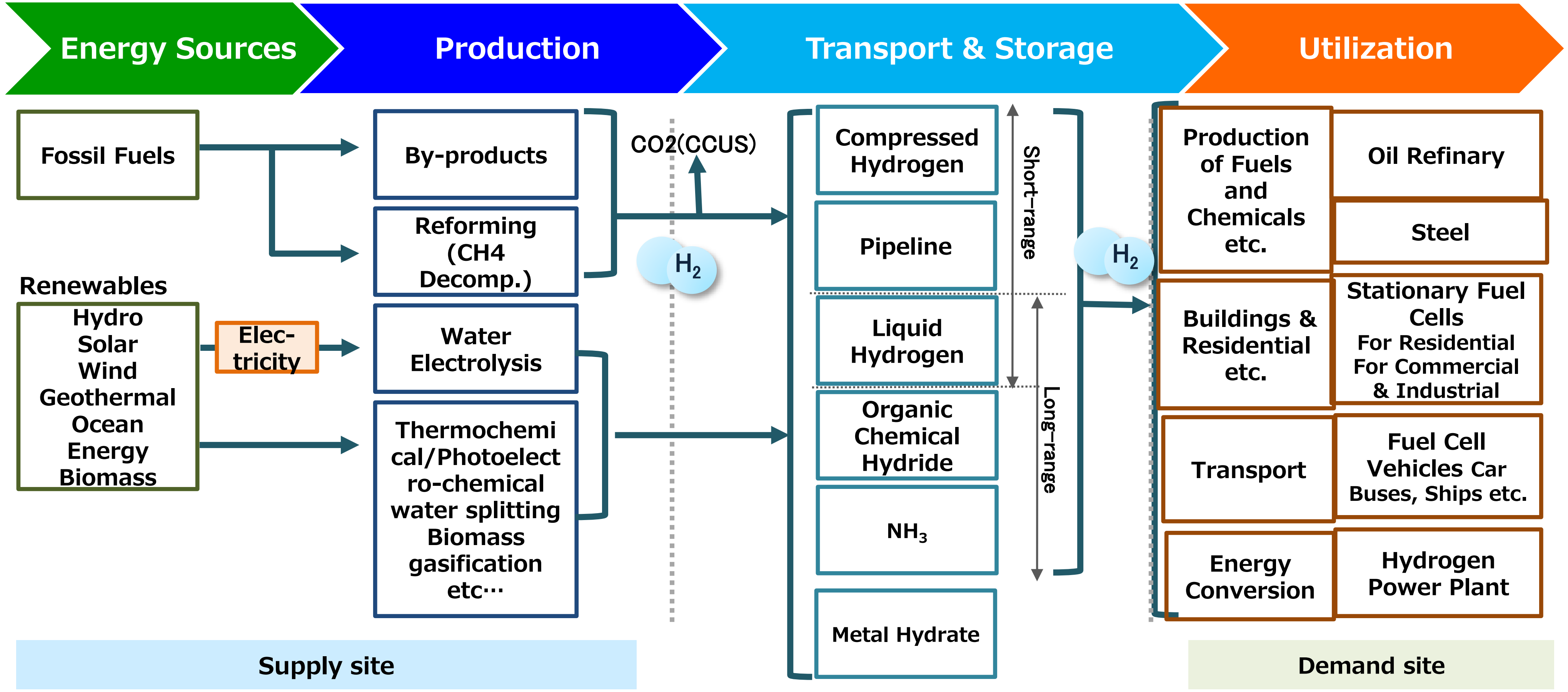
2016 part of hydrogen strategy opened
2020 hydrogen storage and industrialization planning will be opened

Korea

2019 hydrogen strategy established

Why Hydrogen?

- **Energy Security**: Hydrogen can be produced from various energy sources.
- **Environmental:** Hydrogen does not emit CO_2. Promote Decarbonization
- **Energy Conservation**: High energy efficiency with combining electric and thermal energy by use of fuel cell



Hydrogen Production without CO_2 Emission

- Development and field test of hydrogen production with low CO_2 emission by water electrolysis using renewable energy are widely conducted.
- The hydrogen cost varies greatly depending on technology and regional characteristics(cost of renewable energy).
- For example, under low-cost renewable energy, hydrogen production costs of 0.15 to 0.37 USD/Nm^3H_2 in the Middle East and 0.27 to 0.35 USD/Nm^3H_2 in Europe are estimated[1)].

1) Source : The Future of Hydrogen（IEA 2019)

The world's largest hydrogen production facility "FH2R" using renewable energy & electrolysis completed in Fukushima, JAPAN. (Source: NEDO HP) (March 2020)
※1 Stack size is 10 MW = world's largest

Production technology	Alkaline water electrolysis	PEM(Polymer Electrolyte Membrane) electrolysis
Technology Readiness Level	Large scale development～Field test (TRL9) [2)]	Large scale development～Field test (TRL8) [2)]
Efficiency	65% (LHV) [3)]	57% (LHV) [3)]
Achievements and trends	Nel (Norway), Hydrogenics (Canada), Asahi Kasei (Japan), etc. Asahi Kasei participates in field test projects in Japan and Europe.	Siemens (Germany), Nel (Norway), Hydrogenics (Canada), ITM Power (UK), Hitachi Zosen (Japan), etc.

2) Source : Hydrogen Supply Chains (2018) 3) Source : IRENA Hydrogen from renewable power 2018

Innovative technology (example)
SOEC (Solid Oxide Electrolysis Cell) electrolysis
AEM electrolysis

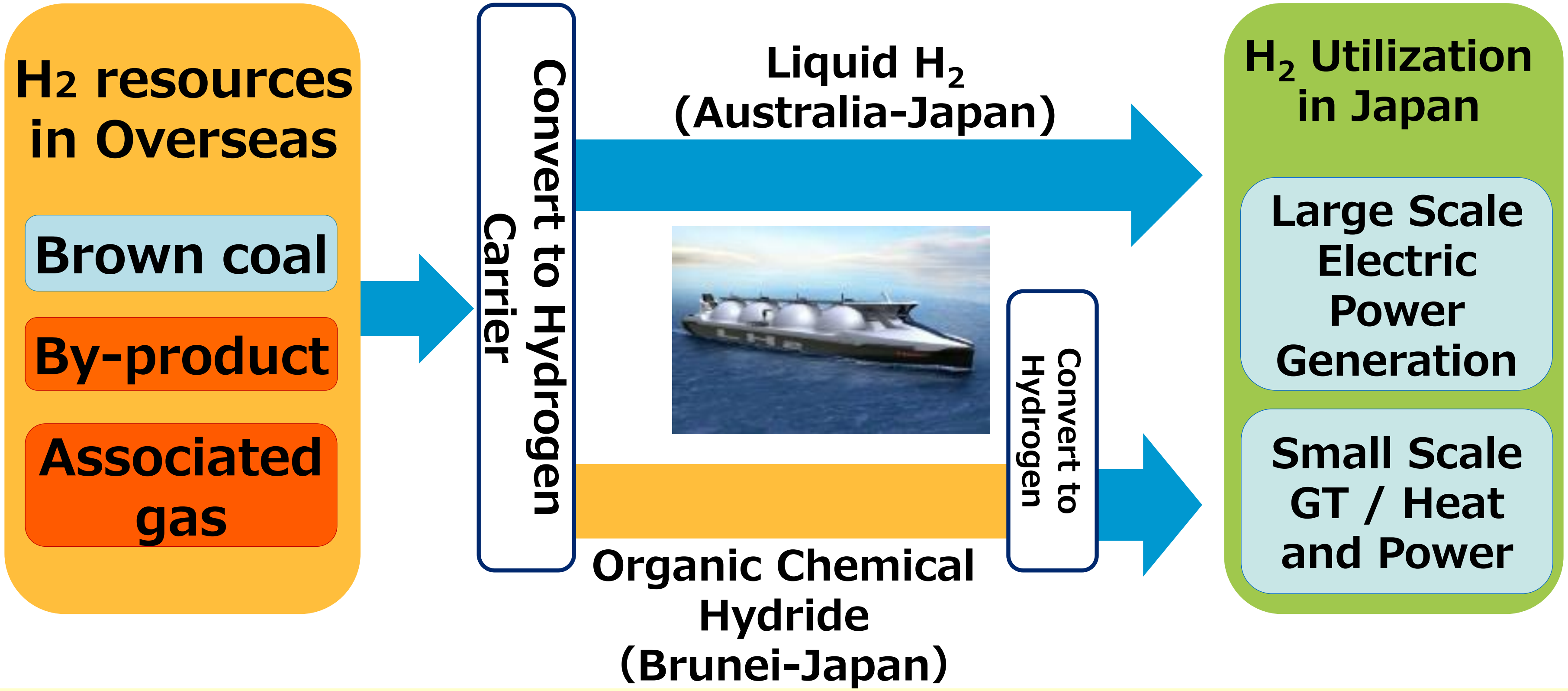
Transport and Storage of Hydrogen

- Long-distance transportation technology is extremely important for establishing the international supply chain of hydrogen.
- Japan was the first to develop technology and field tests for long-distance marine transportation.

Carrier	Features and Challenges	Innovative technology (example)
Liquefied hydrogen	**1/800 volume of compressed hydrogen.** Suitable for supplying **high purity hydrogen.** Challenges in improving liquefaction efficiency and reducing boil-off gas.	Development of innovative hydrogen liquefaction technology (High efficiency)
Organic chemical hydride	**As a liquid chemical product at room temperature and pressure,** it can be transported by a chemical tanker, etc. It is necessary to secure heat during dehydrogenation.(such as MCH)	Development of new organic hydride synthesis technology
Ammonia	**Higher volume hydrogen density** compared to other carriers. Odor and acute toxicity, so care must be taken when handling	Small-scale ammonia production technology from renewable energy
Pipeline	Already commercialized (Mainly domestic transportation)	
Metal hydride	It is not suitable for transportation because the storage capacity per weight is small. In a Power to Gas field test, this is being applied to stationary hydrogen storage. The safety is high (no ignition, etc.)	Development of lightweight and high capacity hydrogen storage material

Project on International Hydrogen Supply Chain

- NEDO started international hydrogen supply chain project.
- Hydrogen is produced from unutilized resources, such as Brown coal, in overseas, converted to hydrogen carrier, and transferred to Japan.



Interest in hydrogen exports from resource-rich countries

Saudi Arabia : Hydrogen production from crude oil (EOR+CCS),Use of renewable energy + water electrolysis

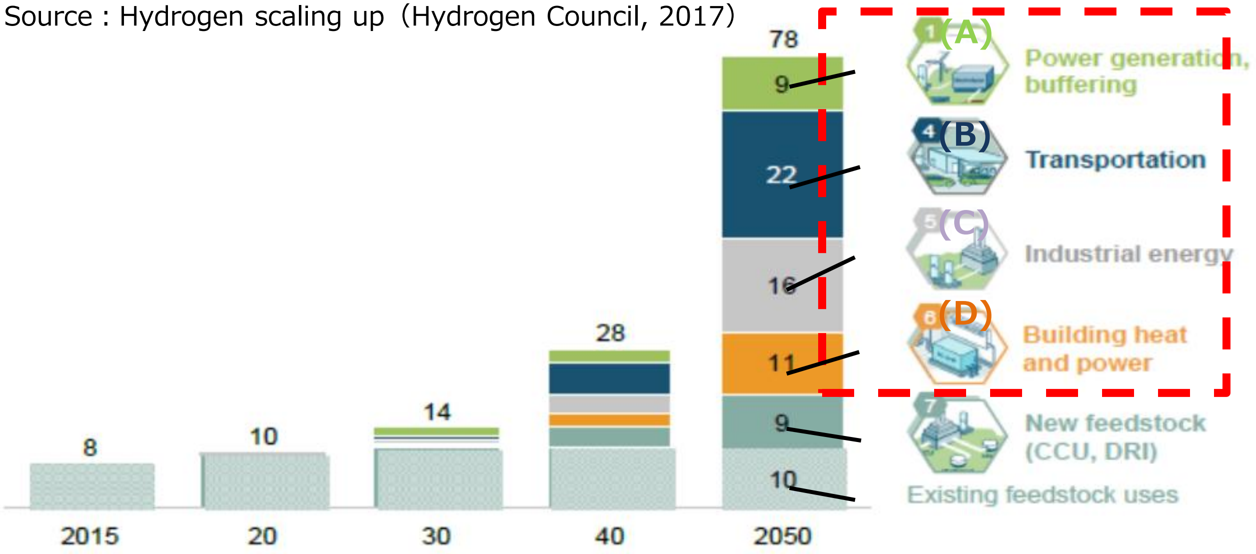
Norway : In the hydrogen strategy, hydrogen produced by water electrolysis or natural gas reforming by ship.

Utilization Technology of Hydrogen

- **Demand for hydrogen is expected to grow by 2050.**
- Japanese hydrogen power generation technology has been utilized to overseas projects.
- Projects for industrial use such as hydrogen use in the steelmaking process have also started in Japan and overseas.

Global energy dem **Global energy demand supplied hydrogen（Unit : EJ）**

Source : Hydrogen scaling up（Hydrogen Council, 2017）

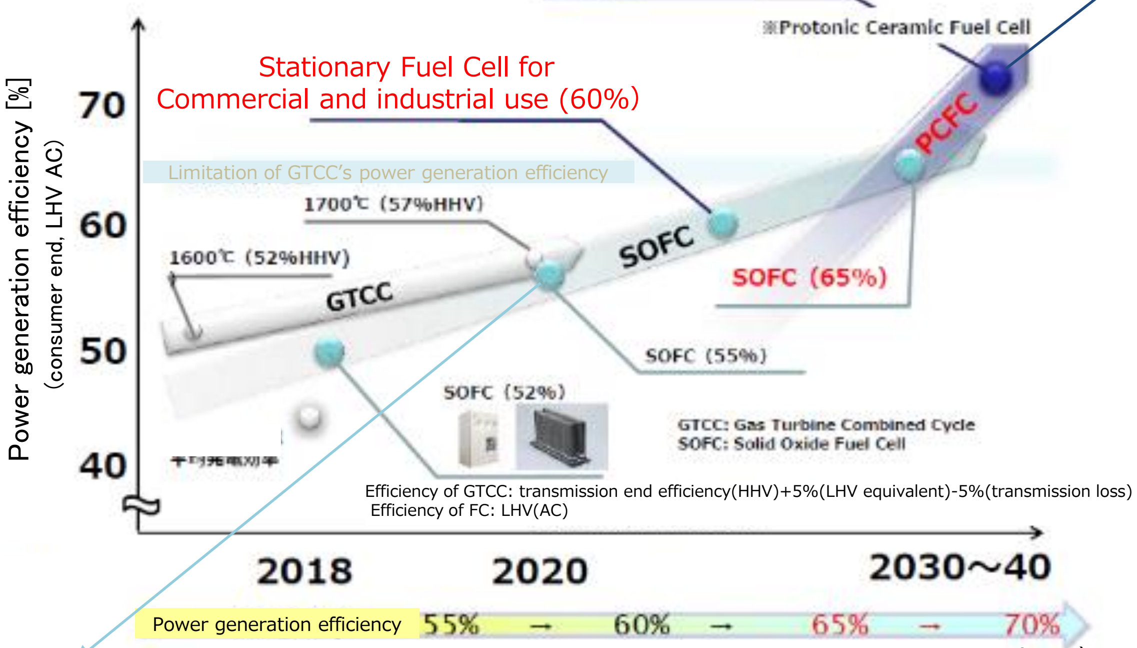


Utilization tech		Japan and International trends
(A)	Hydrogen power generation	Hydrogen gas turbine is being developed in NEDO project. MHPS has implemented an FS for hydrogen gas turbines in the Netherlands, has received an order from the United States, and is aiming to operate at 100% hydrogen in the future. Conducted Siemens and Kawasaki Heavy Industries.
(B)	Fuel cell vehicle	The NEDO project promotes R&D based on industry challenges. DOE: Developing highly durable MEA and low/non-platinum catalyst.
(C)	Petro-chemistry	"REFHYNE" Project: Power to Gas Field Test to Utilize Hydrogen Produced by Water Electrolysis at Refineries (2018-2022)
	Steel-making	"H2Future" project: Field test is underway to apply hydrogen produced by water electrolysis to the steelmaking process. (2017-2021)
(D)	Stationary fuel cell	Established SOFC durability quick evaluation method in NEDO project. Conducted R&D on reversible SOFC-SOEC.

Stationary Fuel Cell for Commercial and Industrial Use

- The target of SOFC is to realize higher efficiency (over 65%) and durability, which will be utilized in the town.

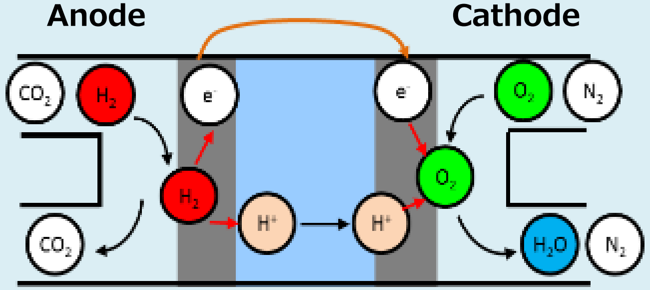
The target of SOFC



Source : FCCJ (2019)

Innovative technology

Proton-conducting solid oxide fuel cells



- PCFC have a potential to achieve 75% Power generation efficiency.
- PCFC is expected to applied distributed power generations in the future.

Manufacturers conditions

	Mitsubishi Power, Ltd	MIURA CO.,LTD	KYOCERA Corporation	FUJI ELECTRIC CO., LTD.	Hitachi Zosen Corporation
exterior					
Capacity (AC)	250kW/1350kW SOFC:227kW/1140kW	4.2kW	3kW	50kW級	20kW級
efficiency [LHV, %]	55%	48%	52%	55%	52%超

Source : METI

- Leading company : Bloom Energy
  Power generation efficiency(LHV) : 53% (Max. over 60%)
  System cost : 3,554＄/kW (2020)
- Japanese manufacturers started commercialization/demonstration PJ in 2018
- PEFC type: Toshiba Energy Systems & Solutions Corporation, Panasonic Corporation, Toyota Motor Corp etc.

Strategic Roadmap for FC & H_2 (by JAPAN)

Technology Strategy Center

2020
Tokyo Olympic/ Paralympics
2030
2040

Phase 1
Installation of Fuel Cell

2009: Micro-CHP "ENE-FARM"
2014: FCV"MIRAI"
2017:Fuel Cell for Commercial/Industrial Use

around 2020:
FCV fuel cost ≦ HEV fuel cost
around 2025:
FCV cost competitive ≧ HEV

Phase 2
H_2 Power Plant/ Mass Supply Chain

- Accelerate RD&D
- Realize reasonable H_2 price

Mid 2020s
-H_2 Cost (CIF) : JPY30/Nm^3
0.21€/Nm^3
-Enhance Supply Chain in Japan
Around 2030
-Import H_2 from overseas
- Full-scale H_2 Power Plant

Phase 3
CO_2-free Hydrogen

- Systematic RD&D

Around 2040
CO_2-free H_2 by combining CCS and renewable energy

Rate: 140.7JPY=1€

■ **Targets**

- **Micro-CHP (Residential FC: ENE-FARM)**
  - Install
  2020: 1.4 million units
  2030: 5.3 million units
  - Price
  PEFC type: JPY 800,000 (US$ 7,800) by 2019
  SOFC type: JPY 1,000,000 (US$ 9,800) by 2021

- **FCV**
  2020: 40,000 units
  2025: 200,000 units
  2030: 800,000 units

- **Hydrogen Refueling Station**
  2020: 160 stations
  2025: 320 stations

Comprehensive R&D Principle for Sustainable Society 〔The NEDO's Principle〕

- **Cooperated with "Progressive Environment Innovation Strategy"** (Japanese Cabinet Office, Jan. 2020), **NEDO** established **"Comprehensive R&D Principle for Sustainable Society". 〔The NEDO's Principle〕**

Presentation at『TSC Foresight』Special Seminar (Feb. 14, 2020)

3 Essential Social Systems for Sustainable Society

ESS Mark

1. **Circular Economy**
   (Blue Color based of Earth)
2. **Bio-economy**
   (Green color based on living creatures)
3. **Sustainable Energy**
   (Orange color based on energy)

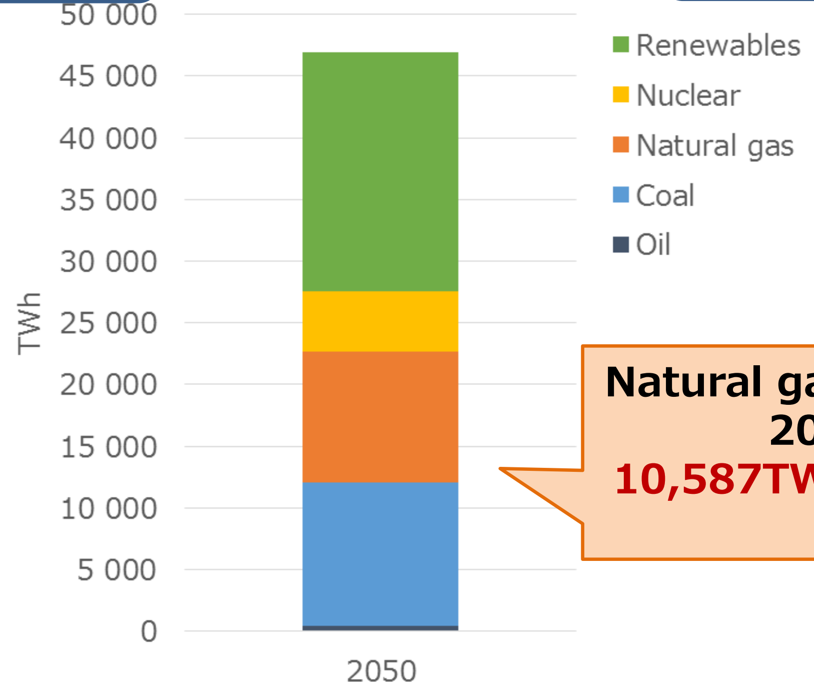
3 essential social systems should be necessary to be continuously promoted for establishing the sustainable society.

Hydrogen Power Generation 〔Potential〕

- Total CO_2 reduction potential is 6 Gt in by hydrogen power production, transportation and storage.
  Source : ”Hydrogen scaling up”（Hydrogen Council, 2017）
- CO_2 reduction potential of hydrogen power generation is estimated at approximately 190 to 580 Million ton when 5 to 15 % of liquid natural gas-fired power generation (whole world) will be replaced by hydrogen power generation by 2050 globally.

Renewable Energy and Unused Energy, etc. → Hydrogen Production → Transport and Storage → Hydrogen Power Generation

*Calculation target of this principle

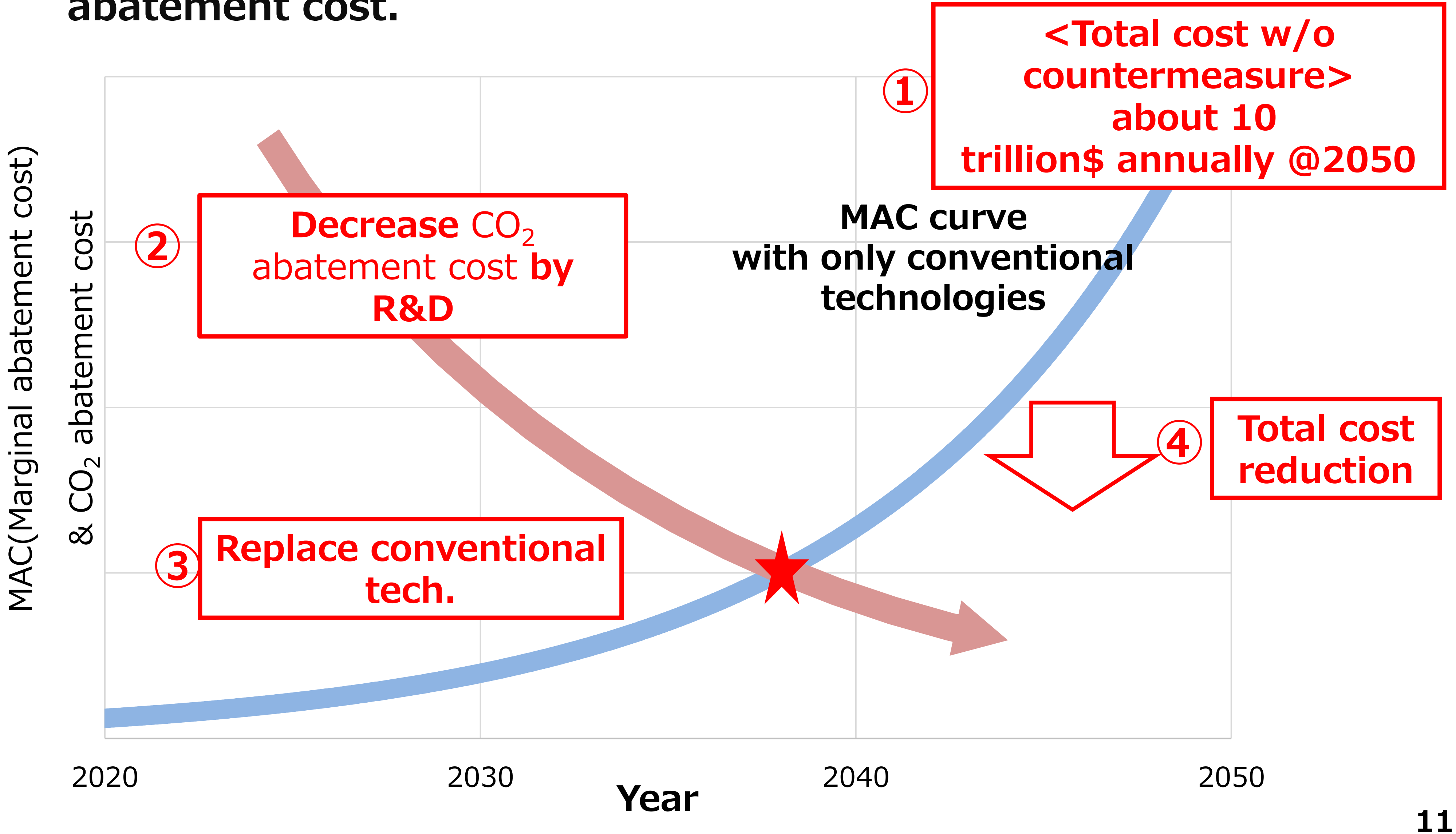


Natural gas-fired power generation of 2050 will be estimated 10,587TWh/year according to RTS of IEA ETP2017

Source ： Compiled by NEDO Technology Strategy Center based on Energy Technology Perspectives 2017（IEA, 2017）（2020）

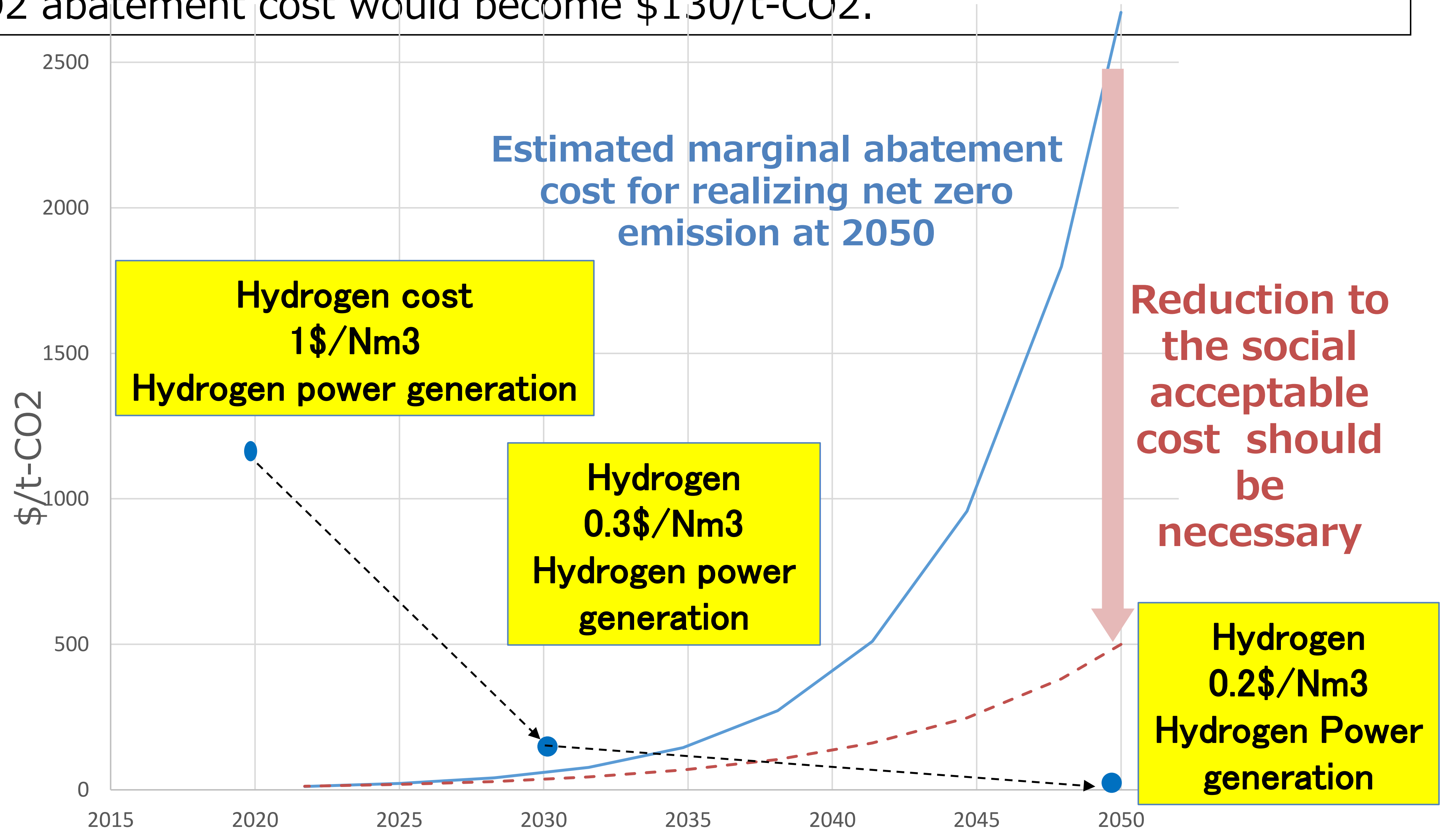
Decrease of CO_2 Abatement Cost by Innovation

- **To reduce 80% of global GHG emissions with conventional technologies, it would cost about 10 trillion$ annually at 2050.**
- **Extraordinary innovation is essential to decrease marginal GHG abatement cost.**



CO2 Abatement Cost for Hydrogen Power Generation

By R&D of hydrogen power generation, the CO2 abatement cost would be decreased largely. By realizing the hydrogen cost of 0.3$/Nm3 at 2030, CO2 abatement cost would become $130/t-CO2.



Prodeced by TSC,NEDO

Summary of Hydrogen Technology

- Hydrogen will be effective for the **decarbonization of many fields such as electric power generation, industry and mobility.**
- **Basic hydrogen strategy** has been **firstly** established **by Japan** in 2017
- The **production cost** of hydrogen with the usage of renewable energy would **depend largely on the production technology and the climate characteristics (renewable energy cost)** of the area in the world.
- **Long distance transport technology of hydrogen for establishing the international supply chain of hydrogen is important**.
- The **advanced technology,** such as the hydrogen power generation technology established by Japan, **has been utilized around the world.**
- **Large reduction of hydrogen cost** should be necessary and important by **realizing** the various kinds of **innovative technology**.
- Education of innovative researchers and the social support for realizing the hydrogen society will be very important.

<Examples of innovative hydrogen technology>

【Production】

- High efficiency electrolysis, artificial photosynthesis

【Transport and storage】

- Low cost and efficient energy carrier of hydrogen

【Utilization】

- Proton-conducting solid oxide fuel cells

Source: **The Strategic Road Map for Hydrogen and Fuel Cells**（METI,2019）