











Liebreich **Hydrogen: The Swiss Army Knife** Associates Medium-haul aviation Aviation **Fuels** Long-haul aviation Hydrocracking e-Fuels, specialist and legacy vehicles Chemicals Short-haul aviation Bulk e-fuels Shipping Desulphurisation Light aviation Chemical feedstock Methanol Shipping Local CO2 remediation Fertiliser Coastal and inland vessels Food industry Island grids Local ferries Steel Clean power imports Long distance trucks and coaches Power system balancing Regional trucks Seasonal power storage Rural trains Commercial heating Long-distance trains Freight Power High-temperature industrial heat Metro trains and buses Mid/Low-temperature industrial heat 2 and 3-wheelers Domestic heating Urban delivery Heat H2FC cars **Transport**



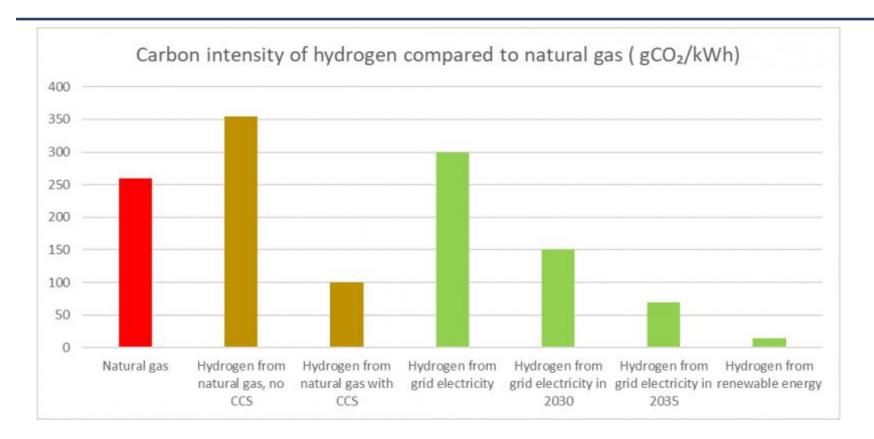


Image: Wenger

COLOUR	DESCRIPTION: FEEDSTOCK
	Grey: natural gas reforming without CCUS
	Brown: brown coal (lignite) as feedstock
	Blue: natural gas reforming with CCUS
	Green: electrolysis powered through renewable electricity
	Pink: electrolysis powered through nuclear energy
	Turquoise: methane pyrolysis
	Yellow: electrolysis powered through electricity from solar
	Orange: electrolysis powered through electricity from wind







For Water Splitting

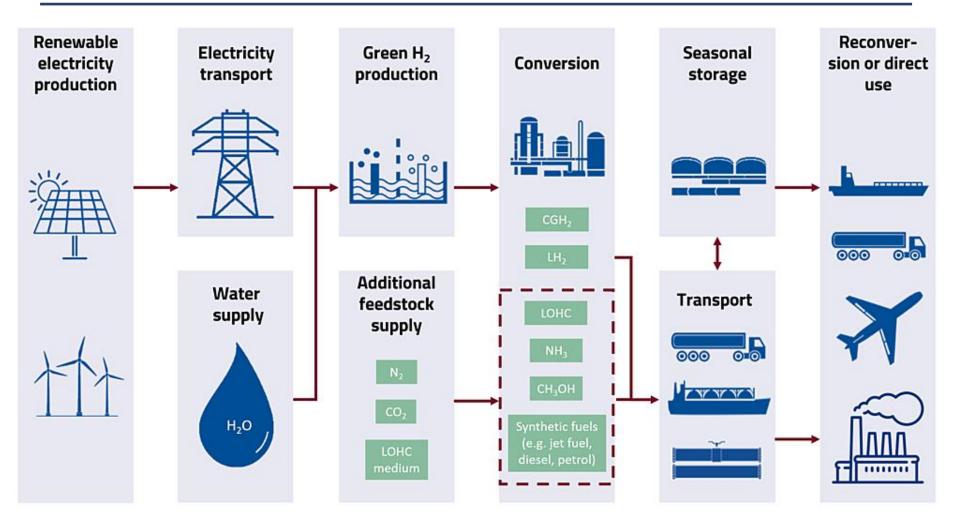
$$285.8 \times 10^{3} \frac{J}{mol} \times \frac{1 \, mol \, H_{2}}{2.016 \, g} \times \frac{1000 \, g}{1 \, kg} = 141.8 \, \frac{MJ}{/kg}$$

$$141.8 \, \frac{MJ}{kg} \times \frac{1 \, Watt. \, sec}{J} \times \frac{1 \, kW}{1000 \, W} \times \frac{1 \, hr}{3600 \, sec} = 39.4 \, \frac{kWh}{/kg}$$

Source: U.S. Department of Energy







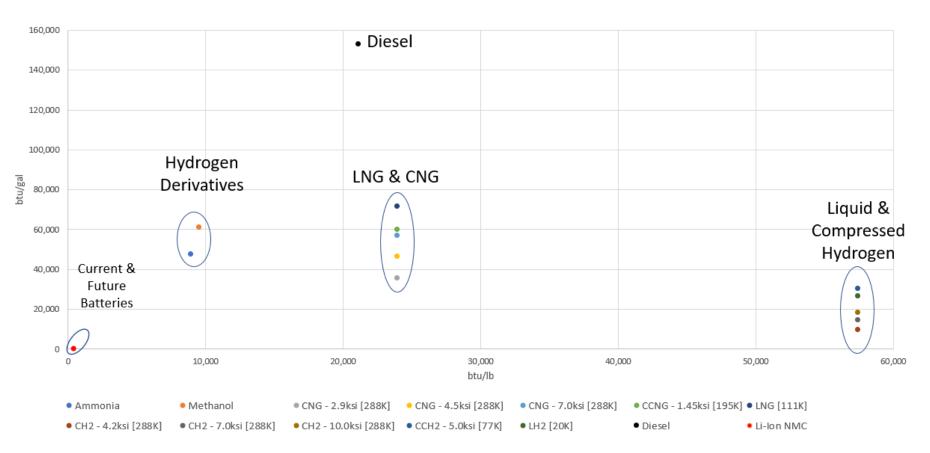
Source: https://www.hoou.de/projects/green-hydrogen/pages/3-4-hydrogen-supply-chains





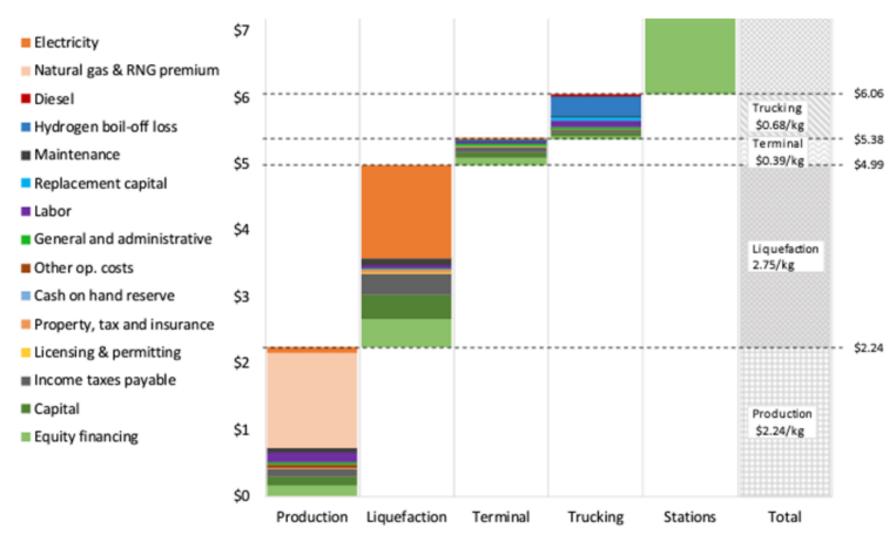
Energy Density of Fuels for Heavy Duty Applications











Source: U.S. Department of Energy

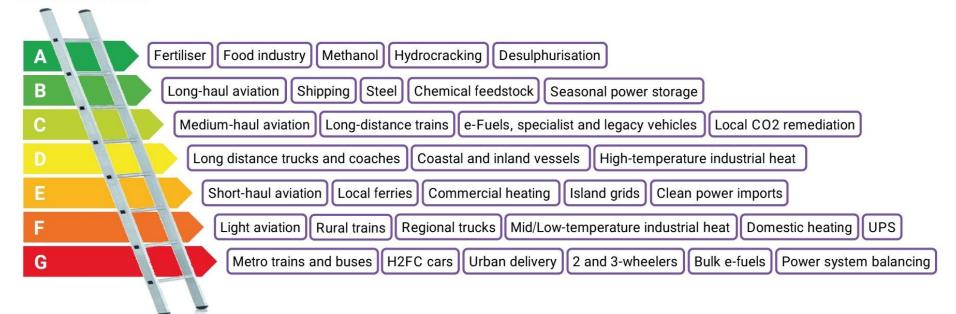




Hydrogen: The Ladder



Unavoidable



Uncompetitive

Source: Liebreich Associates Concept: Adrian Hiel/Energy Cities















