



Cost Structure Analysis on Next Generation Fuels and Associated Technological Trends

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0. Introduction



HIROSHIMA UNIVERSITY



Staffs : 13

Secretaries : 3

Ph.D Students: 14

Master Students: 17

Other Students: 7



1. Hydrogen Storage Materials

Amide-Imide systems, MgH_2 ,
 $\text{MgH}_2\text{-LiBH}_4$, $\text{M-NH}_2\text{BH}_3$,

Conventional H-Storage Alloys for C-Compressor use

2. Li-Ion Batteries

MgH_2 anode, other hydrides anodes, Si anode, LiBH_4
solid electrolyte, $\text{Li}_2\text{S-P}_2\text{S}_5$ electrolyte

3. Ammonia absorbing Materials and Ammonolysis reaction

MCl_x , MBr_x , $\text{M}(\text{BH}_4)_x$, NH_4Cl , Zeolites

4. Ammonia synthesis by Chemical Looping Process

5. Carbon Recycling Process

6. Thermochemical water splitting

Na/Na Compounds-Redox cycle

7. Cryogenic Hydrogen Properties

15K – 77K : Adsorbed hydrogen properties

8. Economic Evaluation

production cost and
storage cost



Toward a **decarbonized society**, “Hiroshima Prefecture” will become a **pioneering research and development base** for carbon dioxide reduction and **carbon recycling**.

We established the council in May 2021 to realize this and contribute to the achievement of global carbon neutrality toward 2050.



- 170 members
- Matching exchange meeting is usually held every month





Outline

0. Introduction

1. Future H₂ in Japan

2. H₂ production cost

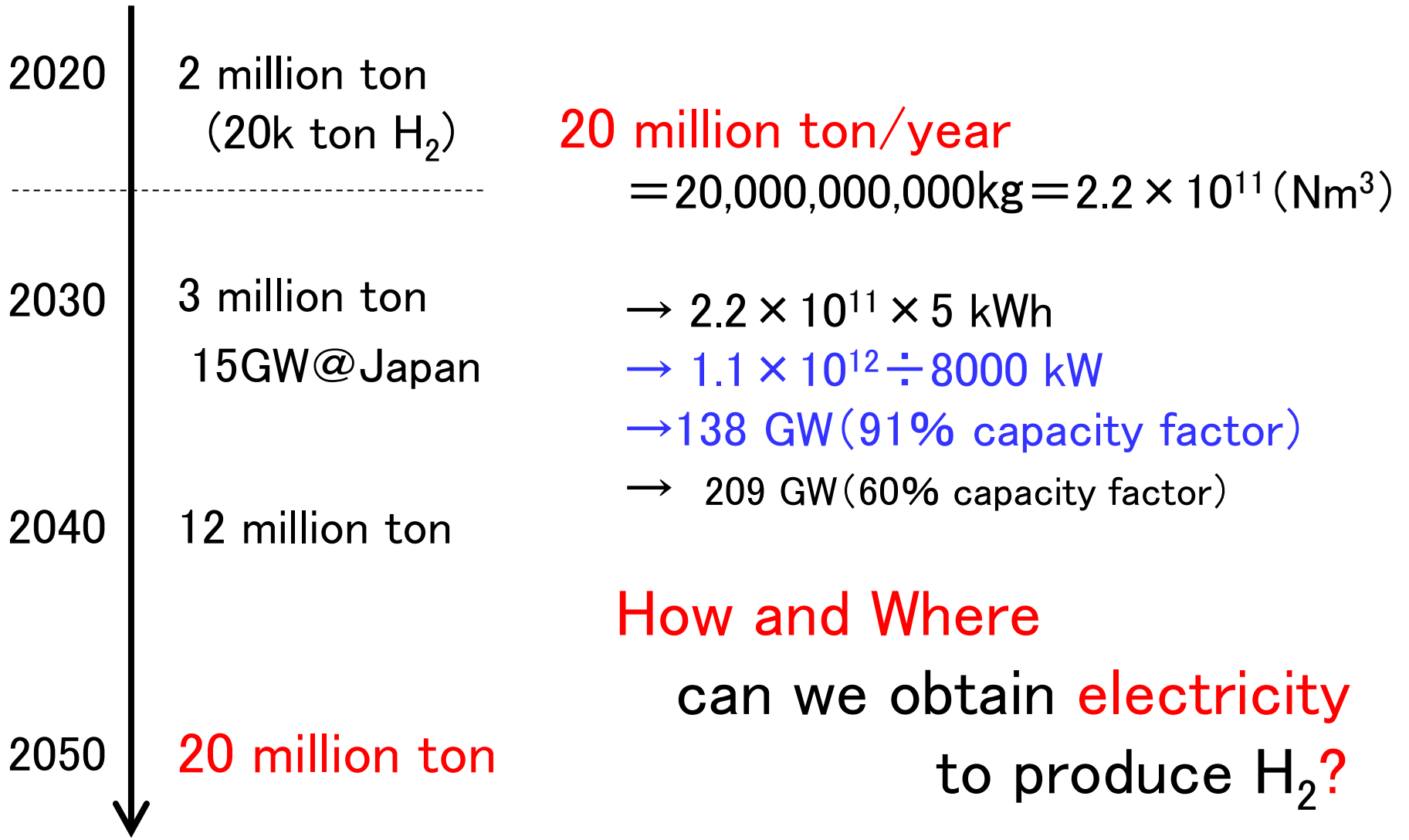
3. Energy Carrier (NH₃ and MeOH)

4. Summary



1. Future H₂ in Japan

Production target of H₂



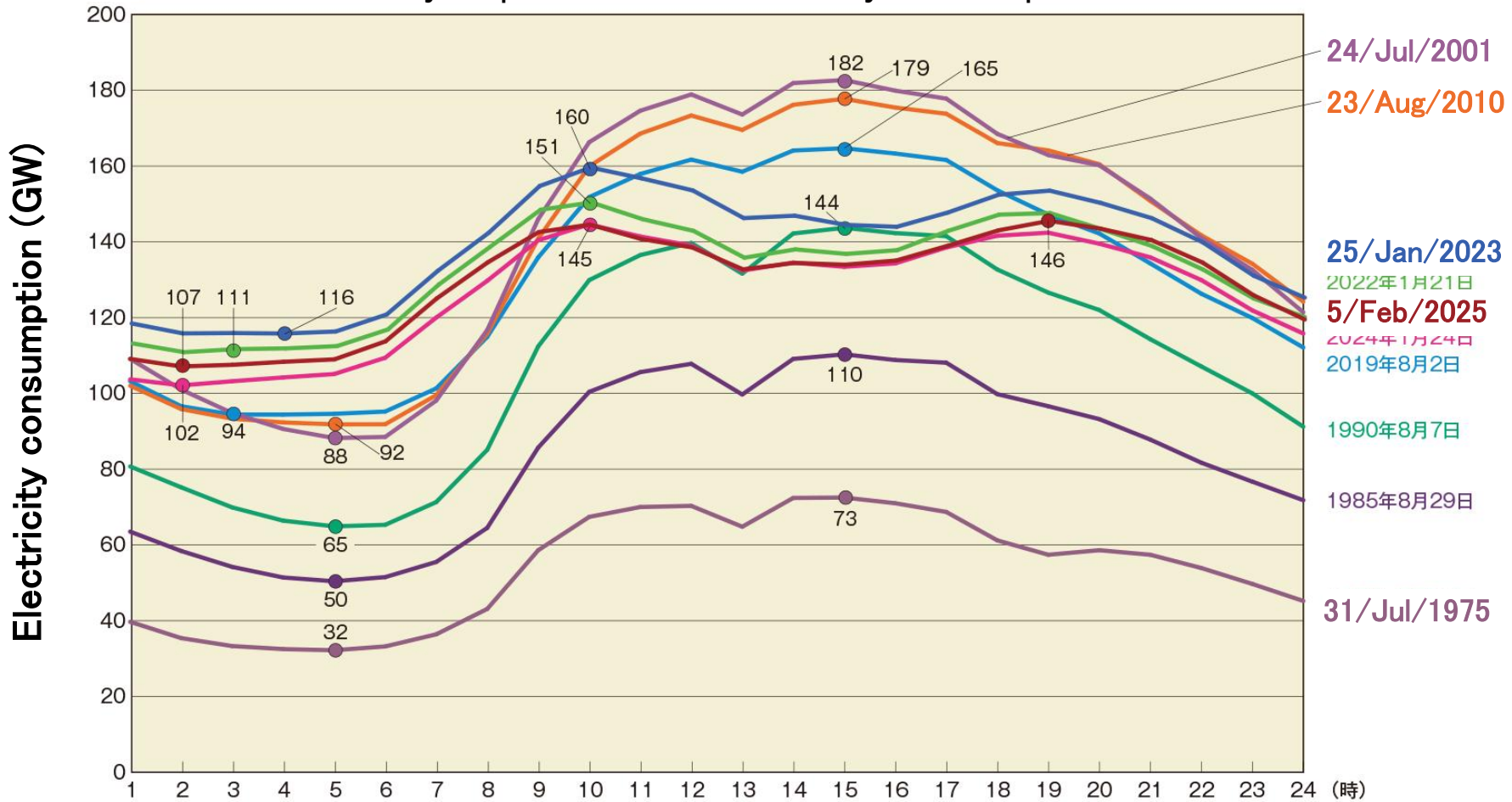
How and Where

can we obtain **electricity**
to produce H₂?

1. Future H₂ in Japan



Daily electricity demand trends
on the day of peak annual electricity consumption



Japanese power supply capacity : ~ 380GW



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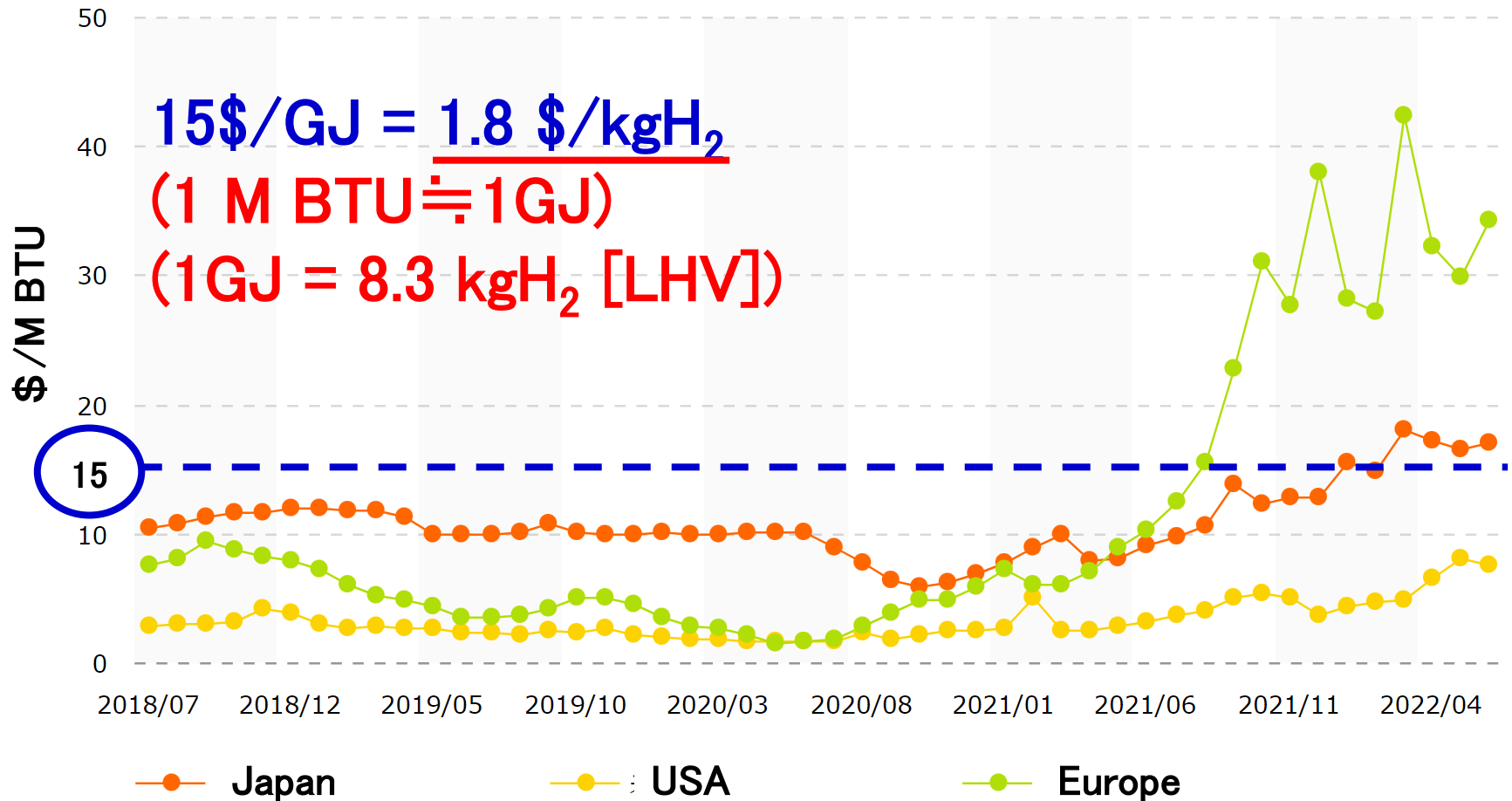
4. Summary

2. H₂ Production Cost



Natural Gas Price (\$/mmbtu)

150JPY = 1 USD



15\$/GJ = 1.8 \$/kgH₂
(1 M BTU ≙ 1GJ)
(1GJ = 8.3 kgH₂ [LHV])

2.2 \$/kgH₂ @2030, **1.5 \$/kgH₂ @2050**

2. H₂ Production Cost



VARIOUS PRICE/COST of ENERGY

Natural Gas	15\$/mmBTU(15\$/GJ)	
Hydrogen in target	1.5 \$/kgH ₂ (13\$/GJ)	200 \$/kg in labo.
Hydrogen in Station	10 \$/kgH ₂ (87\$/GJ)	
Gasoline in Japan	1.3 \$/L (38\$/GJ)	0.6 \$/L w/o tax
Electricity in Japan	0.2 \$/kWh (55\$/GJ)	0.05 \$/kWh for PV
Thermal Coal in Japan	120\$/ton (4.8\$/GJ)	
Ammonia in Japan	300\$/ton(13.6\$/GJ)	
Methanol in Japan	0.27 \$/kg(14\$/GJ)	

Cost of 1kg H₂ production (Electrolysis)

$$\underbrace{AB(1+r)/(8760yN)}_{\substack{\text{CAPEX} \\ \text{(Initial cost etc.)}}} + \underbrace{zB}_{\text{Electricity}} + \underbrace{1142M/(xy)}_{\text{Labor cost}} + \alpha_{\text{Others}}$$

z [USD/kWh]: Electricity price (0.2 USD/kWh?)
 B [kWh/kg]: Efficiency (50~55 kWh/kgH₂)

CAPACITY: x [kg/h], CAPACITY RATE: $100y$ [%], LIFETIME: N [Yeas], ELECTRICITY PRICE: z [USD/kWh], LABOR COST: $100k \times M$ [USD/Year], MAINTENANCE COST: $100r$ [%]
 EFFICIENCY: B [kWh/kg], EC COST: A [USD/kW], TOTAL H₂ PRODUCTION: $8760xyN$ [kg]

2. H₂ Production Cost



PV Cell



1300 kWh/1 kW in Japan
(Capacity Factor : 15%)

Assuming it could perfectly track
output fluctuations of PV,

~25 kg/y/kW

Realistic scale of solar capacity : 10MW(D), 1GW(I)
Electricity Cost : 0.05USD, 0.02USD /kWh
(Corresponding Electricity cost/kgH₂): 2.5 USD, 1 USD /kgH₂

250 ton/place (D)

250,000 ton/place (I)



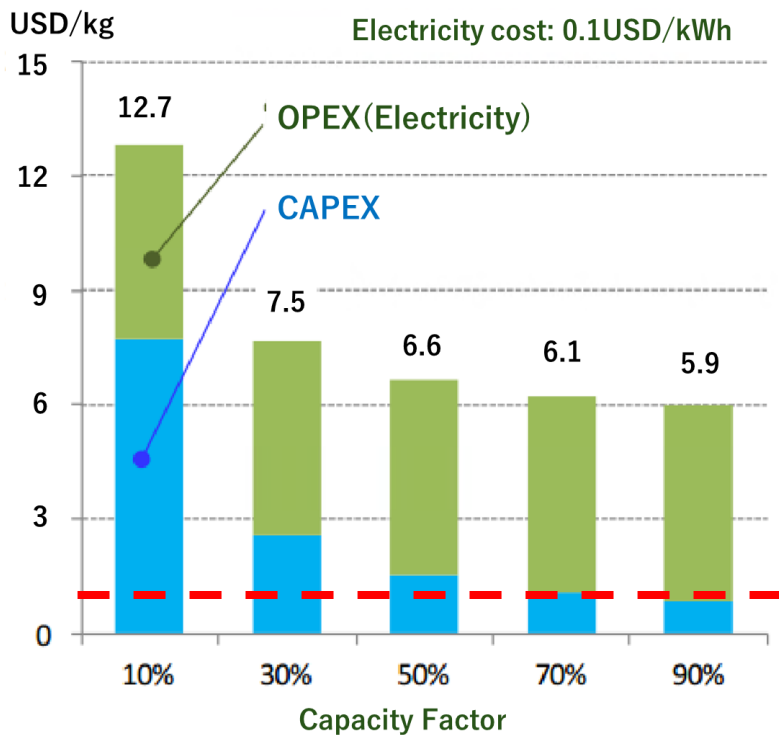
Cost of 1kg H₂ production (Electrolysis)

$$\frac{AB(1+r)}{(8760yN)} + zB + \frac{1142M}{(xy)} + \alpha$$

CAPEX
(Initial cost etc.)

Electricity **Labor cost** **Others**

Required Capacity Factor > 50%



To decrease the production cost,
 Capacity factor : **increase**
 Electricity cost : **decrease**

How to **decrease Electricity** cost?

- Some place for high capacity factor of PV and the other renewable energy
- Value division to high value (stable part) for ELECTRICITY and low value (fluctuation part) for HYDROGEN

How to **increase Capacity** factor?

- Levelling by Battery (COST UP)

→ It's necessary to find the optimal condition



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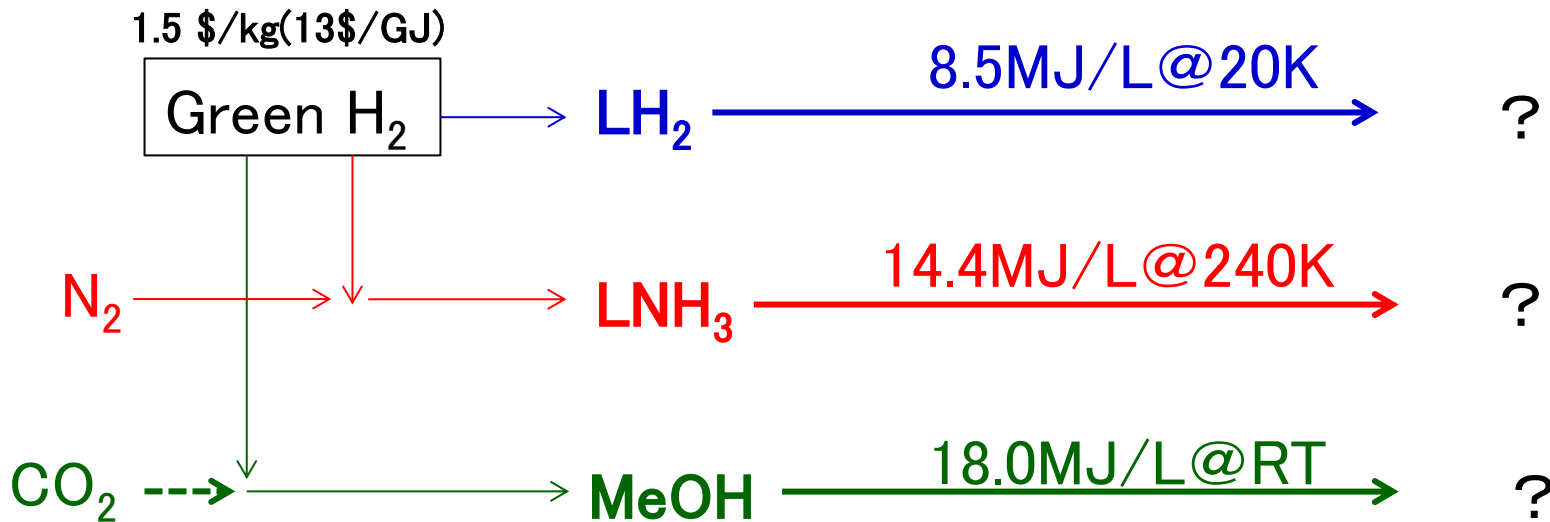
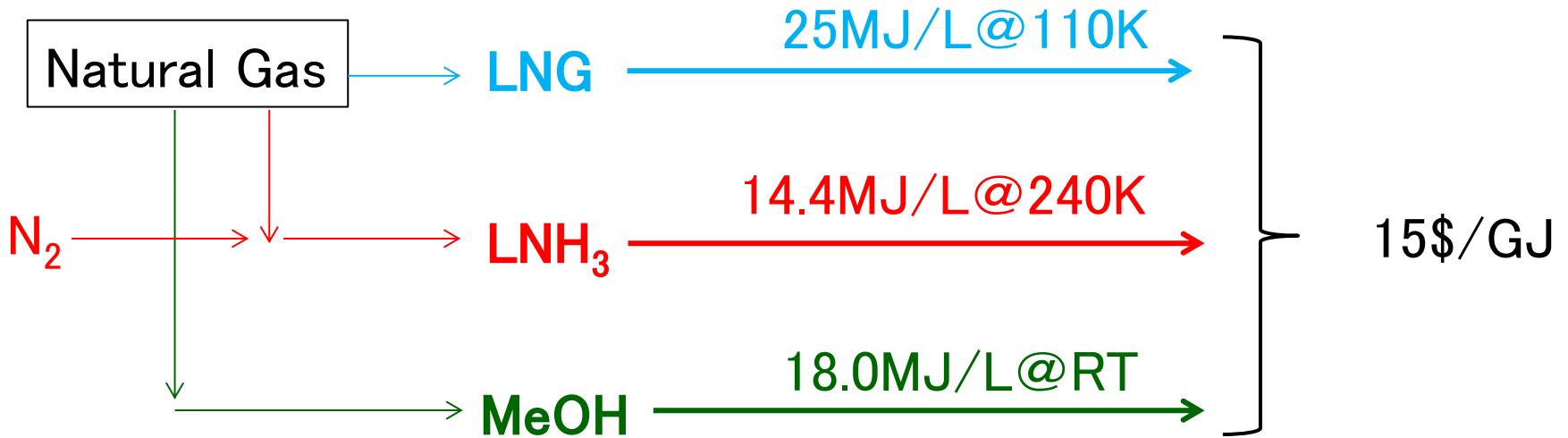
3. Energy Carrier (NH₃ and MeOH)

4. Summary

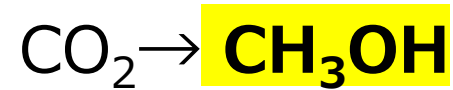
	Energy Density (LHV)	Notes
LNG	0.46kg/L→25MJ/L@110K	high insulation
LH ₂	0.07kg/L→8.5MJ/L@20K	Super high insulation, 34% of LNG
LNH ₃	0.64kg/L→14.4MJ/L@240K	58% of LNG
MCH	0.77kg/L→5.7MJ/L@RT	1.4MJ/L heat is required 15% of Petro
MeOH	0.79kg/L→18.0MJ/L@RT	CO ₂ emission 47% of Petro
Petro	38.3 MJ/L@RT	

NH₃ is expected as a fuel (co-firing) for coal fired power plant.
MeOH is expected as a marine fuel (but NOT as energy carrier).
LH₂ and MCH are viewed somewhat negatively.

3. NH₃ and MeOH



3. NH₃ and MeOH



ΔH = -49.4 kJ/mol (Exothermic) 200~300°C

CO₂ : 44kg

→ H₂ : 67Nm³ Necessary

→ 32kg MeOH can be produced

For 1 ton MeOH production,

187 kg H₂ and

1.4 ton CO₂ are necessary.

Material cost (ton)

H₂ : **280 USD**

CO₂ : **14~46.2 USD**

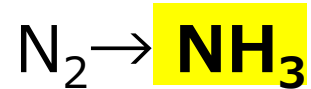
NH₃ : **394~326 USD**

H₂ : **1.5USD/kg**

CO₂ : **10~33 USD/ton** (CO₂ Capture Cost target)



3. NH₃ and MeOH



$\Delta H = -45.9 \text{ kJ/mol}$ (Exothermic) 300~400°C

N₂ : 11.2Nm³

→ H₂ : 33.6Nm³ Necessary

→ 17kg NH₃ can be produced

For 1ton NH₃ production,

176 kg H₂ and

823 kg N₂ are necessary.

Material cost (ton)

H₂ : 264 USD

N₂ : 22.2 USD

NH₃ : 286 USD

H₂ : 1.5USD/kg

N₂ : 27USD/ton (Rough estimation)

PRICES

The maximum net product price was set at 1,280 €/t.

Fertiglobe

An ADNOC and OCI Company

811 €/t

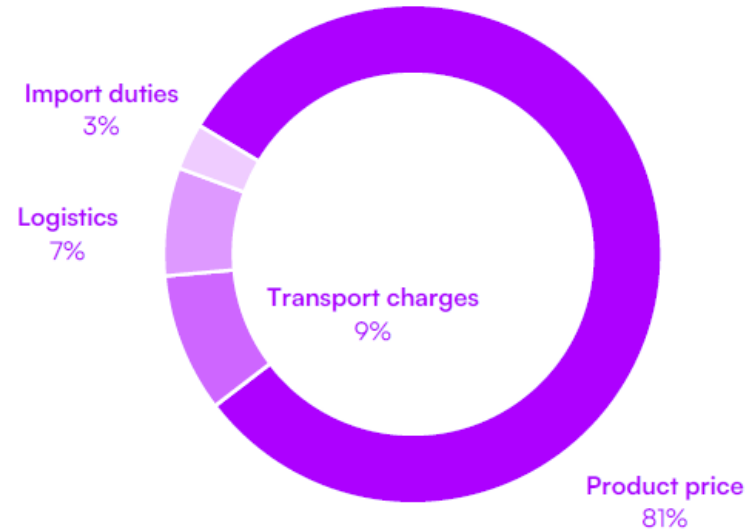
(ex-factory) net product price

37%

lower than the bid cap

TOTAL **1,000 €/t**

incl. net product price,
transport and logistic
charges, import and export
duties



1 million ton NH₃ → 200 MW Coal Fire Power Plant

40 \$/GJ (G-NH₃)

4.8\$/GJ (Thermal Coal)

13 \$/GJ (C-NH₃)



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- Even in Japan, 20 million ton @2050 is extremely high target.
- From the cost structure of green H₂, electricity cost should be decreased and capacity factor should be increased.
- As the material costs, N₂ and CO₂ are not considerable, but the contribution from hydrogen is significant.
- Regarding liquid hydrogen, is it not necessary to adopt a strategy that takes into account its added value as a cryogenic refrigerant?
- In any cases, investment in mass production and cost reduction is strongly required.



Thank you very much for your kind attention!

