

NH₃ Energy Implementation Conference, Session 6 : Ammonia Market(B)
Nov. 1, 2018 @ Pittsburg, USA

International Cooperation for Implementation of Green Ammonia

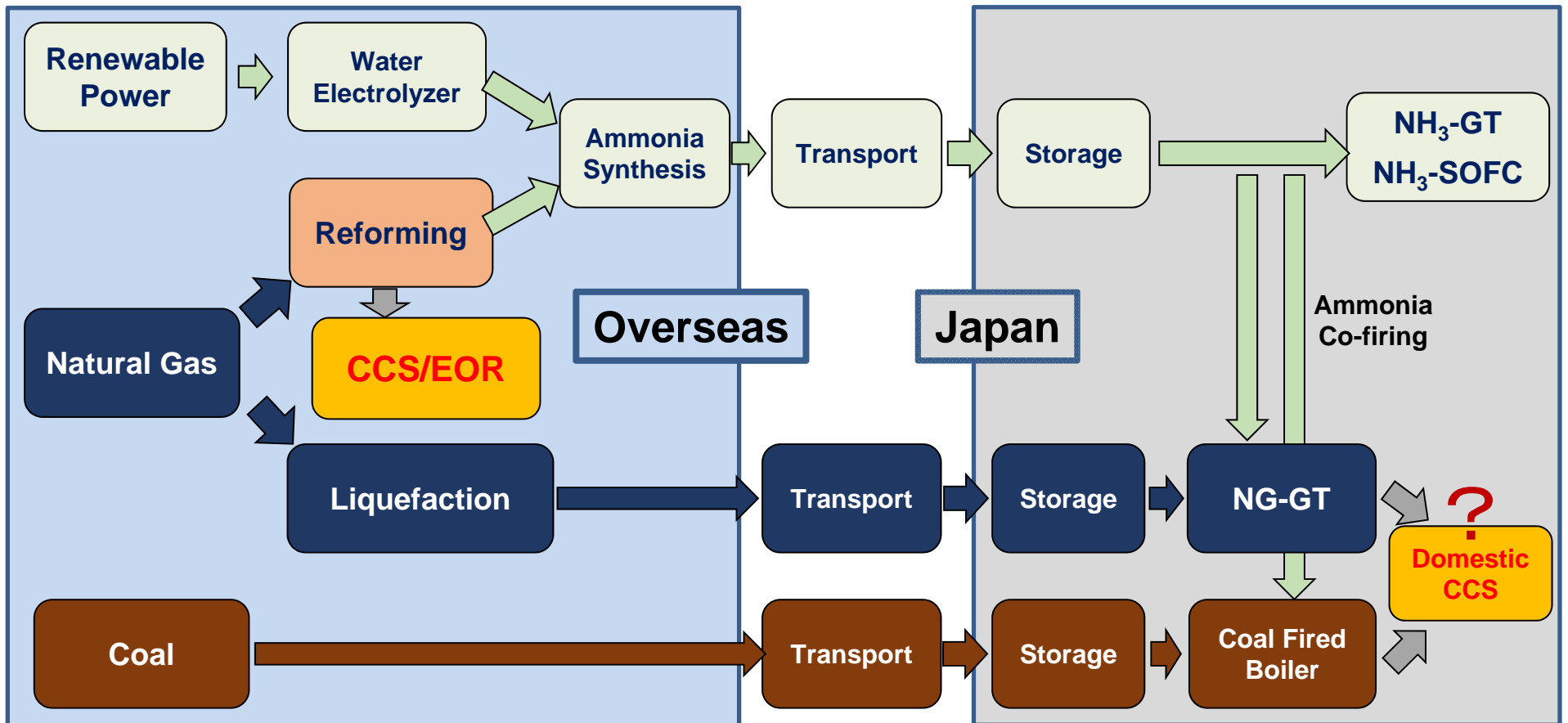


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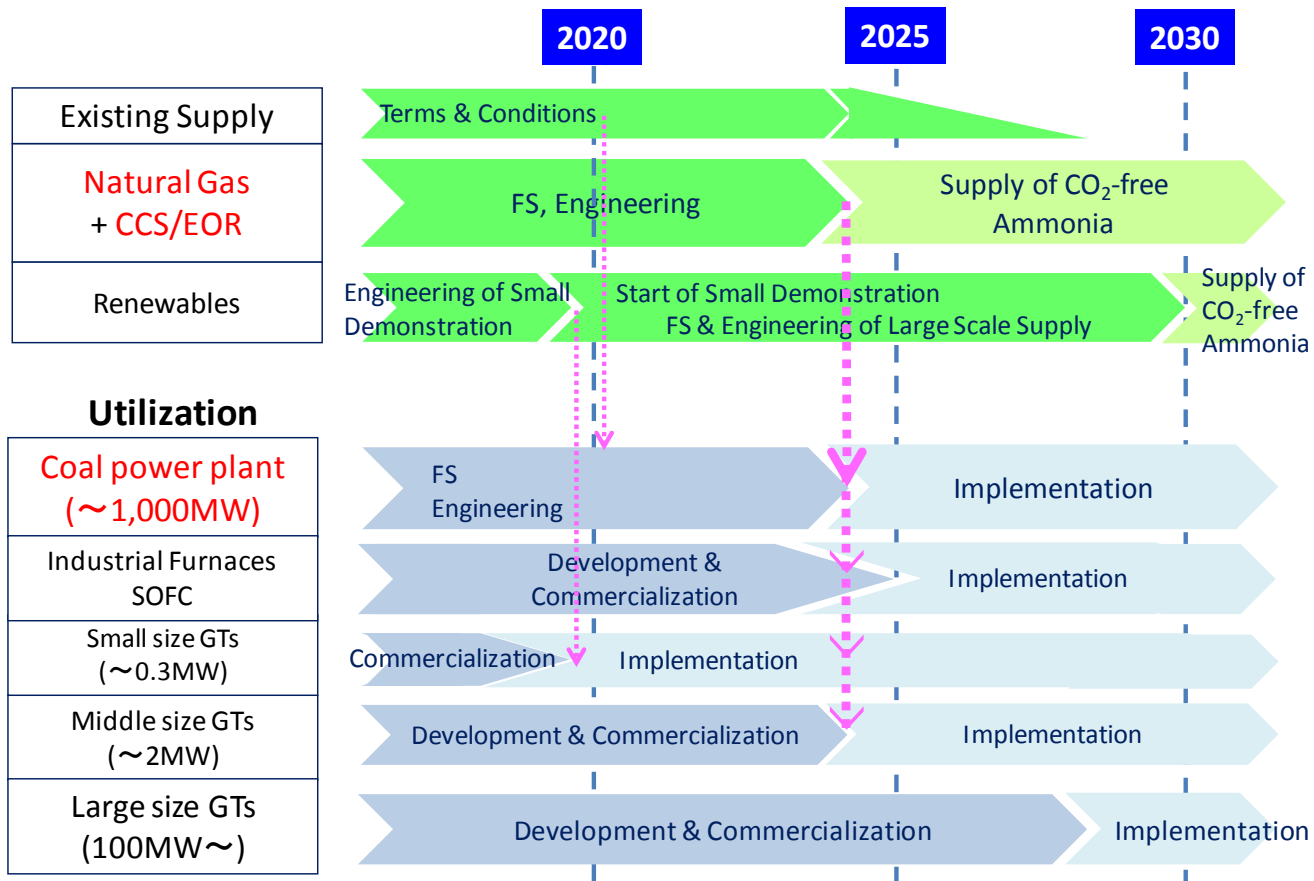




Green Ammonia Supply Chain for Power Generation in Japan



Roadmap of Ammonia Supply Chain

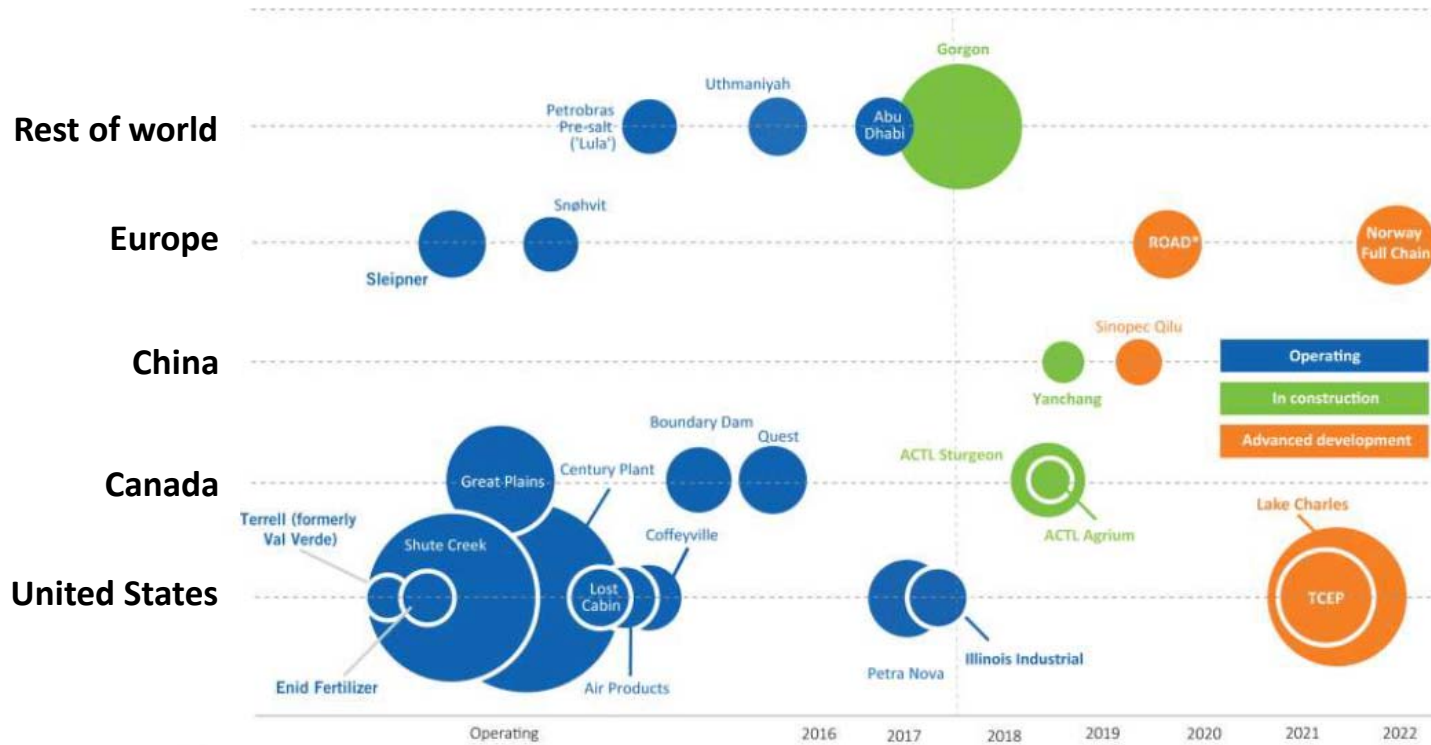




Required amount of Ammonia Fuel for Power Generation

Application	Small Gas Turbine	Medium Gas Turbine	Large Boiler	Large Gas Turbine
in Commercial	2020	mid 2020s	mid 2020s	late 2020s
Scale	300 kW	20 MW	1000 MW	400MW
Fuel	NH ₃	20% NH ₃ + 80% NG cofiring	20% NH ₃ + 80% Coal cofiring	H ₂ combustion combined with NH ₃ decomposition
Required ammonia	8 ton/day 2,500 ton/y	50 ton/day 17,000 ton/y	1,900 ton/day 630,000 ton/y	3,100 ton/day 1,000,000 ton/y

Actual and expected operation dates up to 2022 for large-scale CCS facilities



○ = 1Mtpa of CO₂ (area of circles proportional to capacity)

*Uniper and Engie have announced they are withdrawing from ROAD, effective September 2017

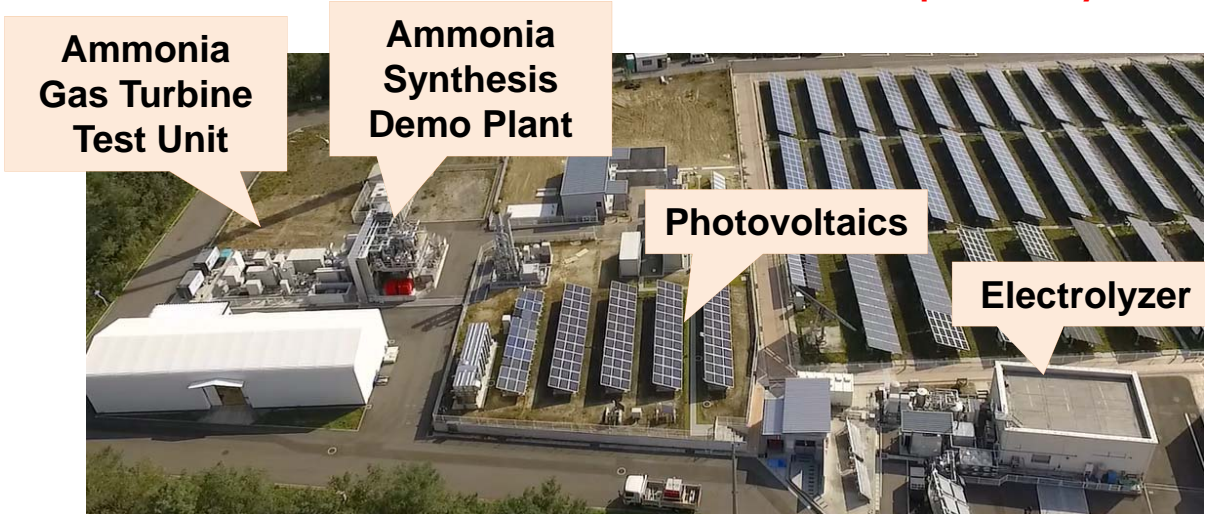
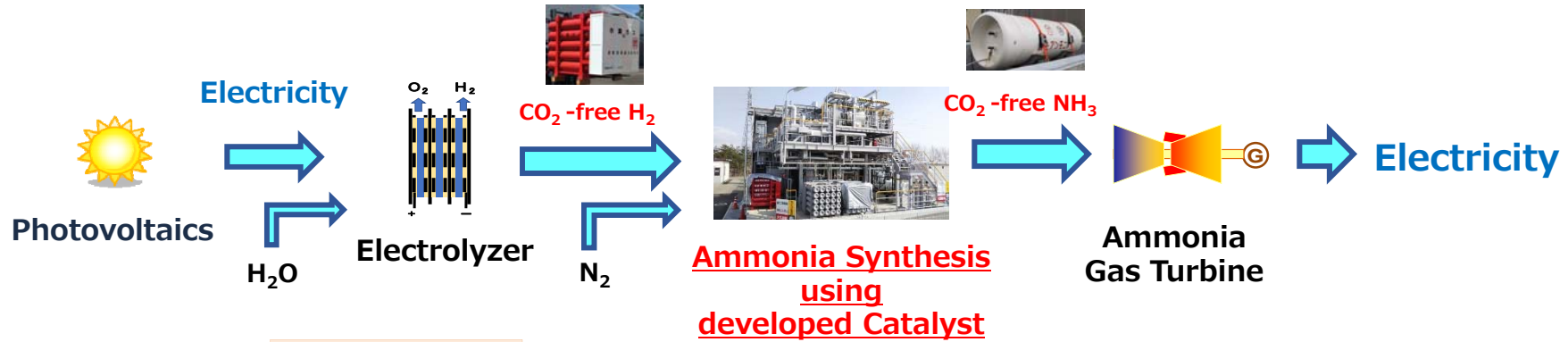
Challenges for Green NH₃ Production from Natural Gas

- Combination with CO₂ recovery from flue gas and CCS or EOR
- Further cost reduction of ammonia product
 - Low-cost natural gas, Larger scale
- Certification of “Green” Ammonia
 - related to price and incentives

International cooperation for natural gas based green ammonia

- Green Ammonia production
 - Resource and price of natural gas
 - Readiness of CCS/EOR
 - Construction cost of production plant
 - Transportation cost to Japan
 - Geopolitical risk
- Technical and financial support
 - Flue gas CO₂ capture, CCS/EOR technology
 - Governmental support for initial adoption
 - Green Investments
- Pricing mechanism
- Safety, Public Acceptance

- Improvement of economic efficiency in a smaller plant
- Cost reduction of renewable power
- Cost reduction and efficiency improvement of water electrolyzer
- Maximization of capacity factor of the total system
 - Load following operation and/or stabilization of fluctuation
- Innovation?
 - Electrolytic ammonia synthesis, Battelyzer,



- PV based Hydrogen
- Low pressure (5-8MPa) Ammonia Synthesis
- 47kW power generation by ammonia fueled GT
- Load following operation is planned

Pushing toward renewable ammonia

International semi-commercial Pilot Project will be expected.

- Low renewable power price
- Increasing of added value of ammonia
 - Leveling of variable renewable energy
 - Green ammonia supply in remote area
- Reduction of investment cost
 - Utilization of existing ammonia plant and/or infrastructure
- Financial support