Hydrogen – a role in the future?

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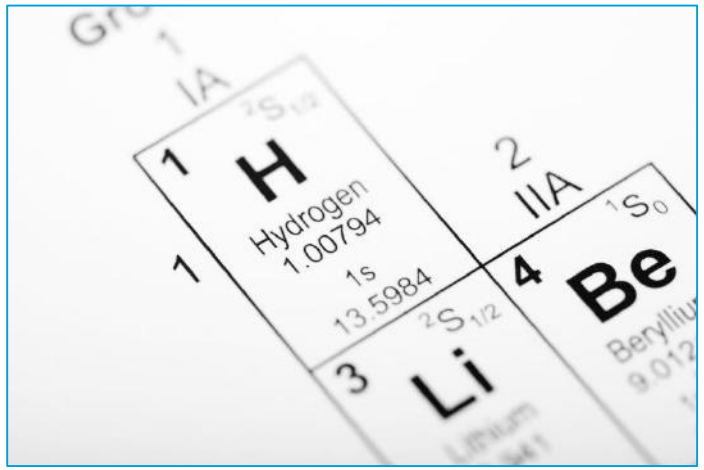
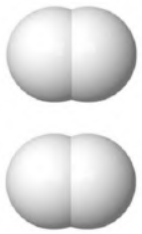
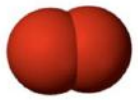
Can the lightest element have the heaviest impact?

Greek: “hydro-gène” – “water producer”

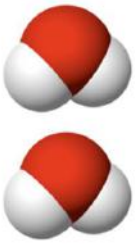




$2H_2$



O_2

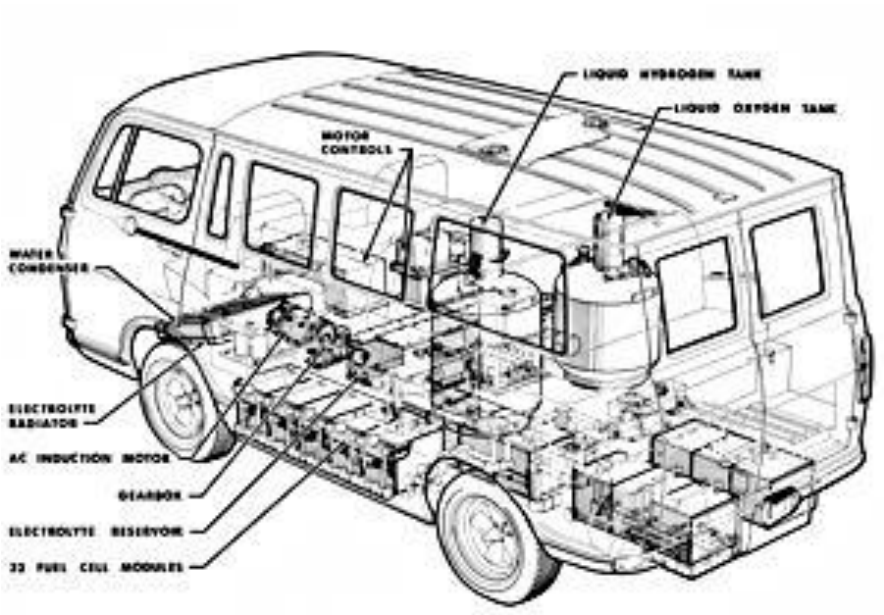


$2H_2O$

Hydrogen is not a new energy source or energy carrier

Space Travel 1960s

Fuel cell car 1966



CUTAWAY VIEW OF GENERAL MOTORS ELECTROVAN

Source: https://history.gmheritagecenter.co

Hydrogen has great flexibility and a variety of potential uses

Heating

Mobility

Storage

Power generation

Hydrogen has potential as the fuel of choice - Low Emission – High Energy Density – Fast fill

95%

Lower Well-to-Wheel GHG emissions for hydrogen from wind in H_2 fuel cell vehicles compared to gasoline

2.4 x

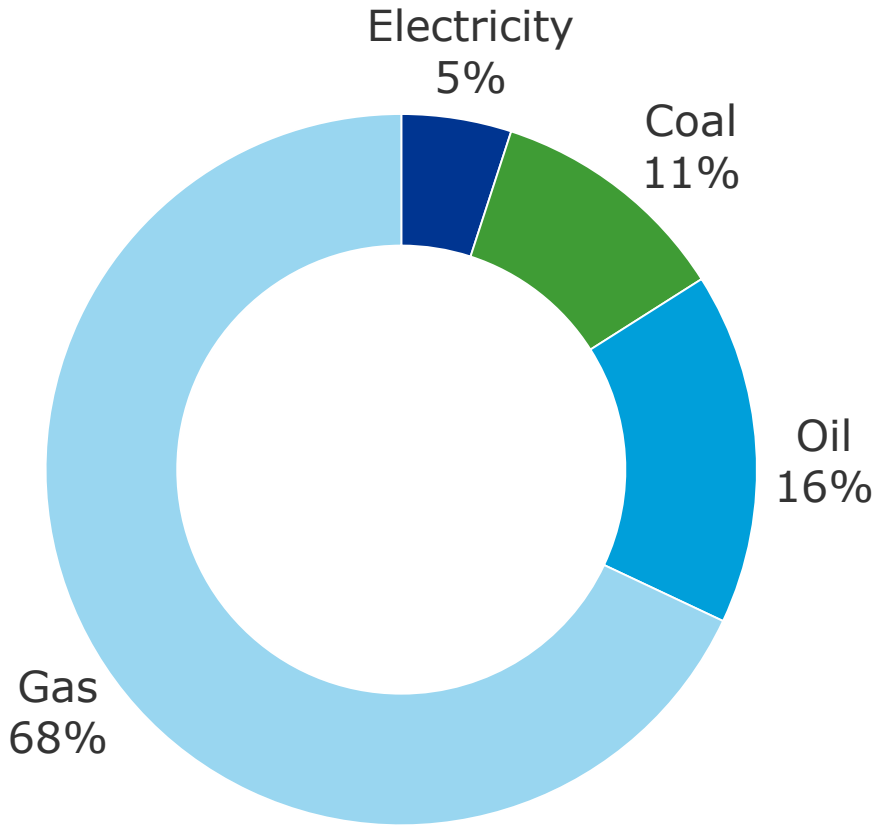
More energy per kg compared to natural gas and >160x compared to Li-Ion batteries

10-20 min

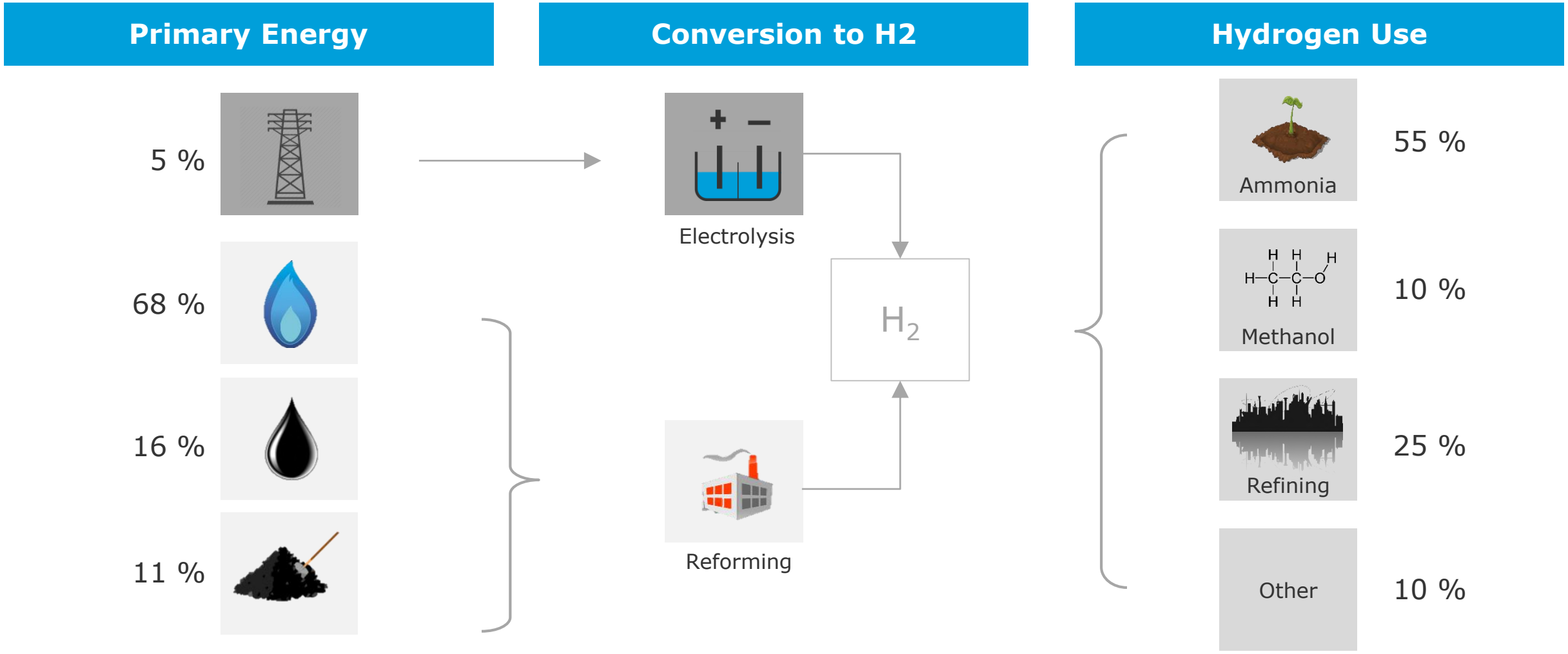
Filling time for 45 kg @350-700 bar (range 300km for electric bus)

Hydrogen is today primarily produced from natural gas

- Hydrogen from fossil fuels ca 95% - Hydrogen from electrolysis ca 5%
- Global production: ca 50 Mt
- Predominantly used (on-site) by producer, only ~4% is traded freely



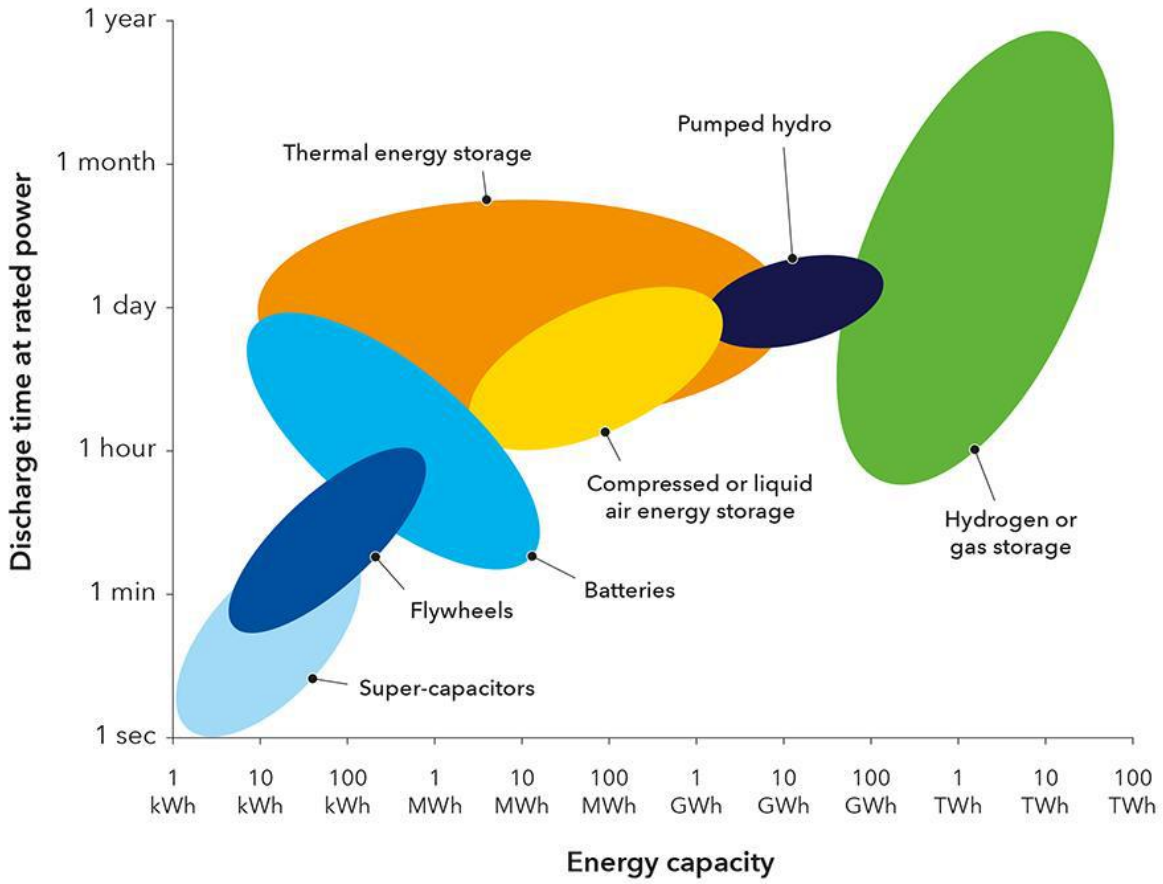
Hydrogen is primarily used in ammonia production



For hydrogen to scale it must meet the Energy Trilemma

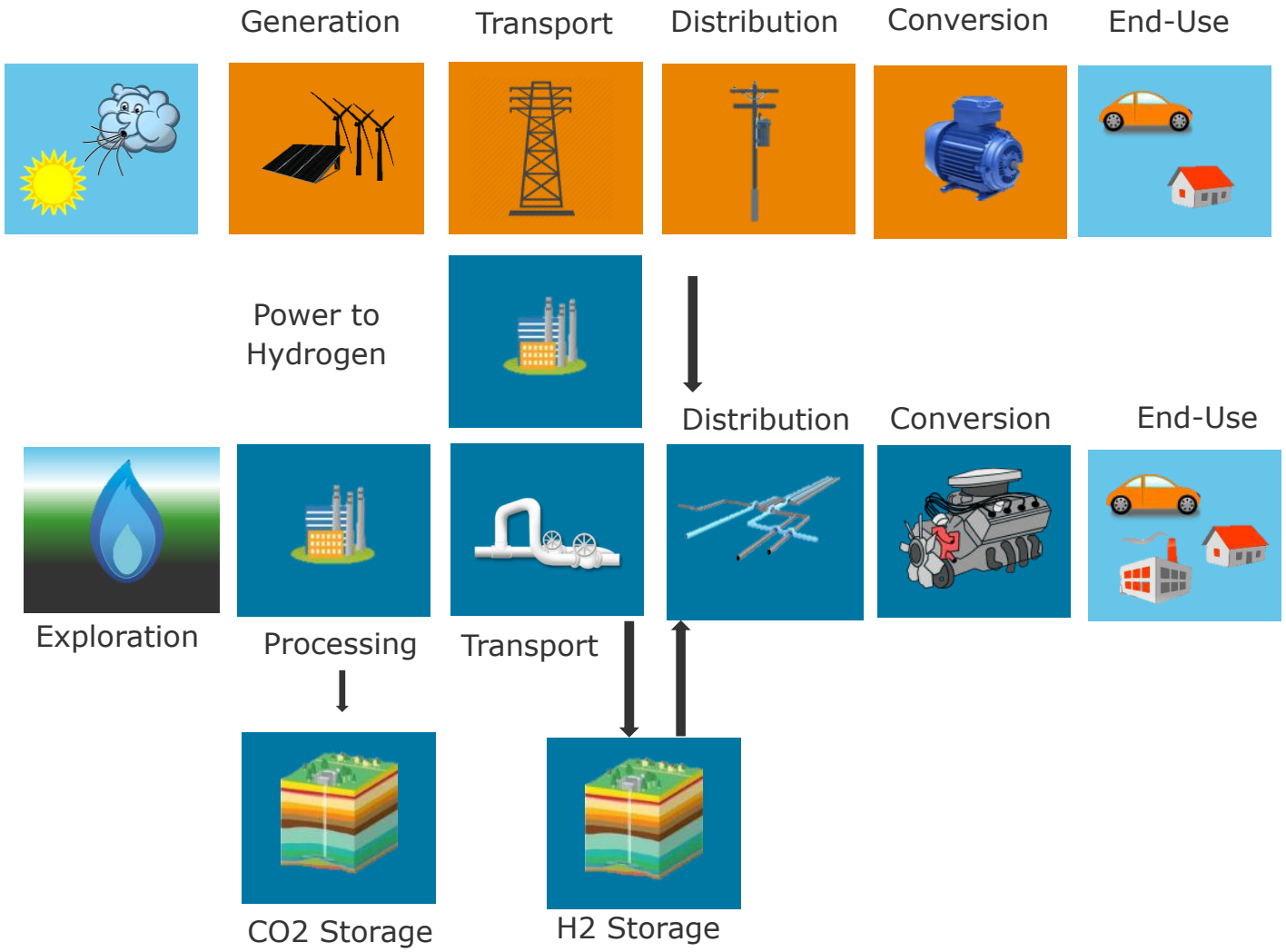
**Any solution which does not properly address all three issues will not be sustainable.
At the same time, the three issues are often at odds with each other.**

Hydrogen provides an attractive means of storage

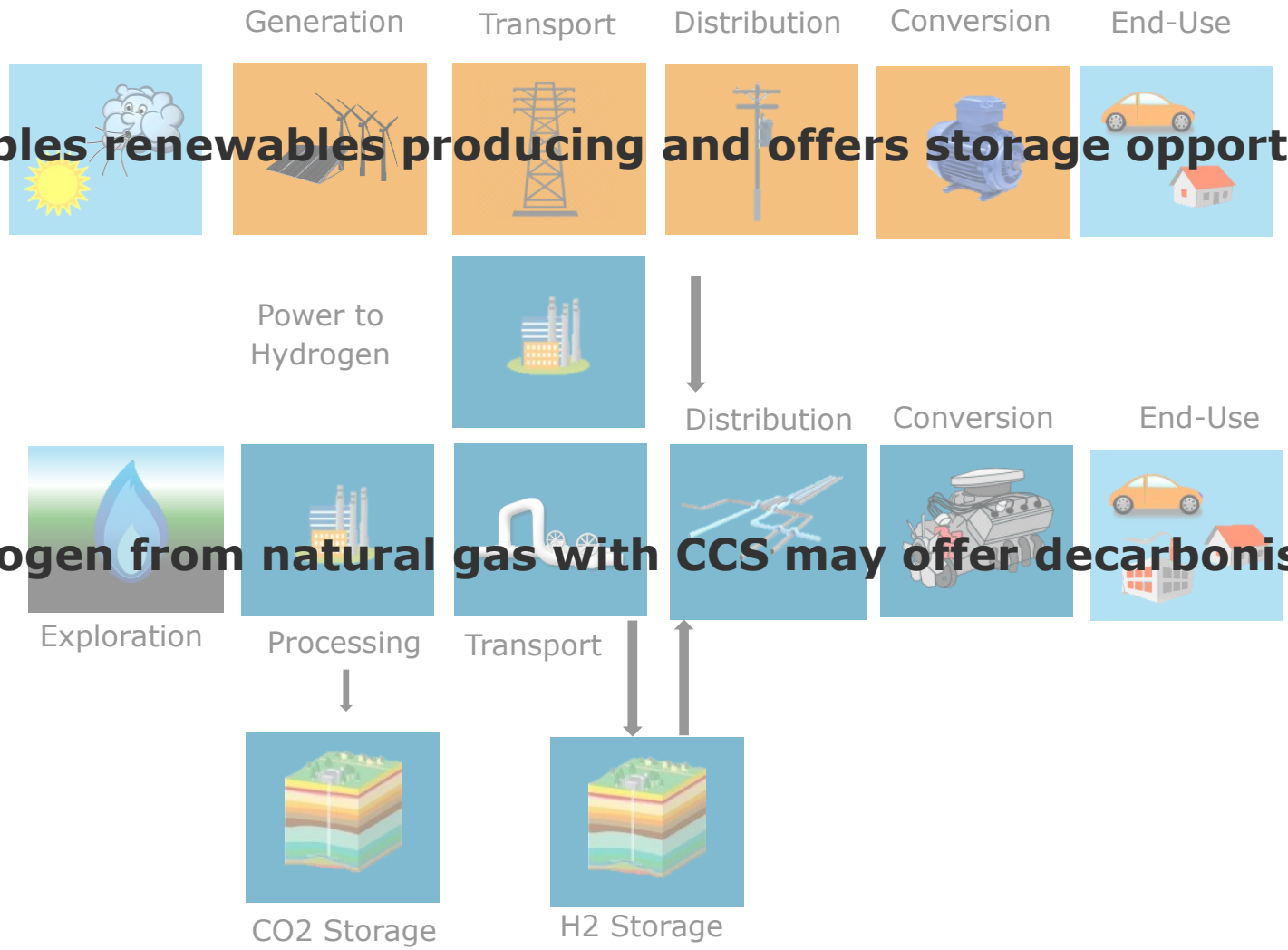


Hydrogen may provide both large volumes and long-term (seasonal) storage

Hydrogen can be produced in low-carbon value chains

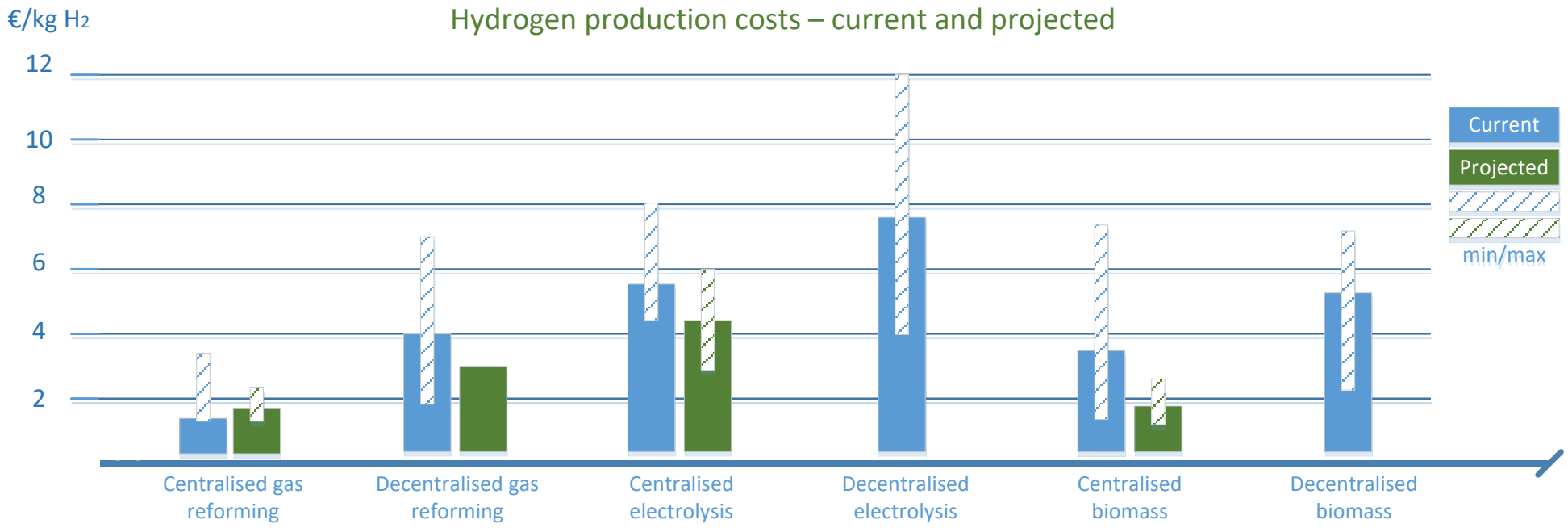


Hydrogen can be produced in low-carbon value chains



Costs are coming down – Economy of scale and further cost compression may be achieved

- Centralised production preferable – more efficient
- Cost of electricity and value of grid balance and storage key to bring costs down
- Cost of carbon and CCS important for entire value chain

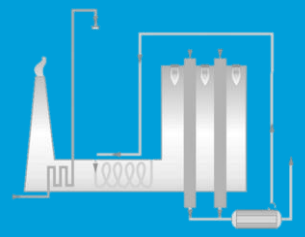


Source: Shell Hydrogen Study, Shell Deutchland Oil Gmbh (Own diagram)

Hydrogen purity vs applications

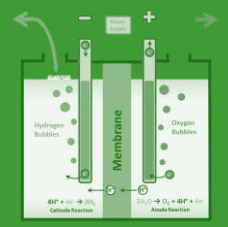
Output hydrogen purity from steam methane reforming

Hydrogen (~97%)



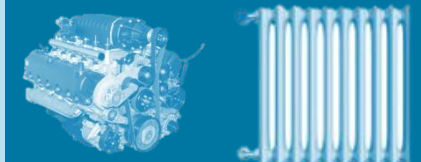
Output hydrogen purity from water electrolysis

Hydrogen (~99,9%)



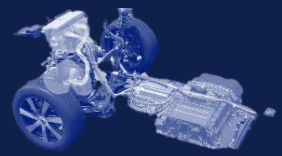
Input hydrogen purity requirement for hydrogen internal combustion engines

Hydrogen (~97%)



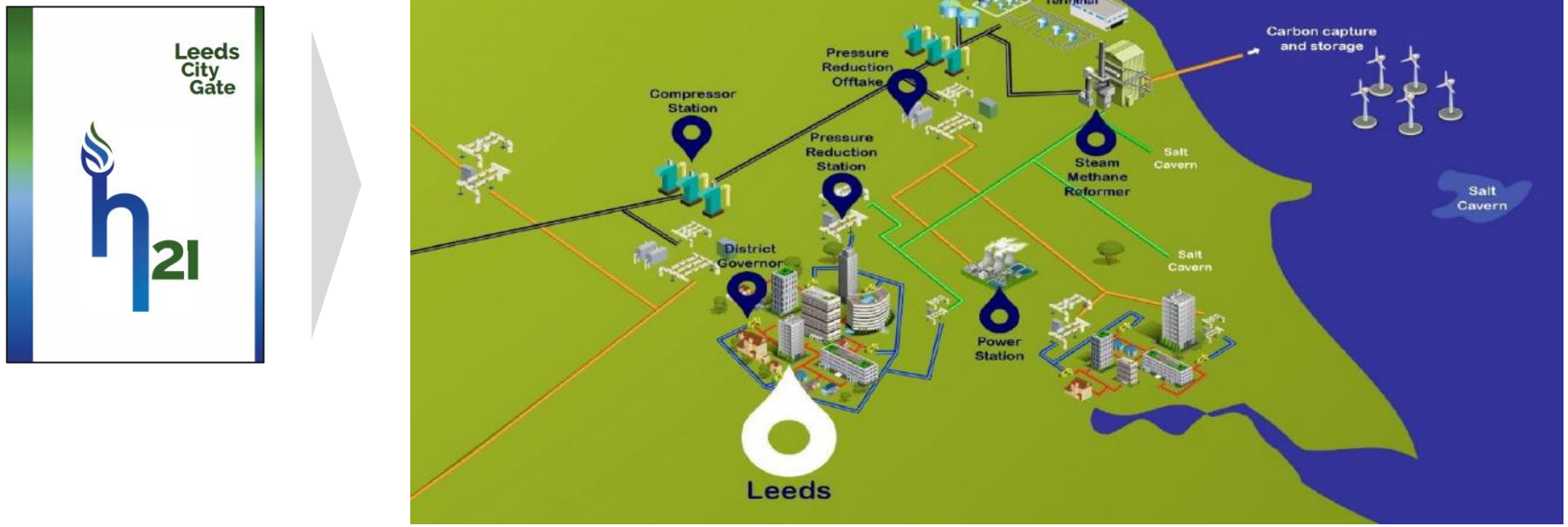
Input hydrogen purity requirement for hydrogen fuel cells

Hydrogen (~99,99%)



Major efforts drive hydrogen forward – H21 project in UK

- Convert City of Leeds to 100% Hydrogen
- 75% per cent reduction in CO_2 - 1.5million tonnes captured per year
- "..converting the gas network to hydrogen is technically feasible and economically viable.."



International collaborations to resolve technical uncertainties

Scalability

Upscale of electrolysismodules - beyond 5 MW

Balancing of grid

Transport

Pipeline, sea and road transport

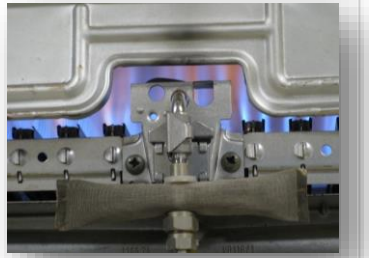
Embrittlement issues

Safety

Underground diffusion

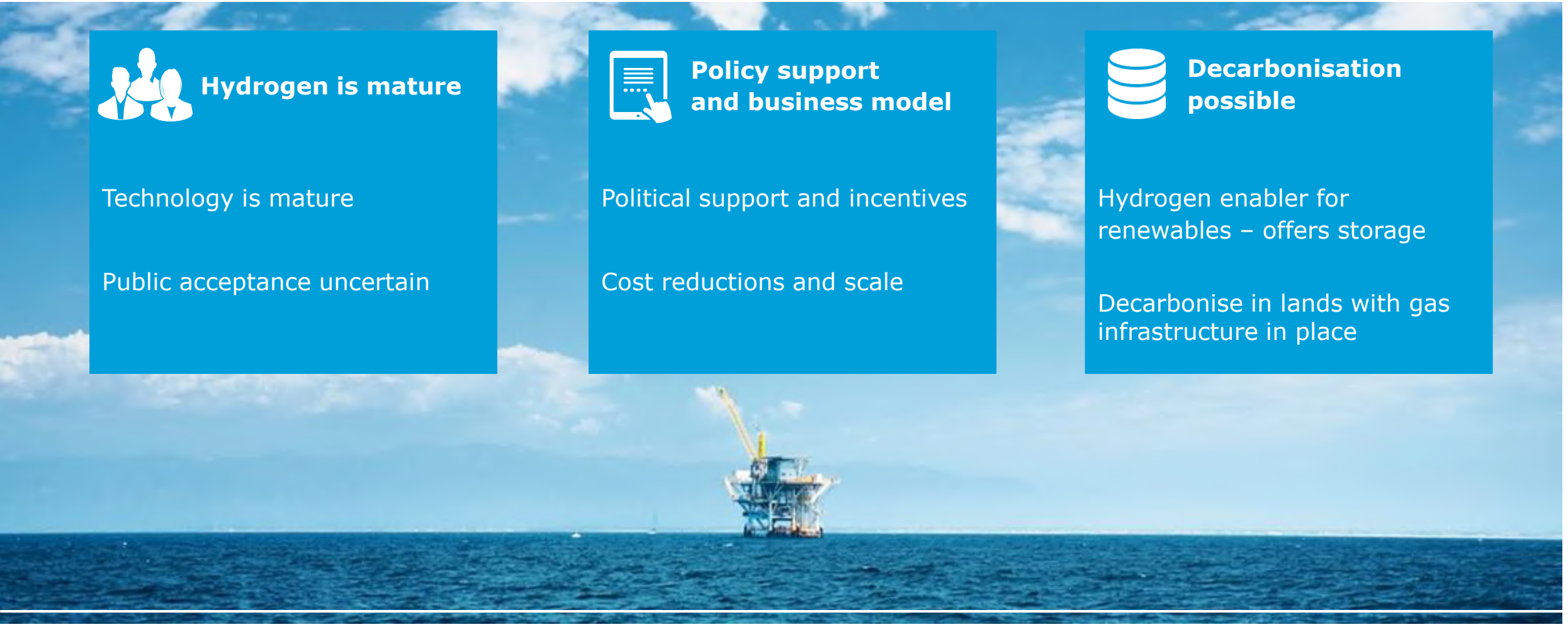
Better safety understanding

Appliances



Hydrogen appliances for domestic, commercial and industrial sectors

Hydrogen – a role in the future?



Hydrogen is mature

Technology is mature

Public acceptance uncertain

Policy support and business model

Political support and incentives

Cost reductions and scale

Decarbonisation possible

Hydrogen enabler for renewables – offers storage

Decarbonise in lands with gas infrastructure in place

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