Solar Energy Conversion to Hydrogen

Solar to Heat

Collectors
（50-80%）

Heat

〈Heat to Electricity〉

CSP （Global ～16%）

Solar to Electricity

Electricity

Solar Cell
(PV)

〈Heat to Hydrogen〉
Thermochemical processes
（～30%？）

〈Electricity to Hydrogen〉

Electrolysis

Global: Solar to Fuel 15～24%?

Fuels(H_2,etc.)

Photocatalysis

Photo to chemicals

Chemical storage (liquid)

- Cost-effective energy storage
- Large capacity
- Long-term storage over seasons and years
- Oversea Transportation

Results from Levelised Cost of Fuel calculations (2020)

5.6 AU$/GJ or 1.25 AU$/kg of H_2 = 10 JP¥/Nm^3

Process	Input fuel cost	Solar product gas LCOF	Final fuel LCOF	Final fuel LCOF	Technology readiness	GHG intensity
Conventional crude oil at $100/bbl	$16/GJ		$20/GJ	$0.56/L	Current technology	High
Solar gasification of brown coal	$1/GJ	$3.45/GJ	$11/GJ	$0.31/L	Medium	High
Solar reforming of natural gas	$8.4/GJ	$10.30/GJ	$17/GJ	$0.48/L	High	Medium
Solar gasification of biomass	$8/GJ	$9.75/GJ	$17/GJ	$0.48/L	Medium	Zero-Low
Solar water splitting	Zero	$29–46/GJ	$34-51 /GJ	$4-6/kg H_2	Low	Zero
PV Electrolysis (2020)	Zero		$94/GJ	$11/kg	High	Zero

Assumes: 2020 solar field costs of $173/$m^2$ for heliostats. 6.4% discount rate, 30 year amortisation

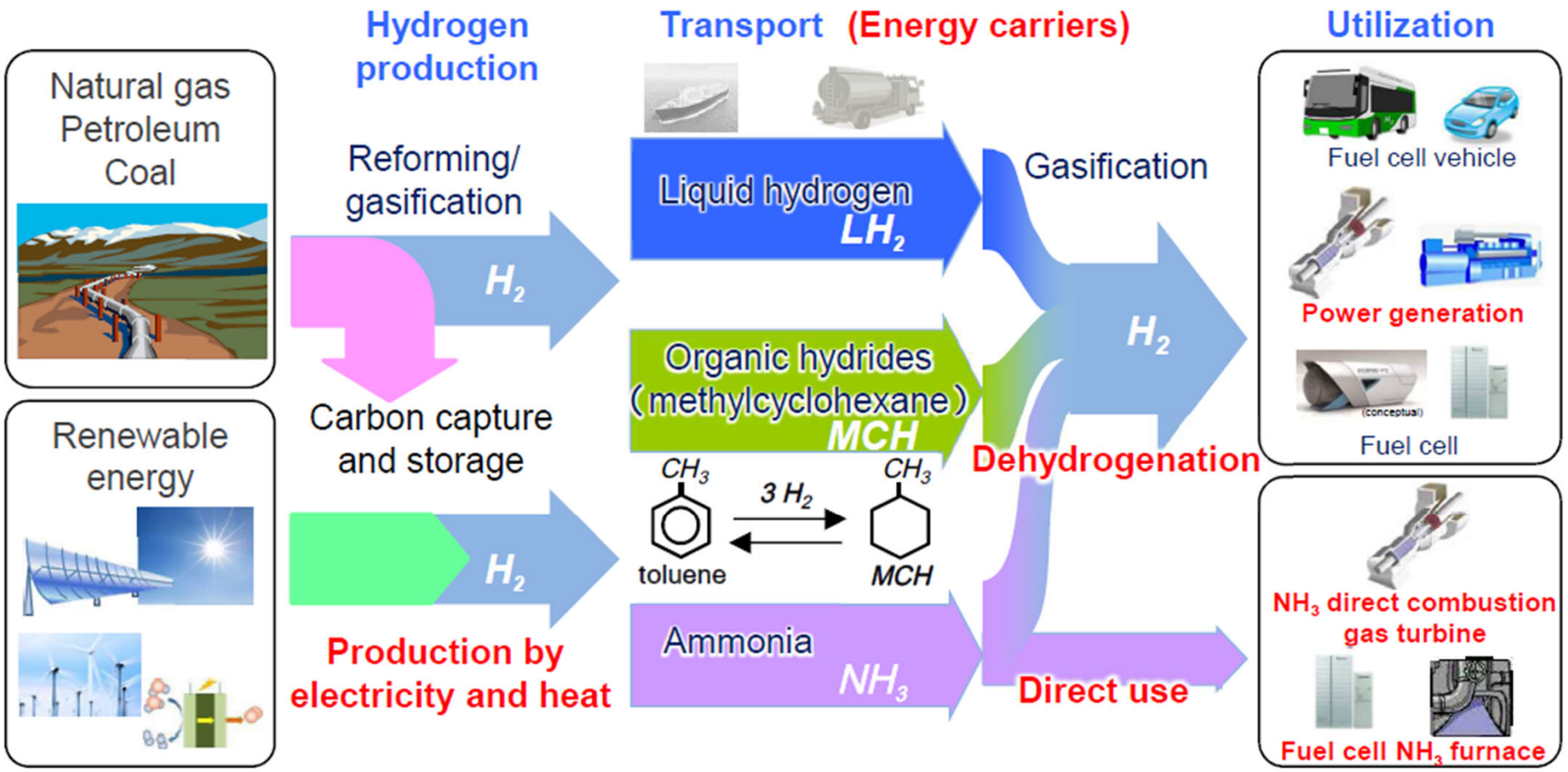
"Concentrating Solar Fuels Roadmap Final Report CSIRO"

https://arena.gov.au/assets/2016/05/Concentrating-Solar-Fuels-Roadmap-Final-Report-CSIRO.pdf

Assuming 2030 solar field costs of AU$90/$m^2$, H_2 cost via solar thermochemical water splitting could be AU$2.9-4.4/kg of H_2 or AU$21-33/GJ (23-35 JP¥/Nm^3 of H_2).

Hydrogen Supply Chain - Hydrogen Carriers

Technologies related to carbon-free H_2 production, transport & and utilizations



Source: Onozaki, M., The Institute of Applied Energy (IAE, Japan) Adelaide, Australia, HiTeMP, Sep. 17, 2018.

Power Generation Costs in Japan for H_2 Energy Carries

Current H_2 cost at H_2 station in Japan: 100 JP¥/Nm^3 of H_2 → Power generation cost: 52 JP¥/kWh

Coal or NG fired plant with CCS → Power generation cost: 16 - 18 JP¥/kWh
(but, if operation rate ↓ (eg. 25%) , the cost ↑(+ 3.2 -7.6 JP¥/kWh))

Energy Carriers	Liquid H_2		Ammonia			Methanol			Methane (LNG)		
Cost for each session	Cost on H2 Basis	Cost on Power Generation Basis	Cost on H2 Basis	Ammonia cost to Power Generation Plant	Cost on Power Generation Basis	Cost on H2 Basis	Methanol cost to Power Generation Plant	Cost on Power Generation Basis	Cost on H2 Basis	Methane cost to Power Generation Plant	Cost on Power Generation Basis
	JP¥/Nm^3-H_2	JP¥/kWh	JP¥/Nm^3-H_2	JP¥/kg-NH_3	JP¥/kWh	JP¥/Nm^3-H_2	JP¥/kg-CH_3OH	JP¥/kWh	JP¥/Nm^3-H_2	JPY/kg-CH_4	JP¥/kWh
CO2 Capture & Supply	0.0	0.0	0.0	0.0	0.0	0.0	13.1	5.2	0.0	26.1	4.2
Fuel Production	10.0	5.5	10.0	19.8	7.9	10.0	21.0	8.3	10.0	56.0	7.0
Transport, etc.	27.5	15.0	14.1	27.9	11.2	8.2	17.2	6.8	12.9	36.1	5.9
Sum	37.5	20.5	24.1	47.7	19.1	18.2	51.3	20.3	22.9	118.2	17.1

- **Including the cost of newly installing the plant.**
- **CO2 is transported from Japan(JP) to Australia(AU). Cost of Transportation: 4,000JP¥/t-CO2. Adding capture, compression, & unloading costs, CO2 cost goes to 10,000JP¥/t-CO2.**
- **Ammonia transport ships from AU to JPN can be used to transport CO2 from JPN to AU. Assumption: ¼ CO2 transport ships are also used for ammonia transportation.**
- **Power generation efficiency: GTCC for H2 and CH4; 52%, Coal-fired plant for NH3 and CH3OH; 40%.**

Made from the repot by The Institute of Applied Energy (IAE, Japan) on "Research on Energy Carrier System": Japanese title of the report「エネルギーキャリアシステム調査・研究　エネルギーキャリアシステムの経済性評価と特性解析」, NEDO Report, (2016).