Cost Evaluation Study on Low Carbon Ammonia and Coal Co-Fired Power Generation

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Objective of Ammonia Introduction as Fuel

Increase of threat due to global warming issue → **Movement for reduction of CO_2 emissions has gained momentum.**

Technology for stable firing of ammonia and low NOx emissions has been developed in Japanese national project(SIP*).

CO_2 emissions from power generation sector are large in Japan.
(Approx. 1/3 of total CO_2 emissions are from power generation sector)

Application to ammonia-fired thermal power generation is desired to reduce the large amount of CO_2 emissions

* SIP stands for Cross-ministerial Strategic Innovation Promotion Program

Our Definition of Low Carbon Ammonia

① Production from Fossil Fuel Integrated with CCS

Feedstock:Fossil Fuel

Natural Gas

Scope of Study

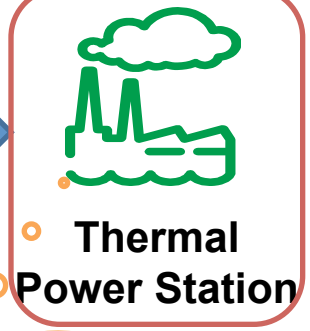
NH_3 Production

CO_2

CCS

CO_2 from feedstock and utility is stored.

Marine Transportation



Thermal Power Station

Electricity Cost?

②Production from Renewable Energy

Renewable Energy

Water

Nitrogen

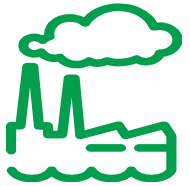
H_2 Production

NH_3 Production

CO_2

CCS

Marine Transportation



Thermal Power Station

CO_2 from utility is stored.
(In the case that fossil fuel is used as fuel for production)

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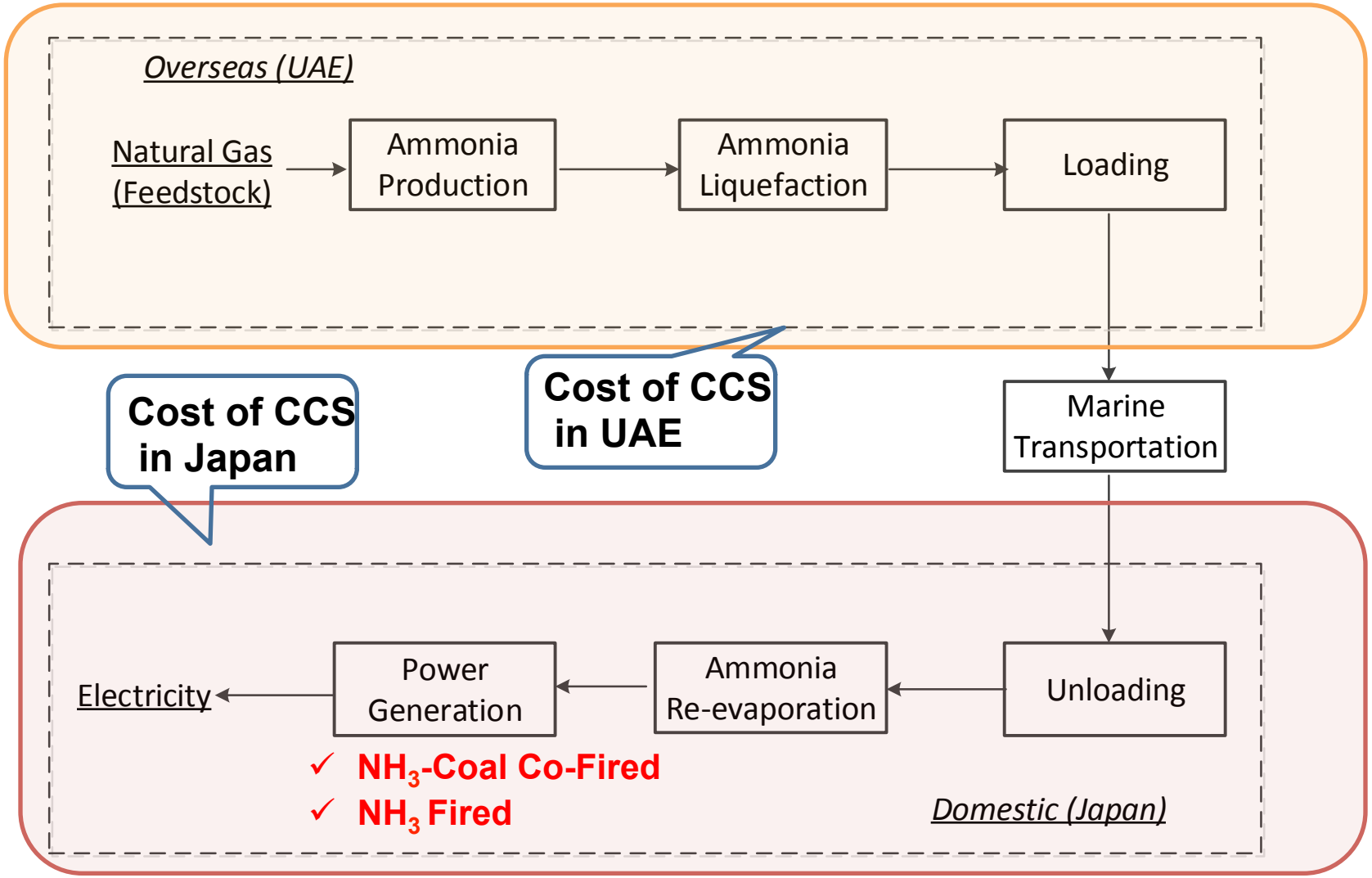
Supply Chain of Low Carbon Ammonia



Premise of Study (1/3)

Items	Values
NH_3 Supply Amount in Japan	1.27 Million Ton/Year
Ratio of NH_3 and Coal Co-firing in Power Generation	20 %-NH_3 on HHV Basis
Efficiency of Power Generation on NH_3-Coal Co-firing/Coal firing (Boiler power generation)	36.5 % on HHV Basis at Power Generation End
Efficiency of Power Generation on NH_3 firing (Gas-turbine power generation)	50 % on HHV Basis at Power Generation End
Operation Period	30 Years
Capacity Utilization Ratio	Power Generation： 80 % Other Facilities： 90 %
Currency Exchange Rate	121 JPY/USD

✓ Scope of CAPEX/OPEX

CAPEX*： Plant Construction Cost, Decommissioning Cost
OPEX* ： Feedstock Cost, Utility Cost, Labor Cost, O&M Cost
Taxes, Insurance Fees, Overhead Costs, Cost of CCS

* CAPEX/OPEX were set by taking information from public reports and hearing of experts into consideration.

Premise of Study(2/3)

✓ **Determination on Price of Feedstock and Utility**

Timing of large NH_3-coal co-fired power generation commercialization is assumed to be around 2025.

→ **Price has been determined taking future market into consideration.**

Items	Unit Value
Natural Gas Price in UAE	2.6 USD/MMBtu
Electricity Price in UAE	7.1 US cent/kWh
Electricity Price in Japan	10.3 US cent/kWh
Marine Fuel Oil	4.5 US cent/1,000 kcal
Pure Water	4 USD/t
Industrial Water	1 USD/t
Coal Price in Japan	60 USD/t-Coal

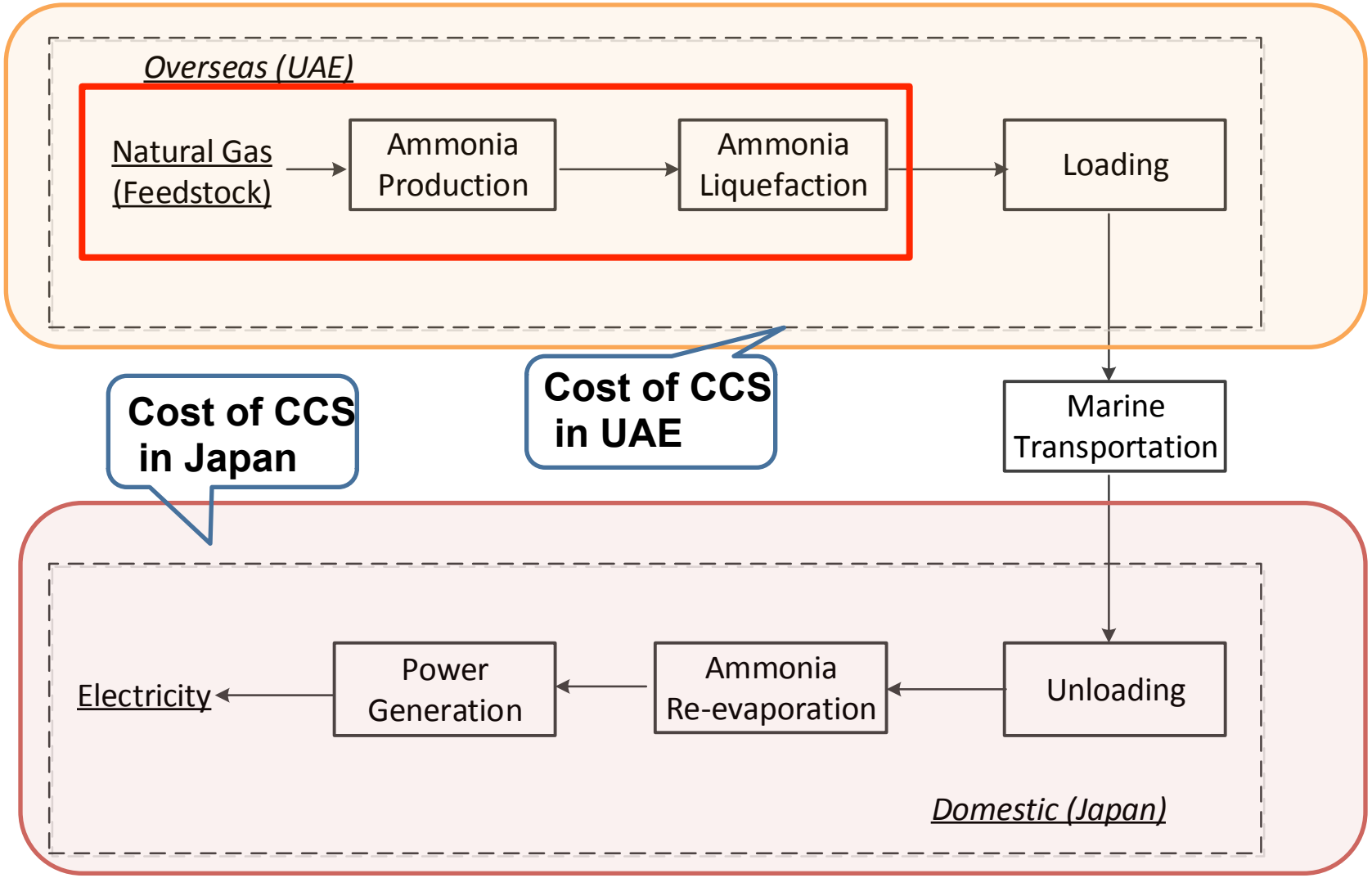
✓ **Levelized cost calculation method**

$$\sum_t ((CAPEX + OPEX) \times (1+\alpha)^{-t} / \sum_t (\beta \times (1+\alpha)^{-t}))$$

α：Discount ratio（5 %）

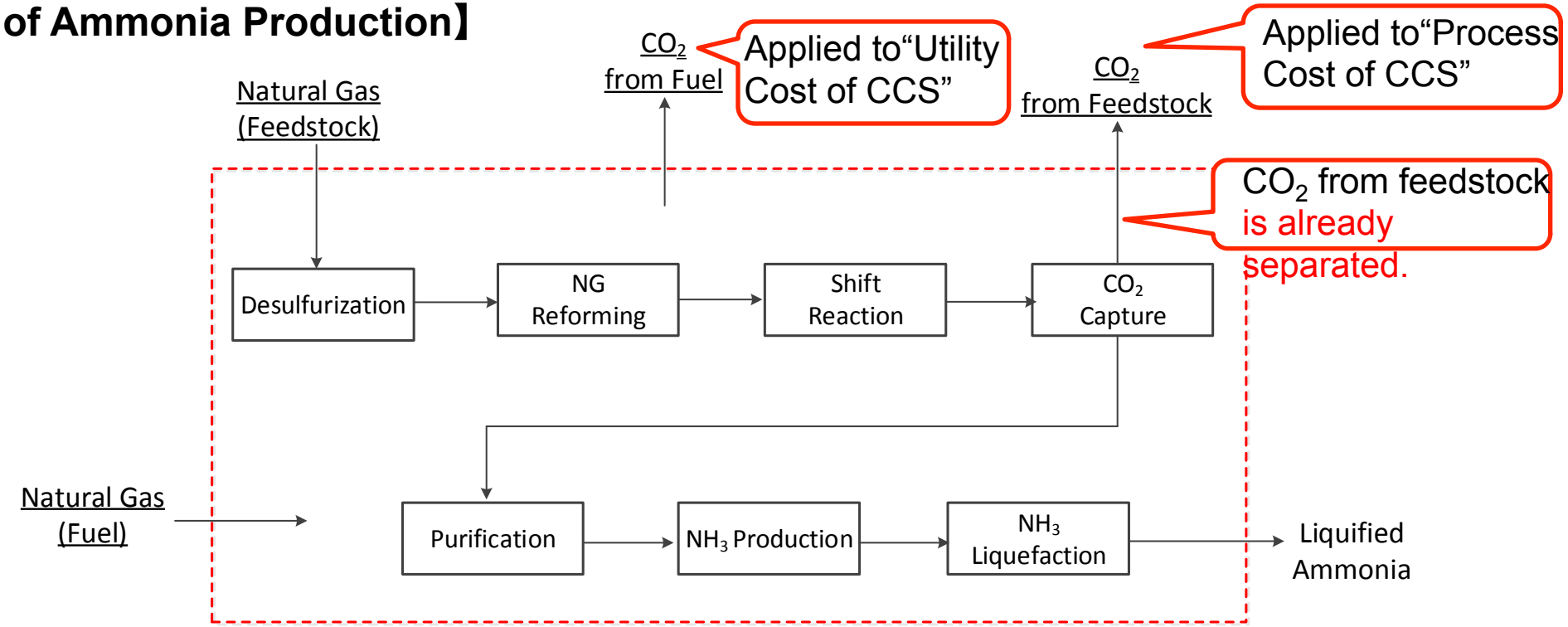
β： Annual NH_3 amount or annual electricity volume

Supply Chain of Low Carbon Ammonia



Premise of Study（3/3)

【Block Flow of Ammonia Production】

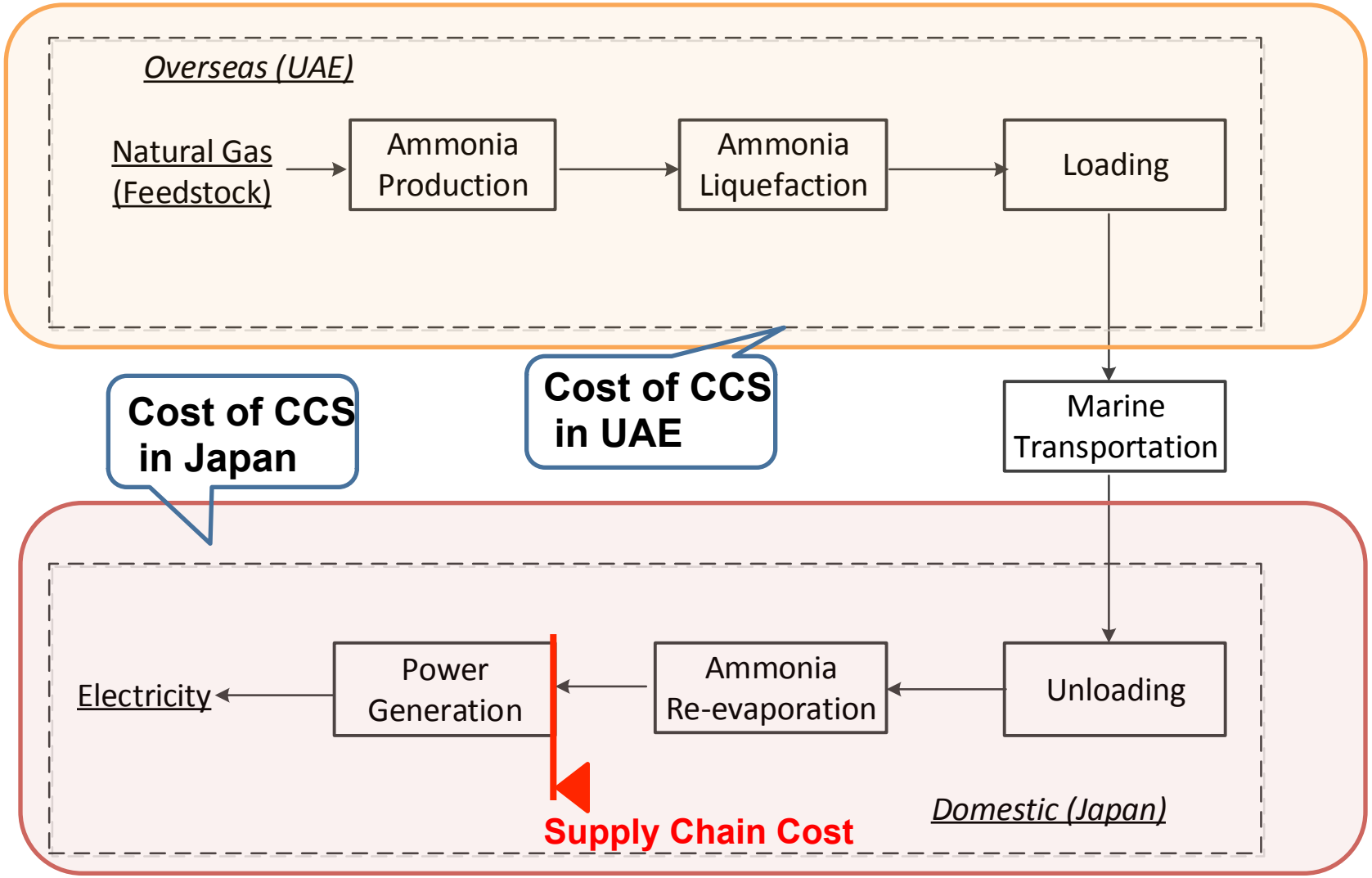


Cost of CCS	Unit Value
Process Cost of CCS in UAE	35 USD/t-CO_2
Utility Cost of CCS in UAE	50 USD/t-CO_2
Cost of CCS in Japan	125 USD/t-CO_2

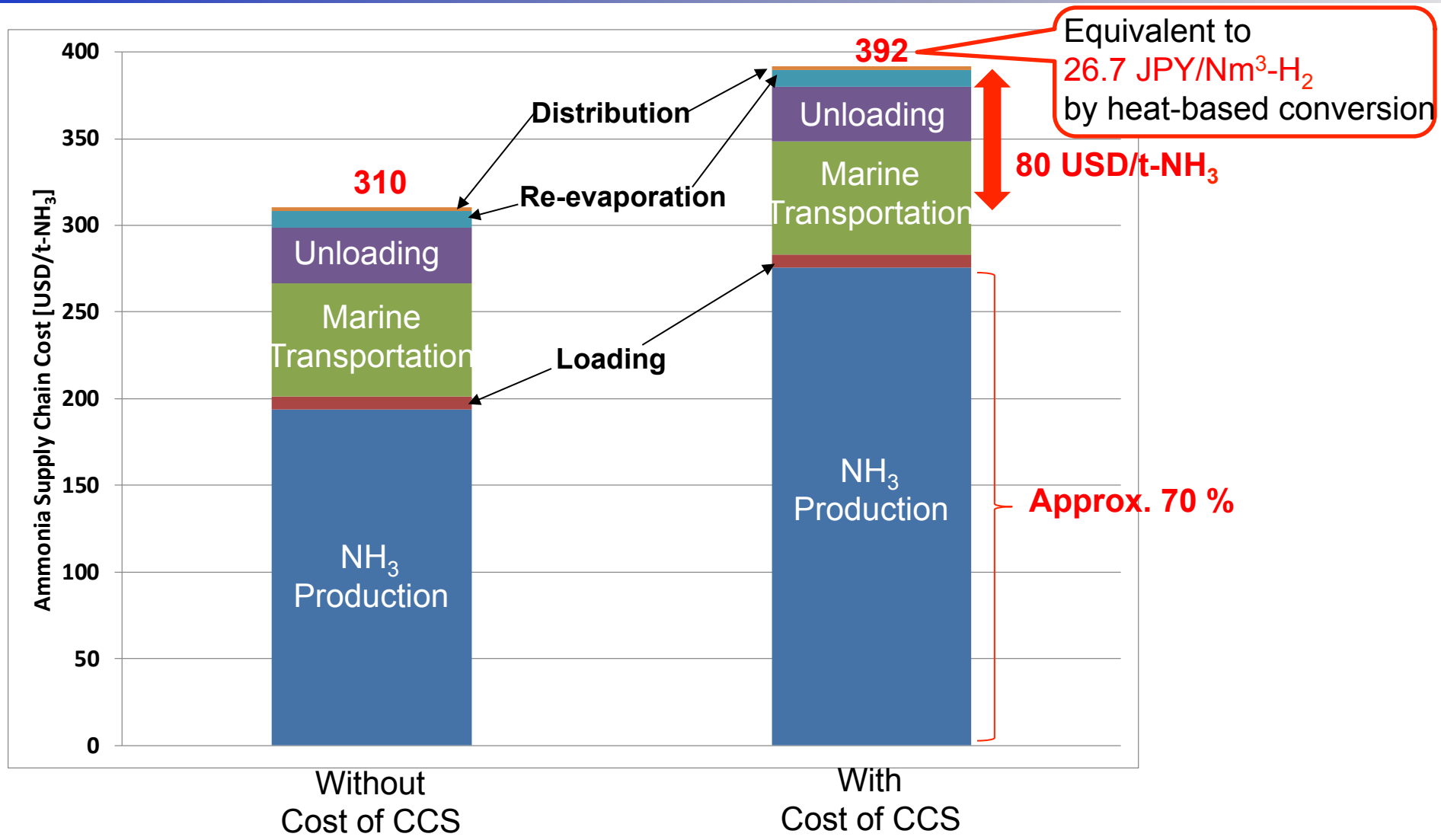
(without capturing cost)

* These values were set by taking information from public reports and hearing of experts into consideration.

Supply Chain of Low Carbon Ammonia

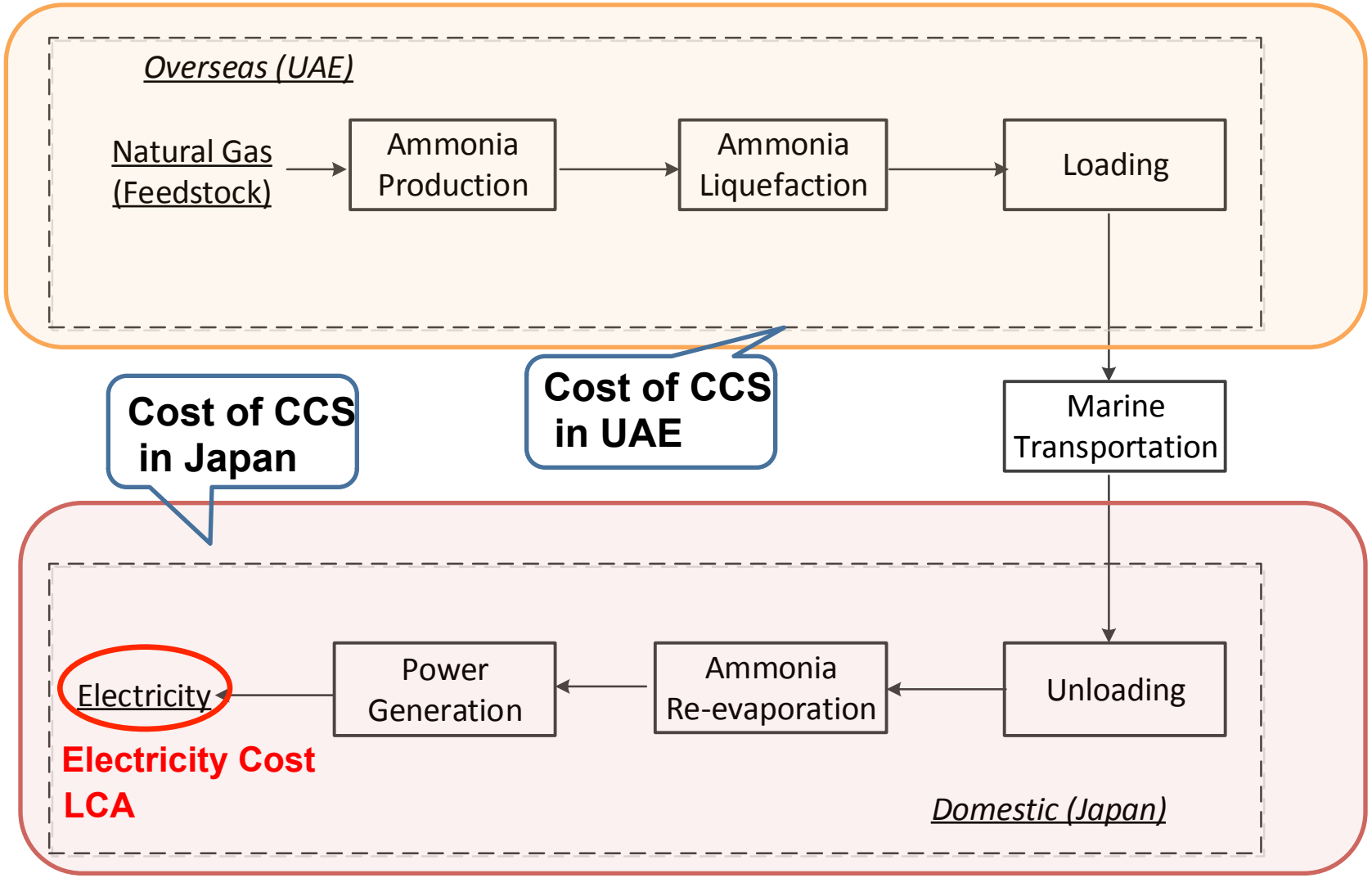


Estimation of NH_3 Supply Chain Cost

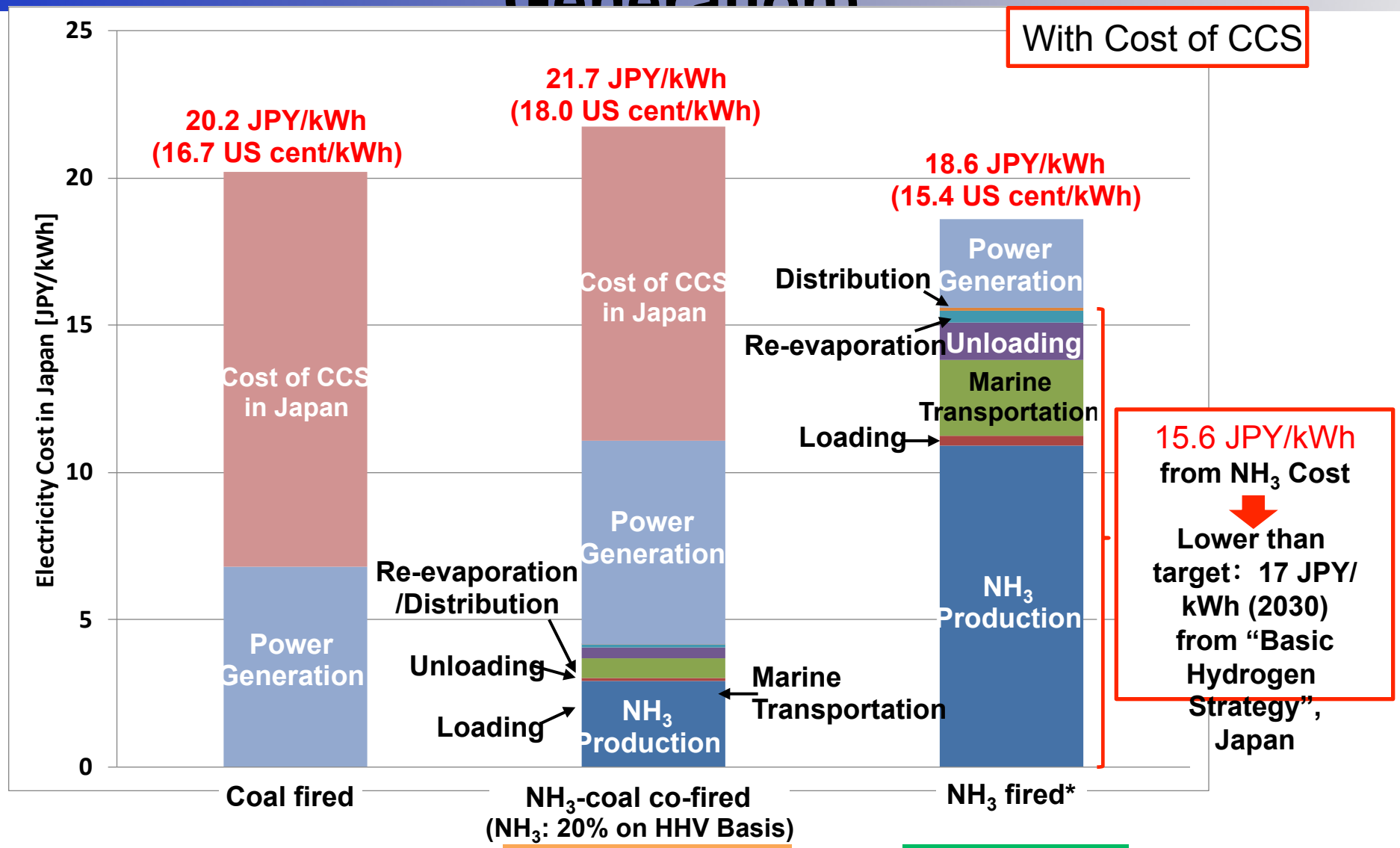


Estimated NH_3 supply chain cost is lower than the target of H_2 cost (30 JPY/Nm^3-H_2 in 2030) from "Basic Hydrogen Strategy", Japan

Supply Chain of Low Carbon Ammonia

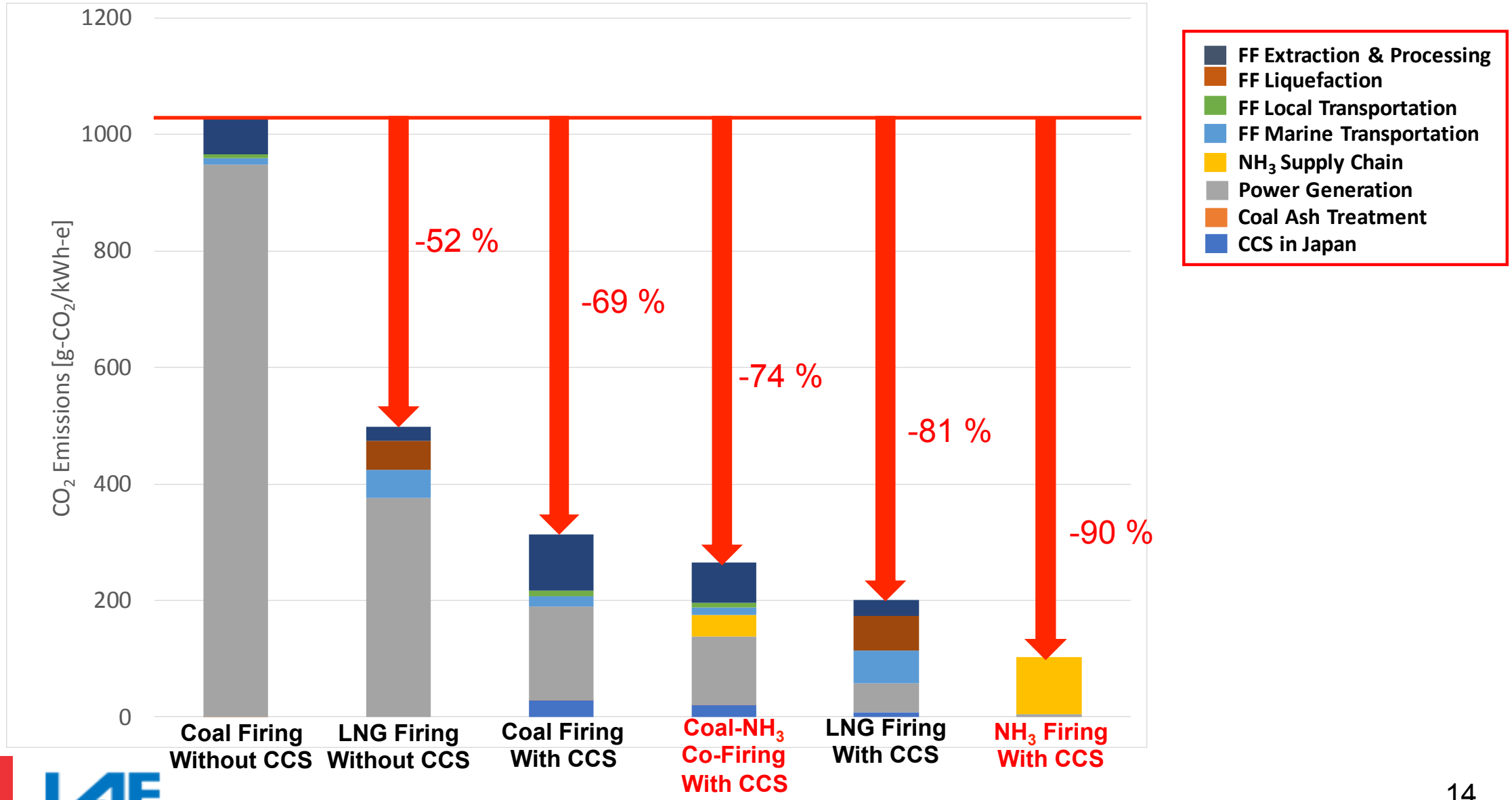


Estimation of Electricity Cost (Comparison with Coal Fired Power Generation)



*Compared to other two case (boiler power generation), gas-turbine power generation is introduced for

Comparison in Terms of Life Cycle CO_2 emissions



Calculated using the method presented by AIST at the 13th Int. Conf. on EcoBalance , October 11 2018, Tokyo, Japan

Summary

- NH_3 cost difference between the case with and without the cost of CCS was 80 USD/t-NH_3 in supply chain cost estimation.
  The estimated cost meets the target of H_2 supply chain cost in 2030 set by the "Basic Hydrogen Strategy" in Japan by the conversion on heat basis.

- Electricity cost of NH_3-coal co-fired power plant is estimated as competitive compared to that of coal power plant in the case of the cost of CCS is included. Regarding NH_3 fired power generation, that is the ultimate goal, electricity cost originated from NH_3 supply chain cost meets the target set by the "Basic Hydrogen Strategy".

- Moreover, both NH_3-coal co-fired and NH_3 fired power generation brings the benefit of CO_2 reduction in terms of LCA.

Thank You for Your Attention!

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