

# HYDROGEN PRODUCTION FROM ELECTROLYSIS: ITS POTENTIAL AND COSTS

Decarbonising Trucks, Trains, Boats and Planes

REA

3 December 2019

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## Presentation Contents

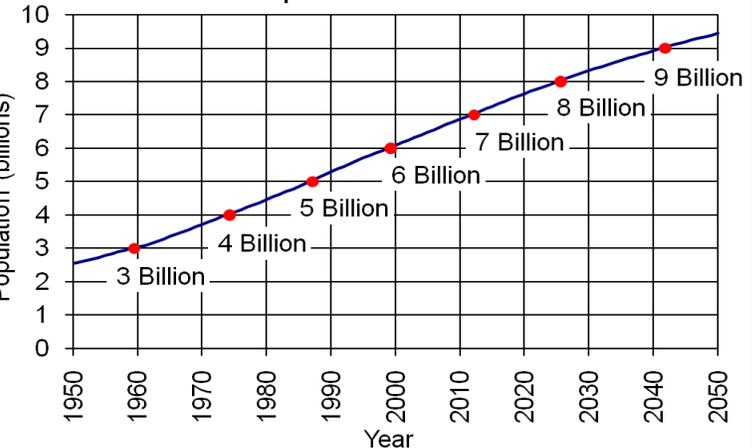
- Green hydrogen for a zero-carbon energy system
- Hydrogen properties
- Economic trends
- FCEV and HRS
- Future Trends



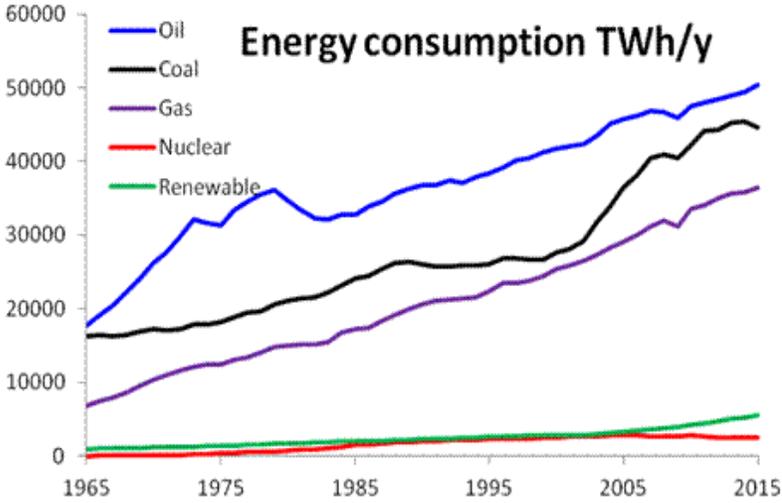
# PLANET EARTH



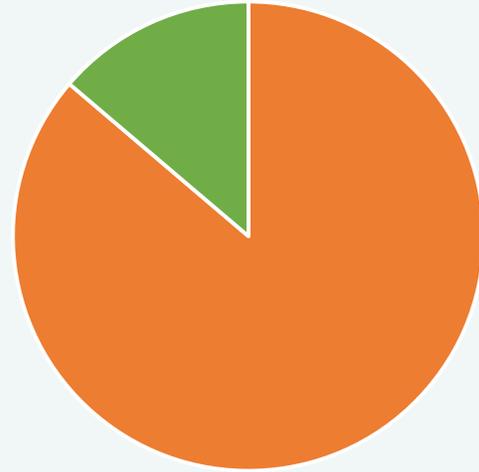
### World Population: 1950-2050



Source: U.S. Census Bureau, International Data Base, June 2011 Update.



## EU-28 : Energy Consumed as Molecules and Electrons (14,200 TWh)



■ Primary energy consumption excluding fuel use for electricity generation (Molecules)

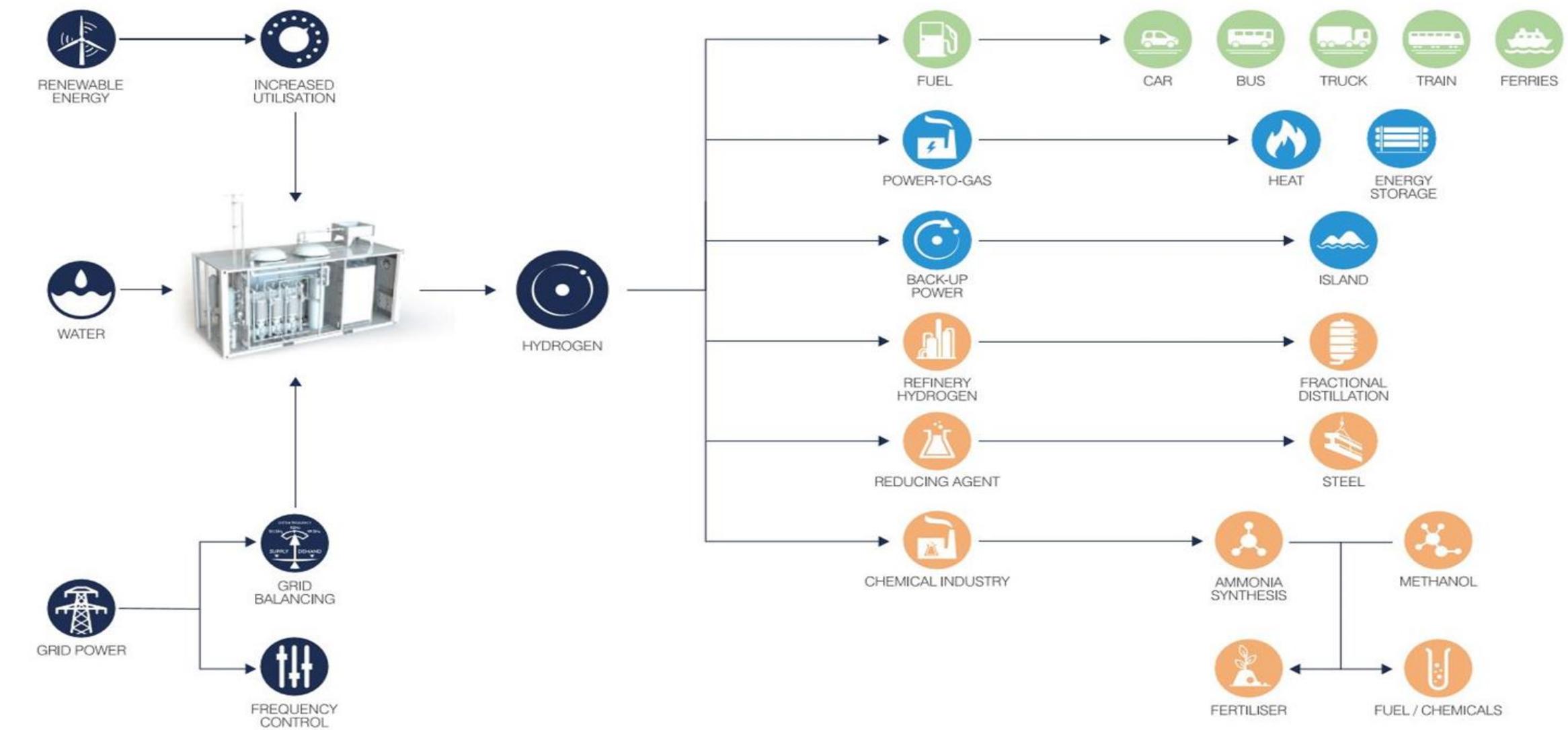
■ Electricity consumption (Electrons)

Source data: DG ENER, June 2017

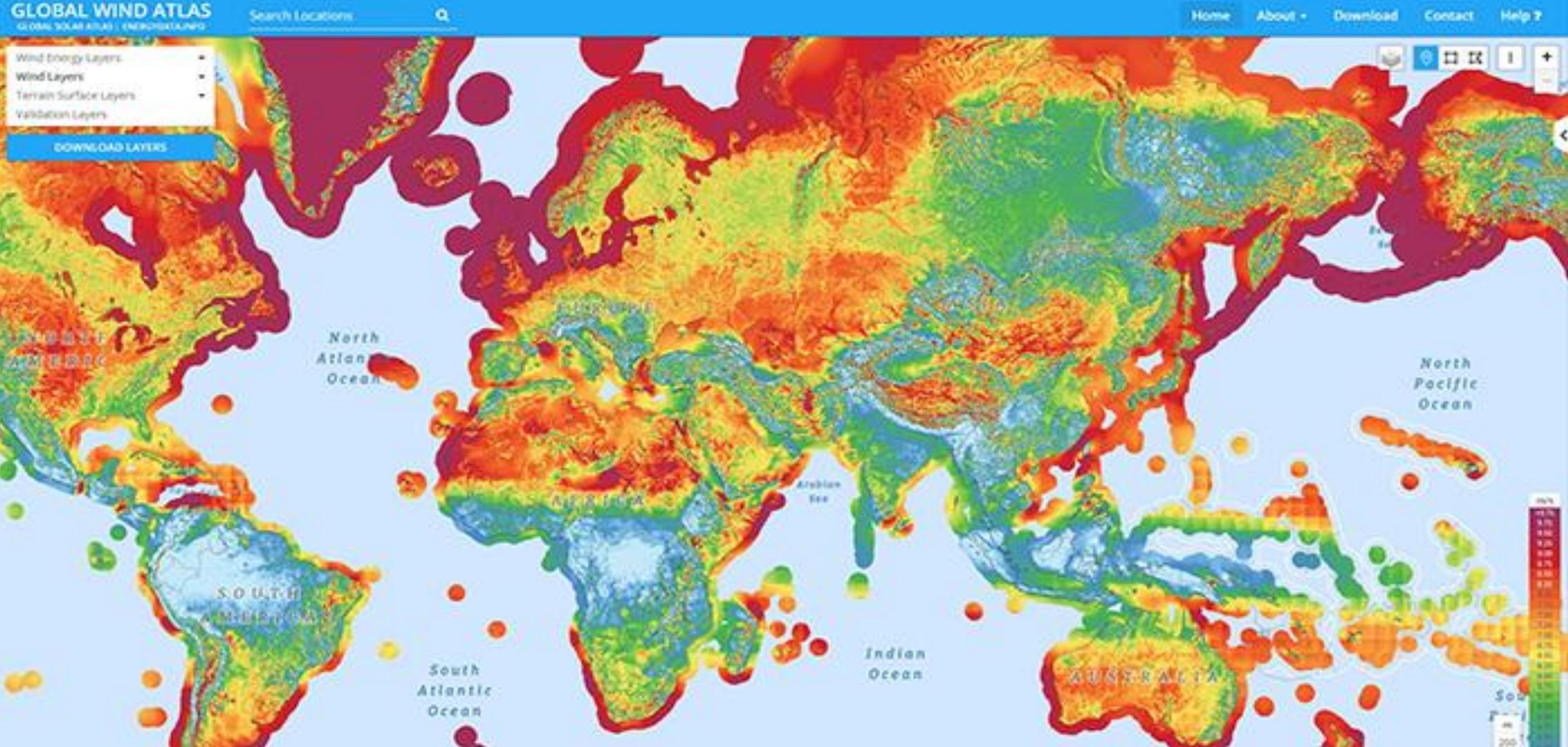
- Electrolysers convert electrons to molecules
- Electricity cannot be stored; renewable hydrogen can be stored and in vast amounts

# GREEN HYDROGEN FOR A ZERO-CARBON ENERGY SYSTEM

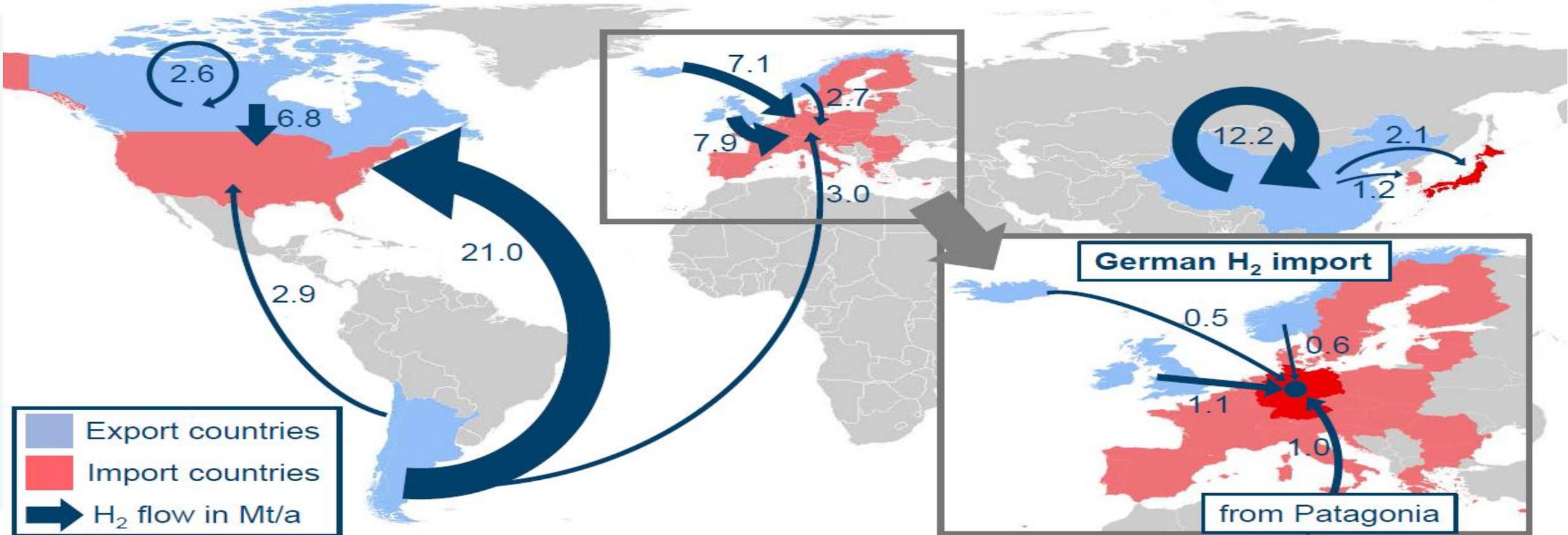
## INPUT      VECTOR CONVERSION      PROCESS APPLICATION      INDUSTRY



# RENEWABLE ENERGY RESOURCES



## Worldwide H<sub>2</sub> Flow Allocation with Minimized Overall Costs (75% Scenario)



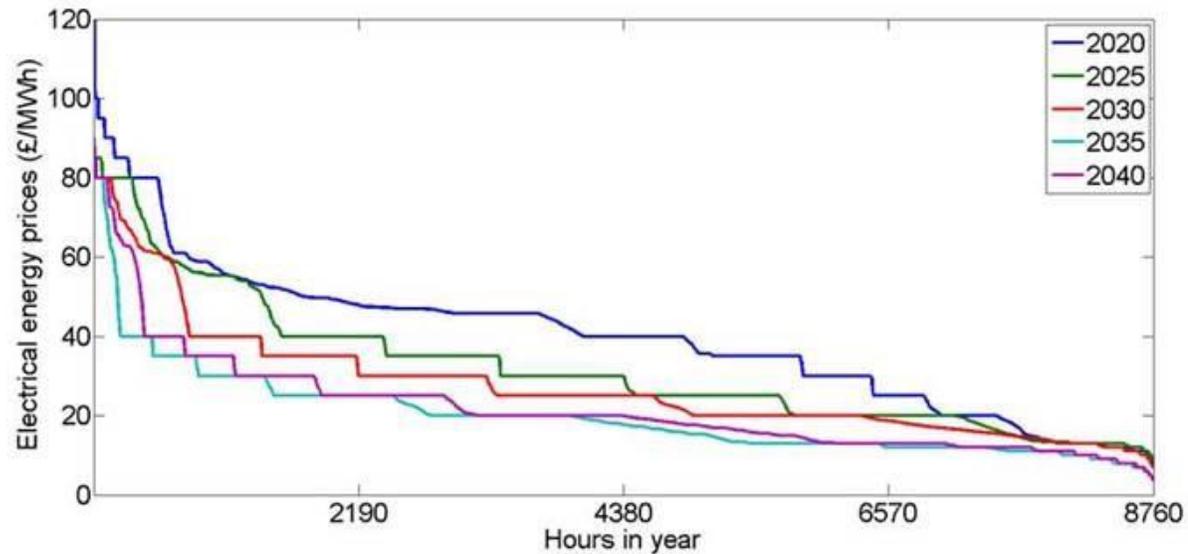
	Germany	Japan	EU	USA	Canada	China	South Korea
<b>Demand in Mt/a (75% Scenario)</b>	3.14	2.05	17.58	30.61	2.55	12.22	1.15
<b>Import LCOH in €/kg (*)</b>	4.66	4.81	4.67	4.34	4.66	4.71	4.77

(\*) Import LCOH incl. shipping costs

- Very low density (1 kg H<sub>2</sub> at NTP occupies ~ 11.1 m<sup>3</sup>)
- Flammability limits: 4-75% by volume in air
- Detonation limits: 18-59% by volume in air
- Very low minimum ignition energy in air (0.019 mJ, ~ 20% of methane, petrol etc)
- Hydrogen/air flame almost invisible and low emissivity ( $\epsilon < 0.1$ , methane  $\epsilon \sim 0.25$ )
- High octane number (140 RON)
- Very high flame speed (~ 8 times methane)
- High flame temperature (2254°C, ~ 300°C higher than methane)
- Hydrogen combustion produces NO<sub>x</sub>



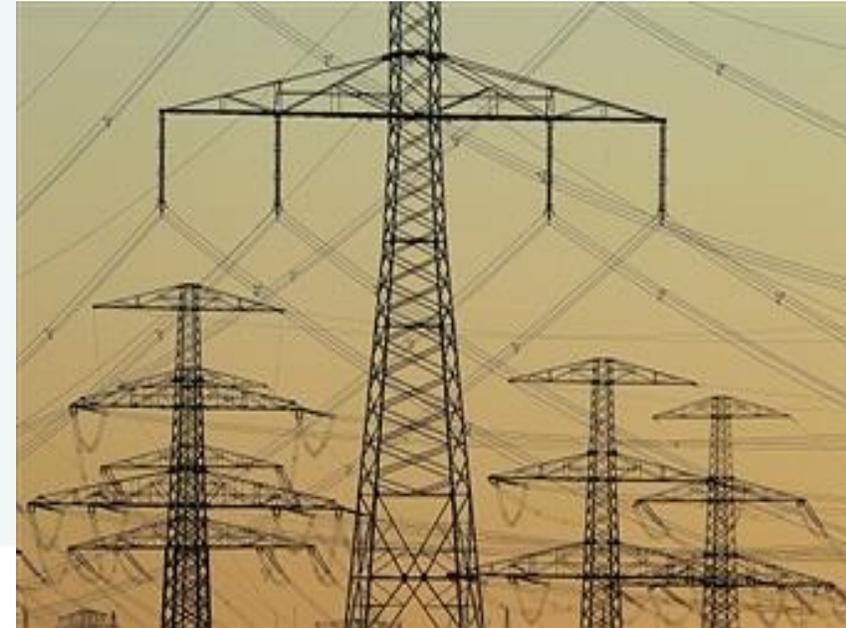
Hydrogen as a fuel, feedstock and decarbonising agent



- Increasing renewables
- Average electricity price decreasing
- Greater availability of low price electricity
- Under-utilised electricity grid

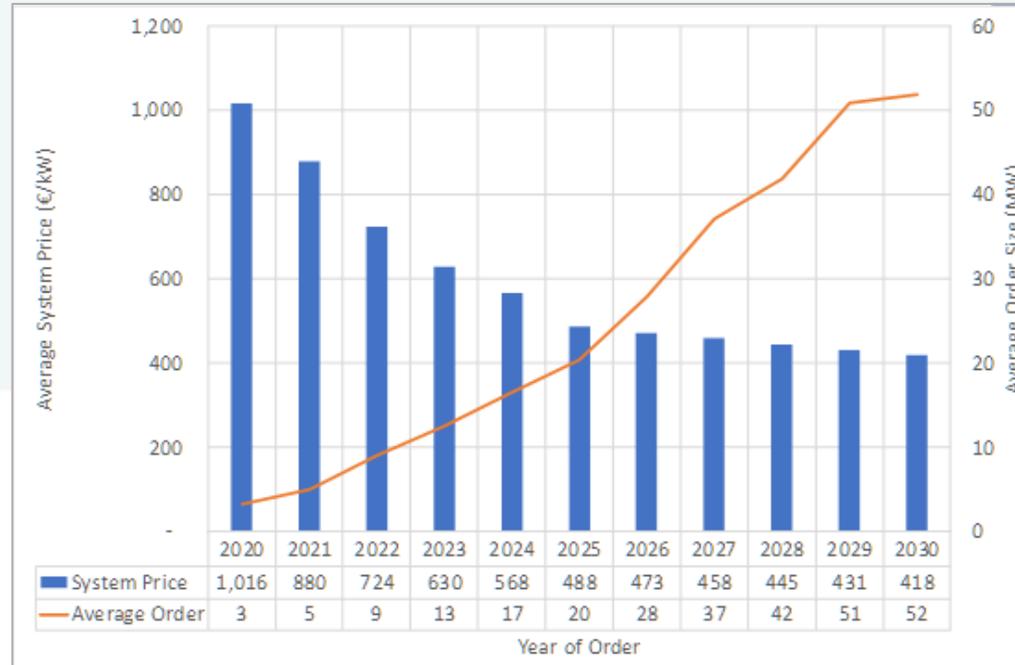
- Closure of coal power plants
- Decreasing use of natural gas for power generation
- Non-synchronous generation (wind and solar) increasing
- Synchronous generation (heat engines) decreasing
- Increasing temporal mismatch between electricity supply and demand

→ increasing need for grid balancing on all timescales (s, h, weeks, seasonal)

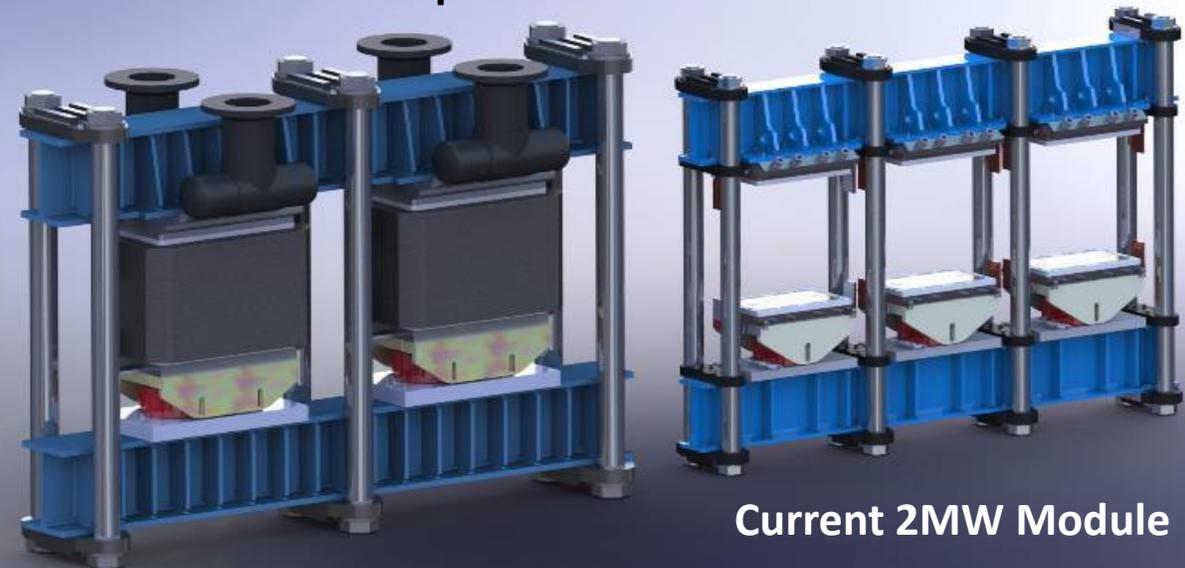


Using the electricity grid to produce hydrogen

- Proton Exchange Membrane technology
- Differential pressure operation ( $O_2$  close to ambient)
- No tie-rods | Rapid assembly | Rapid exchange
- 2MW module today | Upscaling to 5MW module
- Integral water purification and gas drying
- Factory semi-automation
- Continuous R&D and technology improvements

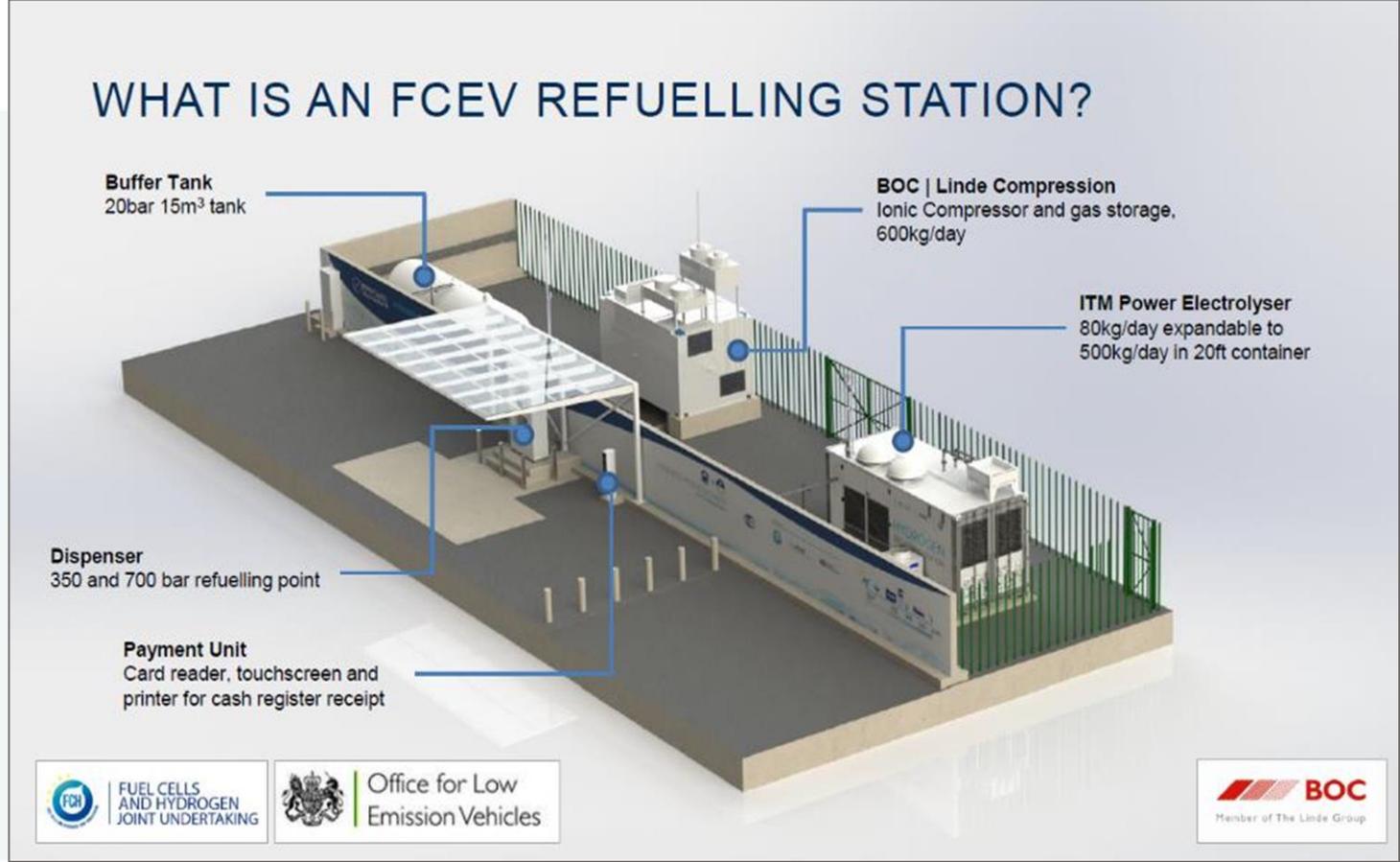
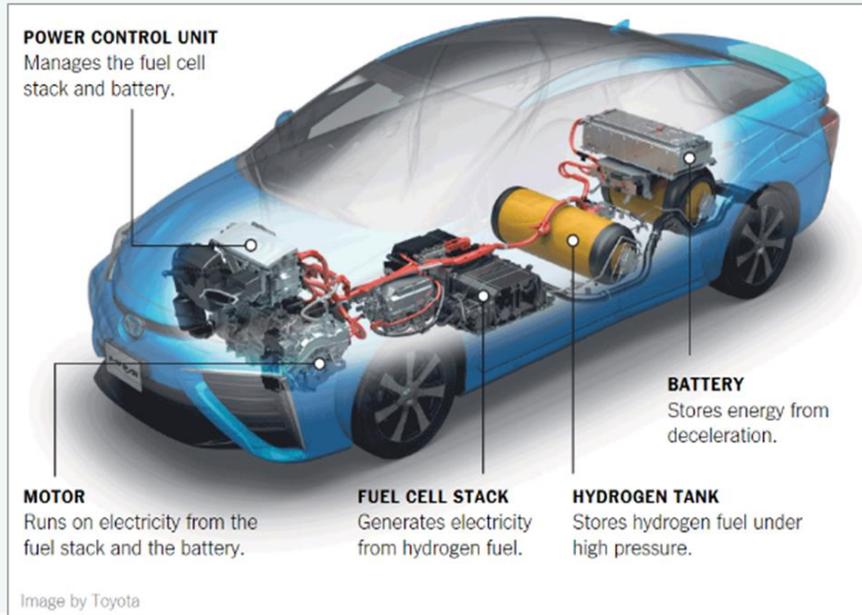


## 5MW Module Development



Current 2MW Module

- Refuel in 3 mins
- Up to 350 miles on 5kg of hydrogen
- Energy consumption ~40% of petrol car
- Zero emissions

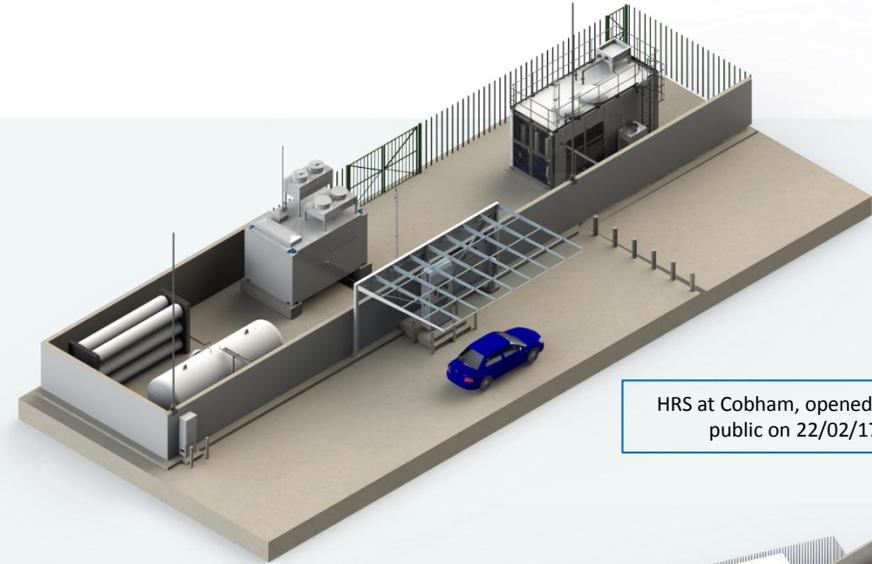


**FCEV: An EV drive train that's refuelled rather than recharged**

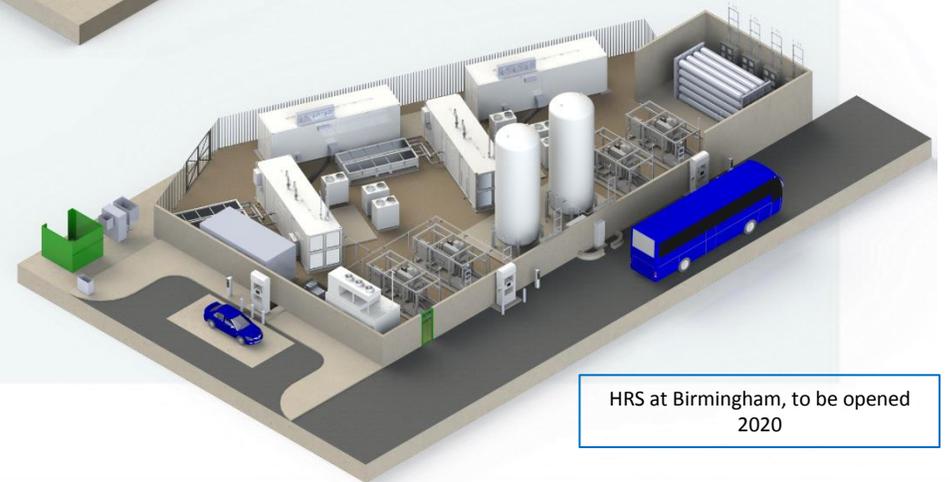
**Electrolyser-HRS: Turnkey solution for establishing a hydrogen refuelling infrastructure**

# HYDROGEN REFUELLING STATIONS

- 8 UK electrolyser-HRS in operation
- 1 US electrolyser-HRS in operation
- 6 UK stations in construction
- Refuelling 700b and 350b FCEV
- Currently dispensing up to 20 tonnes H<sub>2</sub> p.a.
- Load aggregation for Grid Balancing



HRS at Cobham, opened to the public on 22/02/17



HRS at Birmingham, to be opened 2020



HRS at Beaconsfield, opened to the public 27/03/18

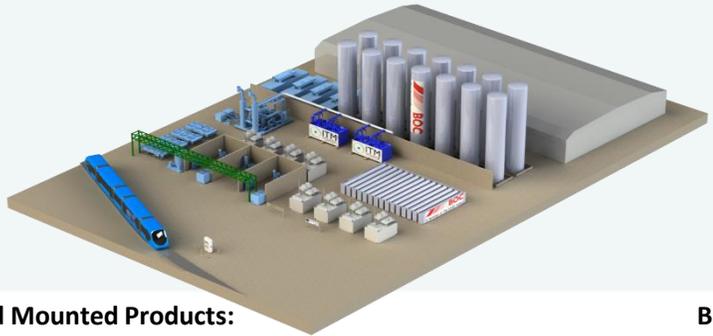
# LARGE SCALE HYDROGEN REFUELLING STATIONS

## Land | Sea | Air

- Buses: 30 kg/day
- Trucks: 75 kg/day
- Trains: 180 – 400 kg/day
- Ferries: 500 kg/day



**Containerised Products:**  
Bus refuelling station



**Skid Mounted Products:**  
Train refuelling station



**Building Housed Products:**  
Refinery electrolyser

Typical electrolyser requirements: 2MW | 10MW | 30MW | 50MW

- Expanding the UK network of HRS
- Developing and introducing heavy vehicles that can be refuelled rapidly
- Increasing recognition that green hydrogen is the transport fuel of the future
- Electrolyser upscaling and cost reduction
- Government policies enabling a 'green electrons + green molecules' sector coupling approach to decarbonisation
- An inter-seasonal storage market for renewable energy via underground storage of green hydrogen

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