Hydrogen and Fuel Cell Development in Japan

February 25, 2020

Daishu HARA

New Energy and Industrial Technology Development Organization (NEDO)

Agenda

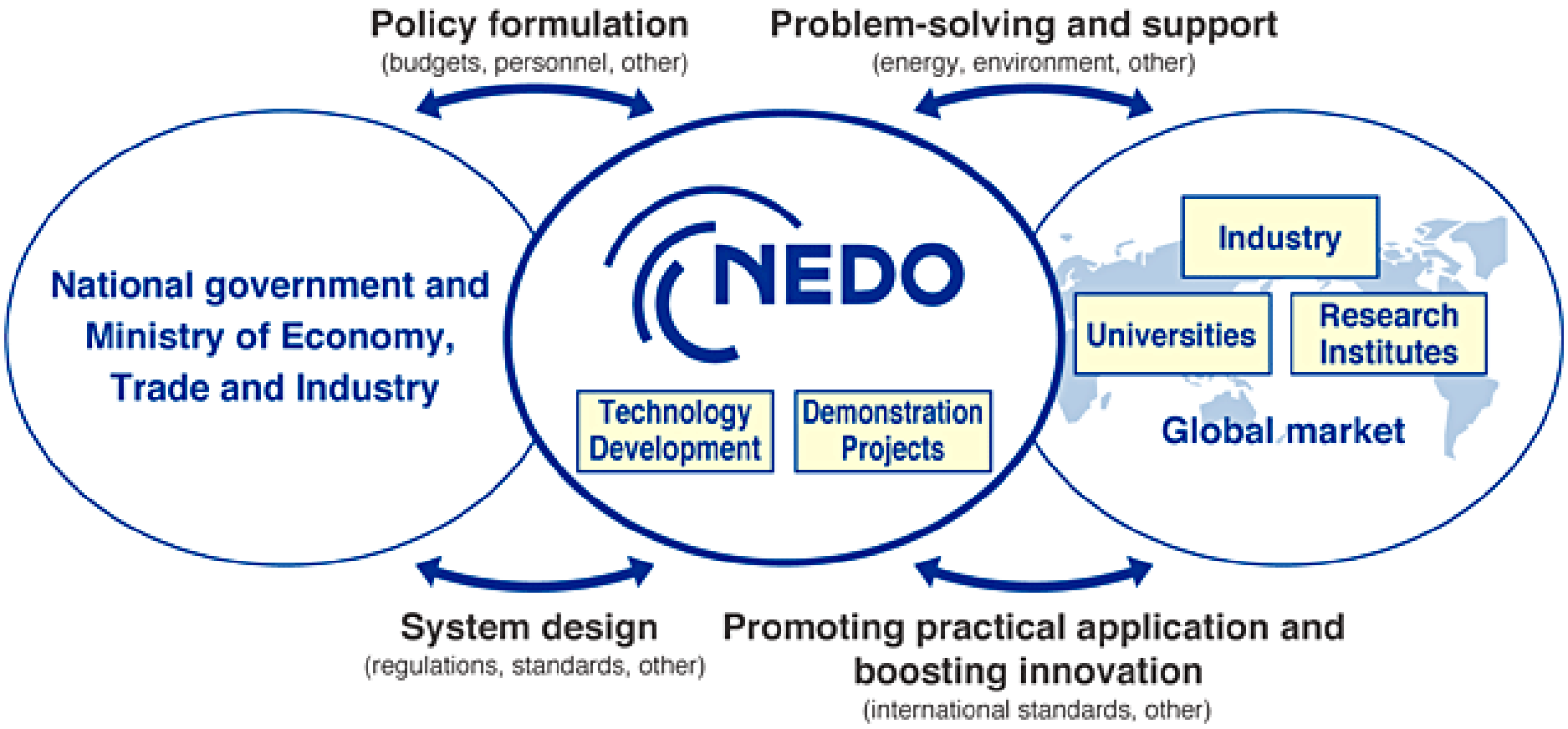
1. NEDO’s role in Japan
2. Hydrogen Strategy
3. Current Status of Fuel Cell Application
4. NEDO’s programs

New Energy and Industrial Technology Development Organization (NEDO)

Foundation	Originally established on October 1, 1980; reorganized as an incorporated administrative agency on October1, 2003
Minister in Charge	Minister of Economy, Trade and Industry
Personnel	About 1,000
Chairman	Mr. Hiroaki ISHIZUKA

Budget:160 billion JPY in FY2019

Who we are…


Policy formulation
(budgets, personnel, other)
Problem-solving and support
(energy, environment, other)
National government and Ministry of Economy, Trade and Industry
NEDO
Technology Development
Demonstration Projects
Industry
Universities
Research Institutes
Global market
System design
(regulations, standards, other)
Promoting practical application and boosting innovation
(international standards, other)

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Why Hydrogen/ Background

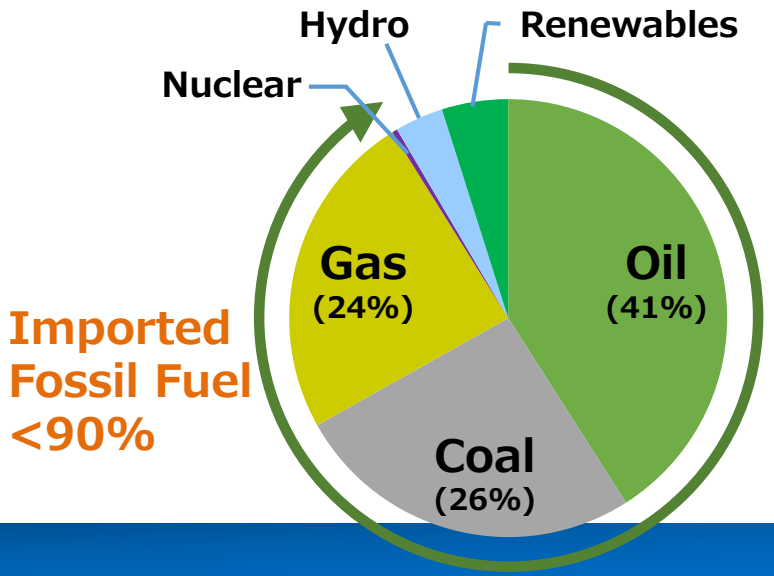
- **Points to be considered;**
  - ✓ Contribute **decarbonization** (**E**nvironment)
  - ✓ Mitigate **dependence on specific countries** (**E**nergy security)
  - ✓ Enable to utilize **low cost feedstock** (**E**conomic affordability)

  + Japan's edge in technology since 1970s

3"E" + **S**afety

- **Measures;**
  - ✓ Energy saving
  - ✓ Renewable energy
  - ✓ Nuclear energy
  - ✓ CCS + Thermal power
  - ✓ **Hydrogen**

Japan's Primary Energy (2015)



Japan's Initiatives on Hydrogen and Fuel Cell

1st Ministerial Council on Renewable Energy, Hydrogen and Related Issues (11th April 2017)

Prime Minister Shinzo Abe stated "***Japan will be the first in the world to realize a hydrogen-based society***. *I request relevant ministers to* ***formulate the basic strategy within this year***."

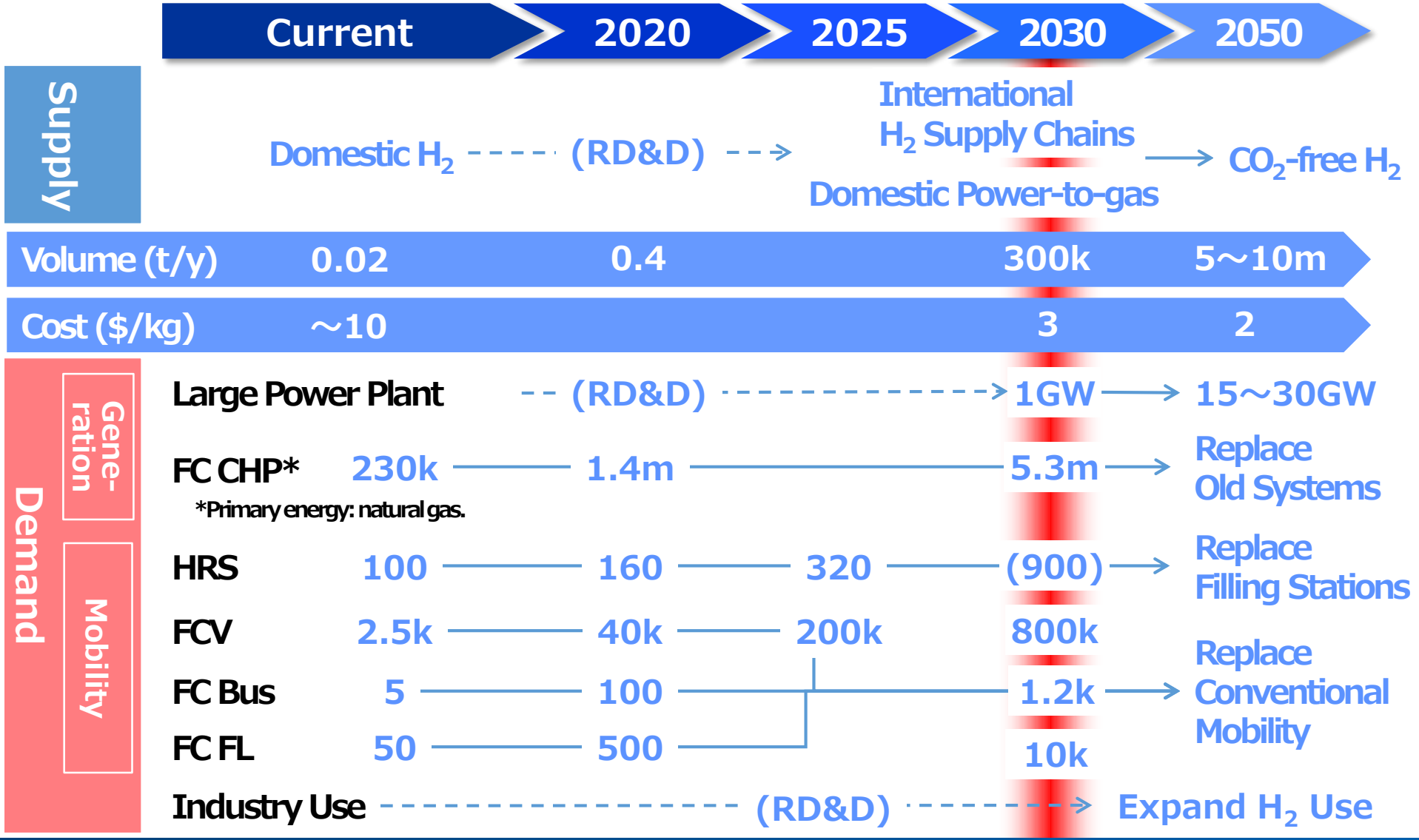
In particular, he requested relevant ministers to

- *accelerate the establishment of hydrogen refuelling stations & streamline regulations*
- *formulate a common scenario toward the building of supply chains and the full-scale introduction of hydrogen power generation*

Basic Hydrogen Strategy

- ✓ **World's first national strategy**
- ✓ **2050 Vision: position H_2 as a new energy option** (following Renewables)
- ✓ **Target: make H_2 affordable**
  ($3/kg by 2030 ⇒ $2/kg)

Scenario


Current
2020
2025
2030
2050
Supply
Domestic H_2 (RD&D)
International H_2 Supply Chains
Domestic Power-to-gas
CO_2-free H_2
Volume (t/y)
0.02
0.4
300k
5～10m
Cost ($/kg)
～10
3
2
Demand
Gene-ration
Mobility
Large Power Plant
(RD&D)
1GW
15～30GW
FC CHP*
230k
1.4m
5.3m
Replace Old Systems
*Primary energy: natural gas.
HRS
100
160
320
(900)
Replace Filling Stations
FCV
2.5k
40k
200k
800k
FC Bus
5
100
1.2k
Replace Conventional Mobility
FC FL
50
500
10k
Industry Use
(RD&D)
Expand H_2 Use

Hydrogen Energy Ministerial Meeting

- October 23rd, 2018 / Tokyo
- Representatives from 21 countries, regions, international organizations

  *Japan, Australia, Austria, Brunei, Canada, China, France, Germany, Italy, the Netherlands, New Zealand, Norway, Poland, Qatar, South Africa, Korea, United Arab Emirates, United Kingdom, United States, European Commission, IEA

Point of Tokyo Statement (Chair's Summary)

1. Collaboration on Technologies and Coordination on Harmonization of Regulation, Codes and Standards

2. Promotion of Information Sharing, International Joint Research and Development Emphasizing Hydrogen Safety and Infrastructure Supply Chain

3. Study and Evaluation of Hydrogen's Potential across Sectors Including Its Potential for Reducing Both CO_2 Emissions and Other Pollutants

4. Communication, Education and Outreach

Hydrogen Energy Ministerial Meeting 2019

H2EM 2019

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

Strategic Roadmap for Hydrogen and Fuel Cells

Approach to achieving target for PEFC

- Sharing technical information and problems in a cooperation area among stakeholders
- Developing technology for reducing the amount of platinum used
- Developing technology for reducing of amount of carbon fiber in hydrogen storage system

Action Plan (key point) ① <Hydrogen Use (Mobility) > Red : New target

In order to reduce cost for full-scale implementation period, thorough establishment of mass production technology and implementation of regulatory reform

Hydrogen Use (Mobility)

	Target to achieve	Approach to achieving target
FCV	● 200k by FY2025, 800k by FY2030 ● Achieving a cost reduction of FCV to the level of HV around 2025 (Price difference ¥3m → ¥0.7m) ● Reducing cost of main elemental technologies around 2025 Fuel cell system around ¥20k/kW→¥5k/kW Hydrogen storage system around ¥0.7m → ¥0.3m Expansion of vehicle types for volume zones in FY2025	・Sharing technical information and problems in a cooperation area among stakeholders ・Developing technology for reducing the amount of platinum used. ・Developing technology for reducing of amount of carbon fiber in hydrogen storage systems
HRS	● 320 by FY2025, some 900 by FY2030 ● Making HRS independent by the second half of the 2020s ● Reduction of cost for construction and operation by FY2025 (construction cost ¥350m→¥200m, operation cost ¥34m/year→¥15m/year) ● Setting of cost target for each component Compressor ¥90m→¥50m High pressure vessels ¥50m→¥10m	・Thoroughly integrate promotion of regulatory reform and technological development (Realization of self-service HRS, use of inexpensive steel material etc.) ・Consideration for nation wide networking of HRS ・Extending opening hours ・Increasing of the number of HRS with gasoline station/convenience store
Bus	● 1,200 FC buses by 2030 ● Expansion of regions where FC buses run ● Reducing FC bus's price by half (¥105m→¥52.5m) ● Independent FC bus by FY2030	・Developing technology for enhancing the fuel efficiency and durability of such vehicles ・Expansion of types other than city buses ・Promotion of deployment of HRS for FC buses
Forklift	● 10k FC forklifts by 2030 ● Expansion to an overseas markets	・Versatile deployment of fuel cell units ・Promotion of maintenance of simple and easy to operate filling equipment

※In addition, promote development of guidelines and technology development for expansion of hydrogen use in the field of FC trucks, ships and train.

of the Action plan ③ <other applications for a global "Hydrogen Society" > Red: New Target

ing and deepening the market to expand the application of hydrogen
ional cooperation led by Japan for realizing a Global "Hydrogen Society"

	Targets	Action to achieving the targets
	● Establishment of the technology for commercialization of hydrogen power generation in about 2030 ✓ Clarify conditions for hydrogen co-firing at existing power plants ✓ Achieve higher efficiency of hydrogen mono-combustion by 2020 (26%→27%) ※1MW class gas turbine	・FS on limit mixture co-firing rate, feasibility etc. ・Development of highly efficient combustor
	● Utilizing CO2-free hydrogen in the future ● Considering the introduction of the various processes for using CO2-free Hydrogen in a sequential manner as the processes achieve economic rationality	・Investigation on utilization and supply potential of CO2-free hydrogen in each industrial process ・Study for practical application of carbon recycling technology
:ne-farm	● Economic independence in about 2020, 5.3 million cumulative sales by 2030 ● Cost reduction to ¥800 thousand (PEFC) ¥1 million (SOFC) by 2020 ● Achieve 5 years as a period to recover investment by about 2030	・Development of markets such as existing housing and condominium. ・Review of regulations for simplification of electrical work
:ommercial and industrial use	● Realize grid-parity combining the utilization of exhaust heat in about 2025 Low voltage : CAPEX ¥500,000/kW, power generation cost ¥25/kWh high voltage : CAPEX ¥300,000/kW, power generation cost ¥17/kWh	・Development of fuel cell stack technologies for higher efficiency and higher power density ・Development of fuel cell stack technologies to eliminate the cause of degradation
	● Realize higher efficiency and durability efficiency : over 55% in about 2025 → over 65% in the future durability : 90,000 hours → 130,000 hours in about 2025	
Global Hydrogen society/ social acceptance	● Realize "Tokyo Statement" announced in Hydrogen Energy Ministerial Meeting ✓ Coordination on harmonization of regulation, codes and standards ✓ Promotion of information sharing, international joint research ✓ Study and evaluation of hydrogen's potential ✓ Communication, education and outreach	・Comparison of regulations with U.S., Europe, etc., sharing information on accidents ・Involvement of resource-rich countries by sharing the outcome of Japan's supply chain demonstration ・Take advantage of all opportunities such as Olympic and Paralympic in 2020, Osaka World Expo in 2025, and publicize the cutting-edge hydrogen technology ・Implement innovative technology development

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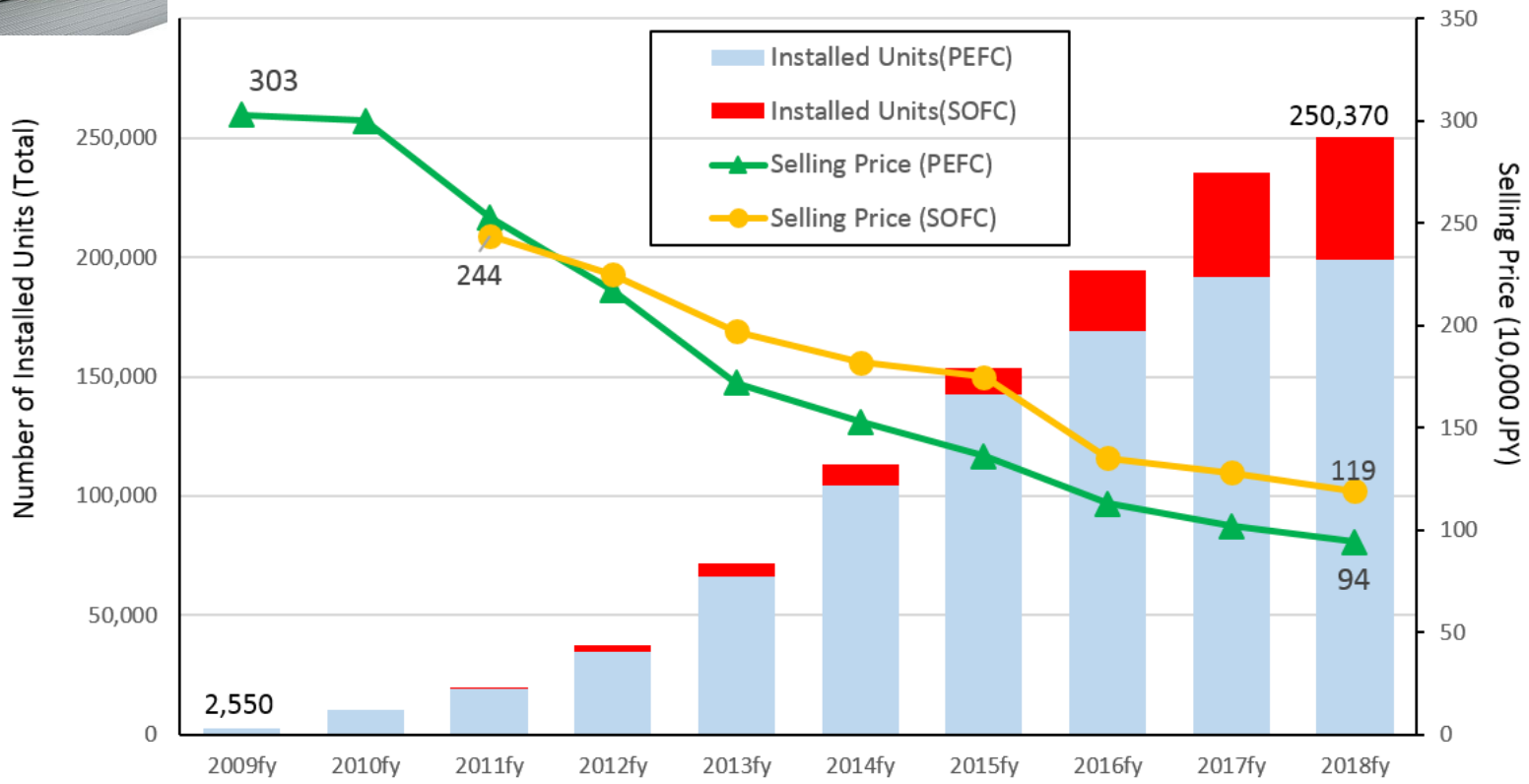
Current status of residential fuel cell “Ene-Farm”

Selling Price of Ene-Farm is getting lower with increasing the number of installed unit.

300,000 unit = 210MW



SOFC unit for commercial / industrial use

Small / Medium size Fuel Cell: 30 units
(for commercial, industry uses: as of March, 2019)

(3kW: Kyocera)
Total efficiency: > 80%

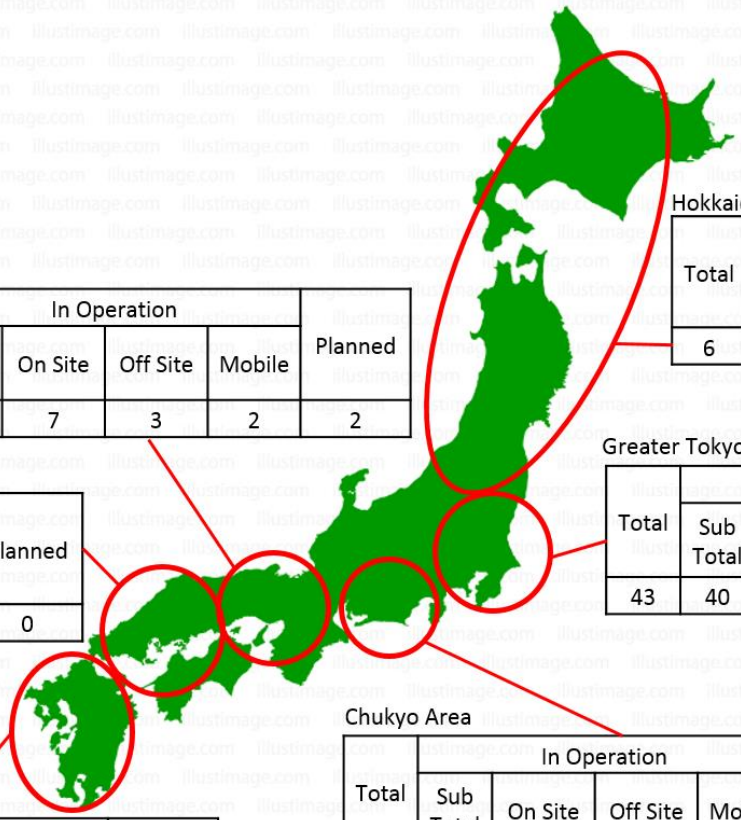
(4.2kW: Miura)
Total efficiency: 90%

(250kW: MHPS)
Total efficiency: > 73% (hot water)
65% (Steam)

Current status of FCV and HRS

MIRAI。ボディカラーはツートーン ピュアブルーメタリック（2NV）。

FCV: 3,500 on road



Hokkaido / Tohoku Area

Total	In Operation				Planned
	Sub Total	On Site	Off Site	Mobile	
6	4	1	0	3	2

Kinki Area

Total	In Operation				Planned
	Sub Total	On Site	Off Site	Mobile	
14	12	7	3	2	2

Chugoku / Shikoku Area

Total	In Operation				Planned
	Sub Total	On Site	Off Site	Mobile	
8	8	2	0	6	0

Greater Tokyo Area

Total	In Operation				Planned
	Sub Total	On Site	Off Site	Mobile	
43	40	24	1	15	3

Chukyo Area

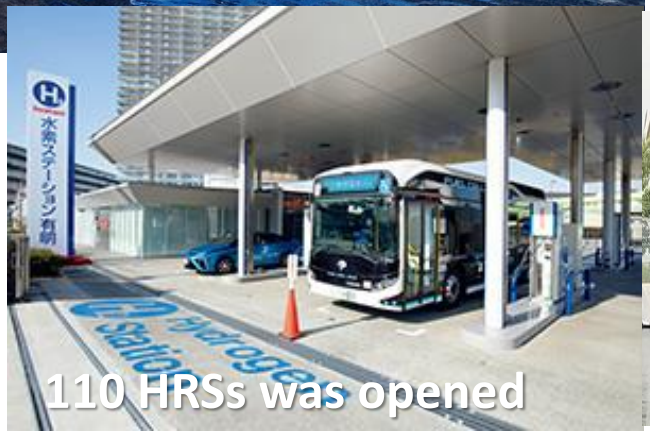
Total	In Operation				Planned
	Sub Total	On Site	Off Site	Mobile	
29	25	8	6	11	4

Kyushu Area

Total	In Operation				Planned
	Sub Total	On Site	Off Site	Mobile	
11	11	5	4	2	0

HRS: 100 in operation + 11 planned

New Fuel Cell Application in 2019



Establishment of Japan H2 Mobility(JHyM)

JHyM(established on Feb. 2018) aims to develop a hydrogen station network for FCVs (Fuel Cell Vehicles) in Japan.

JHyM JAPAN H2 MOBILITY

Strategic deployment of hydrogen stations

Cost down for hydrogen stations

Improvement of convenience for FCV customers

https://www.jhym.co.jp/en

Participating companies

Automakers	➢ Toyota Motor Corporation ➢ Nissan Motor Co. Ltd. ➢ Honda Motor Co. Ltd.
Infrastructure Developers	➢ JXTG Nippon Oil & Energy Corporation ➢ Idemitsu Kosan Co. Ltd. ➢ Iwatani Corporation, Tokyo Gas Co. Ltd. ➢ Toho Gas Co. Ltd., Air Liquide Japan Ltd. ➢ Nemoto Tsusho K.K. SEIRYU POWER ENERGY CO., LTD.
Investors	➢ Toyota Tsusho Corporation ➢ Development Bank of Japan Inc. ➢ JA MITSUI LEASING, LTD. ➢ Sompo Japan Nipponkoa Insurance Inc. ➢ Sumitomo Mitsui Finance and Leasing Company, Limited ➢ NEC Capital Solutions Limited ➢ Mirai Creation Fund (Managing Company :SPARX Group Co,. Ltd.)

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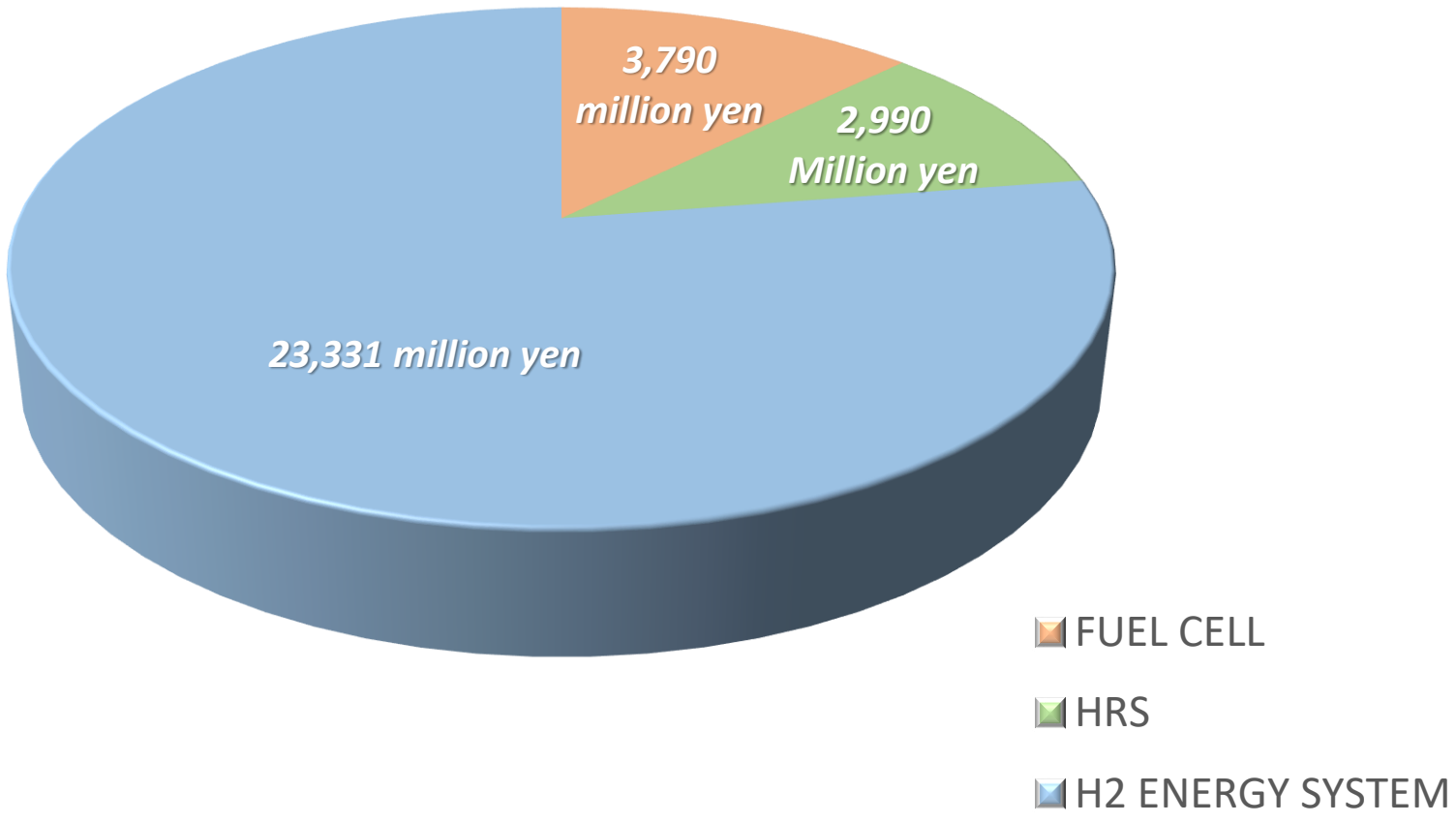
Budget for Hydrogen and FC（2019fy）

Total Budget : JPY 29.2 billion / USD 275 million



NEDO R&D Program

2013 2014 2015 2016 2017 2018 2019 2020

Fuel Cell

Development of Advanced PEFC Utilization Technologies（2015～2019）

Development of Technologies to Promote Practical Application of SOFCs （2013～2019）

Promoting Fuel Cell Application

Hydrogen

Development of Hydrogen Utilization Technologies（2013～2017）

Development of Technologies for Hydrogen Refueling Stations (2018-2022)

Development of Technologies for Realizing a Hydrogen Society (2014～2020)

Developing Hydrogen Demand

Advancement of Hydrogen Technologies and Utilization Project (2014～2022)

Current Direction

First Step: Promoting fuel Cell Application

Fuel Cells:

(1) PEFC: for mobility

- Target: 0.03-0.1 g-PGM/kW (depend on durability), 50,000 hrs. life time (commercial vehicle), Power Density:> 4kW/L (in 2030)
- Focusing on basic research to accelerate material / MEA development
- Improving productivity

(2) SOFC: for stationary use

- Complete co-generation model (> 50%) by 2017
- New target: >60% efficiency (mono-generation)

Hydrogen Refueling Station:

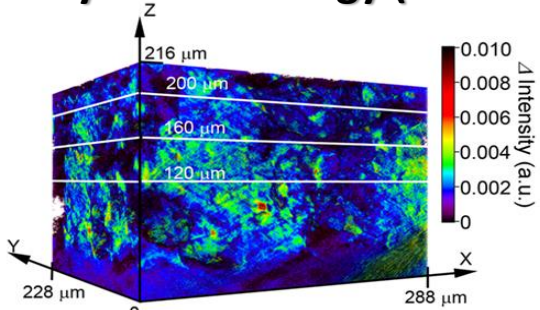
Reducing CAPEX / OPEX

- To address regulatory reform on FCV/HRS in Japan
  ex. Unmanned operation with remote monitoring, Risk assessment on HRS, etc.
- Developing low cost equipment
  incl. Electro-chemical compressor, polymers, etc.)

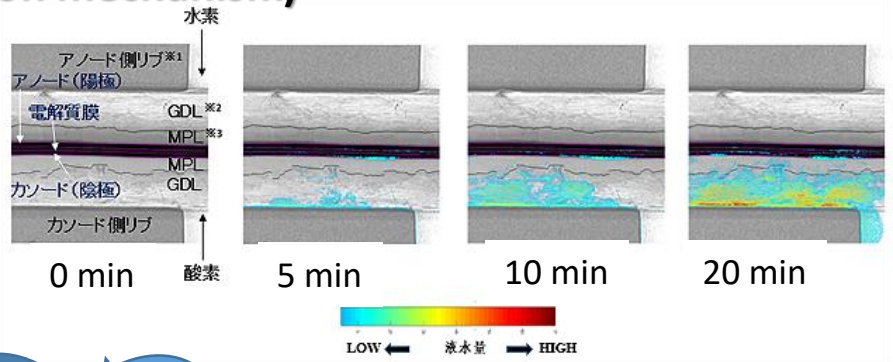
Highlight of NEDO's Program (PEFC)

NEDO focused on basic research.

Analysis Technology (PEFC reaction mechanism)



3D visualization of PFEC anode catalyst degradation

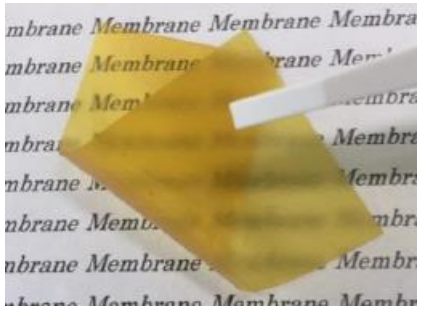


Water distribution in PEFC

PEFC performance evaluation

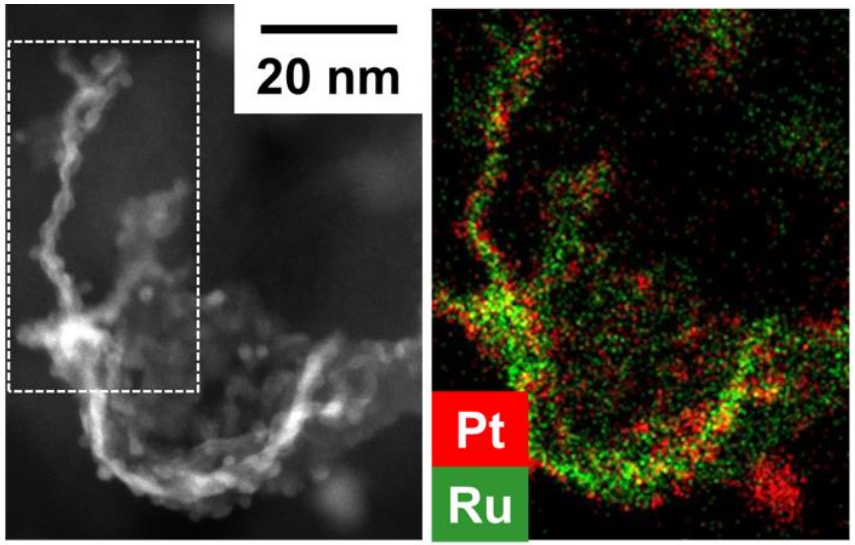
Material Design Concept

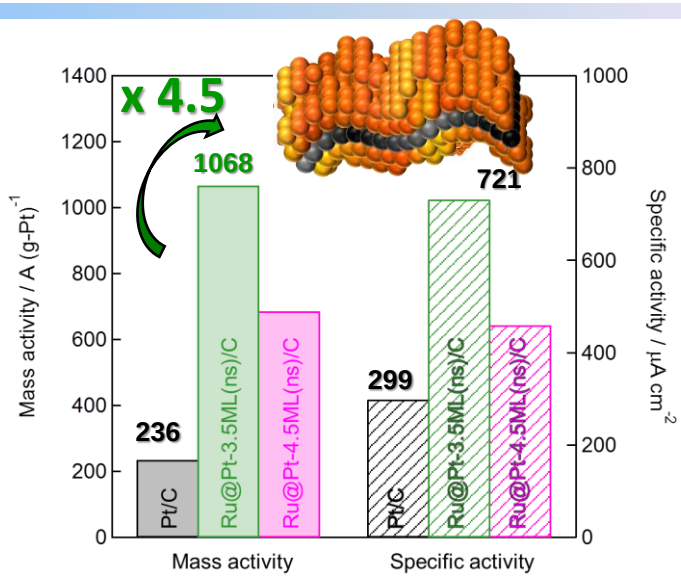
Catalyst



Membrane

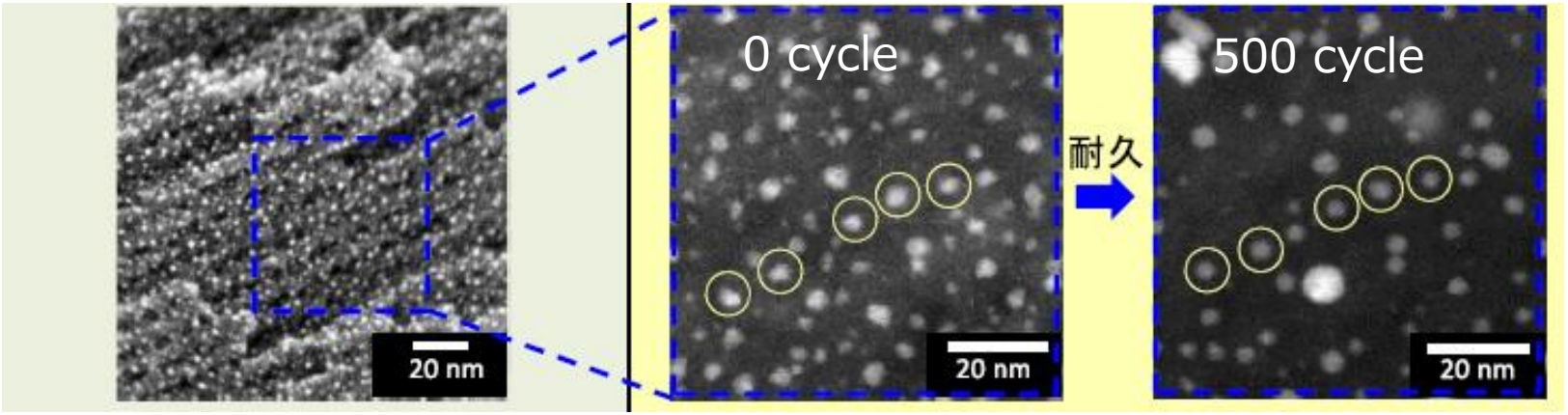
NEDO's Program on PEFC





j_k@E=0.9 V vs. RHE, 0.1 M $HClO_4$ (25°C)

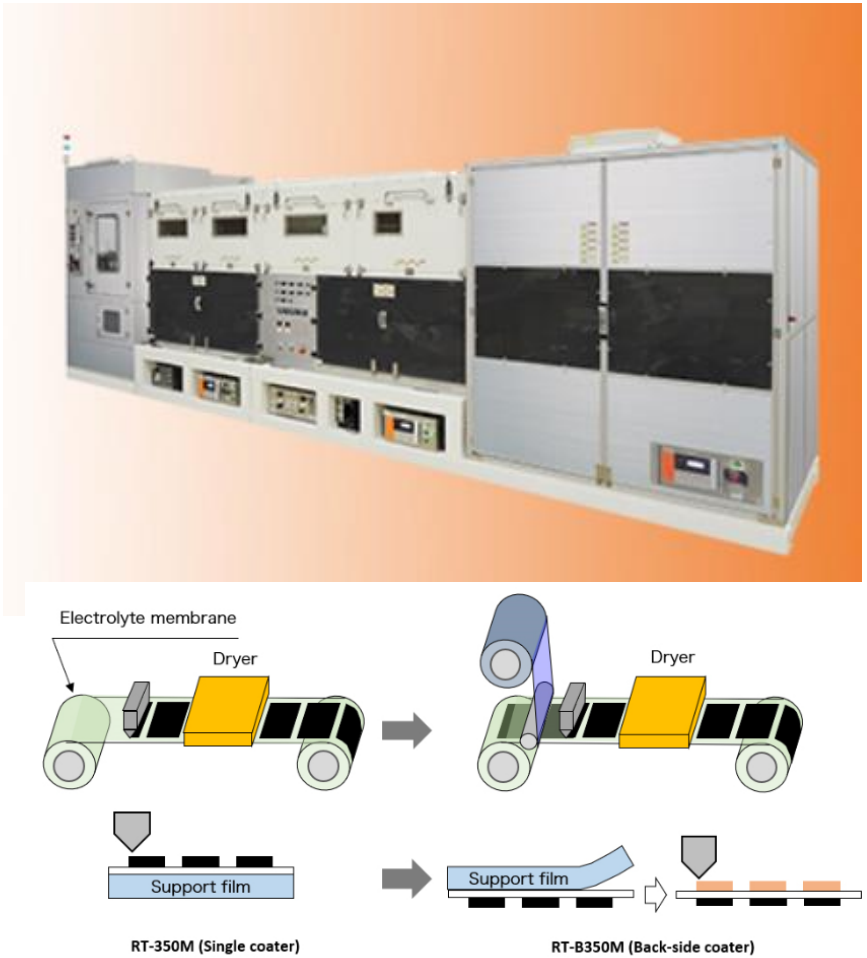
Shinshu University: Ru@Pt Core-shell nano-sheet catalyst



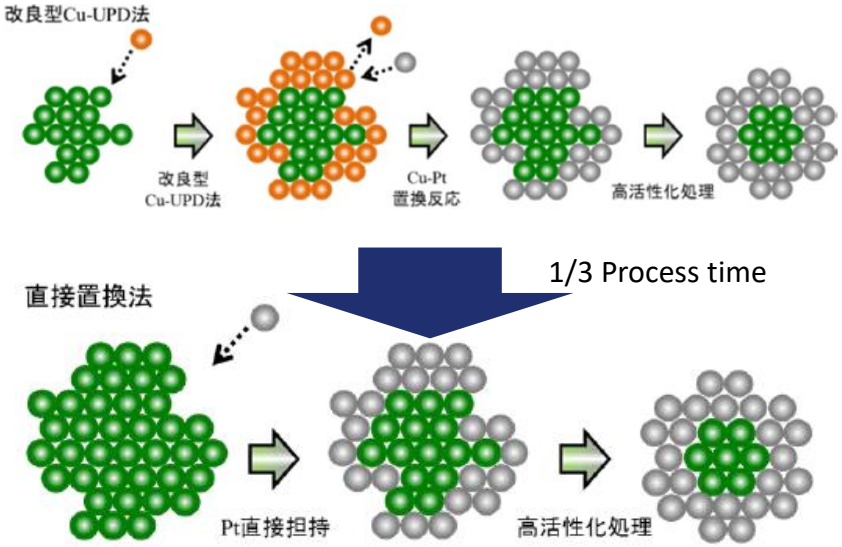
Yamanashi University: Carbon support structure to prevent aggregation of platinum

NEDO's Program on PEFC

Roll to Roll Coater/Dryer



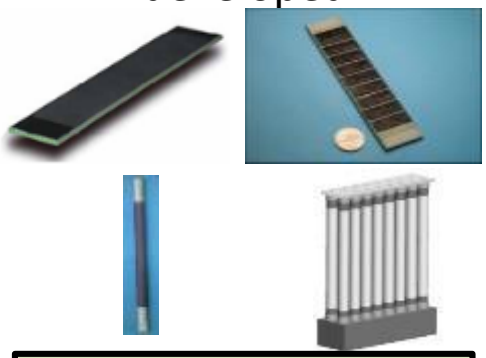
SCREEN Finetech Solutions



Highlight of NEDO's Program (SOFC)

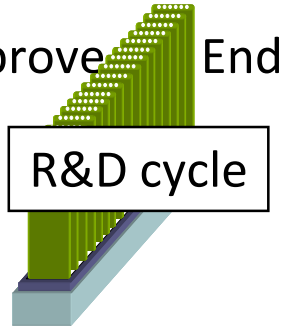
Success model of R&D cycle had been established for 1)valuation/analysis and 2) endurance by public entities, 3) feedback to private sector.

Hi endurance and low cost Cell Stack will be developed



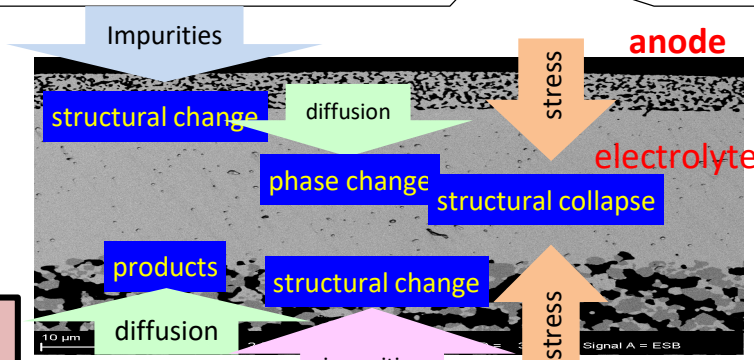
Private sector

Develop & Improve



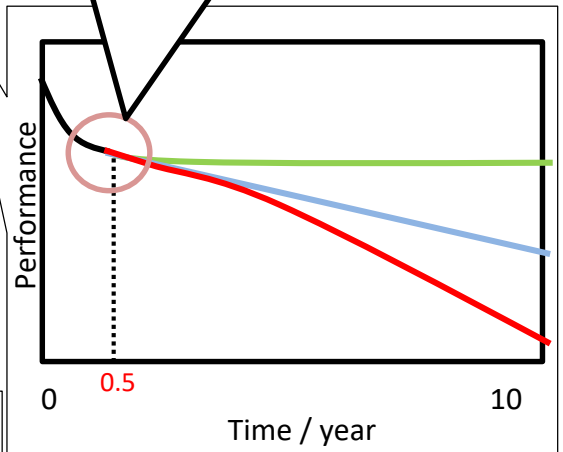
Endurance Test

Evaluation / Analysis



NEDO project

Quantitative Detection of tiny degradation within shot term (several month).
→high resolution with short term forecast of degradation



Endurance Test of Cell Stack

NEDO project

Current Direction

Second Step: Develp H2 demand & Integrate w/ energy system

Hydrogen Supply Chain / Gas Turbine:

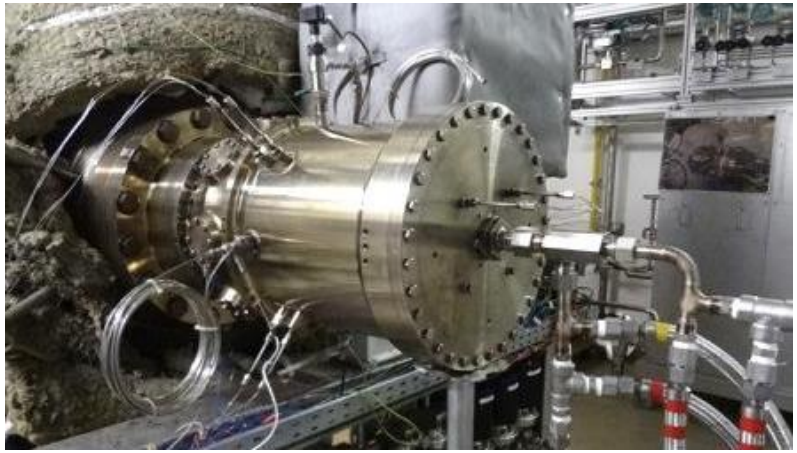
- Developing combustor for Hydrogen Gas Turbine
  Control of combustion for low NOx, back fire, etc.
- Realizing large scale hydrogen supply chain
  Hydrogen carriers for long distance transportation

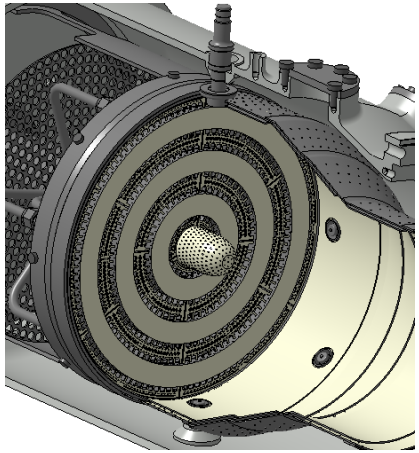
Power to Gas:

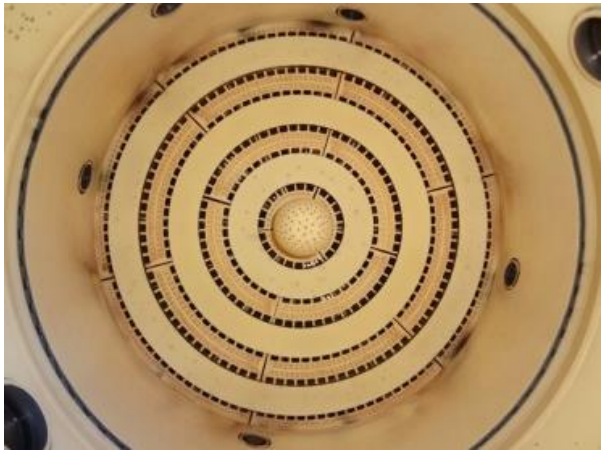
- Developing System Technology
  System Operation, Energy management, Demand response
- Improving electrolysis technology
  Analyzing reaction mechanism, develop lifetime evaluation, etc.
  (Alkaline, PEM, SOEC)

Highlight of NEDO's Program (H_2GT)

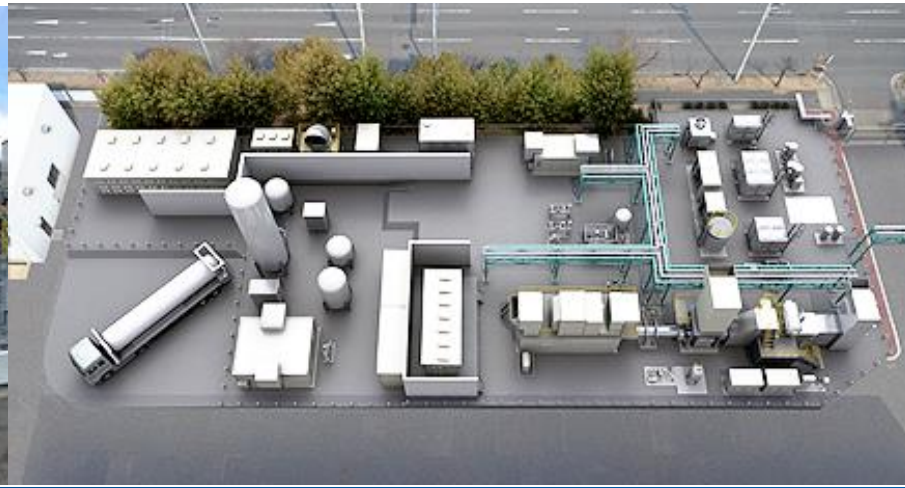
Developing combustor for H_2 gas turbine



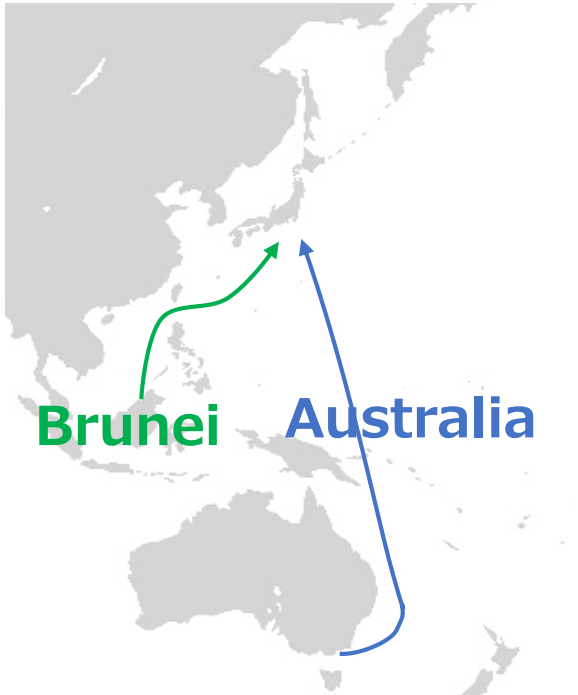




Demonstration project / H_2 gas turbine



Highlight of NEDO's Program (Supply Chain)



Japan-Australia H_2 Supply Chain Project

Japan-Brunei H_2 Supply Chain Project

Present situation of the project (Liquefied hydrogen)

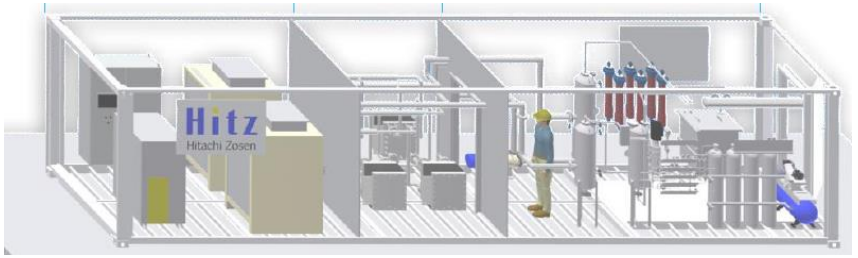
Upper left : H2 tank on the land
Upper middle : Ship on the stocks
Upper right : H2 tank for ship
Lower light : receiving terminal
Provided by : HySTRA

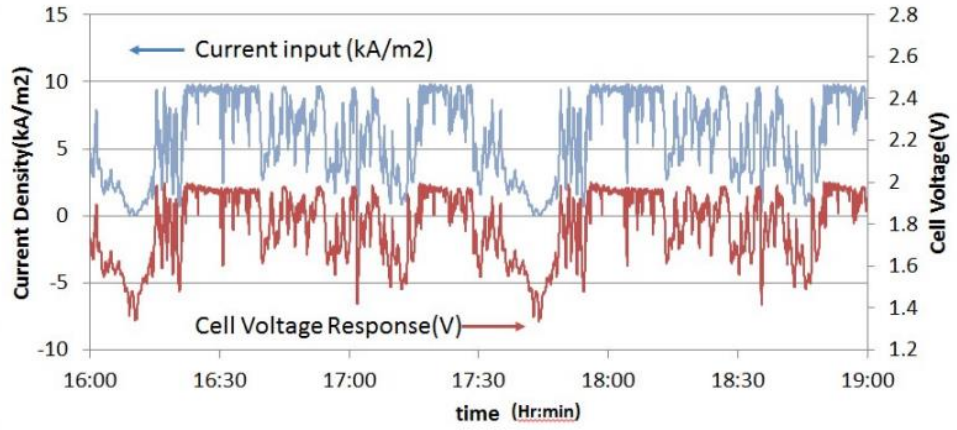
Present situation of the project (organic chemical hydride)

Upper left :
Hydrogenation plant in Brunel
Upper right :
Dehydrogenation plant in Japan
Lower right : Transport tank for MCH

Provided by AHEAD

NEDO's Program on Electrolysis





Highlight of NEDO's Program (Power to Gas)

@ Fukushima Pref.　10MW electrolysis / provide H2 to Tokyo 2020

Present situation of the project (Power to Gas)

【Picture】
Panorama of FH2R
Provided by Toshiba ESS

Highlight of NEDO's Program (Power to Gas)

@ Fukushima Pref.　10MW electrolysis / provide H2 to Tokyo 2020

NEDO's Program on PtG

Fukushima (w/ 10MW Alkaline Electrolysis)

Item	Specification
Function	(1) Manufacturing・Storage・Supply of hydrogen (2) Balancing the supply and demand of the electricity grid
Annual manufacturing capability of hydrogen (Rated output)	900t-H2／year
Input power of electrolyzer	(Max.) 10MW (Rated) 6MW (Range) 1.5MW ～ 10MW

Olympic Village with Hydrogen

Image: Tokyo Metropolitan Government

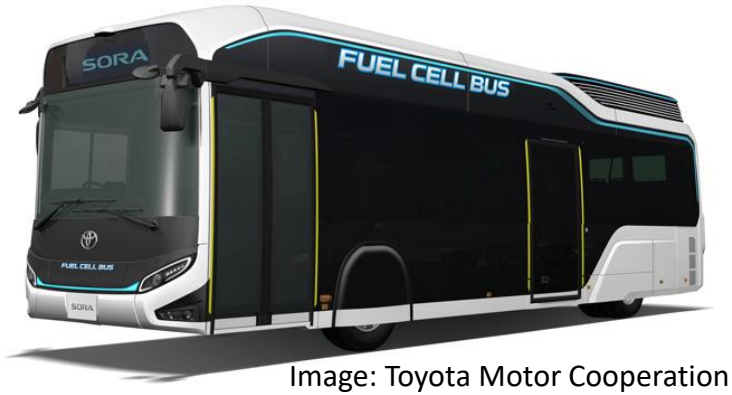


Image: Toyota Motor Cooperation

Image: Tokyo Metropolitan Government

Conclusion

- *Japanese Government strongly promoting*
  - *with Prime Minister's leadership*

- *Just started market penetration*
  - *need to enhance hydrogen energy application*
  - *continue to improve technology*

- *Utilizing hydrogen in energy system*
  - *enhancing hydrogen demand & role*
  - *demonstration at Tokyo 2020*

Thank you!