

Supply for Hydrogen

- Possible sources in the near term -

IEA Hydrogen Workshop

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Contents

1. Objective
2. Perspective of Hydrogen Supply
3. Perspective of Hydrogen Demand
4. Balance of Demand and Supply
5. Summary

- The objective of this work is to provide information on the possibility as the carrier of energy and the stable supply in the near term.
 - ❖ Estimate the volume of hydrogen demand and supply in the near term from the results based on literature searching and hearing surveys.
 - ❖ Summarize the issues for stable supply of hydrogen in the future on considering the balance of demand and supply.
- In this work, the supply and demand of hydrogen which can be traded in a market are only targeted.
 - ❖ Hydrogen made for self consumption is not included in the estimation
 - ❖ As the supply, the following 3-fields are only targeted :
 - Surplus hydrogen from an on-site production for self consumption
 - By-production hydrogen from each industrial devices
 - New large-scale production or import

■ Estimated H₂ supply from 6 industries (○ or △)

❖ considering efficiency and substitutability, capacities of H₂ supply from 6 different industries are estimated.

			Sources / Methods
Existing sources	Oil		○ Hydrogen production equipment and / or catalytic reforming equipment at oil factories. By-product hydrogen.
	Chemistry	NaOH	○ By-product hydrogen.
		NH ₃	× (Companies have low intension to sell hydrogen.)
	Petrochemistry	C ₂ H ₄ , etc.	× (Difficult to sell hydrogen, since plants are designed to achieve energetic self-reliance.)
	Steel	COG	○ H ₂ contained in COG.
		BFG, LDG	× (Unreasonable, because of low content of hydrogen.)
New sources	Natural gas		○ Steam reforming.
	Domestic RE		△ Water electrolysis with electricity supplied by RE.
	Import		○ Import of H ₂

■ Estimated capacity of H₂ supply from oil industry.

- ❖ If prepared (shipping facilities, etc.), H₂ can be sold.
- ❖ Estimation of productivity: based on JPEC (2008)^{*1}, taking following points into consideration:
 - Renewal of equipment in 2007-2011.
 - Operation rate of topping plants.
 - Estimation of future shut down of topping plants.
- ❖ Rationalization of oil factories under Sophisticated Methods of Energy Supply Structures and change of demands for lighter fuels may have some effect on future capacity of H₂ production.

Points of estimation	Estimated capacity	
	2015	2030
• Capacity of hydrogen production equipment and by-product H₂ are considered. • Estimation of future consumption of oil is referred from IEEJ(2012)^{*2}	3.0 - 7.0 billion Nm ³ /yr	4.0 - 7.0 billion Nm ³ /yr

^{*1} JPEC(2008) : PEC-2007L-03

^{*2} IEEJ(2012) : 「Asia / world energy outlook 2012」

■ Capacity of H₂ supply from chemical industry.

- ❖ Considering by-product H₂ from NaOH plant.
- ❖ Sold H₂ can be used except to chemical industries (can be used to power plants, etc.)
- ❖ Rate of by-production is 280[Nm³] H₂ per 1[t] NaOH
- ❖ In future, GDE (Gas Diffusion Electrode Salt Electrolysis) can be introduced, and by-production rate of H₂ can be changed.
 - No H₂ by-production from GDE

Points of estimation	Estimated capacity	
	2015	2030
• Considering by-product H₂ from NaOH plant. • Future activity is referred to Advisory Committee on Energy and Natural Resources(2012), etc. • Assumed number of companies introduced GDE is 1-2 in 2015. In 2030, assumed with range from the same as 2015 to fully introduction.	1.0 billion Nm ³ /yr	0.0 - 1.0 billion Nm ³ /yr

■ Capacity of H₂ supply from steel industry.

- ❖ Considering H₂ contained in COG. (content is 50-60%)
 - (BFG and LDG are not considered, because of low content of H₂)
- ❖ Among H₂ for heating furnaces and power plants currently available, H₂ for power plants is taken into consideration, since fuel for power plants is easier to be substituted by H₂.
- ❖ COURSE50 technology is currently under development. Introduction of this technology can have an effect on future productivity of H₂.
 - If this technology is introduced, H₂ is used for steel production by H₂ reduction, and surplus H₂ is decreased.
 - Currently, this possibility is not clear.

Points of estimation	Estimated capacity	
	2015	2030
• [Amount of COG] × [H₂ content (60%)] × [Efficiency of PSA] (60%) × [Rate of power plant fuel substituted by H₂] (40%) • Future activity is referred to Advisory Committee on Energy and Natural Resources(2012), etc.	0.0 - 2.0 billion Nm ³ /yr	0.0 - 2.0 billion Nm ³ /yr

■ Capacity of H₂ supply from natural gas

❖ Considering H₂ generated by reforming natural gas which is from excess capacity in LNG base

- The amount of excess LNG is 20% of the productive capacity in the LNG regasification plant (based on the results of hearing investigation)
- This estimation is considered H₂ generated from half of the excess LNG
- The extent to which we can use natural gas for the H₂ production is uncertain, because of the excess LNG is stored for seasonal variation and emergency use

Points of estimation	Estimated capacity	
	2015	2030
• This estimated amount of H₂ production is considered 10% of the productive capacity in the LNG regasification plant • The efficiency of H₂ production from natural gas is 80% • Future natural gas consumption is referred from IEEJ(2012)*¹	~7 billion Nm ³ /yr	~8 billion Nm ³ /yr

*¹ IEEJ (2012) : "Asia / World energy outlook 2012"

■ Capacity of H₂ supply from domestic renewable energy

- ❖ H₂ production from wind power generation has relatively high feasibility
 - The wind power generation is low cost in the renewable energy, and its footprint is small compared to solar power generation devices
 - Domestic wind power generation capacity is 546.7GW
 - wind speed assumption : on the ground 5.5 m/s - , on the ocean 6.5 m/s -
(reference data on the ground : Agency for Natural Resources and Energy (2011)*¹)
- ❖ To use wind power generation as H₂ production sources, development and validation are required the water electrolysis technology that can respond to changes in wind power

Points of estimation	Estimated capacity	
	2015	2030
• This estimation is based on the following assumptions Capacity of wind power generation in japan : 546.7 GW Efficiency of water electrolysis : 70% Power loss (H₂ transportation, compression, etc) : 10%	(200 billion Nm ³ /yr)	(200 billion Nm ³ /yr)

*¹ Agency for Natural Resources and Energy (2011):「Project on the basic investigations of renewable energy promotion (Investigation on the possible introduction quantity of wind energy)」

■ Capacity of H₂ supply from overseas

- ❖ There are abundant capacity of H₂ production at overseas
 - H₂ from renewable energy, reforming from coal, by-product in the oil and petrochemical plants, etc.
- ❖ H₂ transportation method is the key(see the planning of following companies)
 - Chiyoda Corporation: transportation of chemical hydride by ship
 - Scheduled for operation in 2015
 - Hydrogen production capacity is 80,000 Nm³/h (installed capacity of hydro-dehydrogenation plant)
 - 800,000 Nm³/h in 2030
 - Kawasaki Heavy Industries, Ltd.: transportation of liquid hydrogen by ship
 - Scheduled for operation in 2025
 - Volume of liquid H₂ transportation: 2.5 billion Nm³/year

Points of estimation	Estimated capacity	
	2015	2030
•Considering the H ₂ generation at abroad (transported by liquid H ₂ and chemical hydride, only chemical hydride in 2015)	0.6 billion Nm ³ /yr	9 billion Nm ³ /yr

■ Summary of perspective H₂ supply

(unit: billion Nm³/yr)

		2015	2030
Existing capacity of supply (domestic)	Oil	3~7	4~7
	Chemistry	1	0~1
	Steel	0~2	0~2
New capacity of supply (domestic)	Natural gas	7	8
	Domestic RE	(200 ^{*1})	(200 ^{*1})
New capacity of supply (import)	Import	1	9
Total ^{*2}	Domestic	11~17	12~18
	Domestic + import	12~18	21~27

^{*1} Domestic RE (Renewable Energy) is estimated from all wind power generation capacity in Japan.

^{*2} The capacity of H₂ supply from domestic renewable energy is not included in this total amount.

■ Estimated H₂ demand from the following 3 fields

			Demands	
Existing Demands	For Industry		○	Production of semiconductor, LCD, steel and chemical industry
New Demands	For Automotive	LDV	○	FCV
		Others	×	Introduction of bus and heavy truck is restrictive in 2030.*
	For Electricity	Thermal Power Generation	○	Hydrogen and LNG mixing combustion
		Others	×	Power generation plant by direct hydrogen combustion or IGFC are restrictive in 2030.*
	For Consumer Use	City Gas	×	The effect of hydrogen-mixing on CO ₂ emission and the receptiveness of gas carrier is low.
		Residential	×	Direct hydrogen FC is restrictive in 2030.*
		Business	×	Hydrogen gas-turbine and direct hydrogen FC as CHP system is restrictive in 2030.*

* Based on hearing surveys

■ Potential Demand of H₂ for Existing Use

- ❖ Amount of hydrogen gas traded in a market is about 160 million Nm³
 - For semiconductor and LCD, steel, chemical industries
 - For fuel of rocket

Point of Estimation	Estimated Demand	
	2015	2030
• Demands in the near term was estimated by the industrial production index and the current demand for industrial use • Industrial Production Index : refer to "Perspective of Energy Demand and Supply in 2030" of METI in Japan	0.17 billion Nm ³ /yr	0.2 billion Nm ³ /yr

■ Potential Demand of H₂ for Automotive

- ❖ Estimate based on the following assumptions from hearing surveys
 - Market size, fuel efficiency and annual mileage of FCV
- ❖ However, the estimation may be influenced by uncertain factors such as price of hydrogen supply, development of infrastructure, receptiveness of user

Point of Estimation	Estimated Demand	
	2015	2030
• Market size : about 1,000 (2015), 2 million (2030) • Fuel efficiency is 100 km/kg-H₂ and annual mileage is 12,000 km : refer to Toyota report (2012)	0.001 billion Nm ³ /yr	3 billion Nm ³ /yr

■ Potential Demand of H₂ for Power Generation

❖ Suggest the possibility of hydrogen demand (2030) as fuel of power generation plants in the following requirements :

- Enhance the limitation of CO₂ emission for power generation
- New construction of the nuclear power plant is not accepted, and the existing plants will stop in the near term
- Technology of CO₂-free hydrogen transportation by the special vessel and hydrogen combustor is established
- Power generation unit price is less than that by domestic RE.

Point of Estimation	Estimated Demand	
	2015	2030
•Hydrogen is mixed in 50% by caloric conversion to fuel of the LNG thermal power generation plants which are newly constructed or replaced in the near term	-	0-22 billion Nm ³ /yr

■ Summary of Potential Demand of Hydrogen

- ❖ Estimation-1 : based on the target without limitation of CO₂ emission
- ❖ Estimation-2 : based on large amount of hydrogen demand for power generation with strong limitation of CO₂ emission

[billion Nm³/yr]

	2015		2030	
	Estimation-1	Estimation-2	Estimation-1	Estimation-2
For Industry	0.2	0.2	0.2	0.2
For Automotive	0.001	0.001	3	3
For Electricity	0	0	0	22
	0.2		3~25	

Demand/Supply Balance

Objective

Perspective
of supply

Perspective
of demand

Demand /
supply
balance

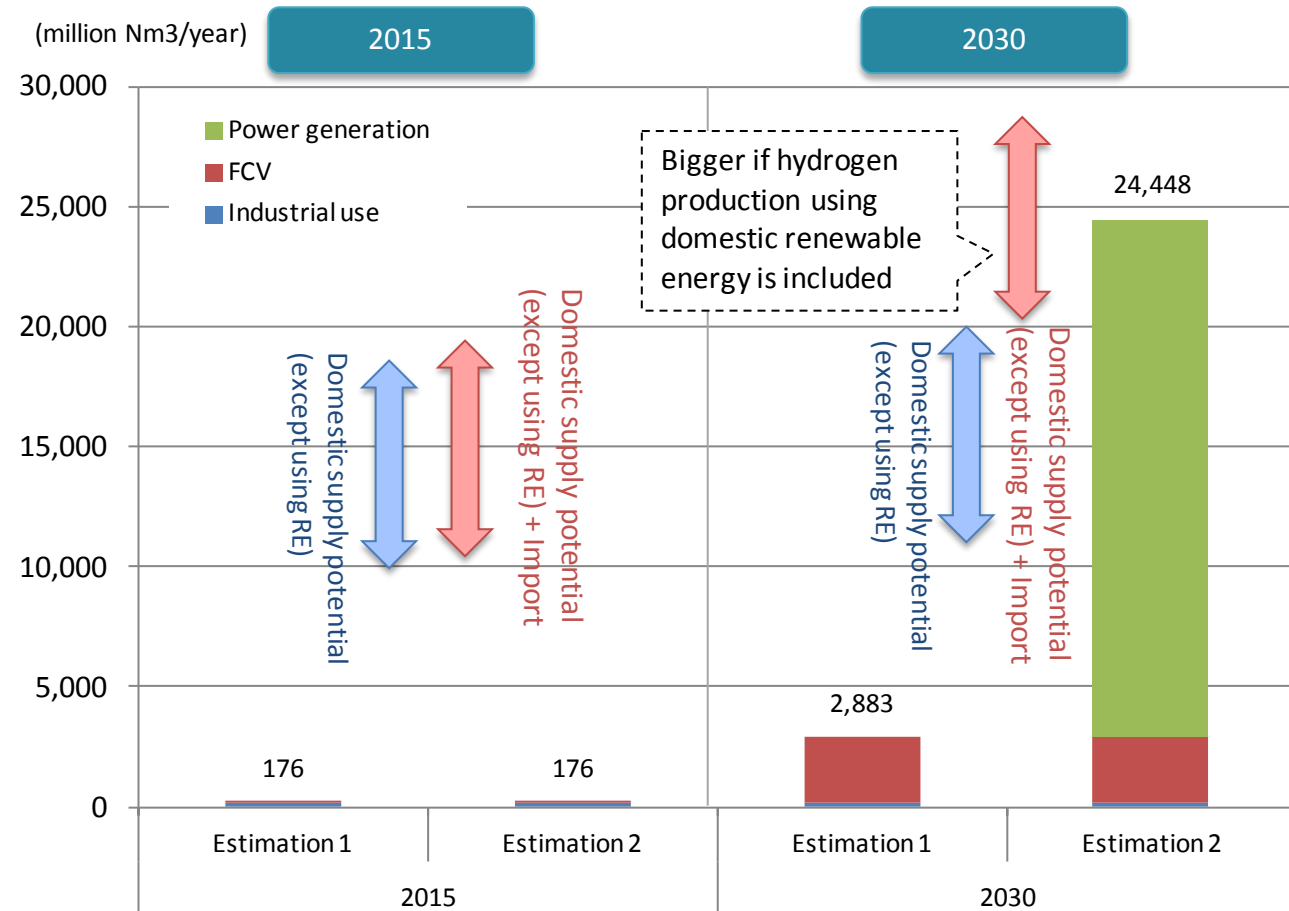
summary

■ 2015:

Domestic supply can be sufficient to satisfy the demand for hydrogen

■ 2030:

The demand of hydrogen may exceed the domestic supply if the markets of FCV and hydrogen power generation spread rapidly in the near term with limitation of CO₂ emission.



- Hydrogen produced by domestic oil, iron and steel, and chemical industries, natural gas reforming, or shipped in chemical hydride or liquid form would be available in 2015 or 2030. Capacity of annual H₂ supply was estimated to be 12-18 billion Nm³ in 2015 and 21-27 billion Nm³ in 2030.
- As for the demand sides, hydrogen may be used as a fuel of power generation plants as well as FCVs if some requirements are satisfied for using hydrogen as fuel, e.g. strong limitation of CO₂ emission. Potential demand was estimated to be 0.2 billion Nm³ at 2015 and 3-25 billion Nm³.
- Considering the balance between demand and supply indicated that hydrogen demand could not be covered with only domestic capability of supply when large amount of hydrogen may be used as a fuel of power generation plants. In that case, it is necessary to import some hydrogen from the foreign countries.

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