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Energy Storage | Clean Fuel

Power-to-Gas:
Enabling the Expansion of Renewables

Marcus Newborough, ITM Power plc

PRESENTATION CONTENTS

HYDROGEN ENERGY SYSTEMS

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- UK Update
- ITM Power Introduction
- Power-to-Gas Projects in Germany
- Grid Balancing
- Hydrogen Refuelling Stations
- Electrolyser Cost Trend
- UK Gas Grid Injection
- Future Projects?

RECENT UK DEVELOPMENTS?

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1. **Clean Growth Grand Challenge** was set out in the 2017 Industrial Strategy by UK government.
   - establish at least one low-carbon cluster by 2030
   - establish the world's first net-zero carbon industrial cluster by 2040
   - up to £170M funding through the Industrial Strategy Challenge Fund
2. '**Clean Growth: Transforming Heating**' which includes electric heat pumps, conversion of gas grid to hydrogen, heat networks, hybrid heat pumps and biogas.
   - '**Logistics of Domestic Hydrogen Conversion**' (study published Nov 2018)
   - **Hy4Heat** (100% hydrogen)
   - **HyDeploy** (H2NG blends of <20% hydrogen)
3. '**Offshore Wind Sector Deal**' which is aiming for 30GW of offshore wind by 2030 (commenced March 2019)
   - '**Solving the Integration Challenge**', using electricity from offshore wind to generate and store hydrogen.
4. **Hydrogen for Transport Programme**
   - expanding the UK's hydrogen refuelling network and increasing station utilisation with new FCEV including buses.
5. **Climate Change Committee 'Net Zero' report** (published May 2019)
   - up to 175 MtCO2 p.a. being sequestered by 2050
   - up to 17GW of electrolyser capacity required by 2050
   - up to 75GW of offshore wind by 2050

ITM Power manufactures integrated hydrogen energy systems

WHAT WE DO?

HYDROGEN ENERGY SYSTEMS

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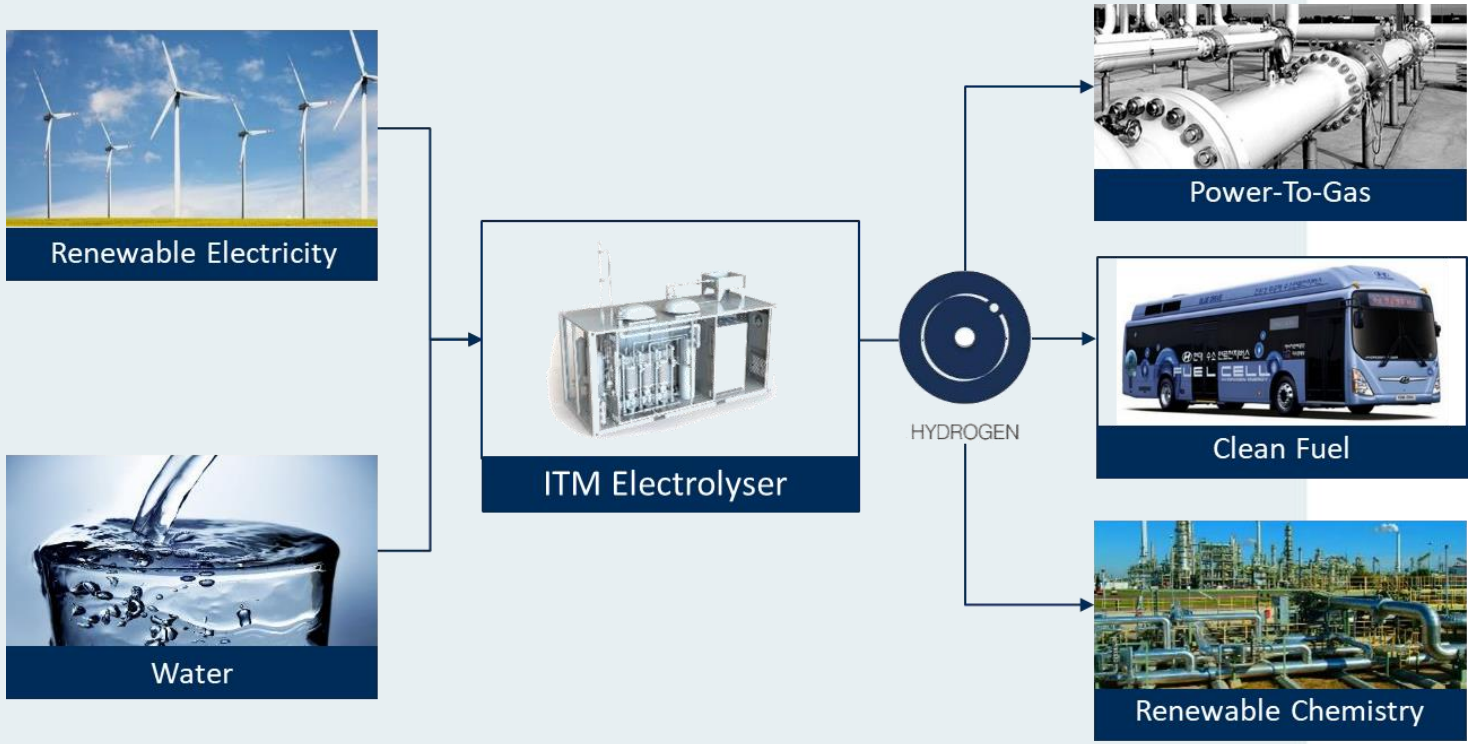
Unique selling points:

- **Rapid response:** less than 1 second
- **Elevated Pressure:** 20 - 50 bar
- **High efficiency:** 70 - 86% (with heat recovery)
- **Small Footprint:** smaller than alkaline
- **Low cost:** approaching large scale alkaline
- **Reference plant:** at MW scale
- **Experience in the field:** in many applications



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WHAT WE DO?

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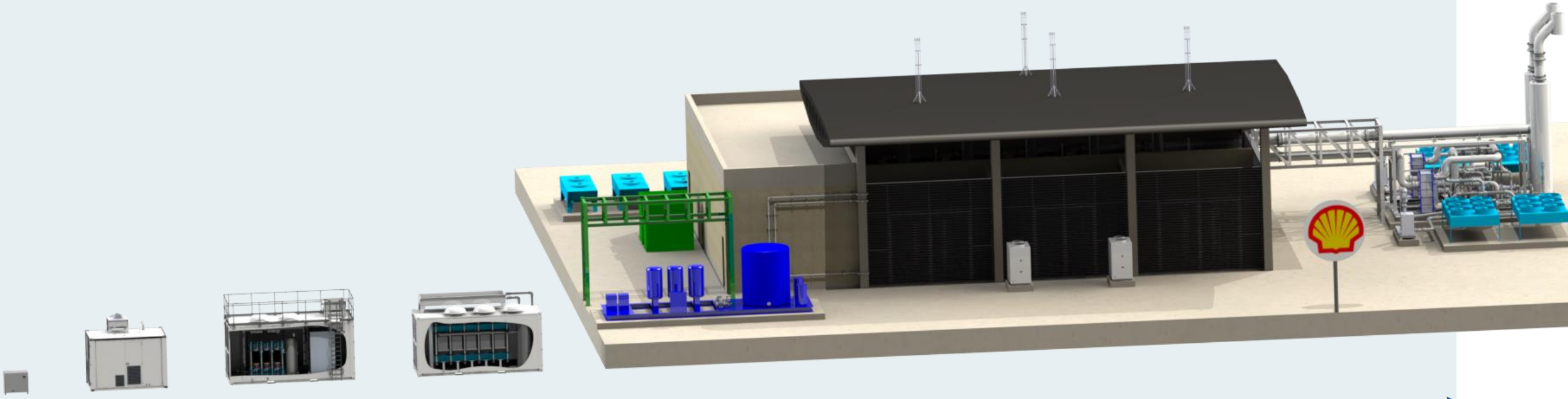

2011 2013 2015 2016 2017 2018

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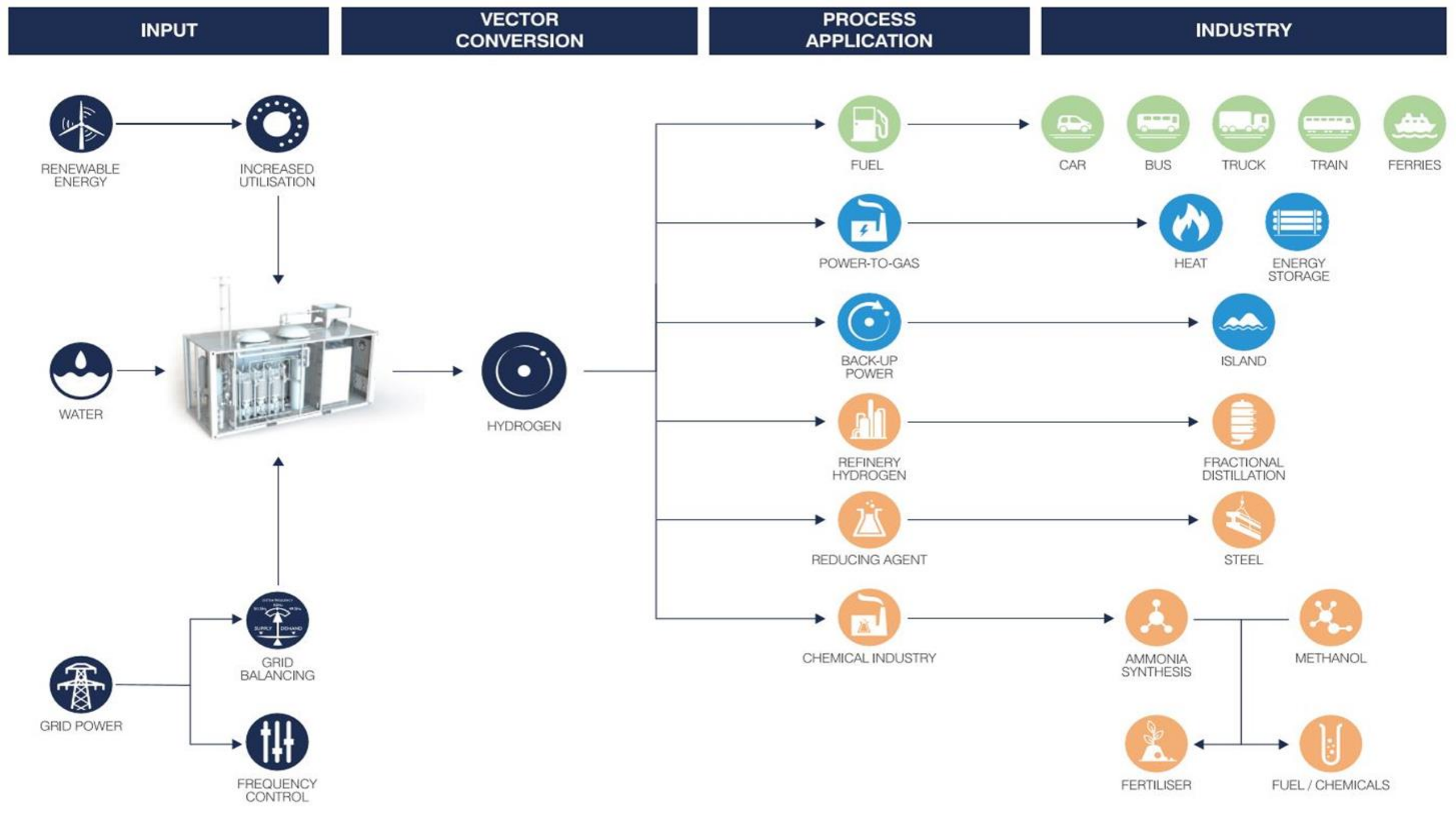
INPUT
VECTOR CONVERSION
PROCESS APPLICATION
INDUSTRY
RENEWABLE ENERGY
INCREASED UTILISATION
WATER
HYDROGEN
GRID POWER
GRID BALANCING
FREQUENCY CONTROL
FUEL
CAR
BUS
TRUCK
TRAIN
FERRIES
POWER-TO-GAS
HEAT
ENERGY STORAGE
BACK-UP POWER
ISLAND
REFINERY HYDROGEN
FRACTIONAL DISTILLATION
REDUCING AGENT
STEEL
CHEMICAL INDUSTRY
AMMONIA SYNTHESIS
METHANOL
FERTILISER
FUEL / CHEMICALS

POWER-TO-GAS: ENERGY STORAGE | PROJECTS IN GERMANY

HYDROGEN ENERGY SYSTEMS

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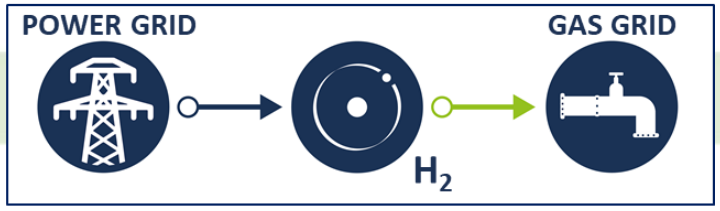
Partner	Date	Type	Power Grid Services	Electrolyser Optimisation	Gas Grid Services	Size	Comments
Thuga	2014	Deployment	Primary GB Bid Live	Yes | 4 Sec	Distribution (10% max) Network Injection	0.3MW	Containerised Mixing Plant
RWE	2016	Deployment	Primary GB Bid live	Yes | 4 sec	Distribution (10% max) Network Injection	0.2MW	No mixing plant Heat Recovery
ZEAG | DLR	2018	Deployment	Various	Skid Installation	Supply to DLR	1MW	In a building
Refhyne	2019	Deployment	Primary GB Load Balancing	Yes | 1 sec	Closed Network	10MW	FCHJU Funded



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ELECTRICITY GRID BALANCING

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Grid balancing:

Sector:	Technique:	Customer:
Frequency	Load | Generator	TSO
Voltage	VARs | Static VAR Compensator	DSO

Dynamic	Supply Side Balancing Action	Demand Side Balancing Action
Rising Frequency	Turn OFF a generator	Turn ON a load
Falling Frequency	Turn ON a generator	Turn OFF a load

In 2017 National Grid spent ~£1.4bn on grid services

LOAD AGGREGATION AND RESPONSE | UK HRS

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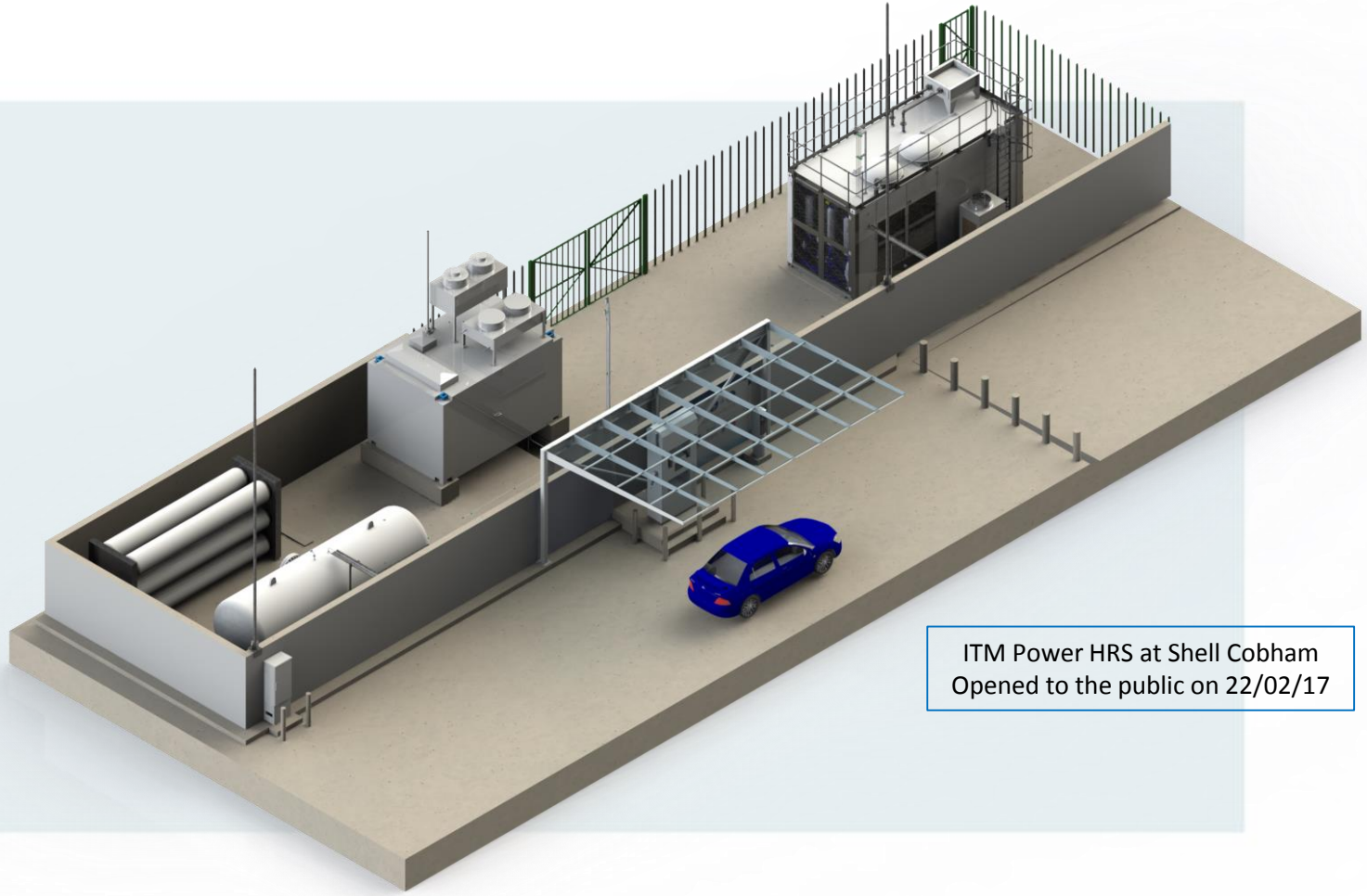
Hydrogen Refuelling Stations:

- 7 UK HRS in operation
- 1 US HRS in operation
- 6 UK HRS in construction
- Currently dispensing 20 tonnes p.a.
- Load aggregation for Grid Balancing
- Working with Open Energi Ltd.



ITM Power HRS at Shell Cobham
Opened to the public on 22/02/17

open energi

Office for Low Emission Vehicles

Innovate UK

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

3MW BUS REFUELLING | BIRMINGHAM

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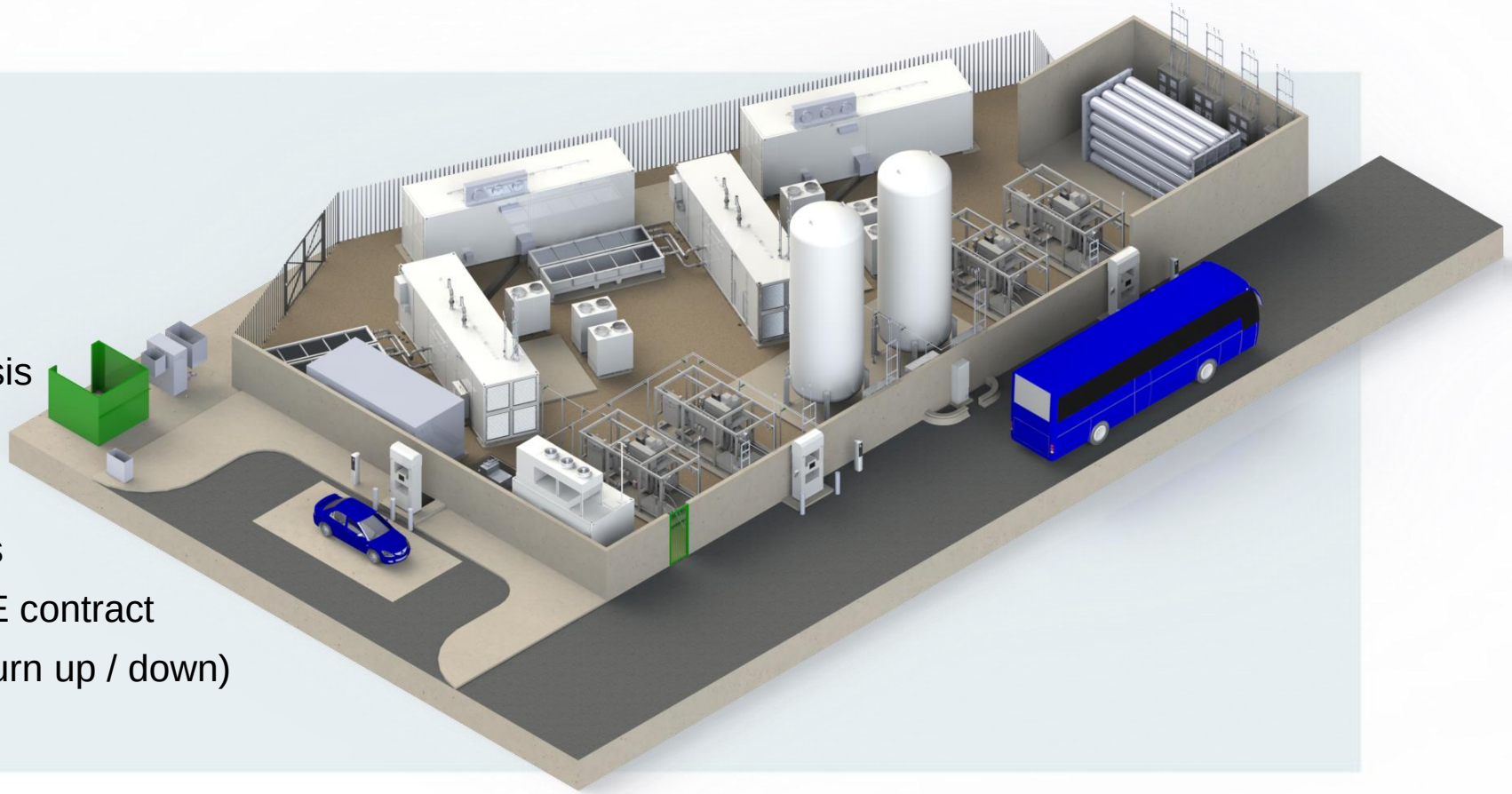
Birmingham Bus Project

- 3MW of rapid response electrolysis
- 350bar bus refueller
- 350 and 700 bar public refueller
- Opening 2019 for cars and buses
- 3MW of FCDM combined with RE contract
- EFR trials (simultaneous 1 sec. turn up / down)



3MW Grid Balancing combined with Bus Refuelling

Office for Low Emission Vehicles

Innovate UK

FCH
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

10MW | 30MW | 50MW HRS SYSTEM DESIGNS

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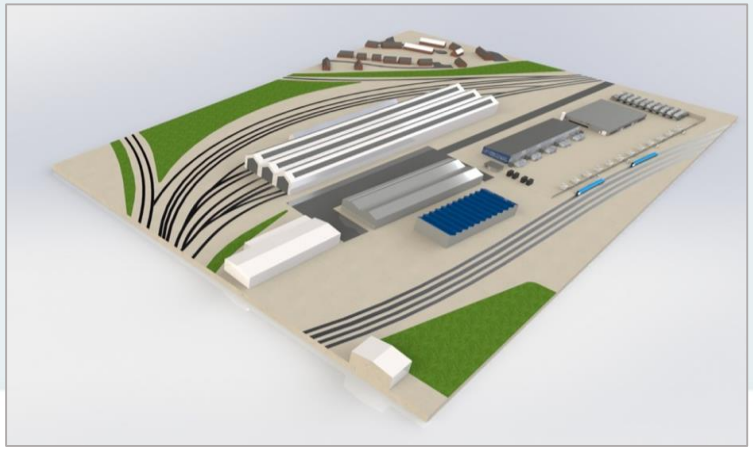

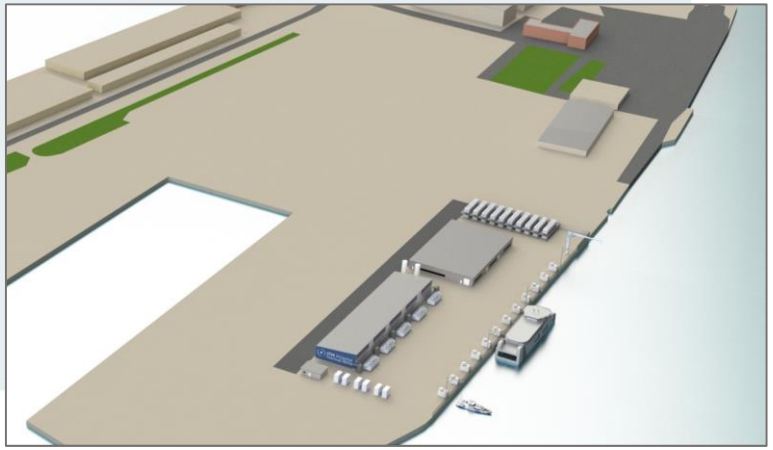

Buses | Trucks | Trains | Ferries

ELECTROLYSER SYSTEM COST TREND

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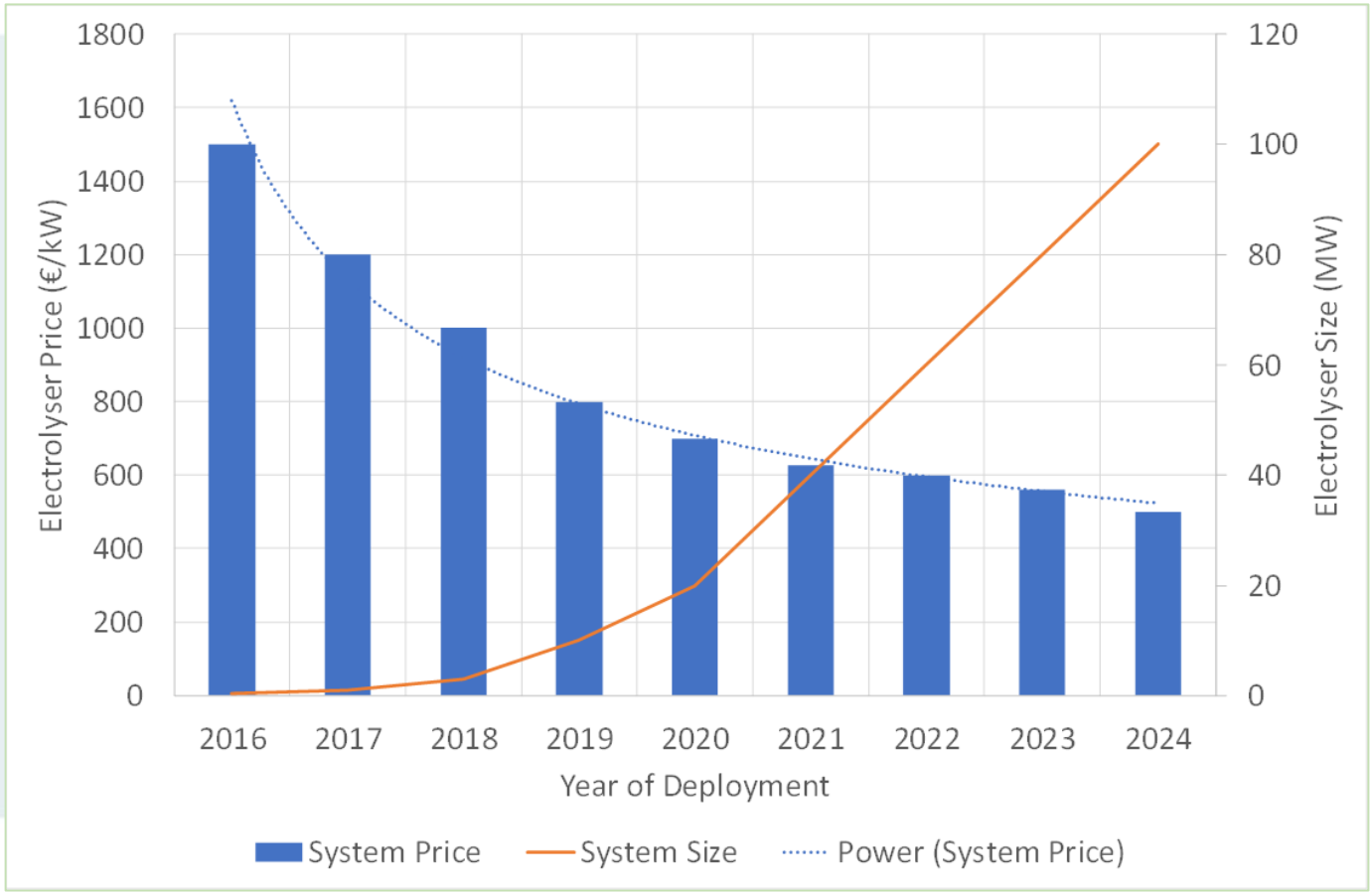
ITM Electrolyser Cost Projections

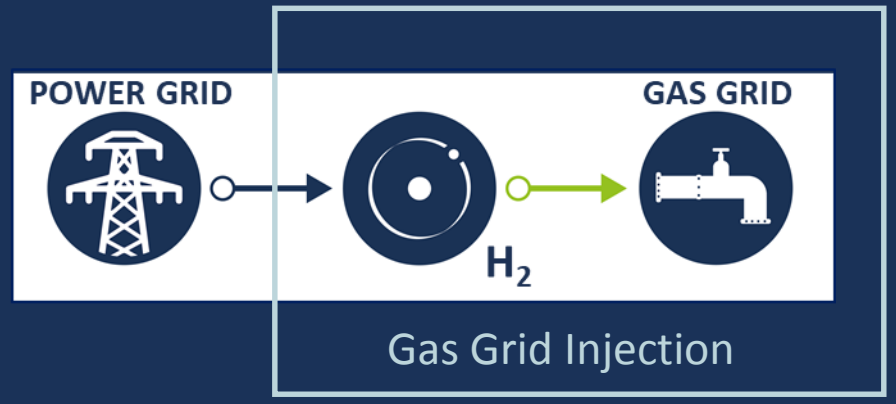
- Expect system sizes to grow over time
- Larger scale enable cost reduction
- Larger manufacturing volume enables efficiencies
- Continuous technology improvements
- Sensitive to electrolyser market growth rate



<€1,000/kW today @ MW scale | <€800/kW @ 10MW | <€500/kW by mid 2020's

UK GAS GRID INJECTION:

- HyDeploy
- HyDeploy II
- Exporting Renewable Energy
- Feasibility Studies
- Future Projects



GAS INJECTION PROJECTS | HYDEPLOY I & II

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HyDeploy | HyDeploy II:

HyDeploy:

- Up to 20% injection
- Closed gas network
- Exemption approved by HSE
- Installation 2019
- Trials 2020

HyDeploy II:

- Two trials on the open network
- Trials 2021 to 2023

Gas Grid Injection ofgem

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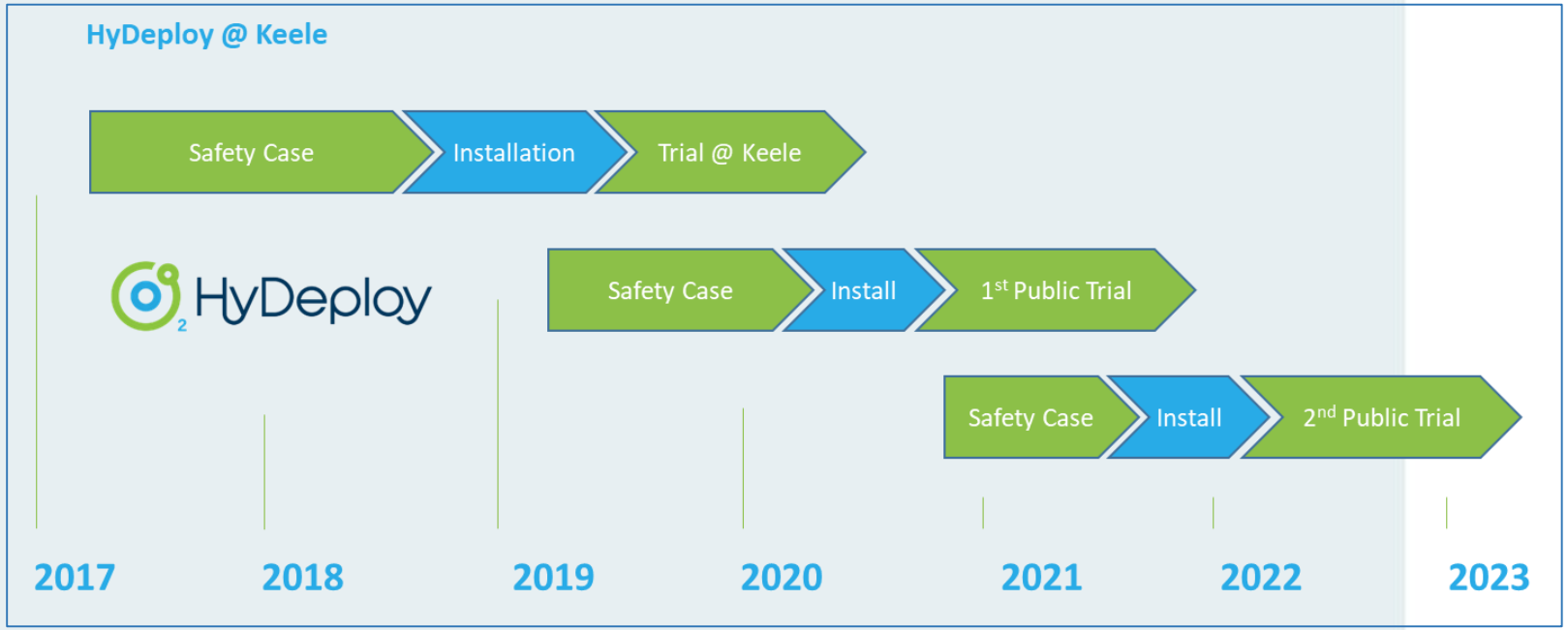

Gas Grid Injection ofgem

EXPORTING RENEWABLE POWER | BY SEA

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EMEC | Big Hit | Surf ‘n’ Turf | Dual Ports

- Producing hydrogen from stranded Renewables
- Exporting renewable energy
- 1.5MW off-grid energy storage
- Transport, repowering and renewable heat

H_2 is the new LNG

BIG H2IT
Building Innovative Green Hydrogen Systems in Isolated Territories

FUTURE PROJECTS?

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Customer engagement | specification

- Large scale projects require significant development
- Typical timescales range from one to three years
- Strategy includes early engagement via feasibility studies
- Leveraging the Shell 10MW project
- Four example projects to indicate engagement

Feasibility Study	Scale	Partner	Status
NE England	50MW	NGN	Completed
British Columbia	300MW	Chyioda, BC Hydro	Active
Massachusetts	20MW	Holyoke	Active
Centurion	100MW	INOVYN, Storengy, Cadent	Active

Customer engagement | application requirements | detailed specification

Department for Business, Energy & Industrial Strategy

CENTURION | 100MW PLANT DESIGNS

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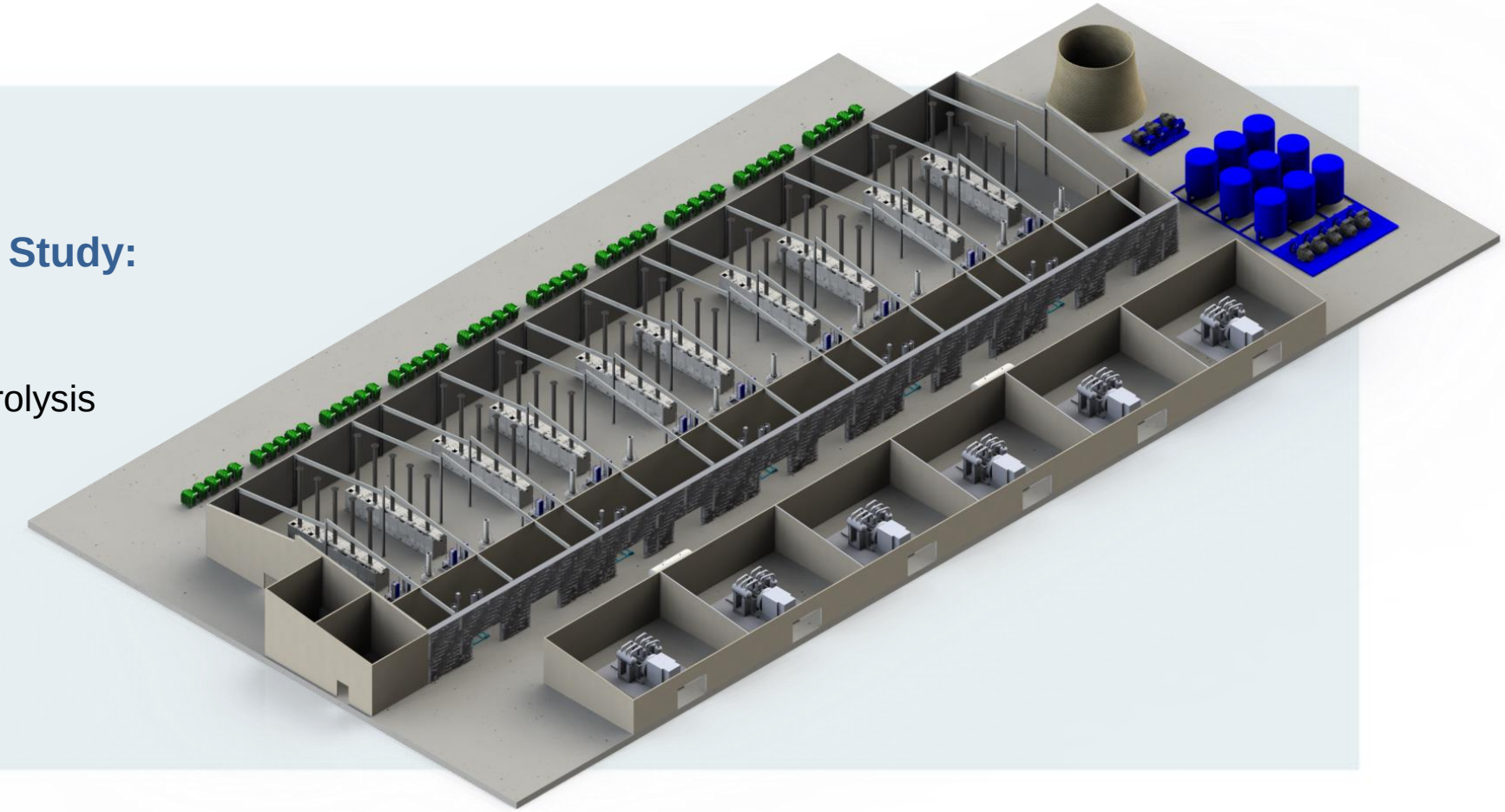
Centurion: 100MW Feasibility Study:

- Based at Runcorn, UK
- 100MW of rapid response electrolysis
- Hydrogen pipeline
- Salt Cavern Storage
- Gas Grid Injection
- Green Hydrogen Export



ITM POWER | inovyn An INEOS company | Cadent Your Gas Network | storengy A company of ENGIE | Department for Business, Energy & Industrial Strategy

PROPOSED INTERNATIONAL PROJECTS

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International Feasibility Studies:

- **Yara:** 30MW renewable Ammonia
- **Innovyn Storengy, ITM** 100 MW UK Centurion Project
- **Energinet, Tennet, GasUnie:** 100 MW North Sea Wind Power Hub project
- **Tata Steel:** 100 MW with Nouryon and the Port of Amsterdam
- **Engie and Gasunie:** 100 MW in Netherlands
- **RWE:** 105 MW power-to-gas plant and 60MW gas turbine
- **BP:** 250 MW with the Port of Rotterdam.
- **ONTRAS:** Eastern Germany, 94% decarb of heat via P2G by 2050
- **Northern Netherlands:** The Green Hydrogen Economy, 1,000 MW electrolysis

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