Japanese Perspective on the Hydrogen Economy

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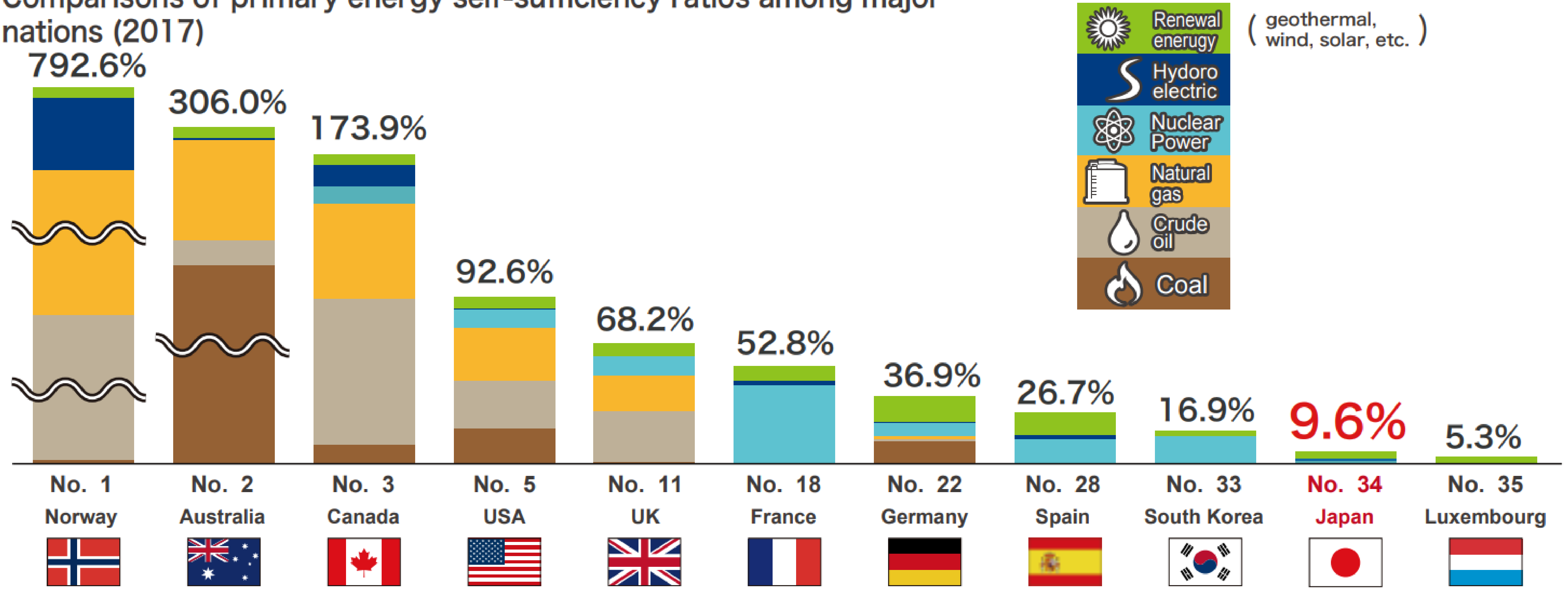
The Canon Institute fro Global Studies

APERC Annual Conference 2021

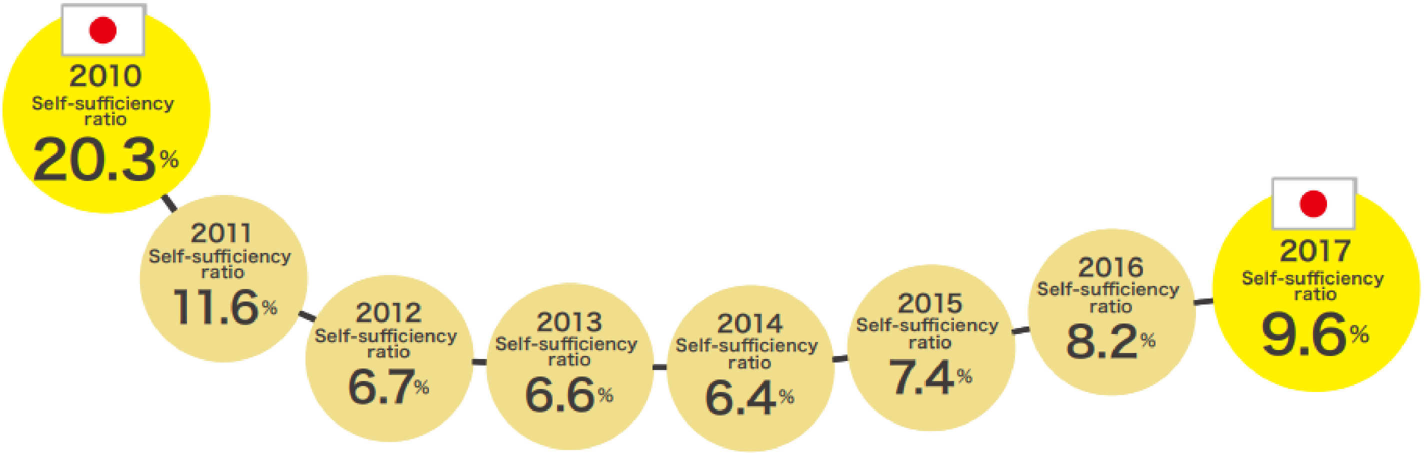
April 20, 2021 @ Tokyo

Comparisons of primary energy self-sufficiency ratios among major nations (2017)



Source: 2017 estimates from IEA "World Energy Balances 2018". For Japan only, FY 2017 figures are from "Comprehensive energy statistics of Japan", Agency for Natural Resources and Energy. ＊ The ranks in the table are those of the 35 OECD member countries.

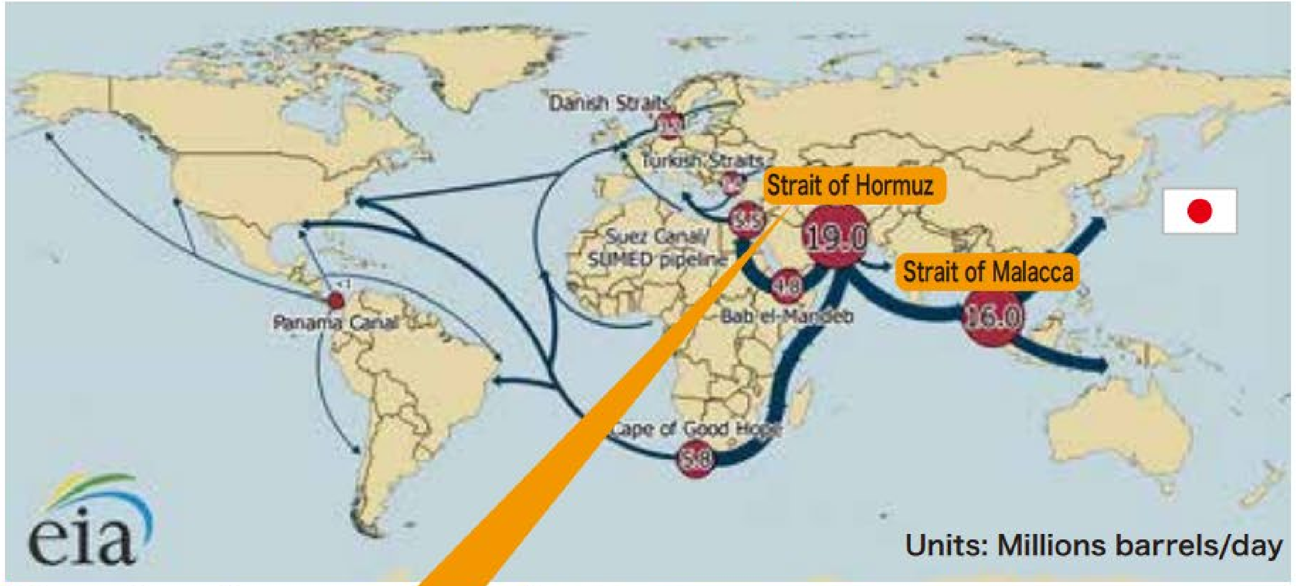
Energy self-sufficiency ratio in Japan



Souce: METI

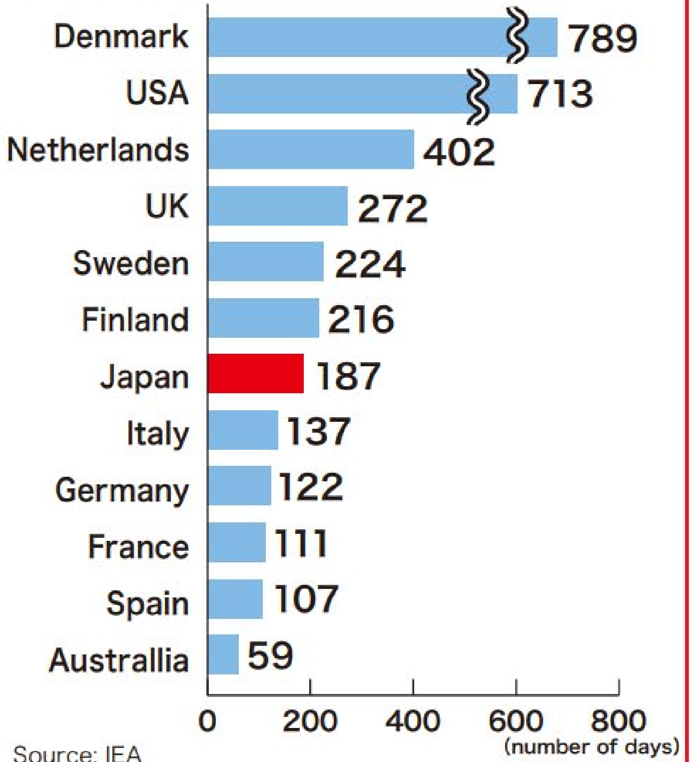
Column: Global crude oil trade and growing tensions in the Middle East

Global crude oil shipping routes and choke points (2016)



The Strait of Hormuz is an important shipping route. It is the largest single route for the transport of crude oil in the world, however, it is susceptible to the effects of Middle East tensions.
An oil tanker flying a Japanese flag was attacked in June 2019.

Oil stockpiling (number of days) of IEA member countries (2019)



Source: IEA
＊ Numbers of days are calculated based on IEA standards. When calculated based on IEA standards, Japan's number of days is approximately 20% less than stipulated in the standards of the Oil Stockpiling Act. (Japan maintains a stockpile of 232 days when calculated based on the standards in the Oil Stockpiling Act.)

Oil is stockpiled in case it suddenly becomes difficult to obtain a supply of crude oil due to a destabilized political situation in the Middle East.

Crude oil choke points: These are key locations where large numbers of oil tankers pass through from countries all over the world pass through. In the event that one of these points becomes impassable, global oil prices are expected to skyrocket.

Souce: METI

Basic Hydrogen Strategy (key points)

METI Ministry of Economy, Trade and Industry

This strategy lays out the vision for the common target that public and private sectors should pursue together with an eye on 2050.

1. Structural challenges involving Japan's energy supply and demand

(1) Energy security and self-sufficiency rate

- Japan depends on overseas fossil fuels for about 94% of its primary energy supply. Oil-based fuels account for 98% of automobile fuels, of which approximately 87% is from the Middle East.
- Japan's energy self-sufficiency rate has remained at 6-7% due primarily to the shutdown of nuclear power plants since 2011's Great East Japan Earthquake. This is the second lowest among the 34 OECD countries.

(2) CO_2 emission restrictions

- Japan's target is to cut GHG emissions by 26% by FY2030 from the FY2013 level (or by 25.4% from FY2005).
- In accordance with the Paris Agreement, Japan will attempt to cut GHG emissions by 80% by 2050.

2. Significance and importance of hydrogen

(1) Diversification of supply/procurement sources to fundamentally reduce procurement/supply risks

- Hydrogen can be **produced from renewable energy and various other energy sources, stored and transported**. Japan's primary supply structure must be diversified to reduce its dependence on specific, individual energy sources.

(2) Reducing carbon in power generation, transportation, heating and industrial processes

- Hydrogen does not emit CO_2 during use. CCS and renewable energy technologies can be used to make hydrogen a **completely CO2-free** energy source.
- Conventional fuels or fuel cells can be combined with hydrogen to ultimately reduce carbon in every area.

(3) Significance as seen from 3E+S viewpoint

- **A hydrogen-based society is a means to an end**. By realizing a hydrogen-based society, Japan will seek to achieve the "3E+S" goal.

(4) Contributions to the international community through world-leading innovation

- **Japan will expand its hydrogen technologies overseas** to lead global carbon reduction.

(5) Industrial promotion and competitiveness enhancement

- Japanese hydrogen and fuel cell technologies are the world's most advanced. Japan will proactively expand these technologies domestically and overseas to **create a new growth industry**.

(6) Leading hydrogen initiatives in foreign countries

- While maintaining a close watch on global trends, **Japan should lead the world in realizing a hydrogen-based society.**

Basic Hydrogen Strategy (key points)

METI Ministry of Economy, Trade and Industry

3. Basic strategy for realizing a hydrogen-based society (i)

(1) Realizing low-cost hydrogen use

: Utilizing unused energy and renewable energy from overseas

- **Reducing the hydrogen procurement and supply costs is indispensable** in realizing a "hydrogen-based society".
- **A basic approach** is to combine cheap, unused energy from overseas with CCS, or **procure massive amounts of hydrogen** from cheap, renewable energy electricity in parallel to the establishment of international supply chains through the development of storage and transportation infrastructure.
- Japan will develop commercial-scale supply chains by around 2030 to procure 300,000 tons of hydrogen annually and ensure that the cost of hydrogen reaches **30 yen/Nm3.**
- In the later future, Japan will try to lower the hydrogen cost to **20 yen/Nm3** to allow hydrogen to have **the same cost competitiveness as traditional energy sources when environmental cost adjustments are incorporated**.

(2) Developing international hydrogen supply chains

- Japan will develop energy carrier technologies to enable efficient hydrogen transportation and storage.
- Japan will demonstrate a **liquefied hydrogen** supply chain by the mid-2020s for commercialization around 2030.
- Japan will establish basic technologies for an **organic hydride** supply chain by FY2020 and commercialize the chain in or after 2025.
- Japan will resolve such challenges as reducing the emission of nitrogen oxide in the direct combustion process and ensuring safety in handling of flammable and deleterious substances in a bid to introduce the use of CO2-free **ammonia** by the mid-2020s.
- Japan will consider how best to disseminate **methanation** technology **that employs** CO2-free hydrogen.

(3) Renewable energy expansion in Japan and regional revitalization

a. Expanding the use of hydrogen from renewable energy in Japan

- To further expand renewable energy use, it is necessary to not only ensure the power supply is regular and stable, but also develop technologies for storing surplus power
- **The power-to-gas technology** that stores renewable energy electricity as hydrogen is a promising method of controlling long-cycle renewable energy power generation fluctuations that are difficult for storage batteries to address.
- The key point is cost reduction. Japan will attempt to develop a technology that cuts the unit cost for water electrolysis systems as core power-to-gas equipment to **50,000 yen/kW** by 2020 in order to realize the world's highest cost competitiveness.
- Japan will attempt to **commercialize** power-to-gas systems by **around 2032**, and reduce the cost of hydrogen from renewable energy to **as low as that of imported hydrogen** in the later future.

b. Utilizing regional resources and regional revitalization

- The utilization of unused regional resources (including renewable energy, waste plastics, sewage sludge and by-product hydrogen) will contribute not only to **expanding the use of low-carbon hydrogen** but also to improving regional energy self-sufficiency rates, **creating new regional industries** and establishing dispersed renewable and other energy systems.
- Relevant challenges include (1) the expansion of regional hydrogen demand and the optimization of regional supply and demand, (2) the reduction of costs of hydrogen facilities, and (3) the reduction of power generation and raw material procurement costs.
- Adopting the findings of ongoing demonstration projects, the central government will **support the development of low-carbon hydrogen supply chains utilizing regional resources.**

Basic Hydrogen Strategy (key points)

METI Ministry of Economy, Trade and Industry

3. Basic strategy for realizing a hydrogen-based society (ii)

(4) Hydrogen use in power generation

- Like natural gas power generation, hydrogen power generation can play a major role as a **regulated power supply and backup power source** required for expanding renewable energy.
- Hydrogen power generation is useful in terms of ensuring stable and large-scale use of hydrogen, bringing stability and economy to the market.
- Japan seeks to **commercialize** hydrogen power generation as well as international hydrogen supply chains and cut the unit hydrogen power generation cost to **17 yen/kWh around 2030**. Japan's annual hydrogen procurement may have to reach **around 300,000 tons (amounting to 1 GW in power generation capacity)**.
- In the future, Japan will attempt to make hydrogen power generation including environmental values as **cost competitive as LNG power generation**. To this end, Japan's annual hydrogen procurement may have to be **5-10 million tons (amounting to 15-30 GW in power generation capacity).**
- For the introduction of hydrogen power generation, Japan must improve economic efficiency of hydrogen power generation and **the assessment of its environmental value** while monitoring discussions on other institutional designs.
- CO2-free methane and ammonia can be used directly. Japan will attempt to mix ammonia with coal at coal power plants by around 2020.

(5) Hydrogen use in mobility

- Japan aims to increase the number of FCVs in Japan to 40,000 units by 2020, to 200,000 units by 2025 and to 800,000 units by 2030. Japan also aims to increase the number of hydrogen stations in Japan to 160 by FY2020 and to 320 by FY2025 and make **hydrogen stations independent by the second half of the 2020s**.
- To this end, Japan will promote **regulatory reform, technological development, and joint, strategic hydrogen station development by the public and private sectors**.
- To secure the optimum locations for hydrogen stations, Japan will attempt to develop renewable-based hydrogen stations in conjunction with commercial hydrogen station development.
- Japan aims to increase the number of FC buses in Japan to around 100 by FY2020 and to **around 1,200** by FY2030.
- Japan aims to increase the number of FC forklifts in Japan to around 500 by FY2020 and to **around 10,000** by FY2030.
- Japan also aims for the development and commercialization of **FC trucks**.
- Japan will promote fuel cells for **small ships**.

Basic Hydrogen Strategy (key points)

3. Basic strategy for realizing a hydrogen-based society (iii)

(6) Potential hydrogen use in industrial processes and heat utilization

- CO2-free hydrogen can (a) be **used as fuel** for energy areas where electrification is difficult, and (b) **replace industrial-use hydrogen from fossil fuels**, contributing to cutting carbon emissions.
- In the future, Japan will attempt to use CO2-free hydrogen for **reducing carbon emissions in the industry sector**.

(7) Utilizing fuel cell technologies

- As for Ene-Farms, Japan will seek to lower the price to 800,000 yen for a standard polymer electrolyte fuel cell (PEFC) and to 1 million yen for a standard solid-oxide fuel cell (SOFC) by FY2020 to secure their later **autonomous diffusion**.
- Japan will explore markets for apartment buildings, cold regions, and Europe and other regions with high heat demand.
- From 2030, Japan will attempt to diffuse **pure hydrogen fuel cell co-generation systems** using CO2-free hydrogen.

(8) Utilizing innovative technologies

- With an eye on 2050, it is necessary to develop innovative technologies for highly efficient water electrolysis for **hydrogen production** as well as low-cost, highly efficient **energy carriers** and highly reliable, low-cost **fuel cells**.
- Relevant government organizations will seamlessly implement individual projects.

(9) International expansion (standardization, etc.)

- Japan will lead **international standardization** through international frameworks. Japan will promote technological development and cooperation with relevant organizations.

(10) Promoting citizen's understanding and regional cooperation

- It is necessary that the understanding of the safety of hydrogen and the significance of hydrogen use is shared among citizens. To this end, **the central government will adequately provide information in cooperation with local governments and business sectors**.
- The central government will proactively exploit "the conference on local governments' cooperation in diffusing and promoting FCVs" and regional councils to share information with local governments and facilitate information sharing between local governments.

Scenario for Basic Hydrogen Strategy

METI
Ministry of Economy, Trade and Industry

Present picture → 2030 → Target future picture

Supply

Fossil fuel-based hydrogen
(by-product hydrogen, natural gas reformation)

Supply chain development and demonstration, scale-up

✓ Developing international hydrogen supply chains
✓ Developing domestic Power-to-Gas for renewable hydrogen supply

Scale-up
Substantial cost cuts

CO_2-free hydrogen
(Brown coal combined with CCS, utilizing renewable energy)

Hydrogen volume (t/year)

(Present) 200 → (2020) 4k → 300k (commercial supply chain capacity) → 5~10m + α (depending heavily on consumption for power generation)

Cost ($/kg)

~10 (hydrogen station price) → 3 (1/3 or less) → 2 (1/5 or less)

Use

Power generation

– (R&D stage) → ¥17/kWh (Commercial stage) → ¥12/kWh Replacing gas power generation

Demonstrating hydrogen power generation, establishing an environmental value assessment system

(Reference) 300kt in hydrogen consumption represents some 1GW in power generation capacity

(Reference) 5-10 million t represents 15-30 GW in power generation capacity

Mobility

"Roadmap" targets

	(Present)	(2020)	(2030)	Target future picture
Hydrogen Stations (locations)	100	160	some 900	Replacing gas stations
FCV (units)	2.5k	40k	800k	Replacing conventional gasoline mobility
FC buses (units)	2	100	1.2k	Introducing large FCVs
Forklifts (units)	40	500	10k	

Halving hydrogen station costs

FCV/Hydrogen stations becoming independent
* 2nd half of the 2020s

Strategic hydrogen station development, regulatory reform, technological development

Relevant government organizations cooperating in developing hydrogen supply networks

Utilization of fuel cells

Ene-Farm (units): 230k → 5.3m → Replacing traditional residential energy systems

Ene-Farms becoming independent

(Reference comparison)

- Natural gas imports: **85 million t/y**
- Natural gas import price: **$0.2/kg***
  *Conversion based on hydrogen's calorific value
- Unit LNG power generation cost: **¥12/kWh**
- Fossil power generation capacity: **132GW**
- Number of gas station: **31,500**
- Number of passenger cars: **62 million**
- Number of households: **53 million**

The Strategic Road Map for Hydrogen and Fuel Cells ～Industry-academia-government action plan to realize "Hydrogen Society"～ (overall)

- In order to achieve goals set in the Basic Hydrogen Strategy,

① **Set of new targets to achieve (Specs for basic technologies and cost breakdown goals), establish approach to achieving target**

② **Establish expert committee to evaluate and conduct follow-up for each field.**

		Goals in the Basic Hydrogen Strategy		Set of targets to achieve	Approach to achieving target
Use	Mobility	FCV 200k by 2025 800k by 2030	2025	● **Price difference between FCV and HV** (¥3m → ¥0.7m) ● **Cost of main FCV system** (FC ¥20k/kW → ¥5k/kW; Hydrogen Storage ¥0.7m → ¥0.3m)	• Regulatory reform and developing technology
Use	Mobility	HRS 320 by 2025 900 by 2030	2025	● **Construction and operating costs** (Construction cost ¥350m → ¥200m; Operating cost ¥34m→¥15m) ● **Costs of components for HRS** (Compressor ¥90m → ¥50m; Accumulator¥50m → ¥10m)	• Consideration for creating nation wide network of HRS • Extending hours of operation
Use	Mobility	Bus 1,200 by 2030	Early 2020s	● Vehicle cost of FC bus (¥105m → ¥52.5m) ※In addition, promote development of guidelines and technology development for expansion of hydrogen use in the field of FC trucks, ships and trains.	• Increasing HRS for FC bus
Use	Power	Commercialize by 2030	2020	● Efficiency of hydrogen power generation (26%→27%) ※1MW scale	• Developing of high efficiency combustor etc.
Use	FC	Early realization of grid parity	2025	● Realization of grid parity in commercial and industrial use	• Developing FC cell/stack technology
Supply	Fossil Fuel +CCS	Hydrogen Cost ¥30/Nm3 by 2030 ¥20/Nm3 in future	Early 2020s	● Production: Production cost from brown coal gasification (¥several hundred/Nm3→ ¥12/Nm3) ● Storage/Transport：Scale-up of Liquefied hydrogen tank (thousands m^3→50,000m^3) Higher efficiency of Liquefaction (13.6kWh/kg→6kWh/kg)	• Scaling-up and improving efficiency of brown coal gasifier • Scaling-up and improving thermal insulation properties
Supply	Green H_2	System cost of water electrolysis ¥50,000/kW in future	2030	● Cost of electrolyzer (¥200,000m/kW→¥50,000/kW) ● Efficiency of water electrolysis (5kWh/Nm3→4.3kWh/Nm3)	• Designated regions for public deployment demonstration tests utilizing the outcomes of the demonstration test in Namie, Fukushima • Development of electrolyzer with higher efficiency and durability

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.

Key points of the Action plan ② (hydrogen supply chain)

Red: New Target

Acceleration of RD&D to establish technologies for future hydrogen mass-consuming society

Goals of hydrogen supply chain

- H_2 CIF cost : ¥30/Nm3 in 2030, ¥20/Nm3 in the future
- The future reduction of the H_2 cost to the same level as conventional energy sources (e.g. LNG) will be necessary .

Hydrogen cost that matches the LNG cost 10$/MMBtu is ¥13.3/Nm3 (calorie equivalent)
※without consideration of the environmental value.

- Expansion of hydrogen supply network by building government-level relationships with resource-rich countries
- The development of the basic technologies to reduce hydrogen cost, targeting all processes, from hydrogen production to hydrogen transport

Hydrogen supply chain

Fossil fuel +CCS

Targets

- Toward realization of hydrogen supply cost of 30/Nm3 around 2030, Targets by the first half of 2020 are set assuming the success of Japan–Australia Brown Coal-to-Hydrogen project.

<Hydrogen production>

✓ Cost reduction of hydrogen production through brown coal gasification
(¥several hundred/Nm3 during brown coal-hydrogen project →¥12/Nm3)

<Hydrogen storage and transportation>

✓ Improvement of the efficiency of liquification
(13.6kWh/kg during brown coal-hydrogen project → 6kWh/kg)

✓ Scaling-up of liquefied hydrogen tank
(several thousand m³ during brown coal-hydrogen project → 50,000m³)

<CCS>

✓ Cost reduction of CO_2 separation
(about ¥4,200/t-CO_2 in Japan → ¥2,000 level/t-CO_2)

Action to achieving the targets

- Technological development for scaling-up and higher efficiency of brown coal gasifier
- Development of an innovative liquefier structure (non-contact bearing) enables highly efficient hydrogen liquefaction
- Development of technologies capable of manufacturing LNG-like large tanks with high insulation properties
- Development of low-cost CO_2 capture technologies (e.g. physical absorption)

Green Hydrogen

Targets

- Establishment of the technology of hydrogen production from Renewable energy

System cost of electrolyzer:¥200,000/kW → ¥50,000/kW by 2030
Energy comsumption:5kWh/Nm3 → 4.3kWh/Nm3 by 2030

Action to achieving the targets

- Expansion of the demonstration in model regions for social deployment utilizing the achievement in the demonstration in Namie, Fukushima
- Development of electrolyzer with higher efficiency and durability
- Development of supply chain utilizing local resources

Key points of the Action plan ③ <other applications for a global "Hydrogen Society">

Red: New Target

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

		Targets	Action to achieving the targets
Hydrogen utilization	Power	● 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
	Industry	● 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
	Stationary fuel cell	Ene-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 Commercial 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) ● 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)	• Development of markets such as existing housing and condominium. • Review of regulations for simplification of electrical work • 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
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

Personal proposal for 2050: “Help and Be Helped”

1. Japan lacks favorable condition for CN-hydrogen as of now
- Costly renewable, few CCS potential, lack of fossil fuel, social barrier for nuclear

2. H is the hardest to import by sea due to physics.
- Major tech breakthroughs prerequisite for large scale economical implementation

3. Think about global boundary condition @ 2050 for CN-H:
- Cheep and plenty CN-H (and electricity) on the continents
- The cheapest for Japan can be import from Russia or Korea by H-pipelines

4. Strategies for Japan toward 2050: “help and be helped”

   First, help the global development of hydrogen society by techs (FC, nuclear-H, CCS, etc)

   Then, be helped from the global hydrogen development (pipeline, nuclear-H, etc)

Links

- Basic Hydrogen Strategy 2017

https://www.meti.go.jp/english/press/2017/pdf/1226_003a.pdf

- Hydrogen and Fuel Cell Strategy 2019

https://www.meti.go.jp/english/press/2019/0312_002.html

https://www.meti.go.jp/english/press/2019/0918_001.html

- Japan’s Energy 2019

https://www.enecho.meti.go.jp/en/category/brochures/pdf/japan_energy_2019.pdf

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