

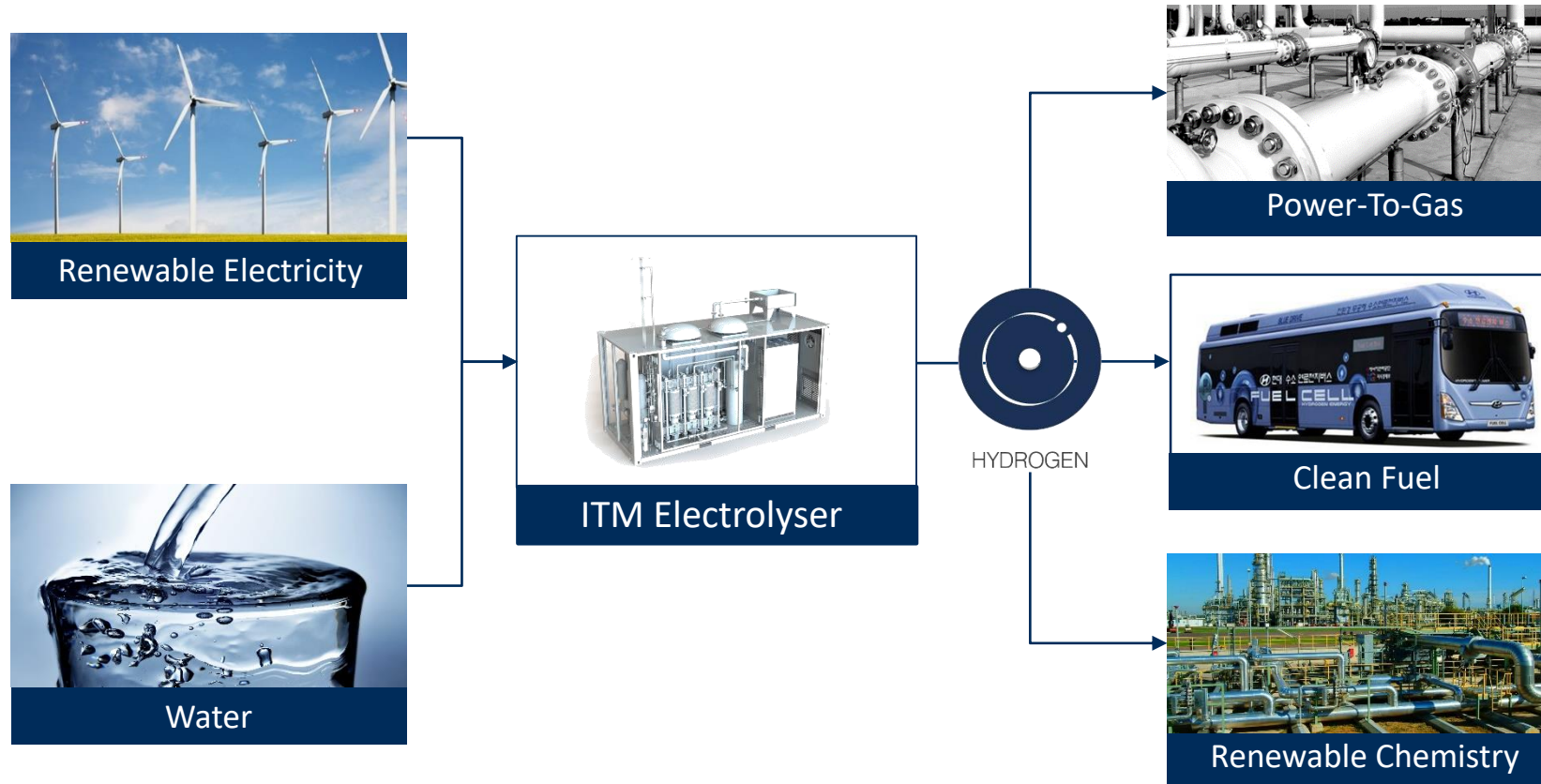
HYDROGEN ENERGY SYSTEMS

NOVEMBER 2018



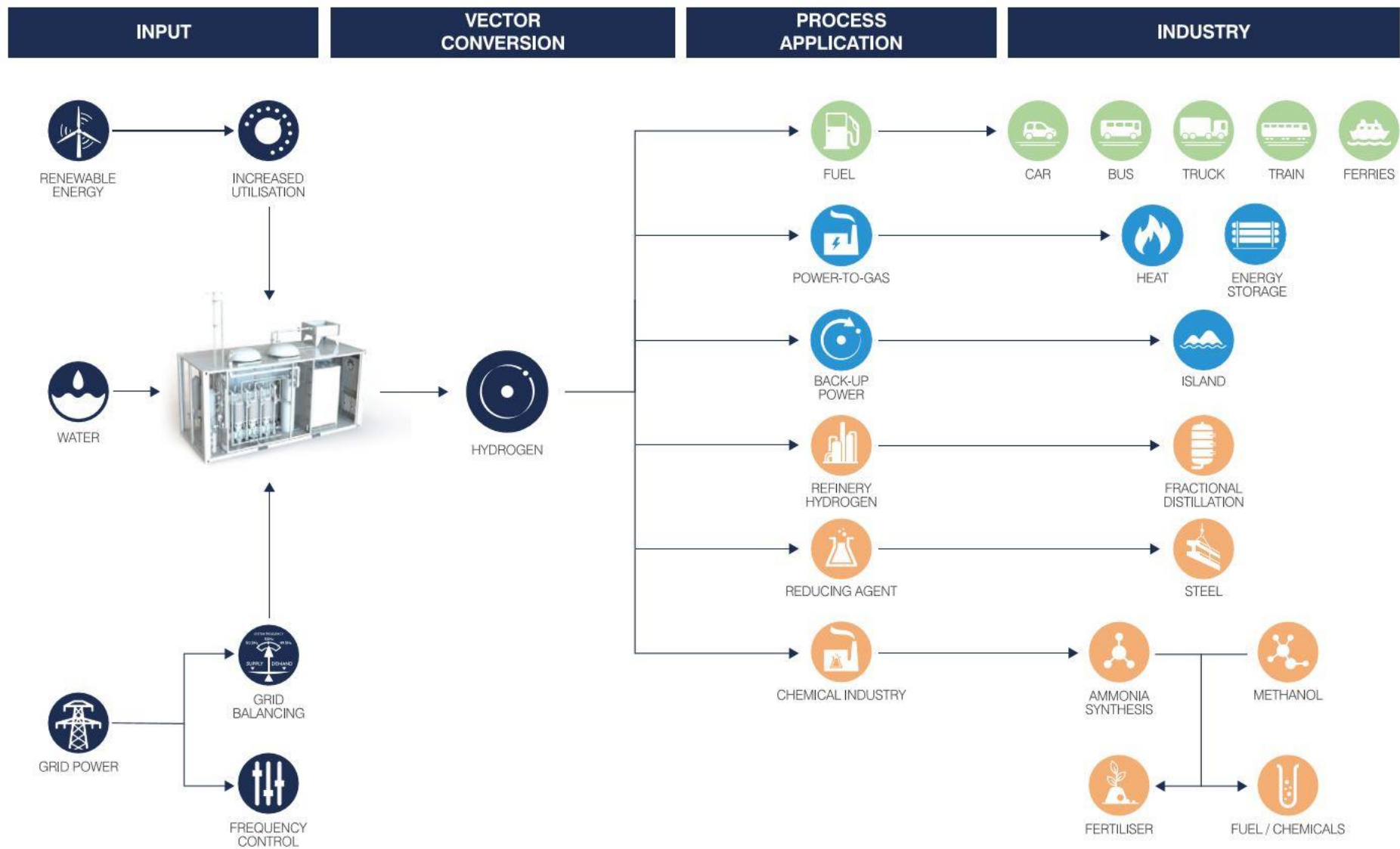
ITM POWER | WHAT WE DO

ITM Power manufactures integrated hydrogen energy systems



ITM POWER | WHAT WE DO

HYDROGEN ENERGY SYSTEMS



MULTIPLE SECTOR APPLICATIONS

HYDROGEN ENERGY SYSTEMS

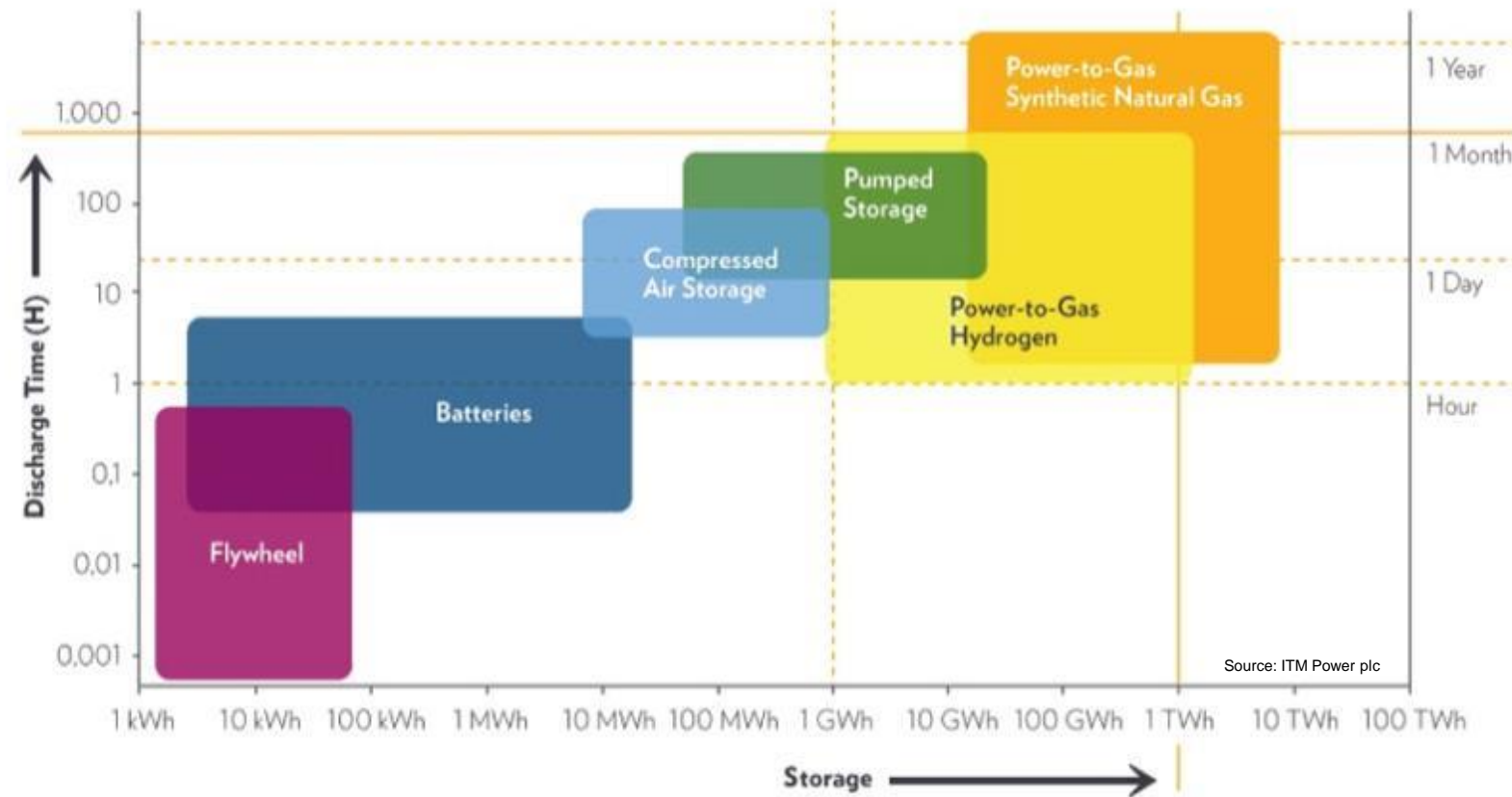
POWER-TO-GAS
ENERGY STORAGE

UTILITY REFERENCE



ENERGY STORAGE TECHNOLOGIES

Power-to-gas is efficient | long term | low energy cost

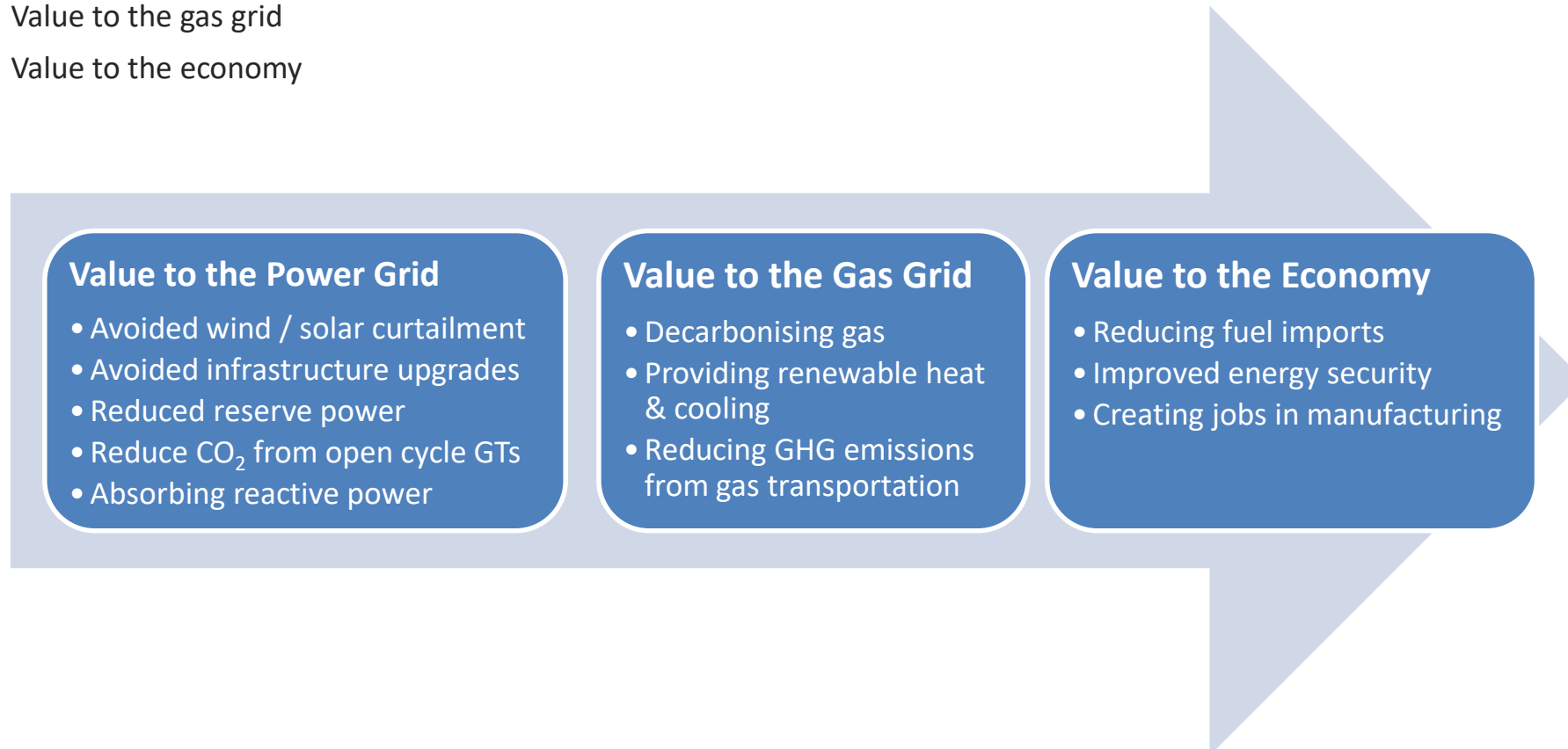


ENERGY STORAGE TECHNOLOGIES

ENERGY STORAGE | CLEAN FUEL

P2G: ELEMENTS OF VALUE

- Value to the power grid
- Value to the gas grid
- Value to the economy



P2G: ELEMENTS OF VALUE

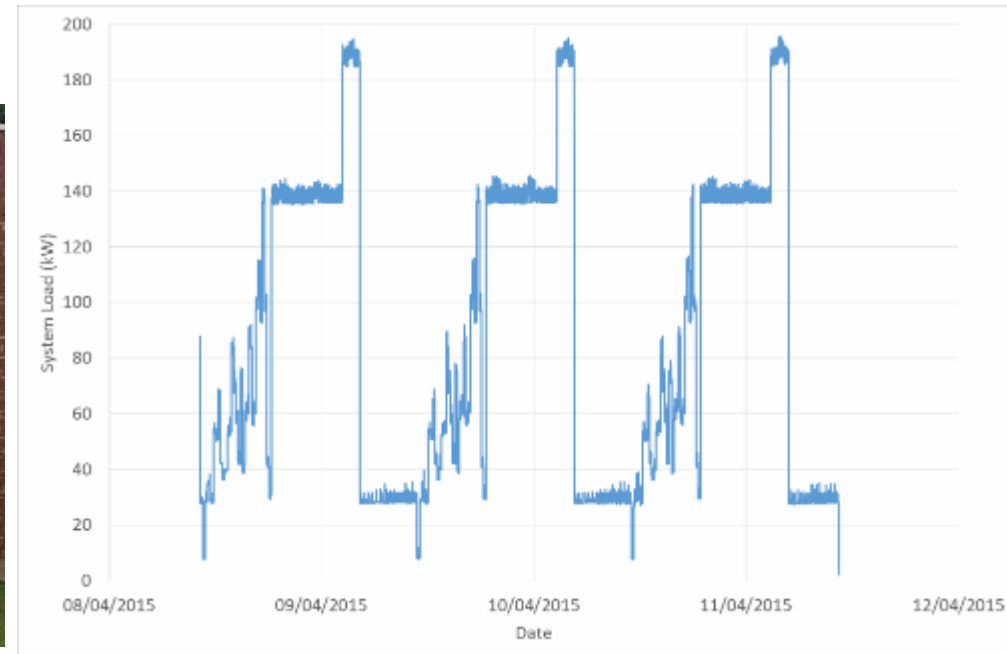
ENERGY STORAGE | CLEAN FUEL

RWE WESTNET DEPLOYMENT



Highest recorded electrolyser system efficiency

- 2nd generation HGas180 product
- Integration of waste heat recovery
- 86% system efficiency achieved
- Official inauguration 18th Aug 2015



POWER TO GAS GRID

ENERGY STORAGE | CLEAN FUEL

FIRST P2G IN THE UK

HyDeploy Project Scope

- Demonstrate first injection of hydrogen into a representative UK gas distribution network & establish practical operational limits
- Co-sponsored by National Grid Gas Distribution & Northern Gas Networks
- Keele University campus is a closed private network
- 0.5MW electrolyser delivering up to 20% hydrogen into the gas network servicing a population of 9000 people



POWER TO GAS GRID

ENERGY STORAGE | CLEAN FUEL



HYDROGEN MOBILITY

STATION ROLLOUT UK & US



WHAT IS A FUEL CELL VEHICLE?

An EV drive train that's refuelled rather than recharged

- Refuel in 3 mins
- Range 300-420 miles
- Managed energy export

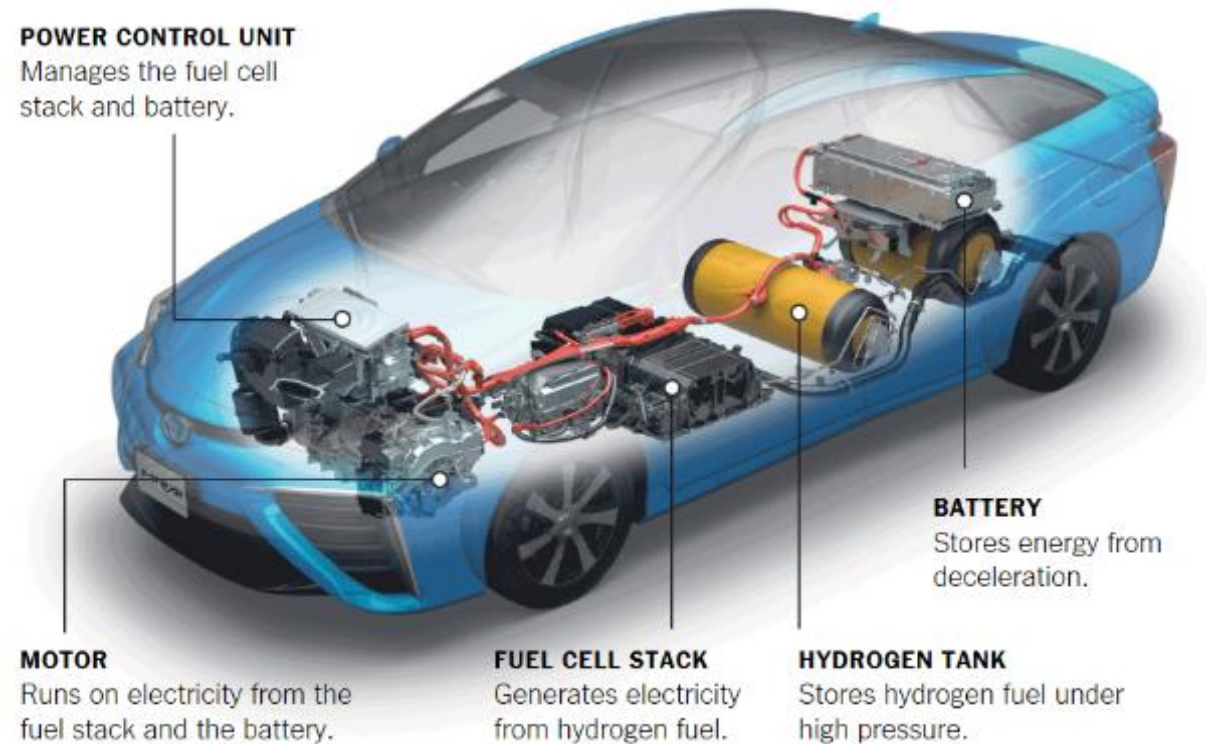
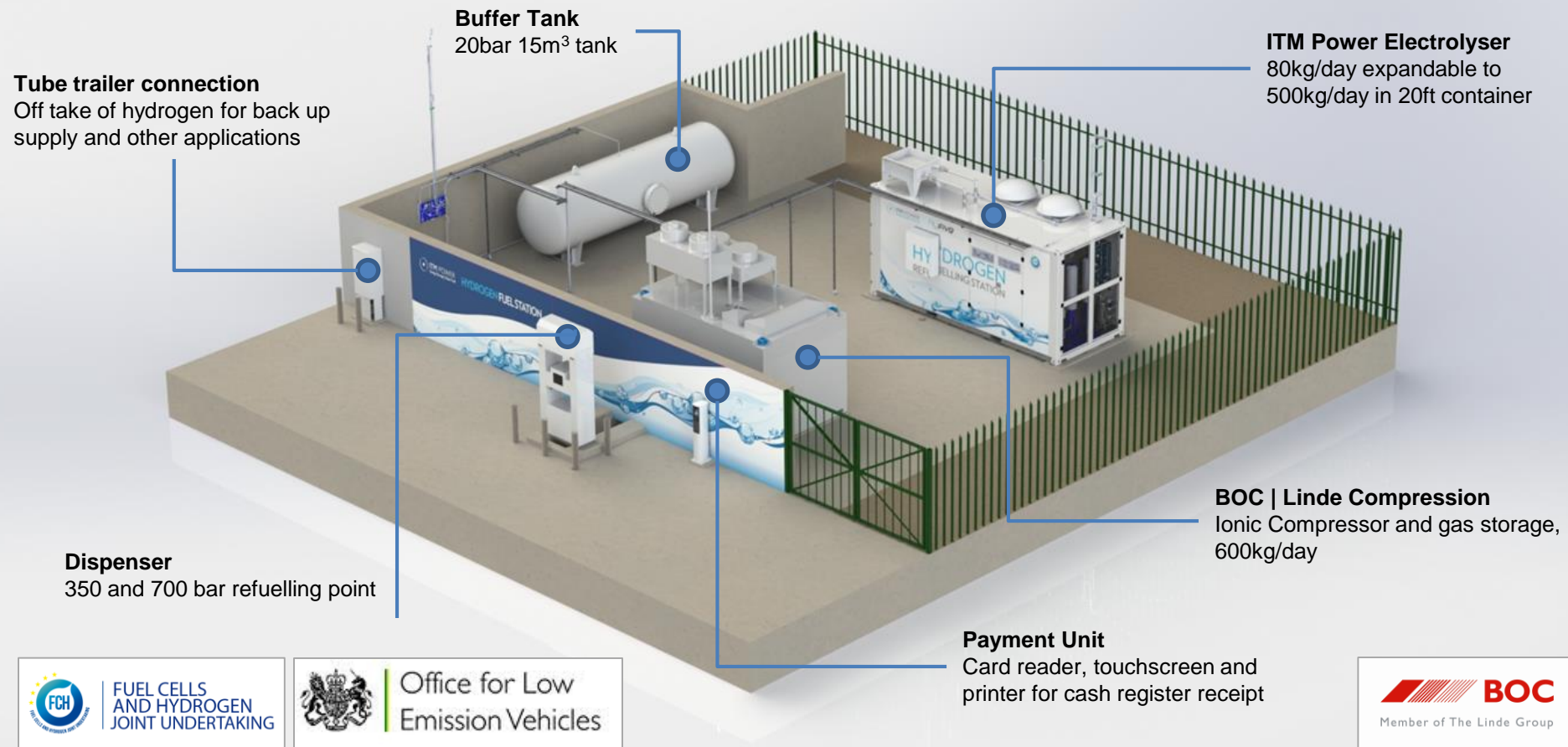


Image by Toyota

FUEL CELL VEHICLES
VEHICLES | ROLL OUT

WHAT IS AN FCEV REFUELLING STATION?



FCEV REFUELLING STATION

VEHICLES | ROLL OUT

HYFIVE | LONDON

FCH JU Project number: 621219

- NPL Teddington London Opened May 2016
- CEME Rainham London Opened Oct 2016
- Cobham M25 Shell forecourt Opened Feb 2017



Company images

HYFIVE | LONDON

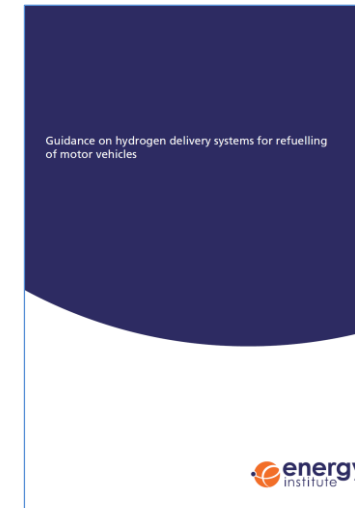
ENERGY STORAGE | CLEAN FUEL



H2ME | UK

FCH JU Project number: 671438

- Beaconsfield M40 Shell Forecourt Opening Q1 2018
- Gatwick M23 Shell Forecourt Opening 2018
- Swindon M4 Junction 16 Opening 2018
- Forecourt integration with dispenser under the main canopy



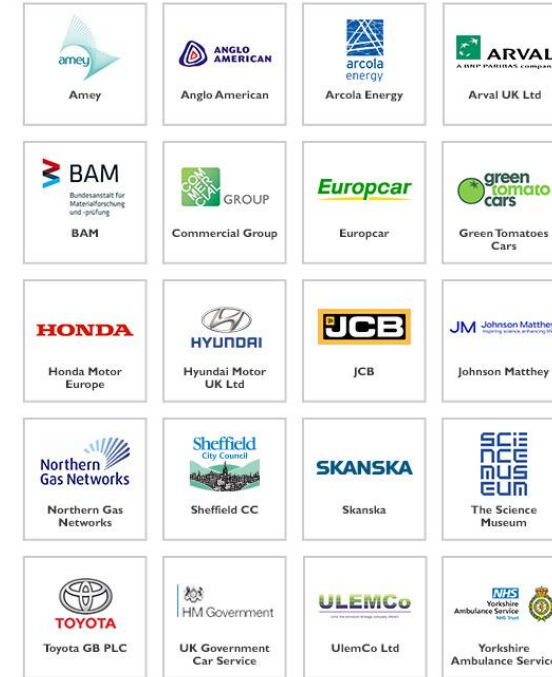
H2ME | UK

ENERGY STORAGE | CLEAN FUEL



ITM POWER | FUEL CONTRACTS

UK stations | £10/kg | dispensing 1tonne/day by the end of 2018



ITM POWER | FUEL CONTRACTS

ENERGY STORAGE | CLEAN FUEL





USA - CALIFORNIA

100kg per day – 33% renewable

Renewable content from on site electrolyser

Delivered hydrogen for remaining 67%

**On public fuel station with CNG,
Diesel, Propane, EV**

350/700bar

Future expansion capacity



PART OF CEC PON 2014 PROJECT

ENERGY STORAGE | CLEAN FUEL

BUSES | TRUCKS | TRAINS | FERRIES

Broad range of refuelling requirements

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

Air quality is driving change:

- National and city bans on fossil fuel vehicles
- Freight and port applications – IMO targets
- Heavy goods vehicles



LARGE REFUELLING STATION DESIGNS

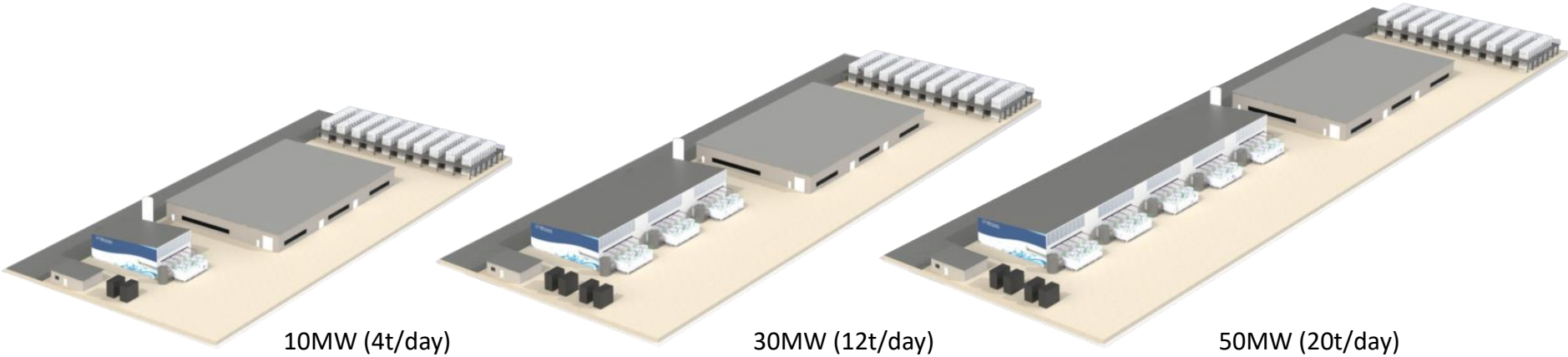
HRS | BUSES | TRUCKS | TRAINS | FERRIES

REPLICABLE 10MW MODULE

HRS scale up through replication

- Ability to satisfy specific refuelling profiles
- Sophisticated modelling to size systems correctly
- Use of proven compressor technology
- Modularity provides flexibility

Vehicle	Capacity (kg)	Refuels/Day			
		5MW (2t/day)	10MW (4t/day)	30 MW (12t/day)	50MW (20 t/day)
Cars	4	500	1,000	3,000	5,000
Buses	30	67	134	402	670
Trucks	75	27	54	162	270
Trains	180	11	22	66	110
Ferries	500	4	8	24	40



REPLICABLE 10MW MODULE
HYDROGEN REFUELLING SYSTEMS

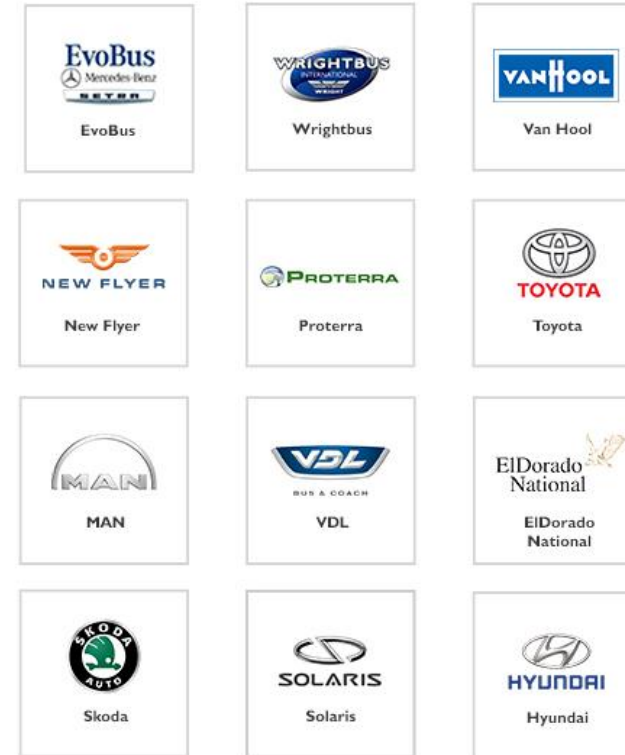
HYDROGEN BUSES

An EV drive train that's refuelled rather than recharged

- Refuel of 40kg in 6 mins | Range 200 miles
- Clean air zones in EU and UK
- Managed energy export



Sadiq Khan said there will be no more pure diesel double-decker buses will be added to the capital's fleet from 2018 (Source: Greater London Authority)



HYDROGEN BUSES

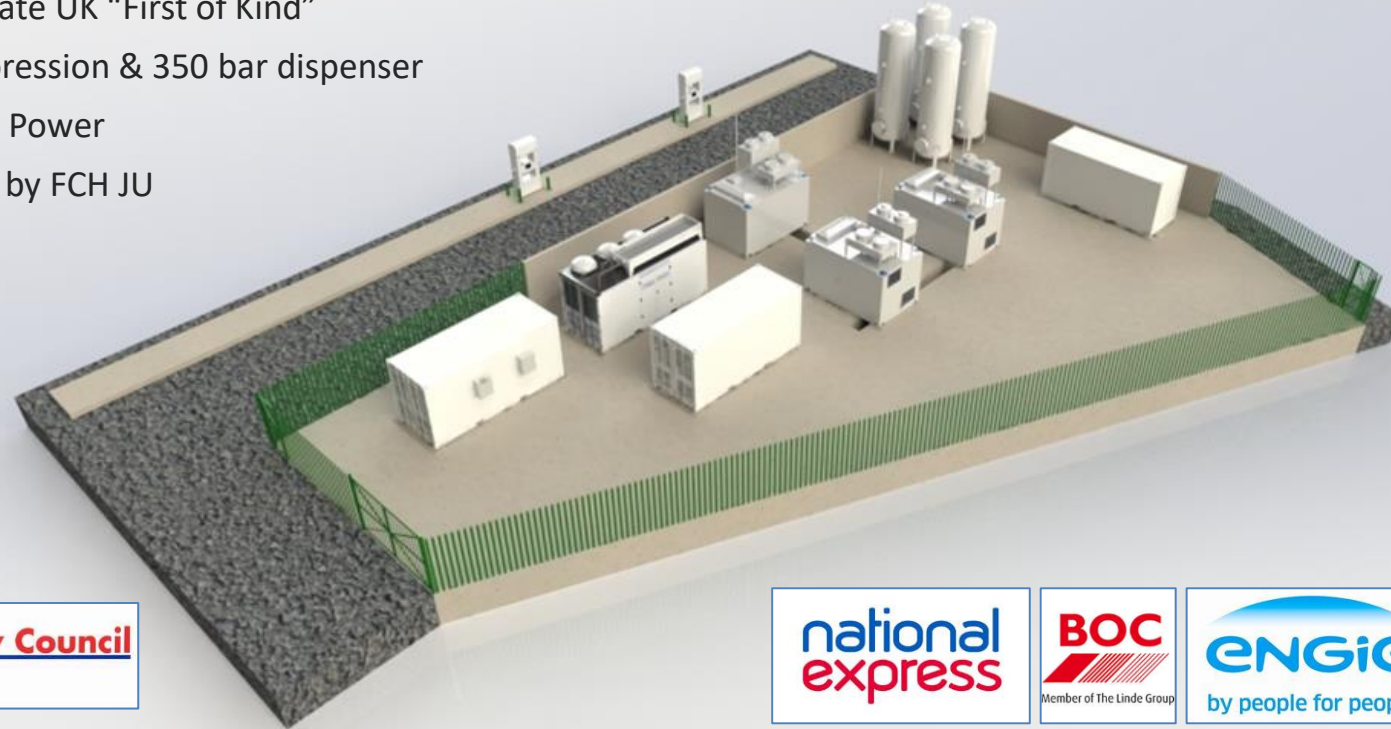
VEHICLES | ROLL OUT

BIRMINGHAM FCEB

Innovate UK
Technology Strategy Board

Tyesley Energy Park | 3MW | 1,500kg/day

- 3MW Grid Balancing Electrolyser
- Funded by Innovate UK “First of Kind”
- Linde ionic compression & 350 bar dispenser
- Grant led by ITM Power
- 20 buses funded by FCH JU



BIRMINGHAM FCEB
BUS REFUELLING STATIONS



GAS-TO-POWER

ENERGY GENERATION



BIG HIT | ORKNEY

FCH JU Project number: 700092

Eday: Curtailed wind and tidal turbines

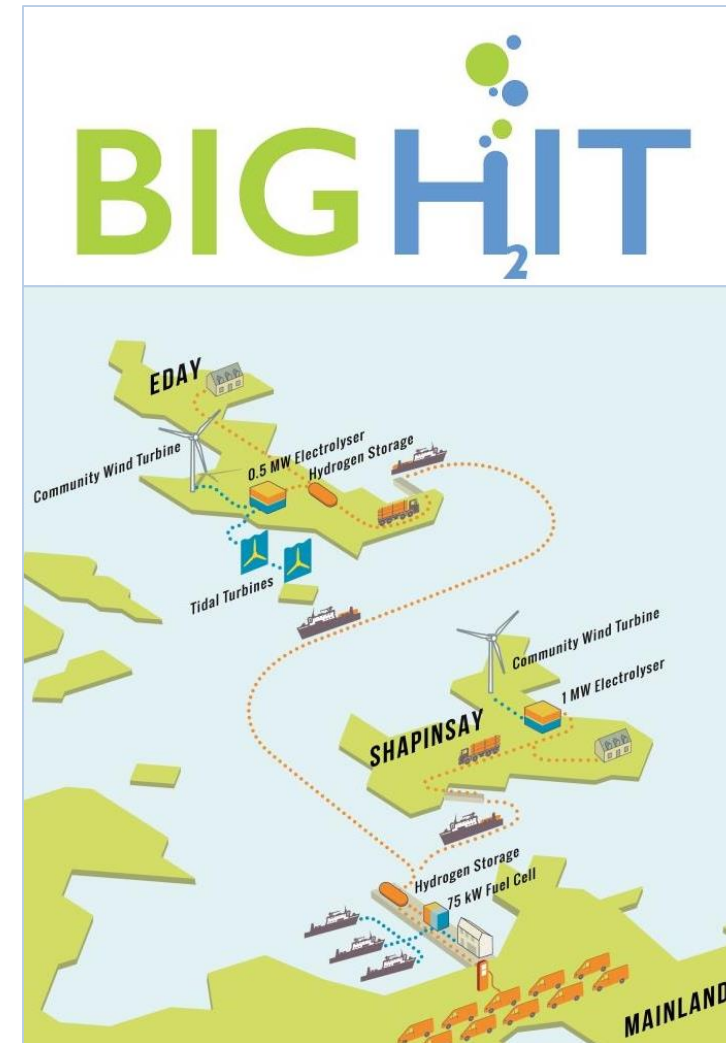
- 0.5 MW of electrolysis | 500kg storage
- Heating of school

Shapinsay: Curtailed wind

- 1MW of electrolysis
- Heating of school

Orkney Mainland:

- 75 kW FC: heat and power to marina
- H2 refuelling station | 10x Symbio FC vans
- Transport: 5x 250 kg tube trailers



ORKNEY HYDROGEN

GAS TO POWER SYSTEMS



RENEWABLE
CHEMISTRY

REFINERY SCALE
REFERENCE



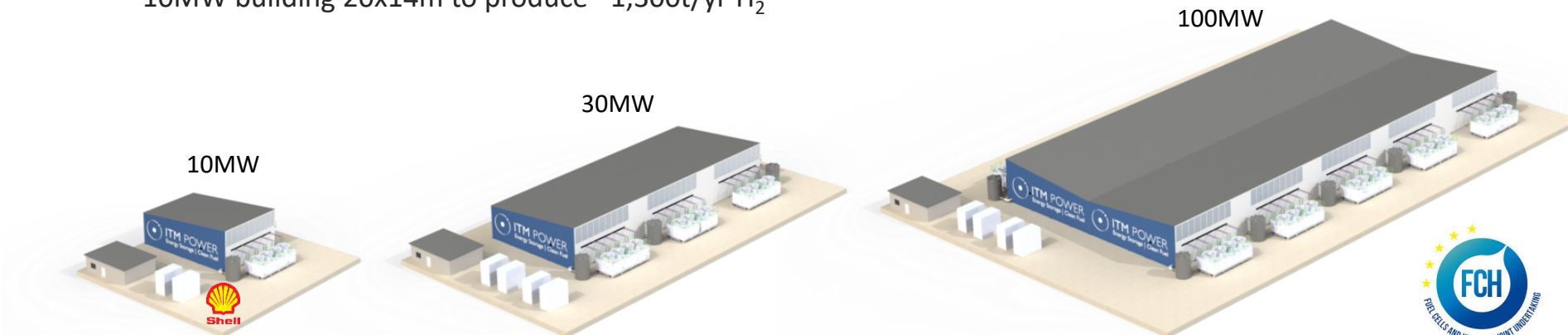
10MW | 30MW | 100MW ELECTROLYSER SYSTEMS

Deployment of worlds largest PEM electrolyser with Shell at Wesseling Refinery

- Utilises proven and modular PEM electrolysis system
- The Wesseling refinery currently uses 180,000t/yr of H₂
- This equates to 1,000MW of electrolysis, worth €1 billion
- Fully integrated & autonomous
- Expandable & industrial scale
- Replication maintains standardisation
- 10MW building 20x14m to produce ~1,300t/yr H₂



REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE



ELECTROLYSER SCALE UP
HYDROGEN ENERGY SYSTEMS



GRID BALANCING

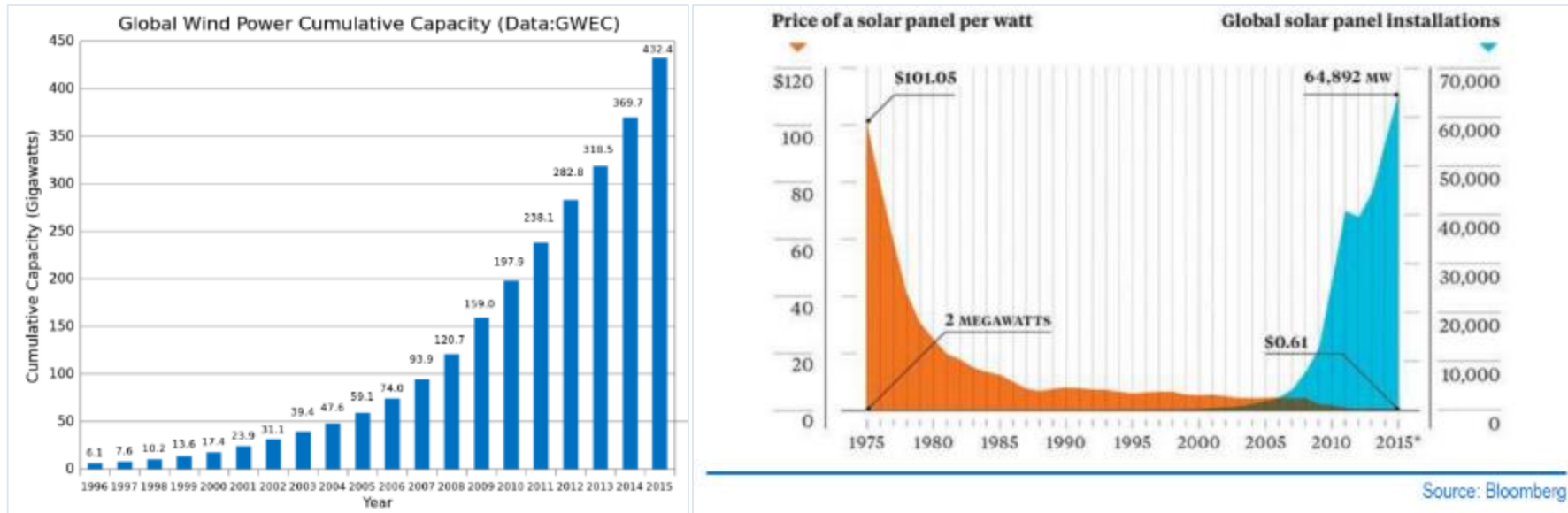
FREQUENCY CONTROL
DEMAND RESPONSE



AN ENERGY REVOLUTION

Renewable Energy is Transforming the Energy Landscape

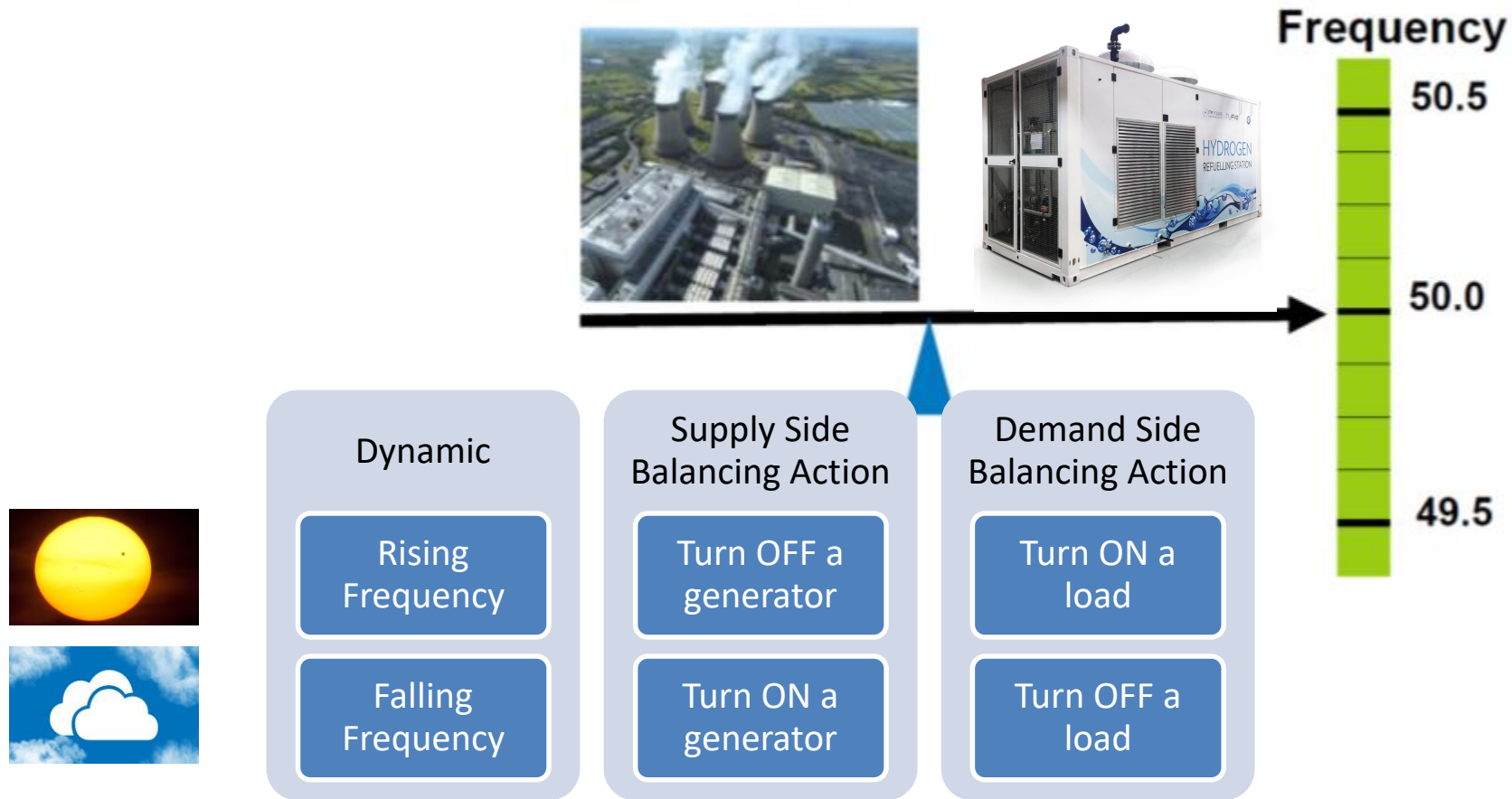
- World power generation reached 5,000GW in 2015
- Wind reached 432GW and solar reached 65GW of global installations in 2015 (~10%)
- Need energy storage to sustain the growth rate in renewable energy contribution



AN ENERGY REVOLUTION

HYDROGEN ENERGY SYSTEMS

BALANCING SUPPLY AND DEMAND: SECOND BY SECOND



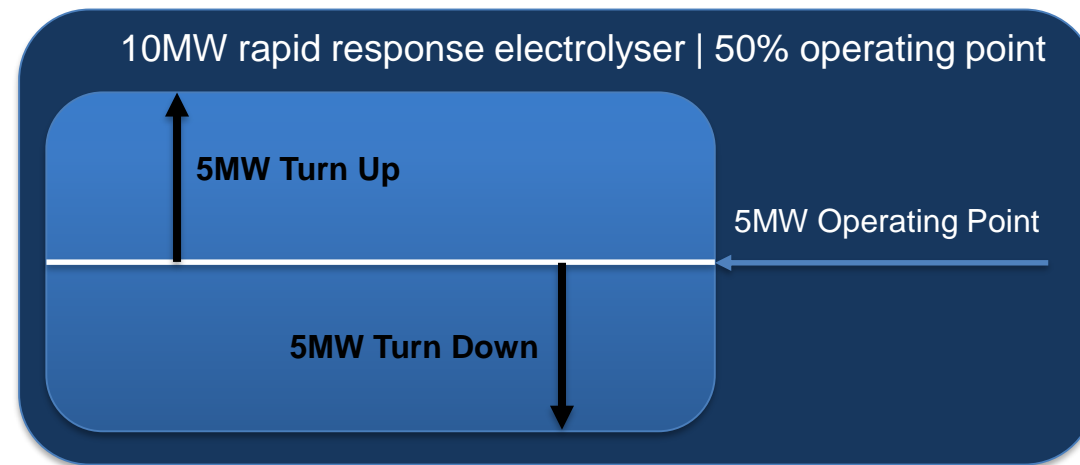
THE NEED: GRID BALANCING

ENERGY STORAGE | CLEAN FUEL

SCOPE | SIZE

Energy Storage | Grid Balancing

- Enhanced Frequency Response
- 10MW rapid response electrolyser | 50% operating point
- Turn Up & Down by 5MW simultaneously
- Sub-second response



THE NEED: GRID BALANCING

ENERGY STORAGE | CLEAN FUEL

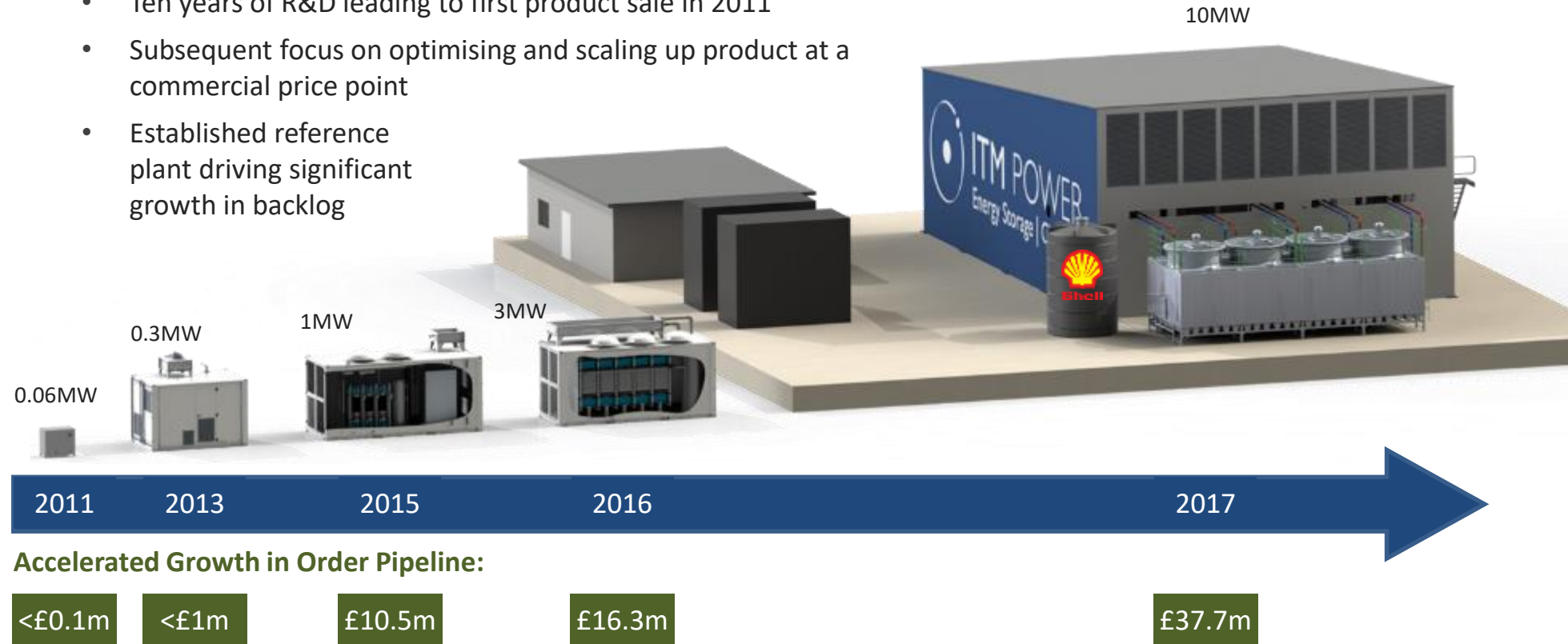
PRODUCTS



COMPANY EVOLUTION | PRODUCT SCALE-UP

A long journey:

- Ten years of R&D leading to first product sale in 2011
- Subsequent focus on optimising and scaling up product at a commercial price point
- Established reference plant driving significant growth in backlog



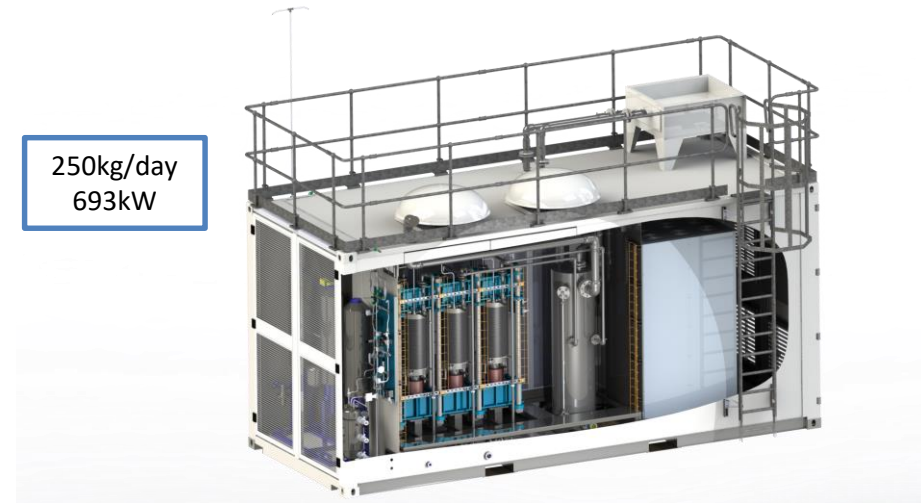
COMPANY EVOLUTION | PRODUCT SCALE-UP

HYDROGEN ENERGY SYSTEMS

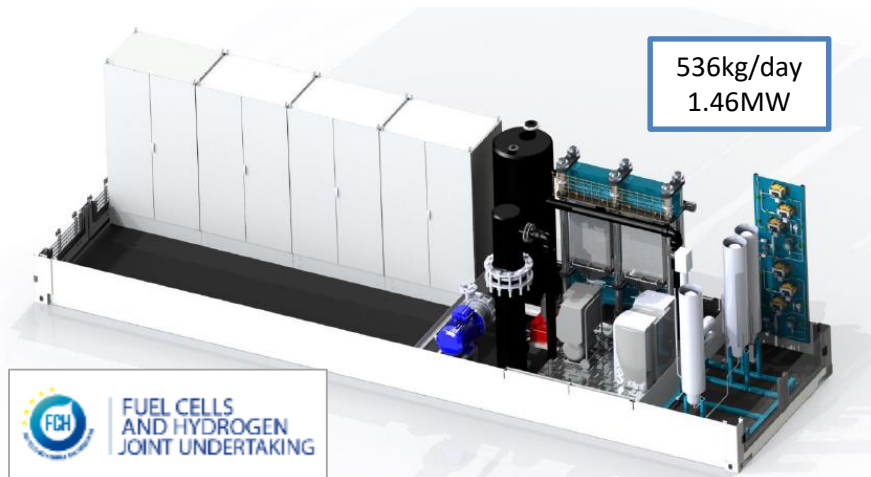
CONTAINERISED PRODUCTS



83kg/day
245kW

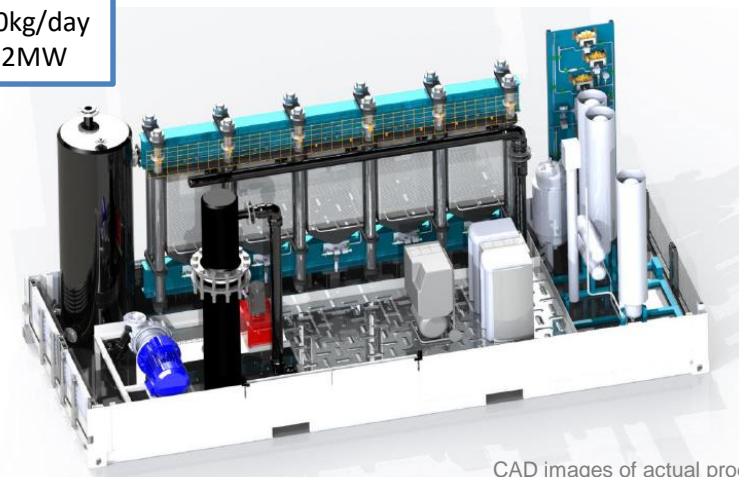


250kg/day
693kW



536kg/day
1.46MW

1,340kg/day
3.62MW



CAD images of actual product

PRODUCT MIX

HYDROGEN ENERGY SYSTEMS

HYDROGEN ENERGY SYSTEMS – SUMMARY

NOVEMBER 2018

Electrolysers – Central to decarbonising Transport | Power | Chemicals

- Renewables need Energy Storage
- Rapid Response Grid Balancing electrolysers can assist at the right scale
- Low cost | Low footprint | Mature Technology
- Offers Cross-sector decarbonisation
- Onsite Electrolysers offer harmony in expansion of renewables & hydrogen mobility
- 2020+ targets will require high purity and v low carbon hydrogen for fuel cell transport
- The gas grid - a useful asset in managing surpluses and deficits in a low carbon power system
- Power to Gas provides a proven route to deep decarbonisation of gas