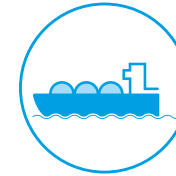


Hydrogen, hydrogen derivatives and e-fuels



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	Hydrogen Gas	Liquid Hydrogen	Liquid Ammonia (Green Ammonia)	Liquid Methanol (eMethanol)	Dimethylether (eDME)	Liquefied Natural Gas (eLNG)	Synthetic Aviation Kerosene (eSAF)
Ideal universal reaction	Compressed H ₂	Liquefied H ₂	$3\text{H}_2 + \text{N}_2 \rightarrow 2\text{NH}_3$	$3\text{H}_2 + \text{CO}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}$	$6\text{H}_2 + 2\text{CO}_2 \rightarrow \text{CH}_3\text{OCH}_3 + 3\text{H}_2\text{O}$	$4\text{H}_2 + \text{CO}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$	$10\text{CO}_2 + 31\text{H}_2 \rightarrow \text{C}_{10}\text{H}_{22} + 20\text{H}_2\text{O}$
Hydrogen yield	100 %	100 %	100 %	4/6 = 67 %	6/12 = 50 %	4/8 = 50 %	22/62 = 35.5 %
Ideal conversion energy efficiency*	100 %	100 %	88,7 %	92,3 %	91,7 %	82,9 %	84,0 %
Reaction temperature °C**	50-80	50-80	350-550	200-300	200-300	300-400	180-250
Volumetric energy density, LHV (MJ/L)	2.43 - 6.8	8.52	12.7	15.7	18.7 Liquefied gas at 20°C	22.2	35
Gravimetric energy density, LHV (MJ/kg)	120	120	18.6	19.9	28.4 Liquefied gas at 20°C	48.6	42.2
Infrastructure readiness for large scale deployment in mid-term	Low	Low	High	High	High	High	High
Transportation and storage temperature	Ambient	-253 °C	-33.3 °C	Liquid at ambient temperature	Liquefied gas at 4.2 bar 20°C	-162 °C	Ambient
Transportation and storage phase and pressure	Compressed gas at 250 to 700 bar	Liquid at atmospheric pressure	Liquid at atmospheric pressure	Liquid at atmospheric pressure	Liquefied gas at 4.2 bar 20°C	Liquid at atmospheric pressure	Liquid at atmospheric pressure
Density	0.017 kg/L	0.071 kg/L	0.68 kg/L	0.79 kg/L	0.66 kg/L Liquefied gas at 20°C	0.46 kg/L	0.83 kg/L
Toxicity	Non toxic	Non toxic	TWA 25 ppm	TWA 200 ppm	TWA 1,000 ppm	TWA 1,000 ppm	TWA 30 ppm
Flammability (% in air)	4 - 74 %	4 - 74 %	14.8 - 33.5 %	6.0 - 36.5 %	3.4 - 18 %	4 - 15 %	0.7 - 4.8 %

Notes

* Ideal stoichiometric reaction energy conversion with no heat losses (LHV fuel / LHV H₂ feed)

** Approximate temperature range at which waste heat is liberated for direct use or steam generation