Fuel Ammonia Production from fossil fuels

APEC Symposium on Pursuing Decarbonization of Fossil Fuels

October 11, 2023

Yoshikazu (Yoshi) Kobayashi
The Institute of Energy Economics, Japan (IEEJ)

Different sources, different uses

- Hydrogen can be produced from both fossil fuels and zero-emission electricity, which makes it a preferred energy not only for climate action but also for energy security.

Grey hydrogen
- Fossil fuel-based hydrogen (SMR, ATR)

Blue hydrogen
- Fossil fuel-based hydrogen with CCUS

Turquoise hydrogen
- Natural gas with pyrolysis

Green hydrogen
- Renewable energy-based hydrogen (Electrolysis)

Pink (or purple) hydrogen
- Nuclear-based hydrogen (Electrolysis, High-temperature reactor)

Hydrogen

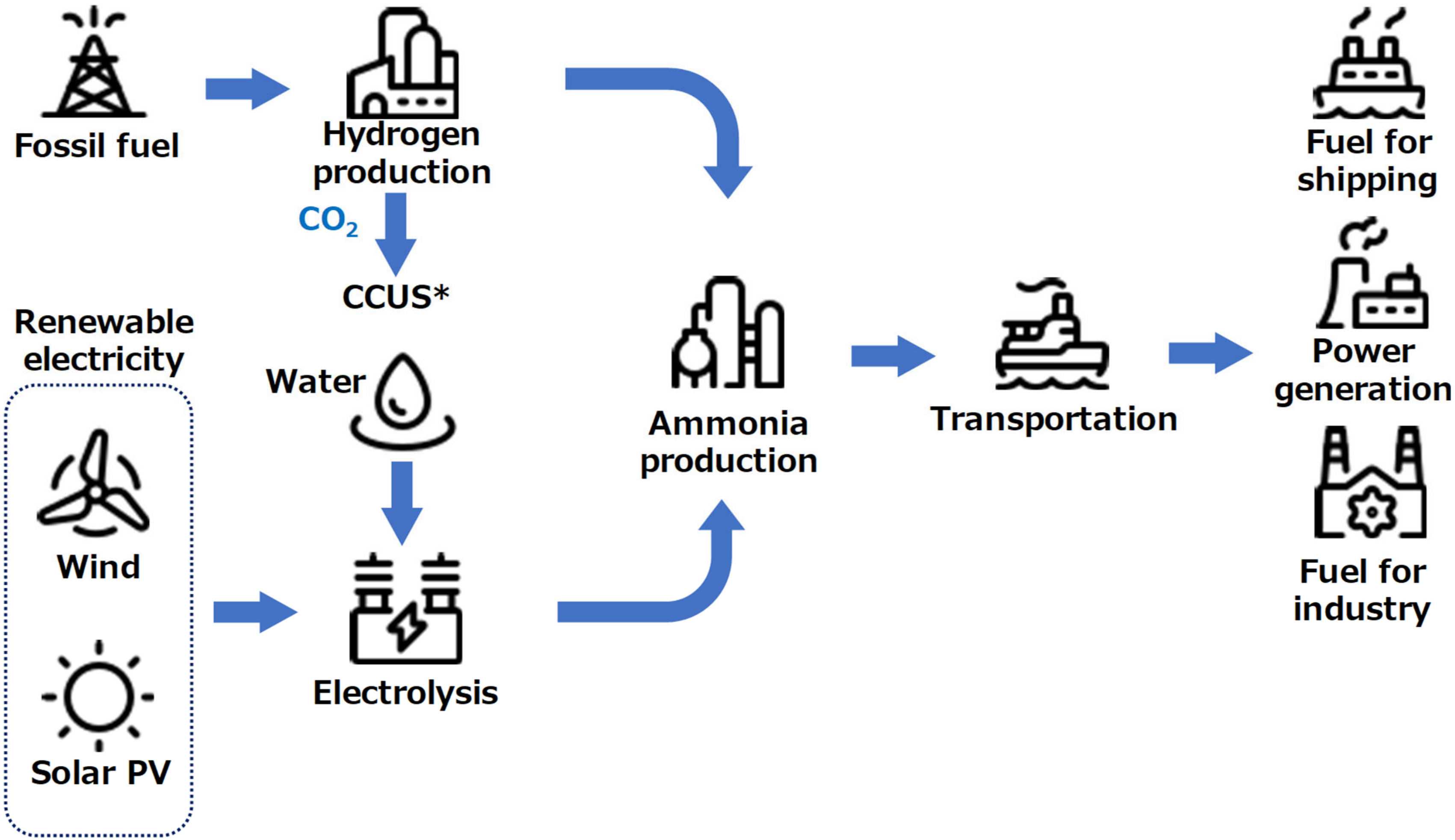
Industrial gas
- Oil refining, Semiconductor, etc.

Zero-emission energy
- Transportation (FCV for land transportation; Hydrogen derivatives for maritime shipping; Synthetic fuel for aviation fuel)
- Industry (Fuel for high temperature; Reduction agent for steel making)
- Building (Hydrogen or synthetic fuel for heating and cooking)
- Power generation (Co-firing/Single-firing of ammonia and hydrogen)

Energy Storage
- Storage of surplus electricity generated from variable (intermittent) renewable energy

Fuel ammonia supply chain

- Ammonia is produced from hydrogen, which can be produced from various sources.
- In most cases, hydrogen and ammonia are produced in an integrated manner.

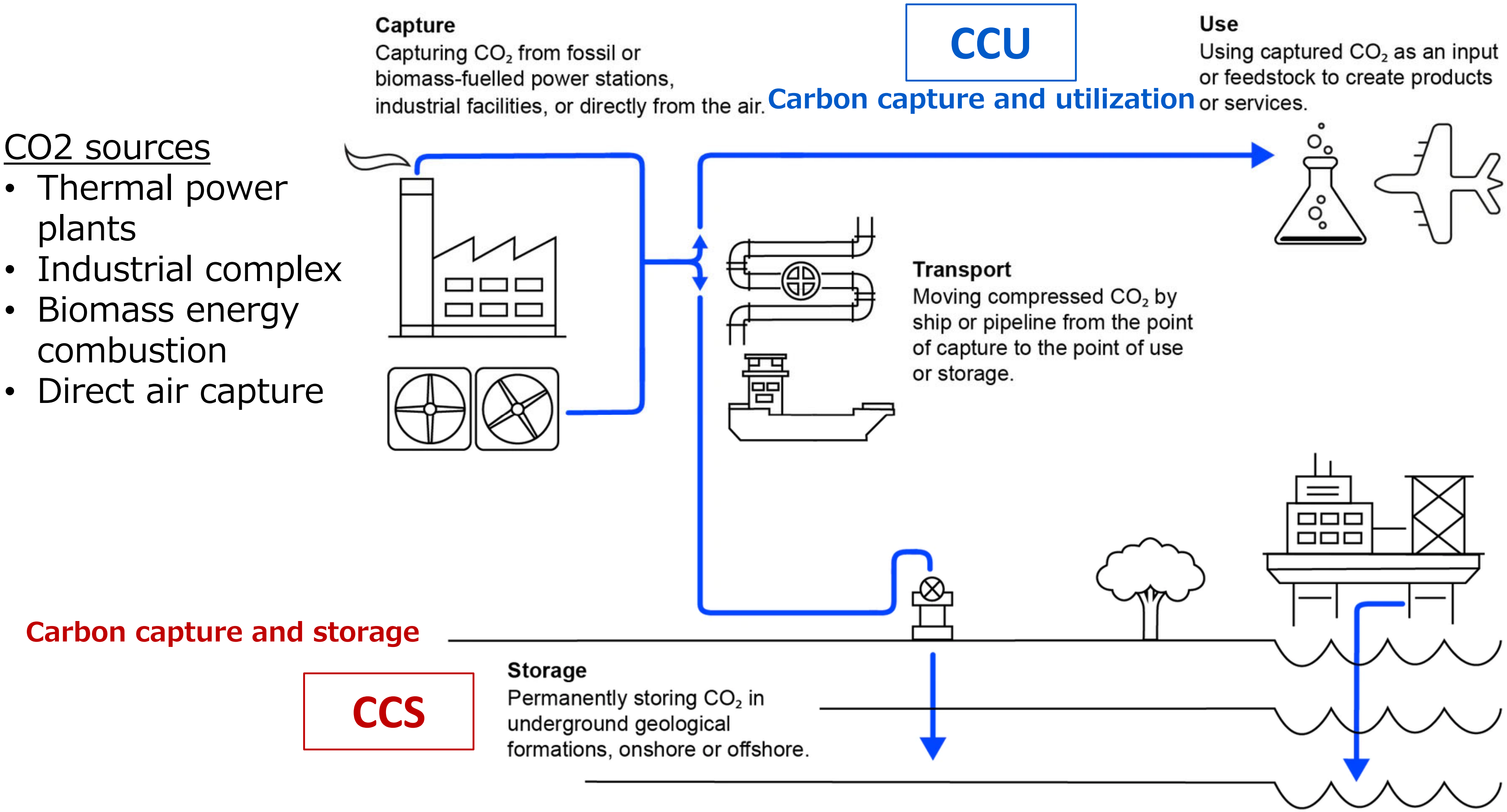


Source: IEEJ

What is CCUS?

- CCUS = Carbon Capture, Utilization and Storage.
- Key technology to make the existing fossil fuel-based hydrogen technology clean enough.

<u>CO2 sources</u>
- Thermal power plants
- Industrial complex
- Biomass energy combustion
- Direct air capture



urce: IEEJ

Importance of low-carbon ammonia

- Low-carbon ammonia (=ammonia produced from fossil fuels” is clearly re recognized as an effective means for decarbonization by G7 leaders this year.

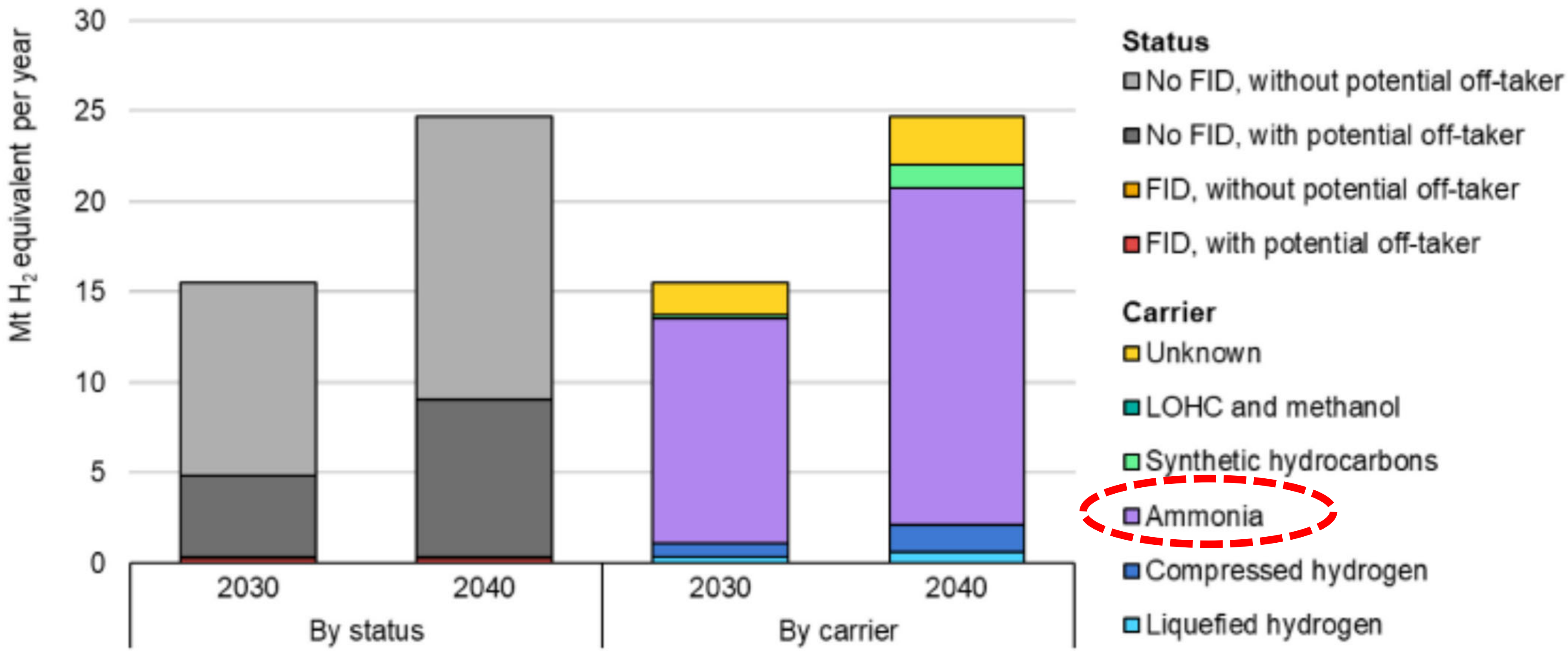
> We recognize that low-carbon and renewable hydrogen and its derivatives such as ammonia should be developed and used, if this can be aligned with a 1.5 °C pathway, where they are impactful as effective emission reduction tools to advance decarbonization across sectors and industries, notably in hard-to-abate sectors in industry and transportation, while avoiding N_2O as a GHG and NO_x as air pollutant.
>
> --- *G7 Hiroshima Leaders’ Communiqué*, Paragraph 25

Source: Ministry of Foreign Affairs of Japan

Ammonia's role for hydrogen trade

- 80% of hydrogen export project currently planned will utilize ammonia as its carrier.
- Some of the exported ammonia will be directly utilized without cracking.

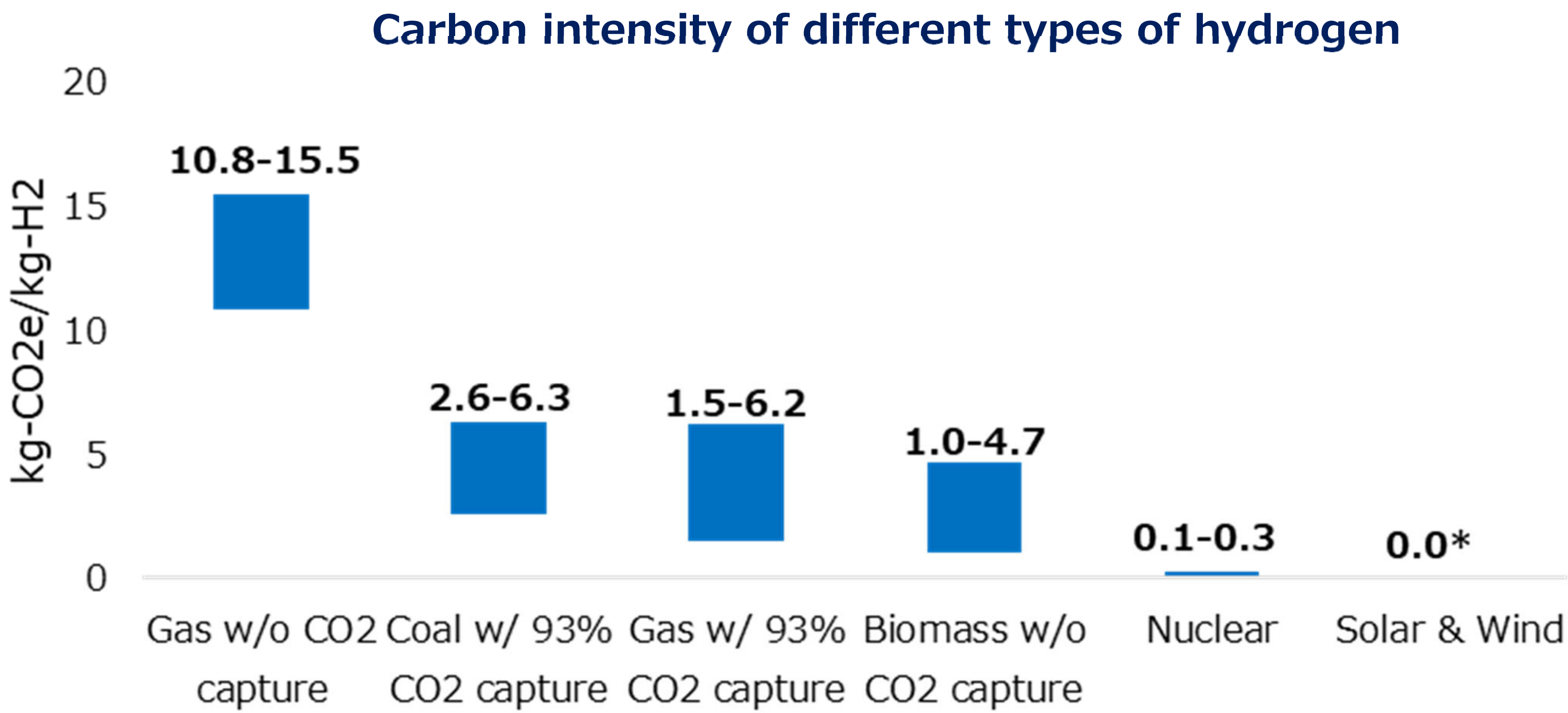
Figure 4.1 Low-emission hydrogen trade by status and by carrier based on announced projects, 2030-2040



IEA, Global Hydrogen Review 2023, p102

Not color but carbon intensity

- Different feedstocks of hydrogen/ammonia have different level of carbon intensity.
- Carbon footprint per unit of production (= carbon intensity) needs to be lowered to zero in the long run.



*Life cycle carbon intensity including the manufacturing process of hydrogen production facilities may go up to 0.9-2.5kg-CO_2e/kg-H_2 in case of solar and 0.4-0.8kg-CO_2e/kg-H_2 in case of wind.
Source: IEA (2023), Towards Hydrogen Definitions based on Their Emissions Intensity, pp39-43

How clean is clean enough?

- Several governments / organizations published threshold of carbon intensity for low carbon or clean hydrogen.
- The amount of subsidy or tax benefit may change subject to the level of carbon intensity.

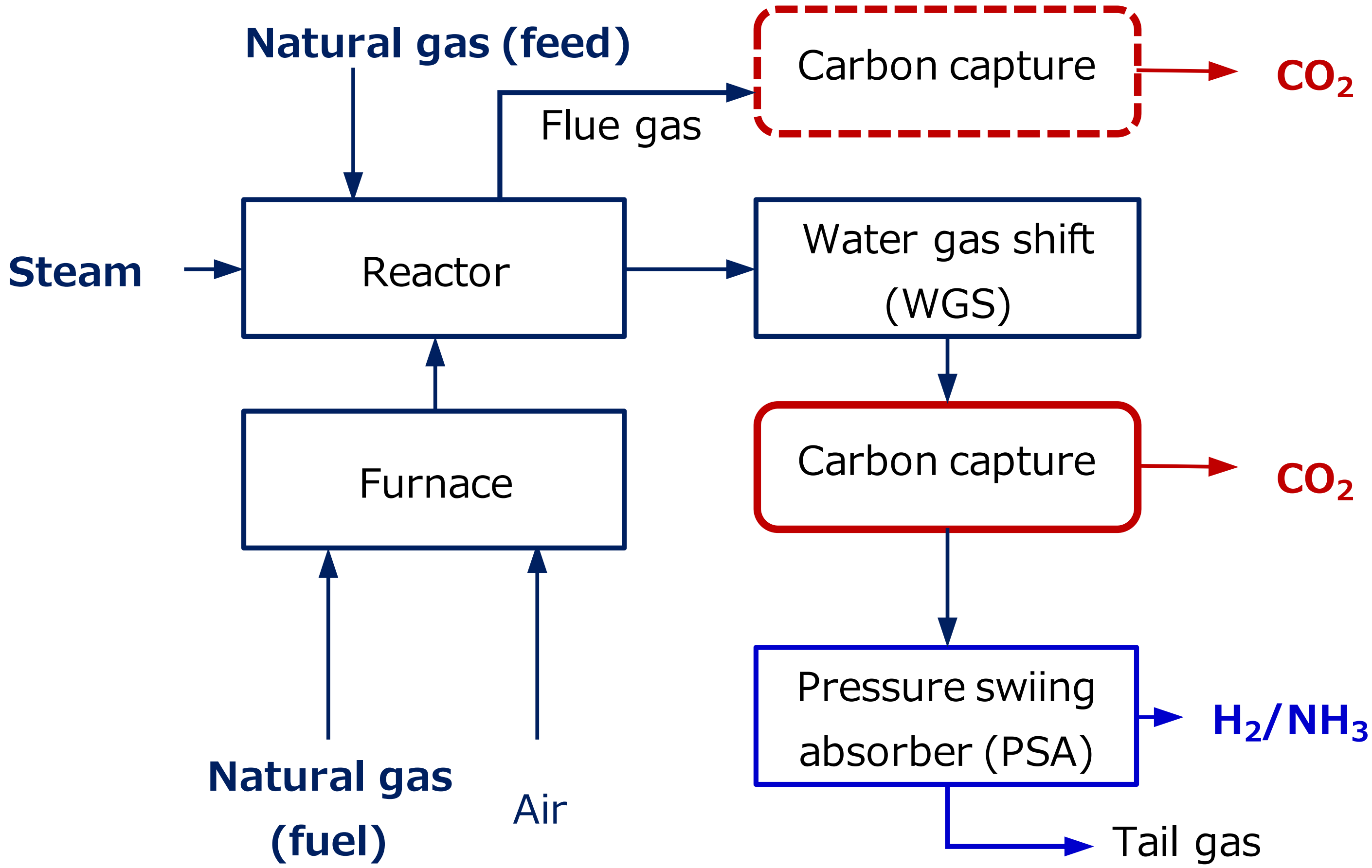
Carbon intensity condition for clean hydrogen

Standard	Carbon intensity (kg-CO2e/kg-H2)	Boundary
RED/RFNBO (EU)	**3.4**	Life cycle
EU taxonomy (EU)	**3.0**	Life cycle
Low Carbon Hydrogen Standard (UK)	**2.4**	Well to gate
Clean Hydrogen Production Standard	**4.0**	Well to gate
Inflation Reduction Act (US)	**0-4**	Life cycle (well to gate)
Japan Hydrogen Strategy	**3.4**	Well to gate
CertifHy Low Carbon (Industry)	**60% reduction**	Well to gate

Blue hydrogen/ammonia: SMR route

- Most of the existing ammonia production plants adopt steam-methane reforming (SMR) process to produce hydrogen as a feedstock of ammonia.
- Matured technologies with very low technological risks.
- Productions costs can be lowered by scale up.

Simplified flow of SMR process

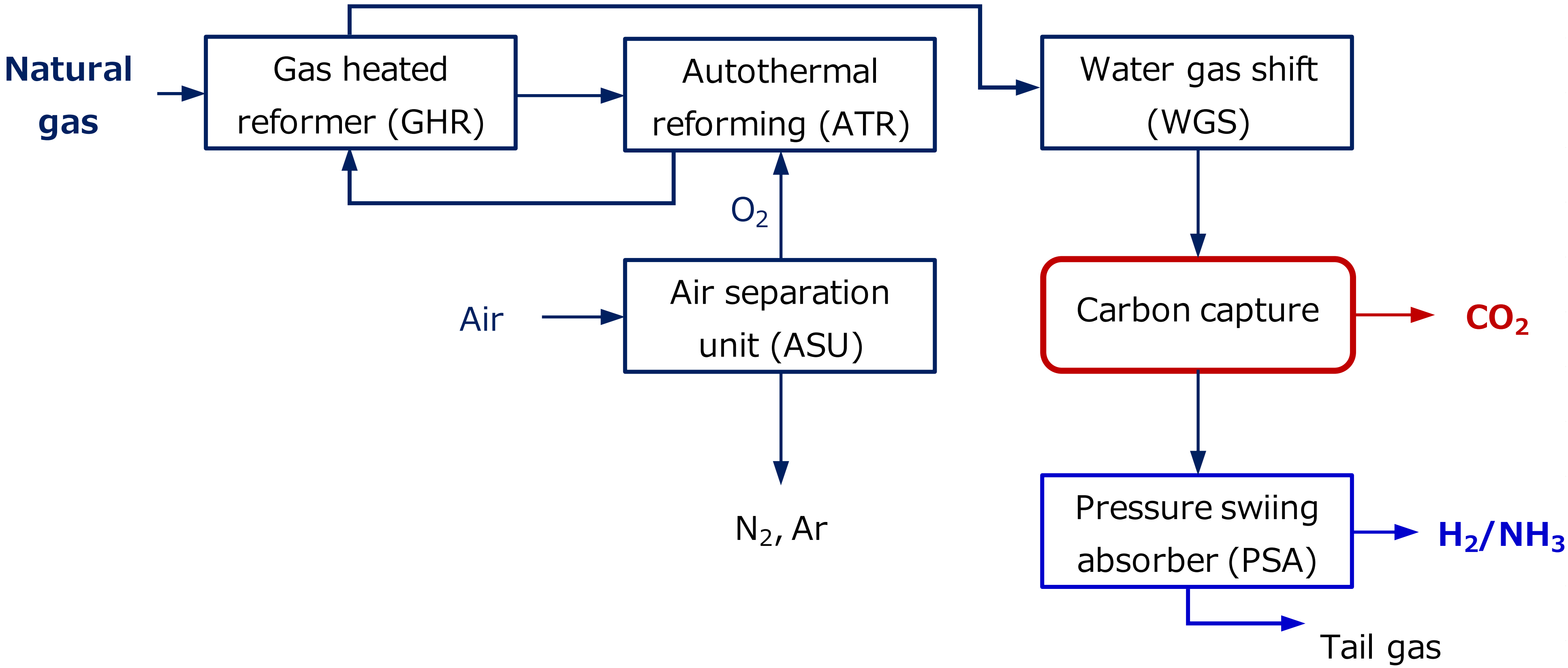


Source: Author

Blue hydrogen/ammonia: ATR route

- Auto thermal reforming process (ATR) uses oxygen and steam or carbon dioxide to partially oxidize the feedstock natural gas. Because of the oxidation, the reaction is exothermic.
- Larger volume of CO2 can be captured easily compared to SMR because ATR needs less energy inputs for the process.

Simplified flow of ATR process

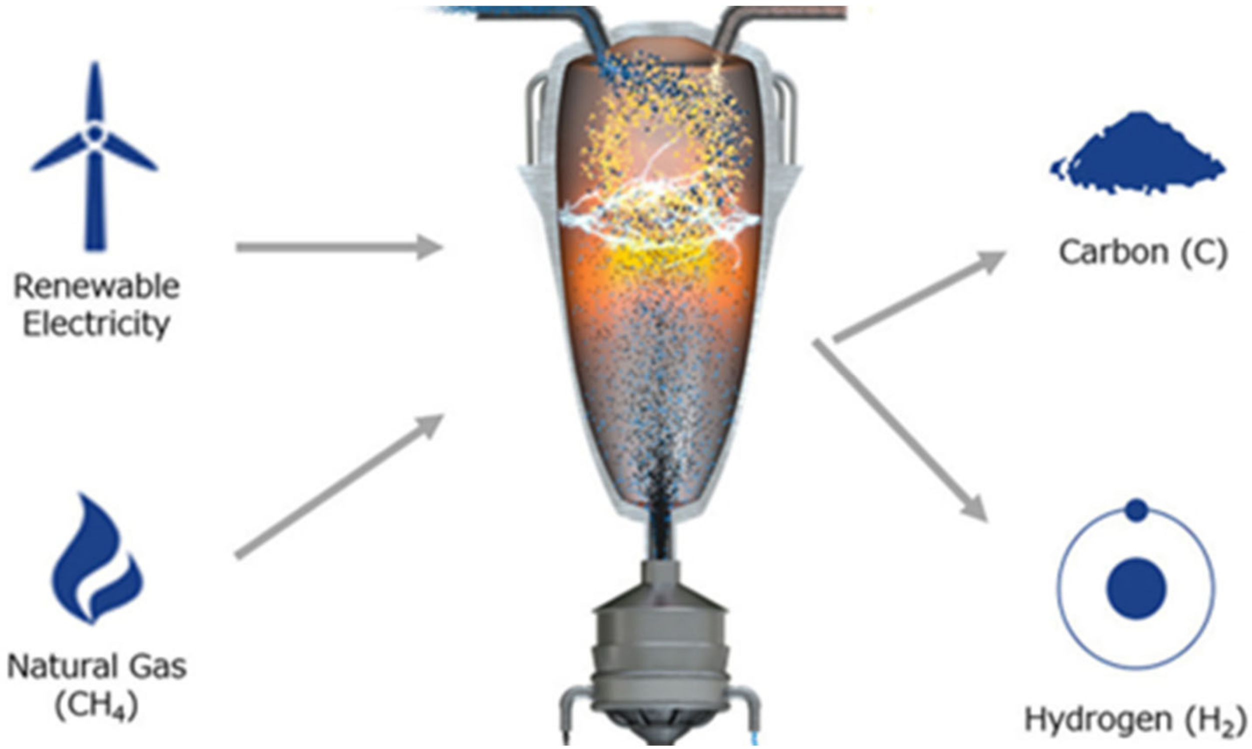


Source: IEEJ

Turquoise hydrogen/ammonia

- Turquoise hydrogen is hydrogen produced from natural gas with pyrolysis process.
- The process does not emit carbon dioxide but carbon; how to monetize the produced carbon is a big challenge for the process.
- Turquoise hydrogen can be of course utilized to produce ammonia

$$CH_4 \Rightarrow C + 2H_2$$

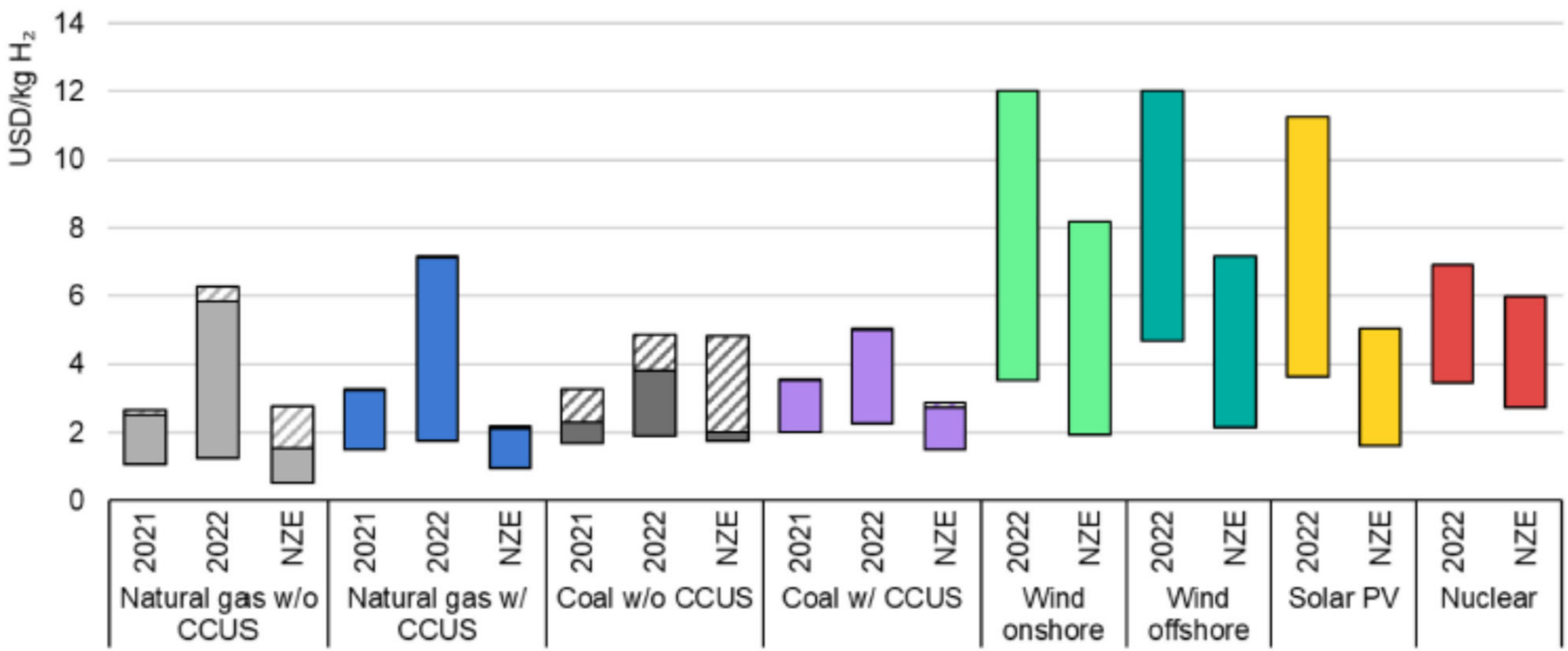


Source: Mitsubishi Heavy Industries

Production cost of hydrogen

- Low carbon hydrogen produced from fossil fuel is likely to maintain cost competitiveness against hydrogen produced by electrolysis by renewable electricity.
- The effects of the recent hike of natural gas and renewable electricity generation cost on the hydrogen / ammonia production cost remain to be seen.

Figure 3.11 Levelised cost of hydrogen production by technology in 2021, 2022 and in the Net Zero Emissions by 2050 Scenario in 2030

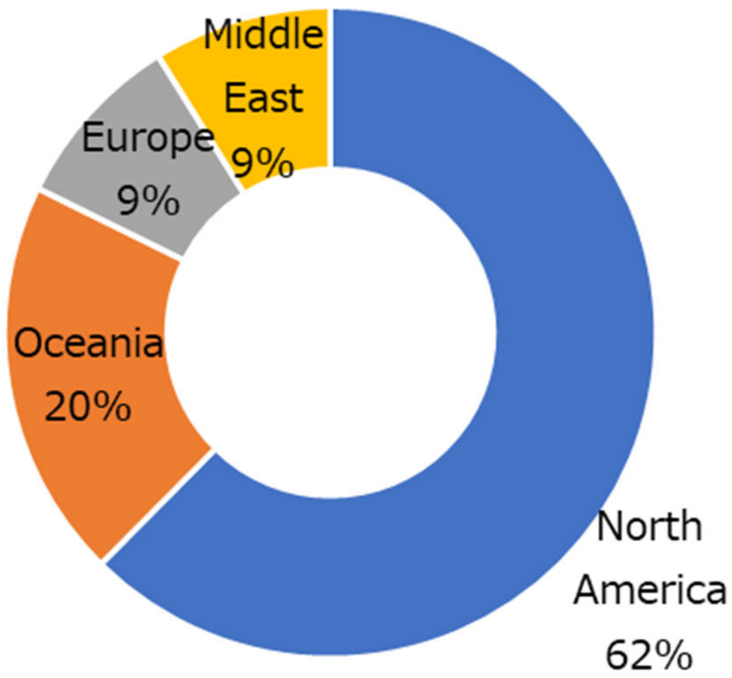


Source: IEA, Hydrogen Projects Database

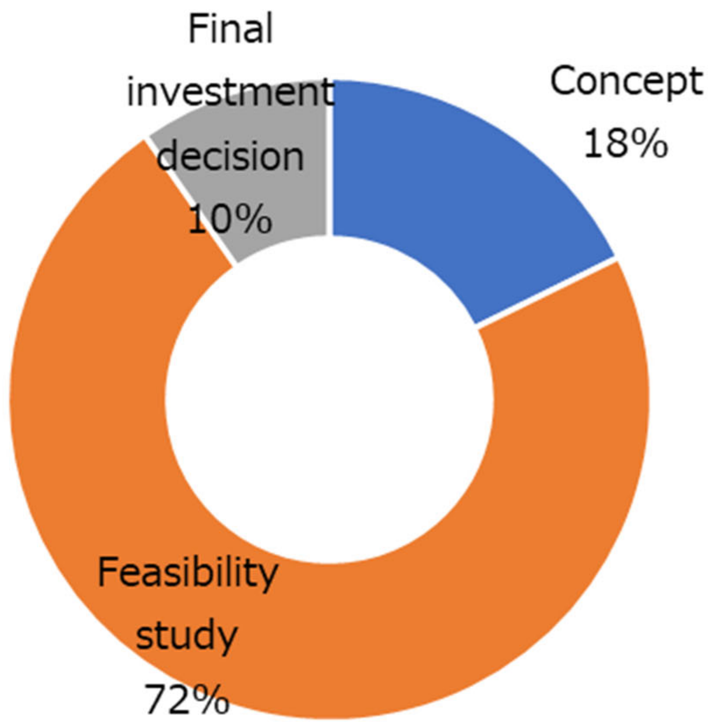
Projects for fossil fuel-based ammonia

- According to IEA's database, currently 12 million tons of ammonia production projects are currently planned.
- More than half of the planned projects are in North America (mostly in the US).
- 90% of the planned capacities are still at either conceptual or feasibility study phase. Policy supports may be needed to accelerate the development.

Fossil fuel-based ammonia projects by region



Fossil fuel-based ammonia projects by status



Source: IEA, Hydrogen Projects Database

Summary

- While hydrogen and ammonia can be produced from various feedstock and inputs, low carbon hydrogen produced from fossil fuel was confirmed as an effective means for decarbonization by the G7 summit leaders.

- Carbon intensity of fossil fuel-based ammonia will be lowered in the long run to realize carbon neutrality.

- Low carbon hydrogen produced from fossil fuel is likely to be more cost competitive than hydrogen produced by electrolysis by renewable electricity.

- Most of the projects for low carbon hydrogen produced from fossil fuels are still at feasibility study stage. Policy supports may be needed to accelerate the development.