Hydrogen:

A Business Opportunity for the North East Region

Chair: Kirsty Lynch, Pale Blue Dot

Session 3: Hydrogen Projects

> **H21 North of England** – Anna Korolko, Equinor

> **Acorn Hydrogen & CCS** – Dave Mackinnon,Total

> **Offshore Power to Hydrogen** – Molly Iliffe, ERM

> **Aberdeen Vision Project** – Charlotte Hartley, Pale Blue Dot

H21 North of England

Speaker: Anna Korolko, Equinor

> Back to contents

H21 North of England

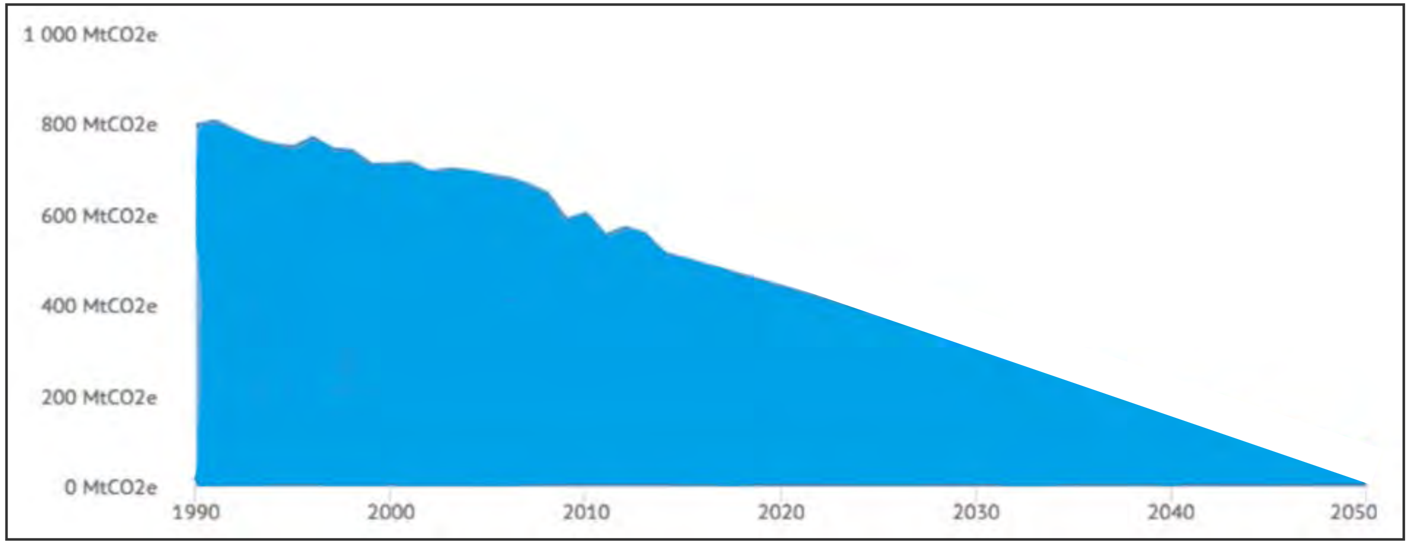
Hydrogen Production, Hydrogen Storage and CCS

Climate change act 2008

The net UK carbon account for all six Kyoto greenhouse gases for the year 2050 is at least ~~80%~~ 100% lower than the 1990 baseline

(june 2019)

- 32% of CO2 in UK comes from heating
- 70% of heating in UK comes from natural gas



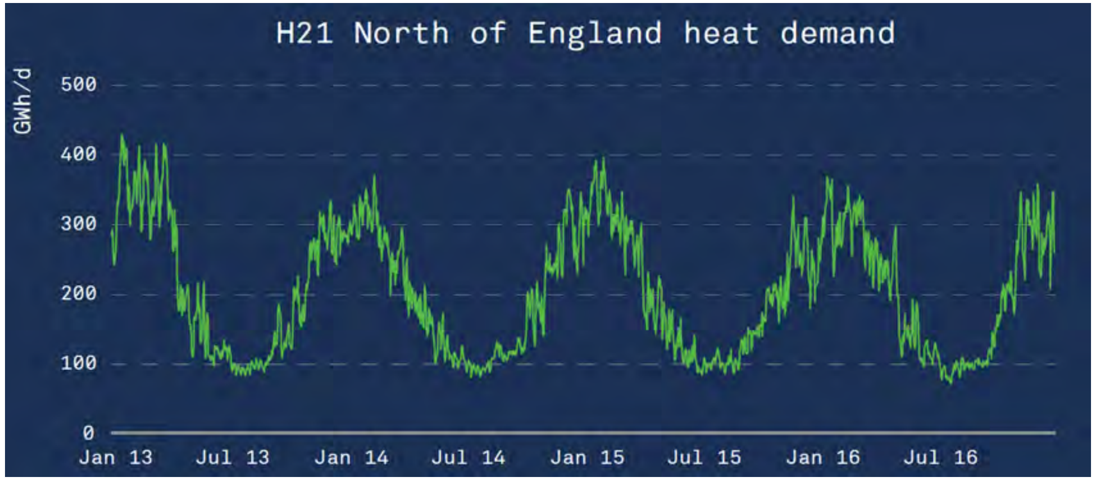
h2I

H21 North of England

Northern Gas Networks

equinor

Cadent
Your Gas Network

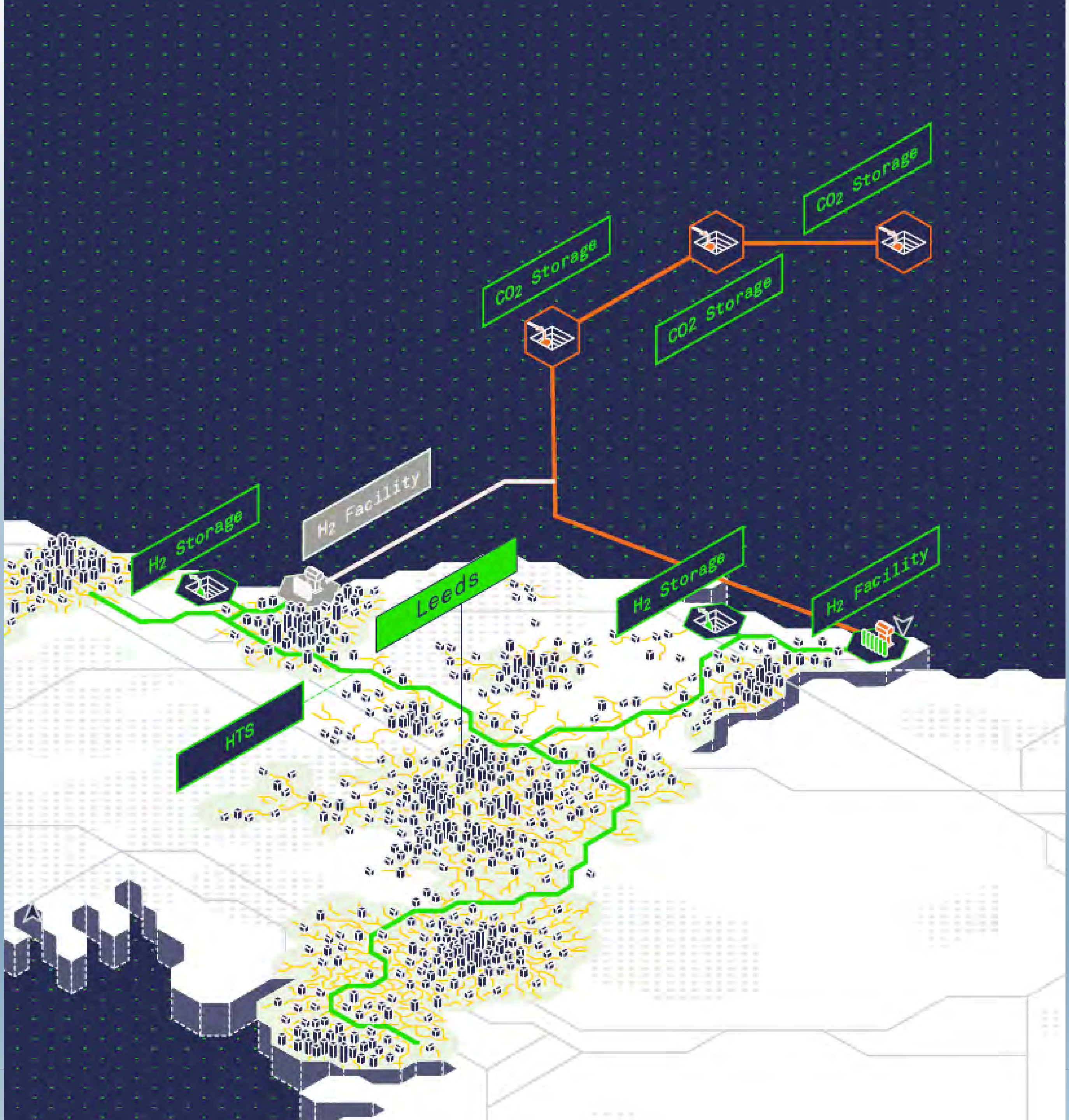


- A deep decarbonization of 14% of UK's heat demand by 2034
- Up to 20 Mt CO2 emission reductions per year

Energising the lives of 170 million people every day

Among the world's largest offshore operators

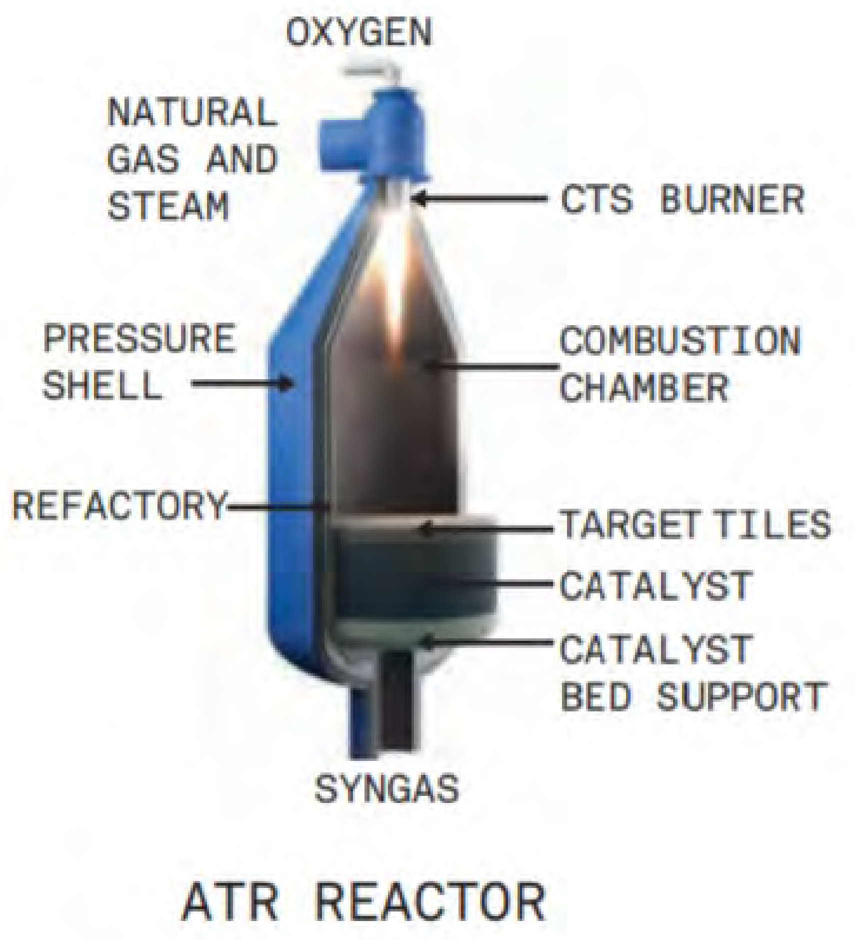
Over 20.000 employees

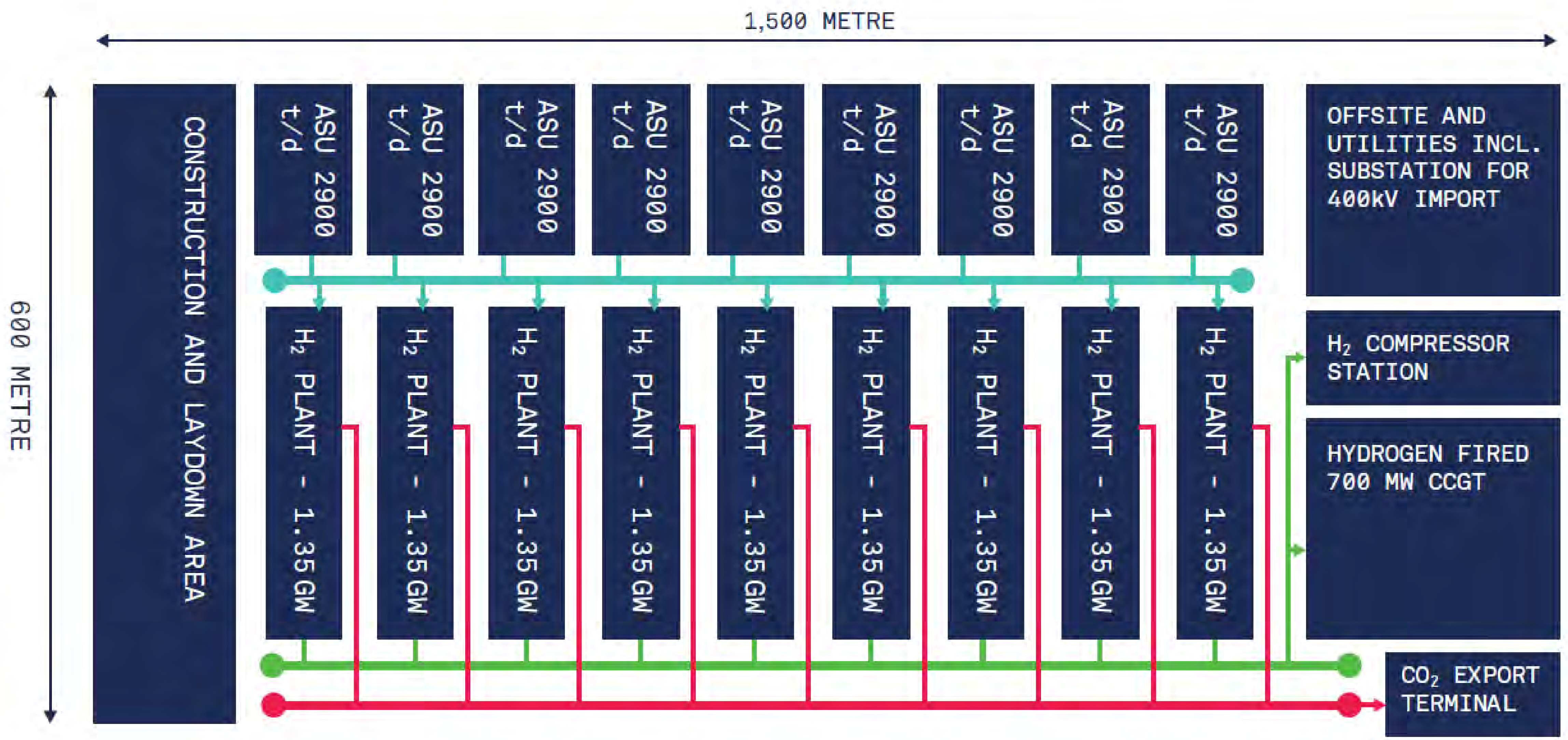


CO_2 Storage
CO_2 Storage
CO2 Storage
H_2 Facility
H_2 Storage
Leeds
H_2 Storage
H_2 Facility
HTS

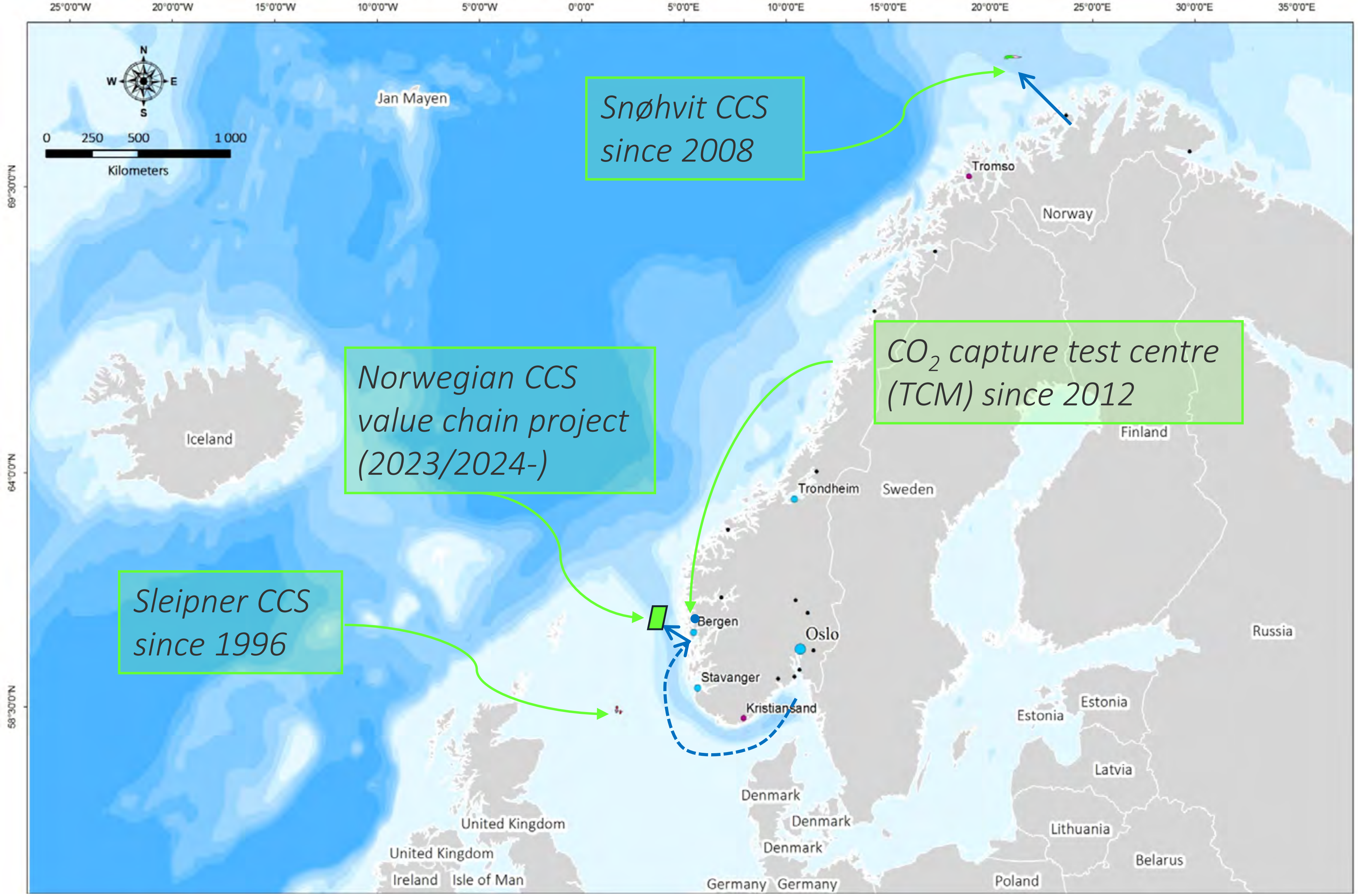
Hydrogen production

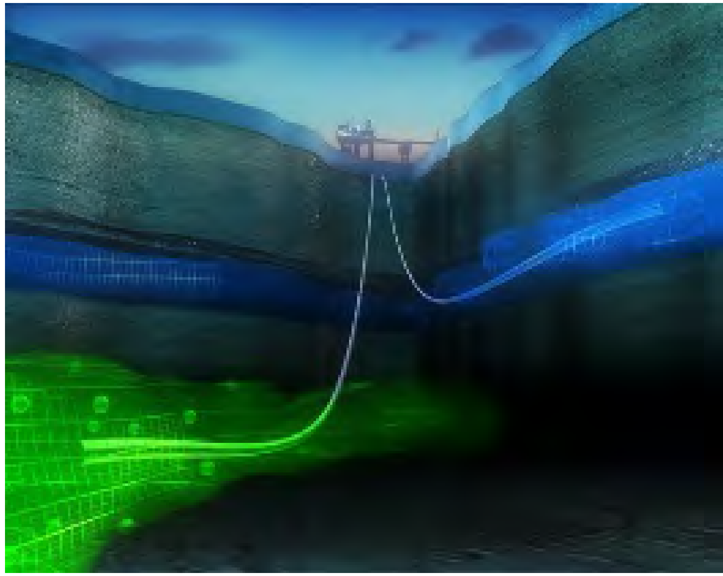
$$CH_4 + H_20 + \frac{1}{2}O_2 = 3H_2 + CO_2$$


OXYGEN
NATURAL GAS AND STEAM
CTS BURNER
PRESSURE SHELL
COMBUSTION CHAMBER
REFACTORY
TARGET TILES
CATALYST
CATALYST BED SUPPORT
SYNGAS
ATR REACTOR


1,500 METRE
600 METRE
CONSTRUCTION AND LAYDOWN AREA
ASU 2900 t/d
ASU 2900 t/d
ASU 2900 t/d
ASU 2900 t/d
ASU 2900 t/d
ASU 2900 t/d
ASU 2900 t/d
ASU 2900 t/d
ASU 2900 t/d
H2 PLANT - 1.35 GW
H2 PLANT - 1.35 GW
H2 PLANT - 1.35 GW
H2 PLANT - 1.35 GW
H2 PLANT - 1.35 GW
H2 PLANT - 1.35 GW
H2 PLANT - 1.35 GW
H2 PLANT - 1.35 GW
H2 PLANT - 1.35 GW
OFFSITE AND UTILITIES INCL. SUBSTATION FOR 400kV IMPORT
H2 COMPRESSOR STATION
HYDROGEN FIRED 700 MW CCGT
CO2 EXPORT TERMINAL

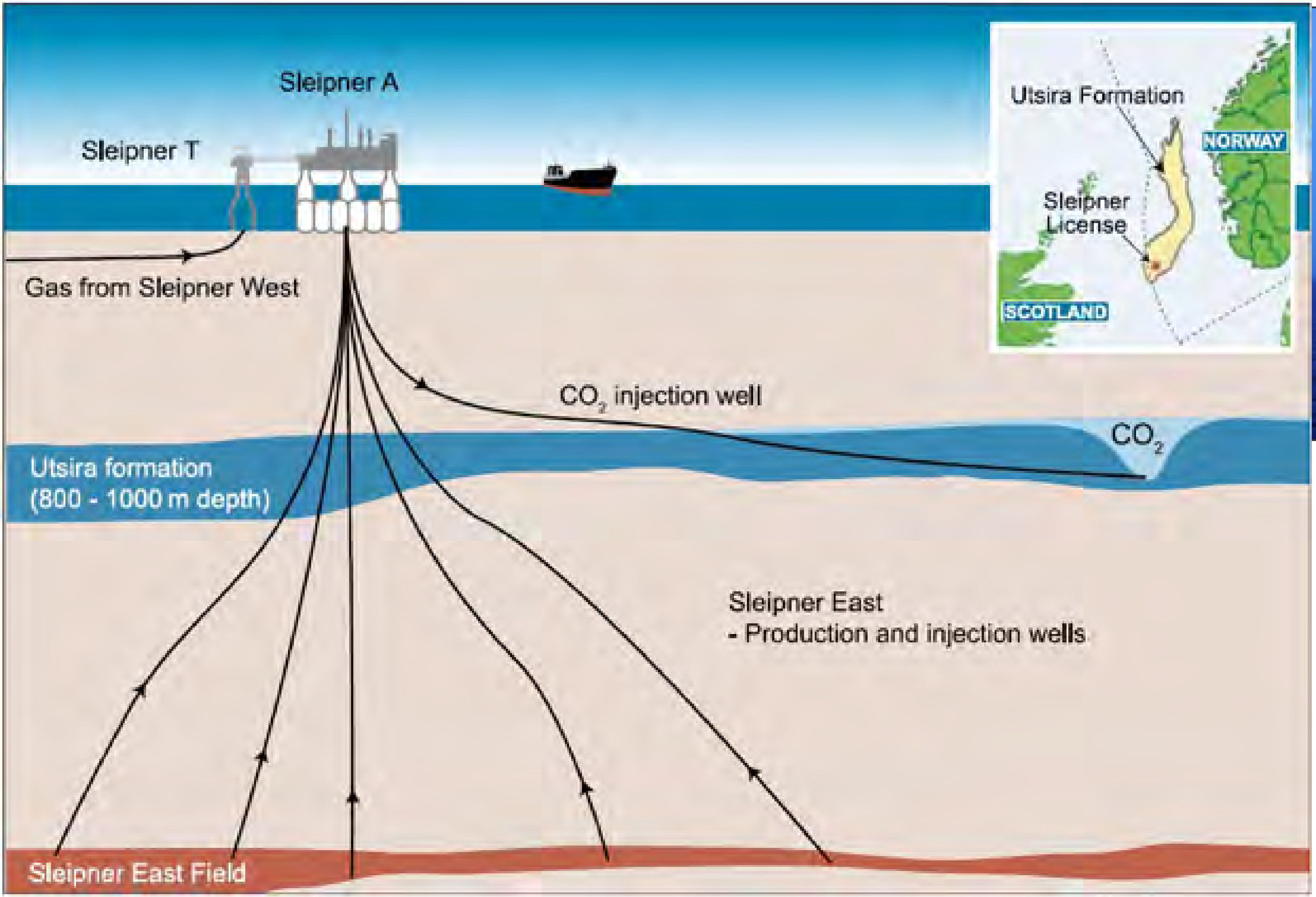
Equinor has >20 years experience of carbon capture and storage





Open

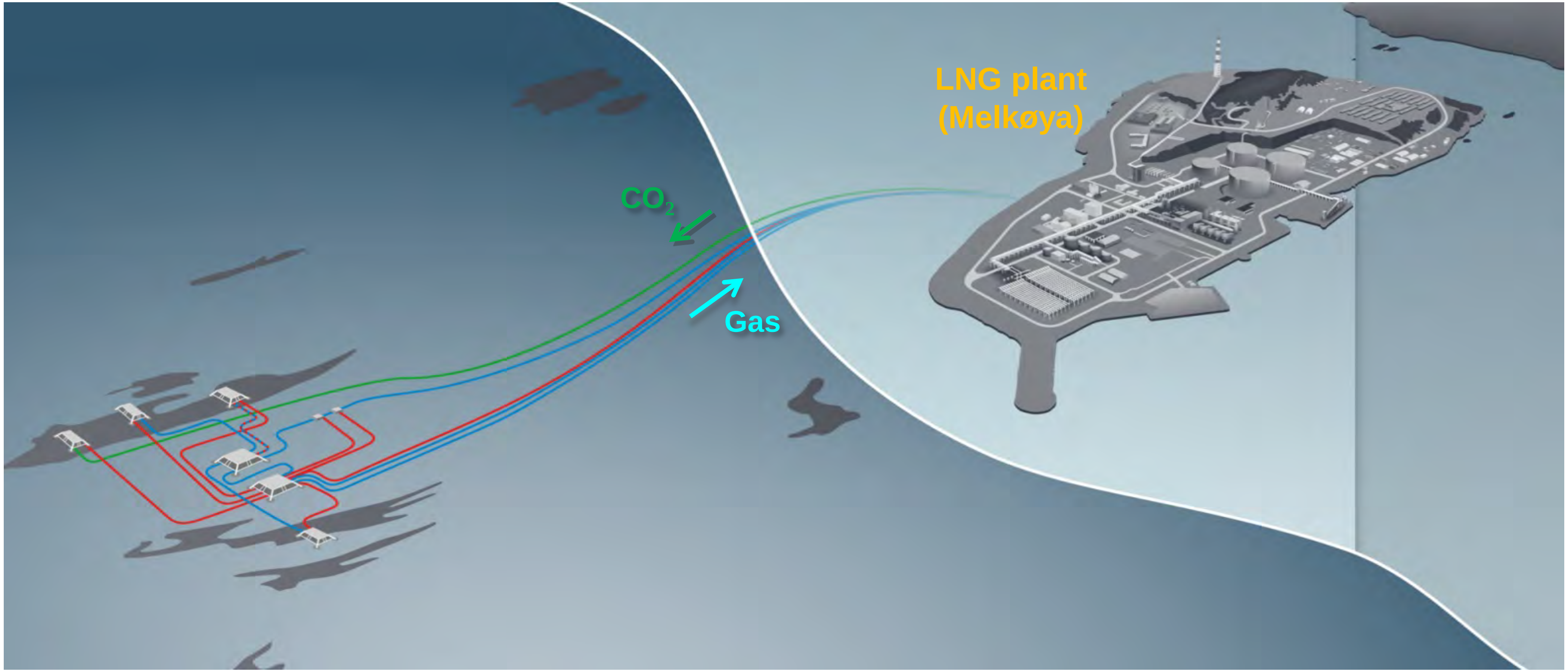
Sleipner



- Gas field with 5-9% CO2 content
- 0.9 MT CO2/year
- Worlds first capture and storage offshore
- Injection started in 1996
- 23 years assurance monitoring
- Since 2017 also includes processing of CO2 from Gudrun field

Snøhvit

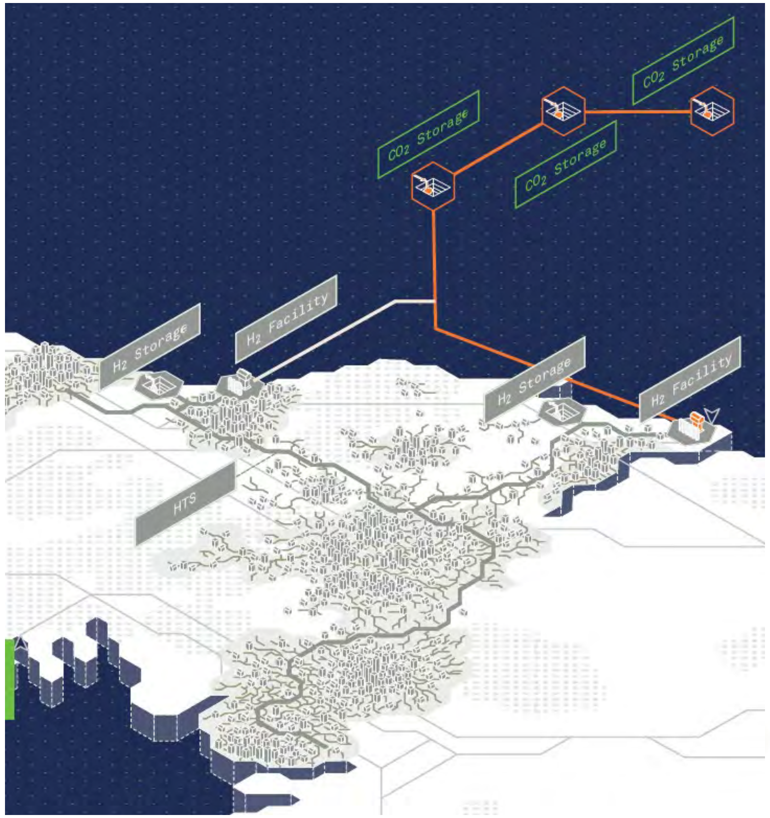
First onshore capture - offshore storage project (combined with LNG)

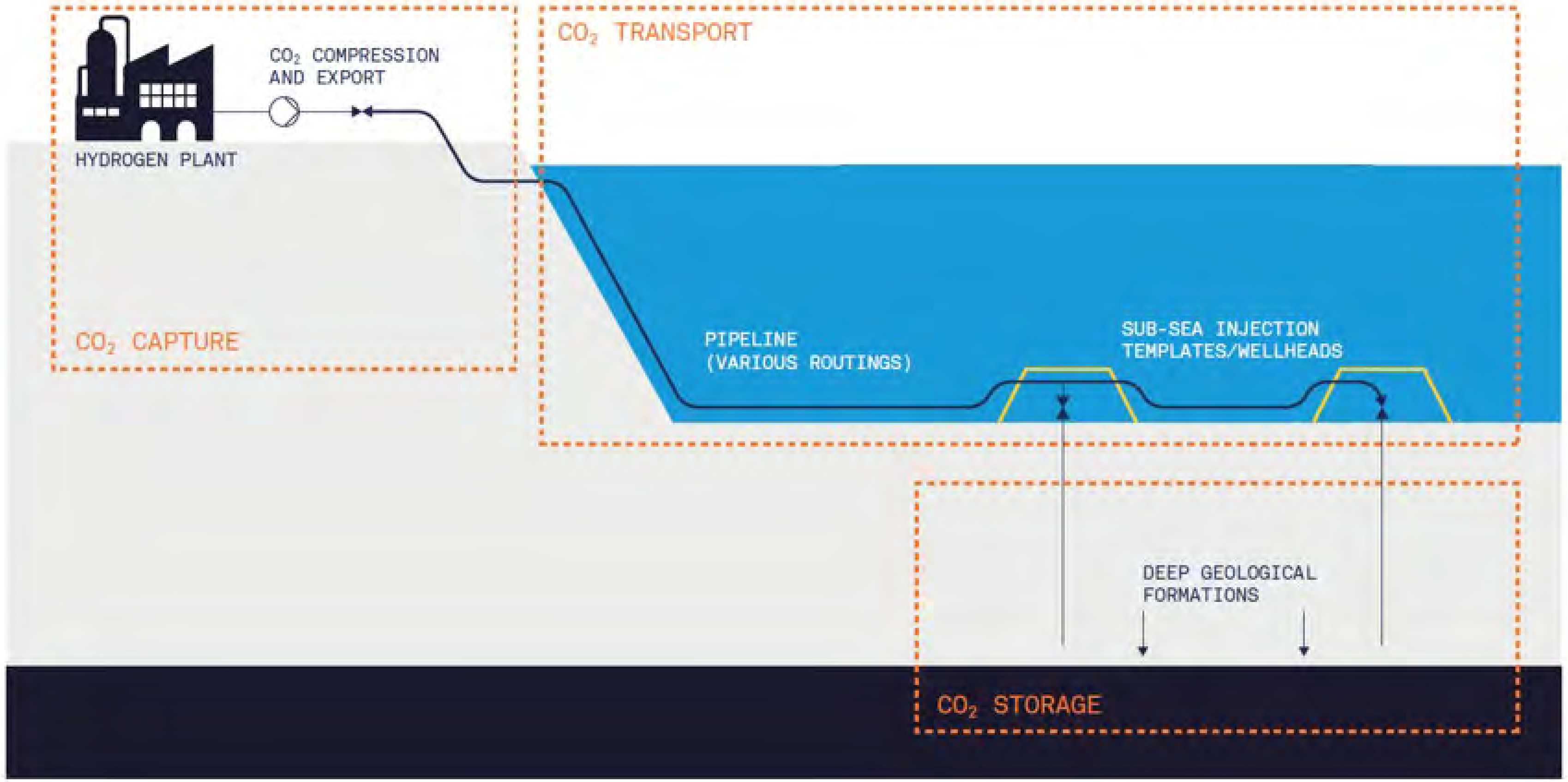


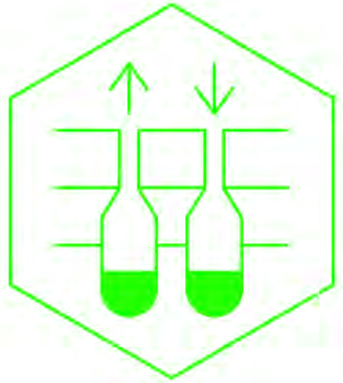
 Open

Engineering concept study for a 17 -20 Mtpa storage scheme for H21 (UK storage option):

- Assessed 3 Triassic Bunter sandstone structures in UK Southern North Sea
- Solutions involve 12 sub-sea wells drilled from 4 templates
- Baseload and seasonal fluctuations assessed

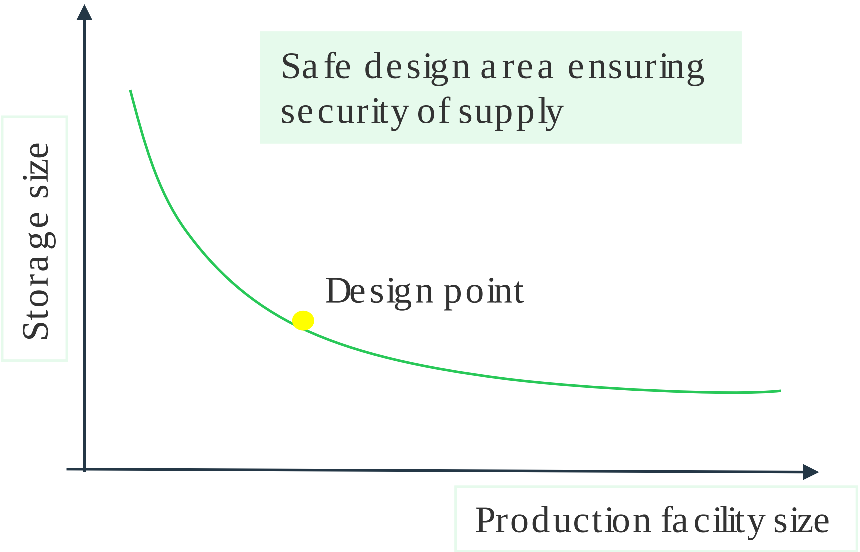


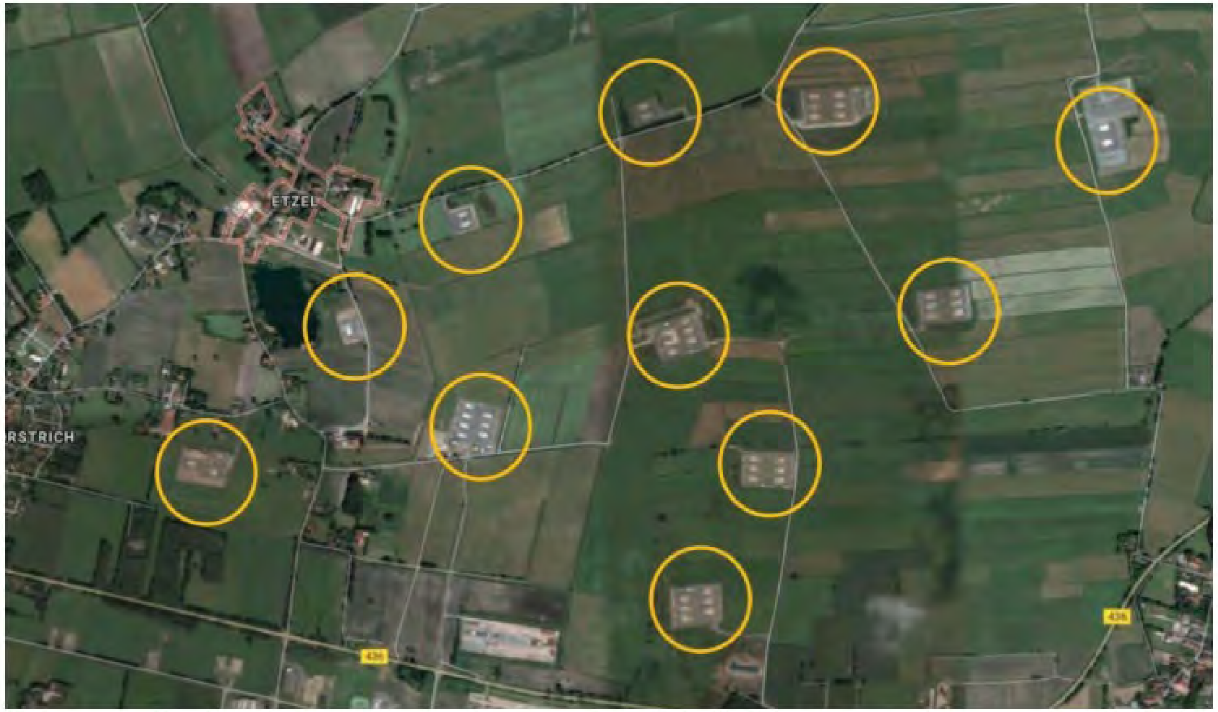




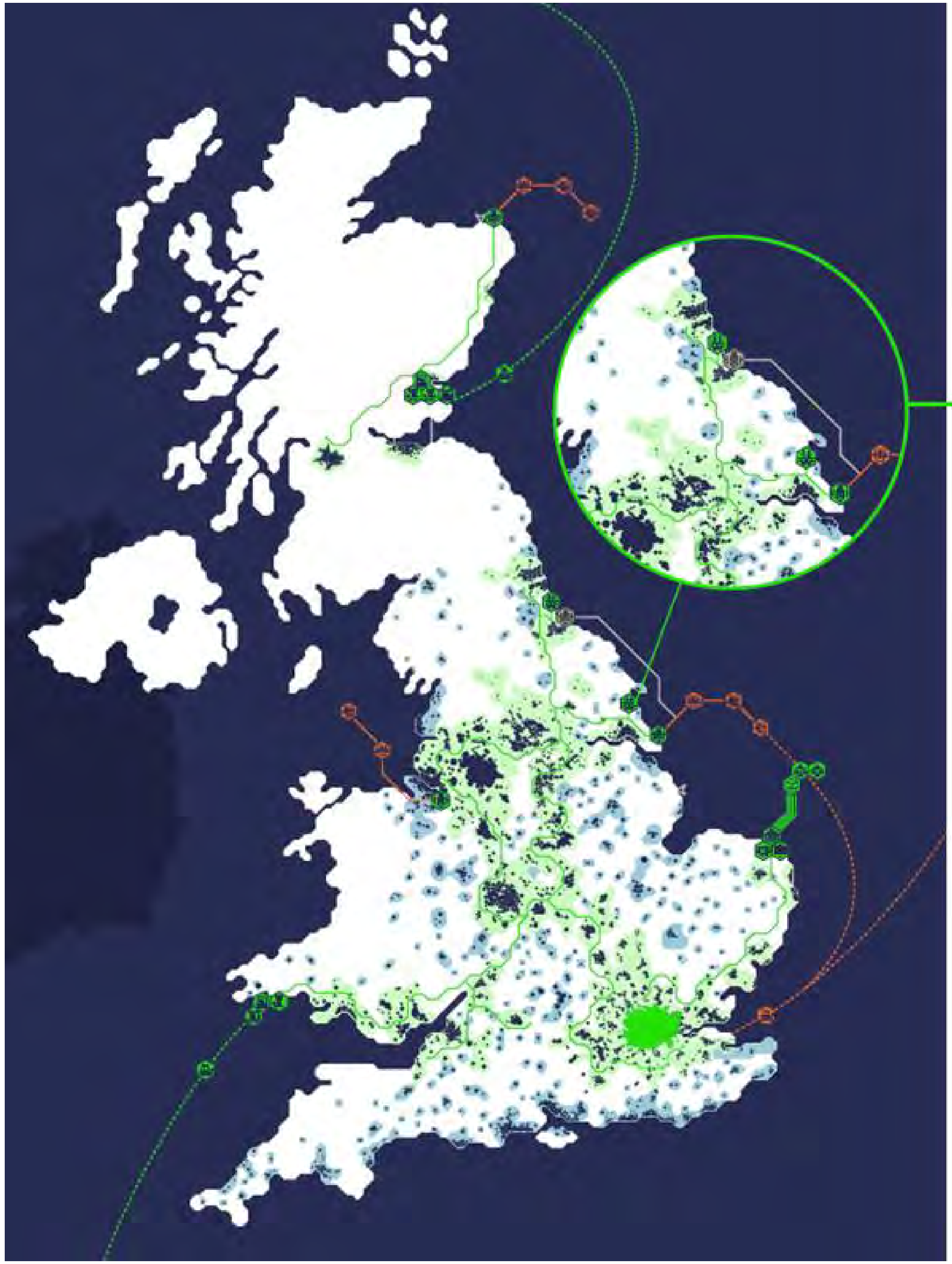
Inter-seasonal hydrogen storage

8 TWh = 62 000 australian megabatteries





	2035 residential prices	CO2 footprint
Electricity	£200/MWh (BEIS projection)	50 g/KWh
Natural gas	£50/MWh (BEIS projection)	100 g/KWh
Hydrogen	£75/MWh (H21)	15 g/KWh



UK **Hydrogen** Conversion Position in 2050

Phase 1
H21 NoE
Conversion 2028 - 2034
14% UK heat
30% Power (H21 XL) for North of England

Phase 2
H21 South Yorkshire & East/ West Midlands
2033-2038

Phase 3
H21 Scotland
2030-2032

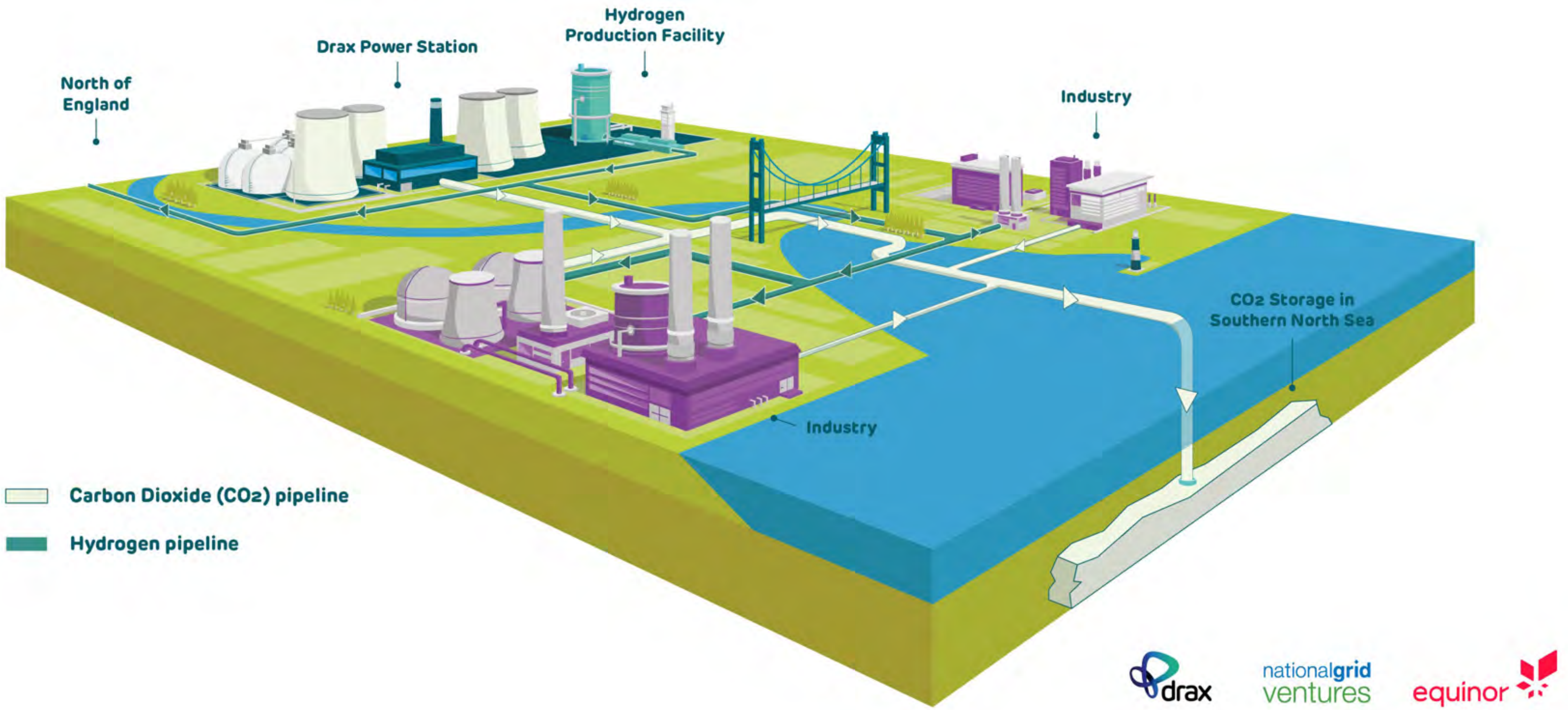
Phase 4
H21 South Wales & South West
2036-2037

Phase 5
H21 East Anglia & Home Counties
2040-2045

Phase 6
H21 London
2045-2050

Open

Zero Carbon Humber



Equinor Hydrogen Portfolio

H2M - Magnum

- Energy: 8-12 TWh
- Utilise existing gas power plants
- Switch fuel from natural gas to clean H2
- Clean electricity
- Clean back-up for solar and wind
- Launch large-scale H2 economy
- Partners: Vattenfal and Gasunie

New Projects

- Maritime transport – Norway
- Clean Hydrogen Pilot - Norway
- Heat and power – Germany with OGE
- Power and Industry – NL (12-20 TWh)
- Power and Industry – France

equinor

Thank you!

Acorn Hydrogen and CCS

Speaker: Dave MacKinnon, Total

> Back to contents

TOTAL
COMMITTED TO BETTER ENERGY

ACORN: HYDROGEN & CCS PROJECT

1st October 2019

DISCLAIMER and COPYRIGHT RESERVATION

The TOTAL GROUP is defined as TOTAL S.A. and its affiliates and shall include the person and the entity making the presentation.

Disclaimer

This presentation may include forward-looking statements within the meaning of the Private Securities Litigation Reform Act of 1995 with respect to the financial condition, results of operations, business, strategy and plans of TOTAL GROUP that are subject to risk factors and uncertainties caused by changes in, without limitation, technological development and innovation, supply sources, legal framework, market conditions, political or economic events.

TOTAL GROUP does not assume any obligation to update publicly any forward-looking statement, whether as a result of new information, future events or otherwise. Further information on factors which could affect the company's financial results is provided in documents filed by TOTAL GROUP with the French *Autorité des Marchés Financiers* and the US Securities and Exchange Commission.

Accordingly, no reliance may be placed on the accuracy or correctness of any such statements.

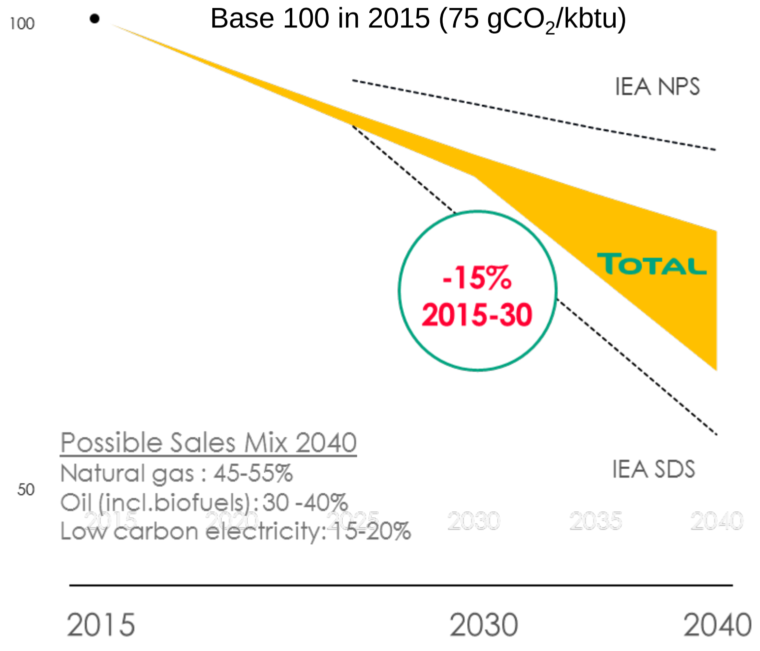
Copyright

TOTAL AMBITION: TO BECOME THE RESPONSIBLE ENERGY MAJOR

Total's ambition is to reduce carbon intensity by 15% between 2015 — the date of the Paris Agreement — and 2030.

Carbon intensity

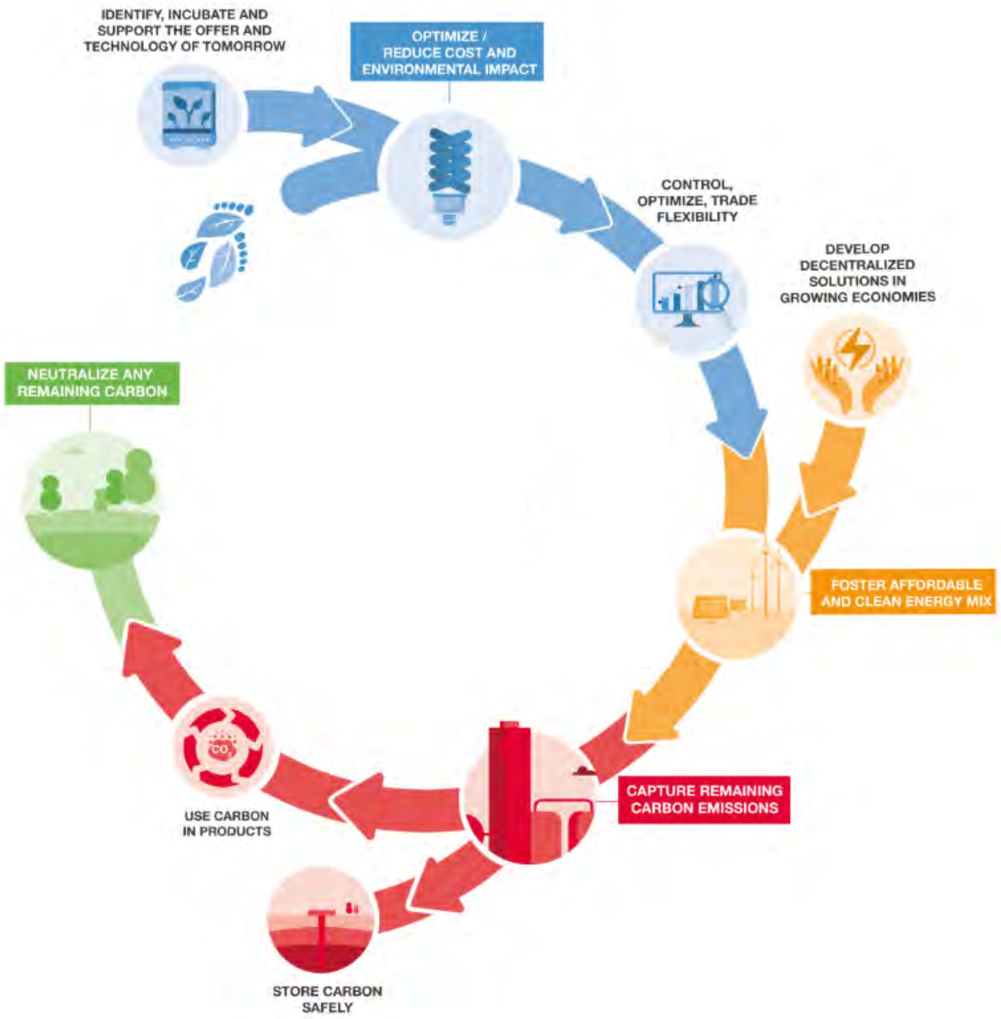
Base 100 in 2015 (75 gCO_2/kbtu)



Improve energy intensity
energy efficiency, optimization, etc.

Develop
greener energies

Emerging CO_2, H_2 solutions
capture, valorize, offset and store



TOTAL

WHO IS TOTAL

98,277
Employees

8 Million
Customers worldwide each day

No.4
Oil and gas
company worldwide
2.6 Mboe/d produced in 2017
of which approximately 48% gas

Refining and Chemicals
A globally ranked
integrated manufacturer

European Leader
In fuel retailing
2.4 Mt of biofuels blended
into gasoline and diesel in 2017

No.2
LNG managed:
15.6 Mt

30% Decrease
In direct greenhouse
gas emissions

Midstream and Downstream Gas
Growing presence further
downstream in the gas value chain

R&D spending of
912 million USD
in 2017

GAS, RENEWABLES & POWER

World's second-largest LNG **operator**

~5 million sites and customers, of which **~80%** are B2C sites

A major player in renewable energies with ~2 GW of capacity developed

5 combined-cycle gas-fired power plants in Europe, including one in development

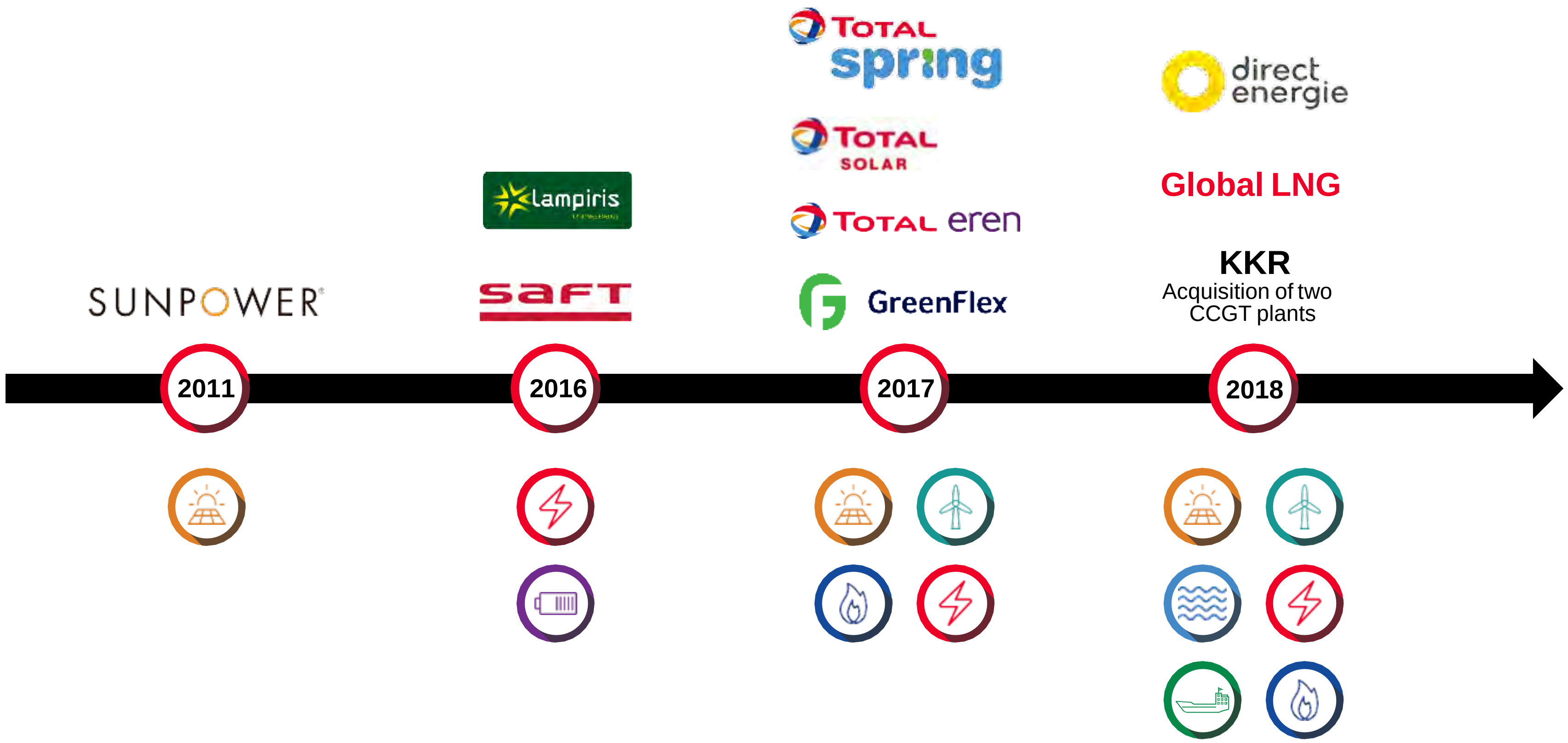
Strategic Partnerships to access emerging technologies e.g. ChargePoint

Present in **more than 30 countries**

SAFT: 4,300 employees 14 production facilities

~10 million people reached by our Access to Energy program

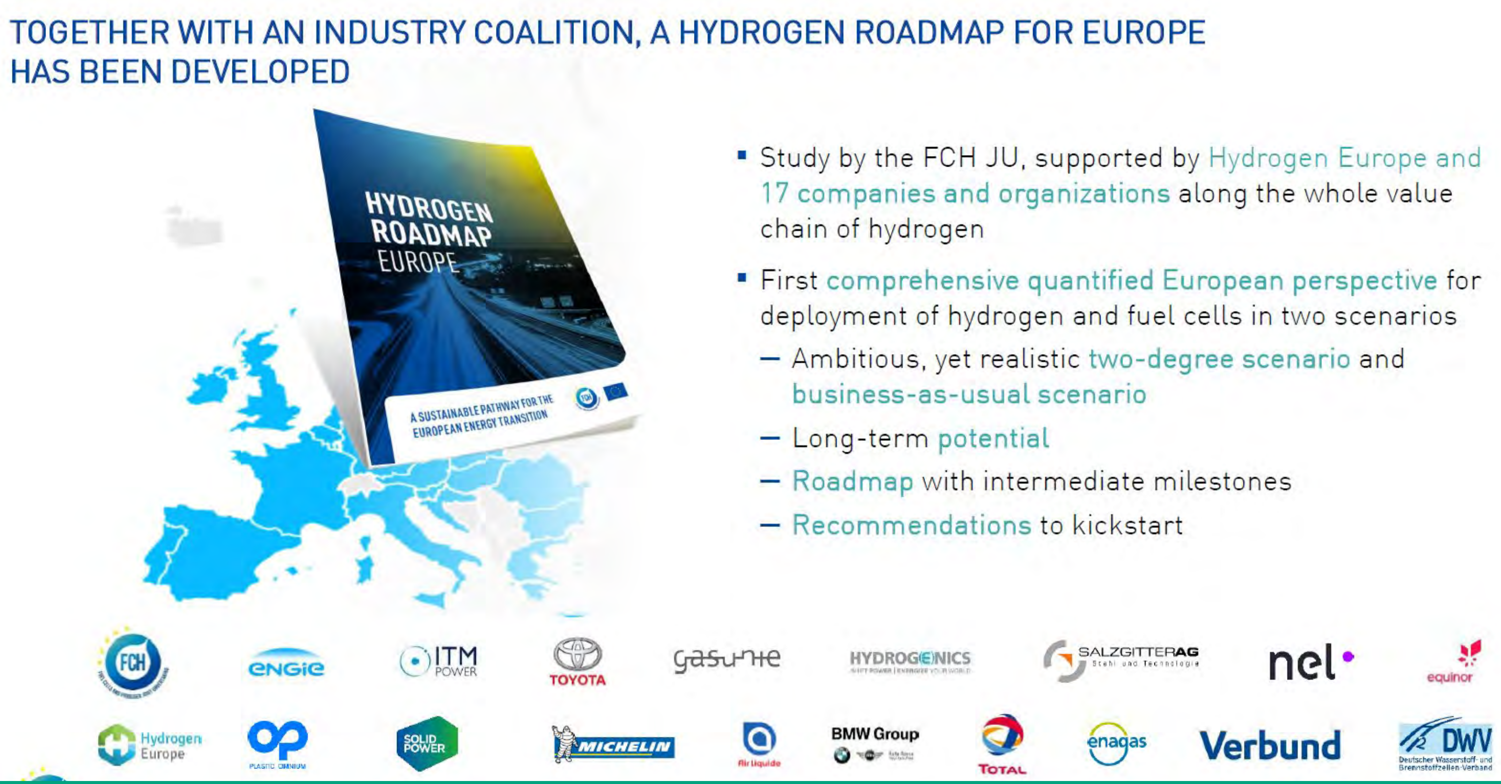
ONGOING INTEGRATION ACROSS THE NATURAL GAS AND ELECTRICITY VALUE CHAINS



EUROPEAN VISION

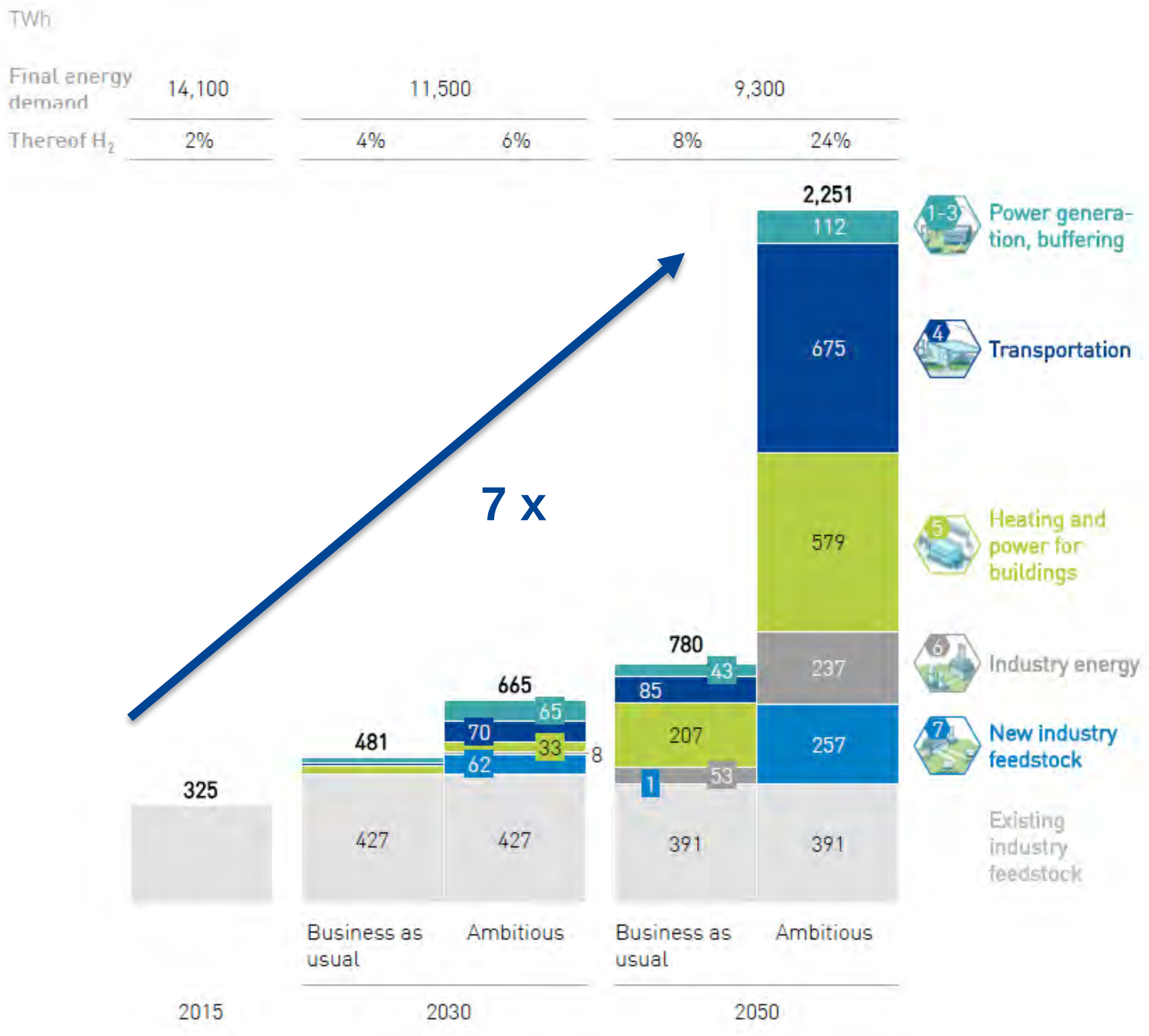
Published
11 Feb. 2019

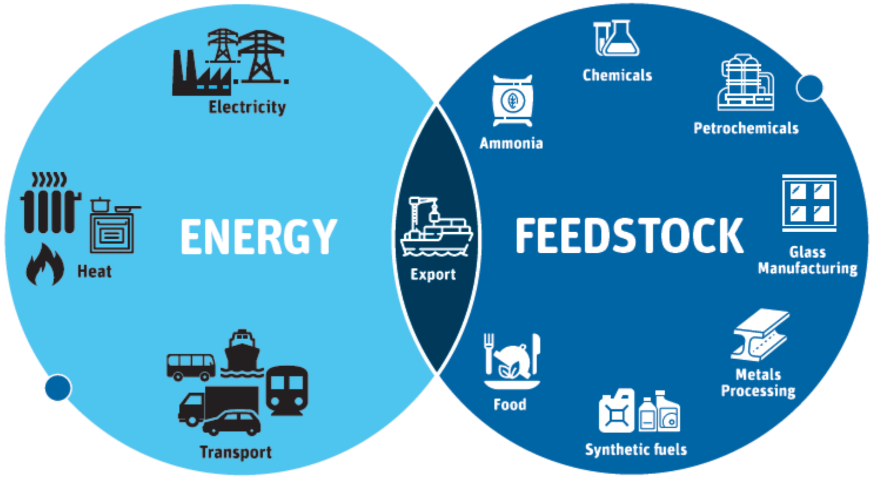
Achieving the energy transition **will require hydrogen at large scale**…



Europe's transition to decarbonised systems is underway

HYDROGEN'S POTENTIAL FOR EUROPE

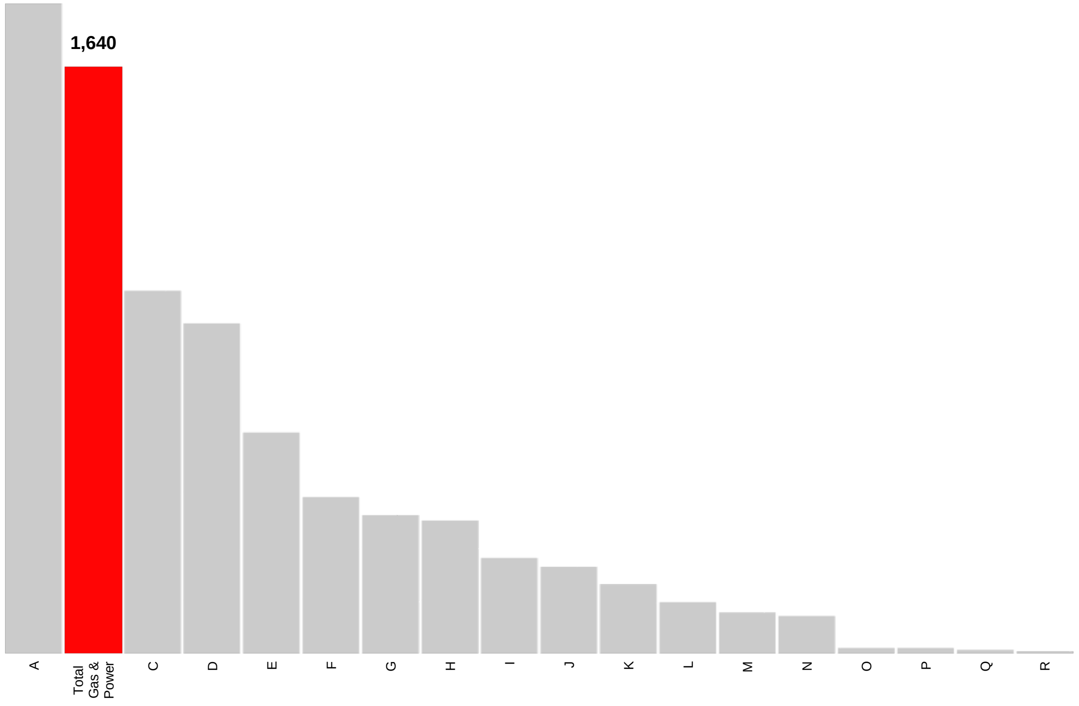




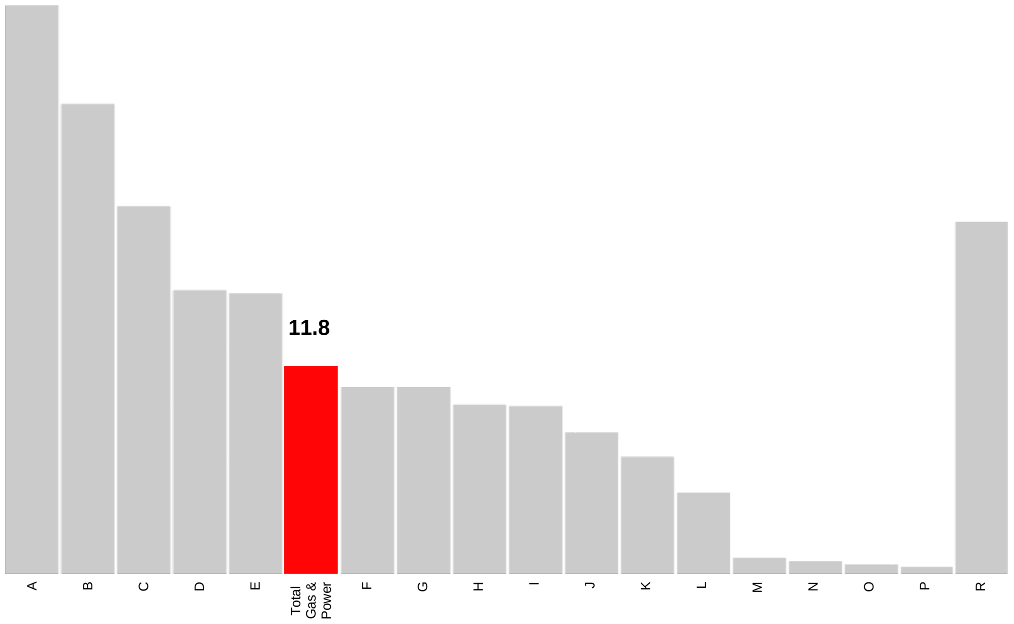
Hydrogen could provide up to 24% of total energy demand, or up to ~2,250 TWh of energy in the EU by 2050

UK B2B ONLY SALES VOLUMES

GAS (MN TH)

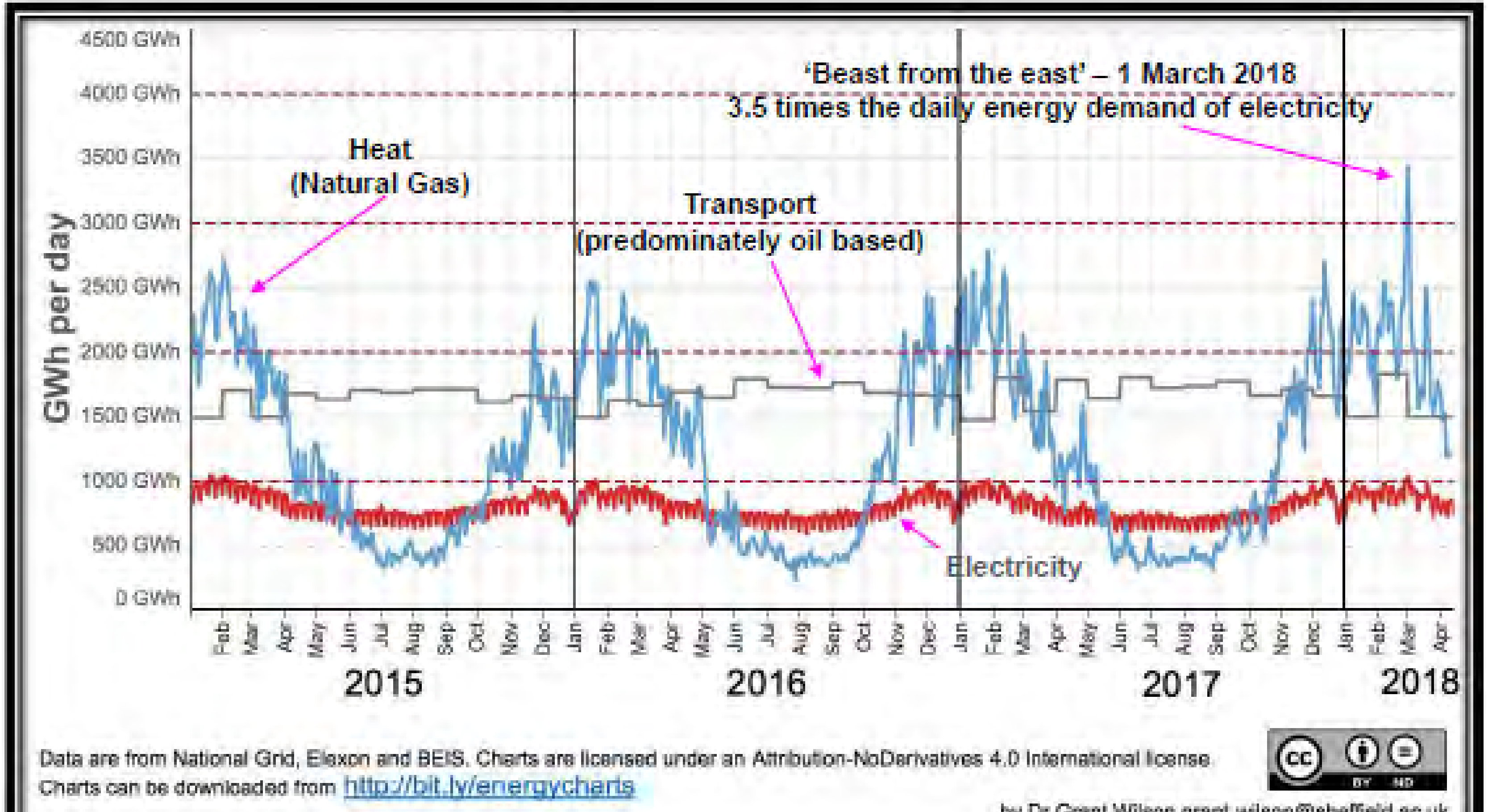


ELECTRICTY (TWH)



Investing in Growing & Transforming Energy Markets

UK NATURAL GAS DEPENDENCY

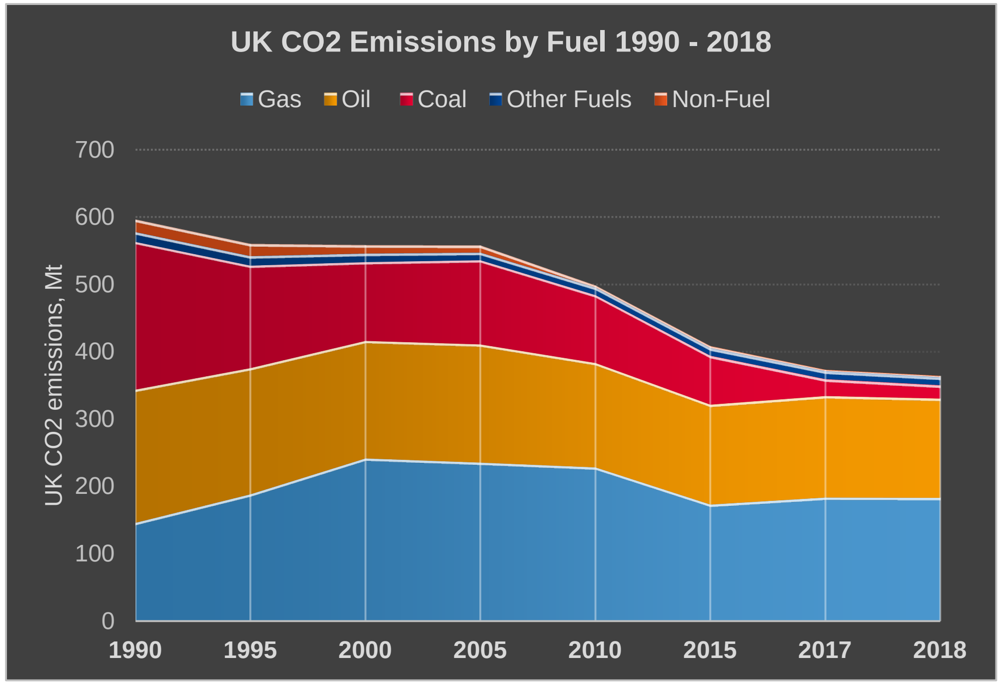


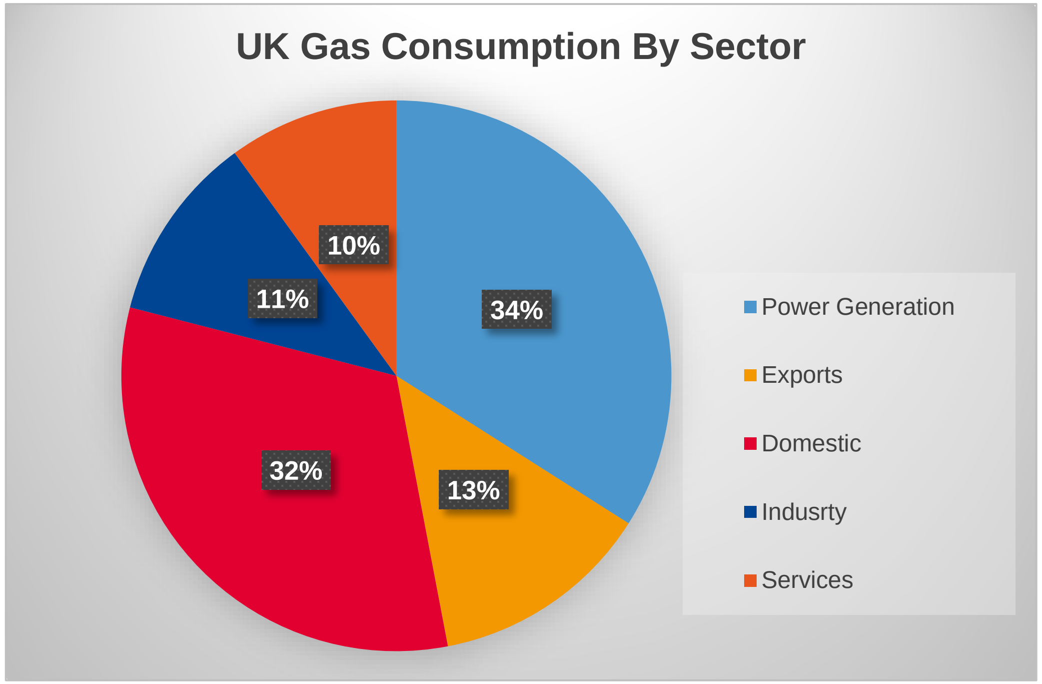
'Future of Gas II – Keynote', Prof. Mark Taylor (BEIS)

UK depends on gas for heat and ~40% of electricity generation

UK 'NET ZERO' CO2 EMISSIONS - GAS DECARBONISATION

The **Scottish government** will legislate to reduce greenhouse gas emissions to **net-zero by 2045,** five years ahead of UK legislation (2050)

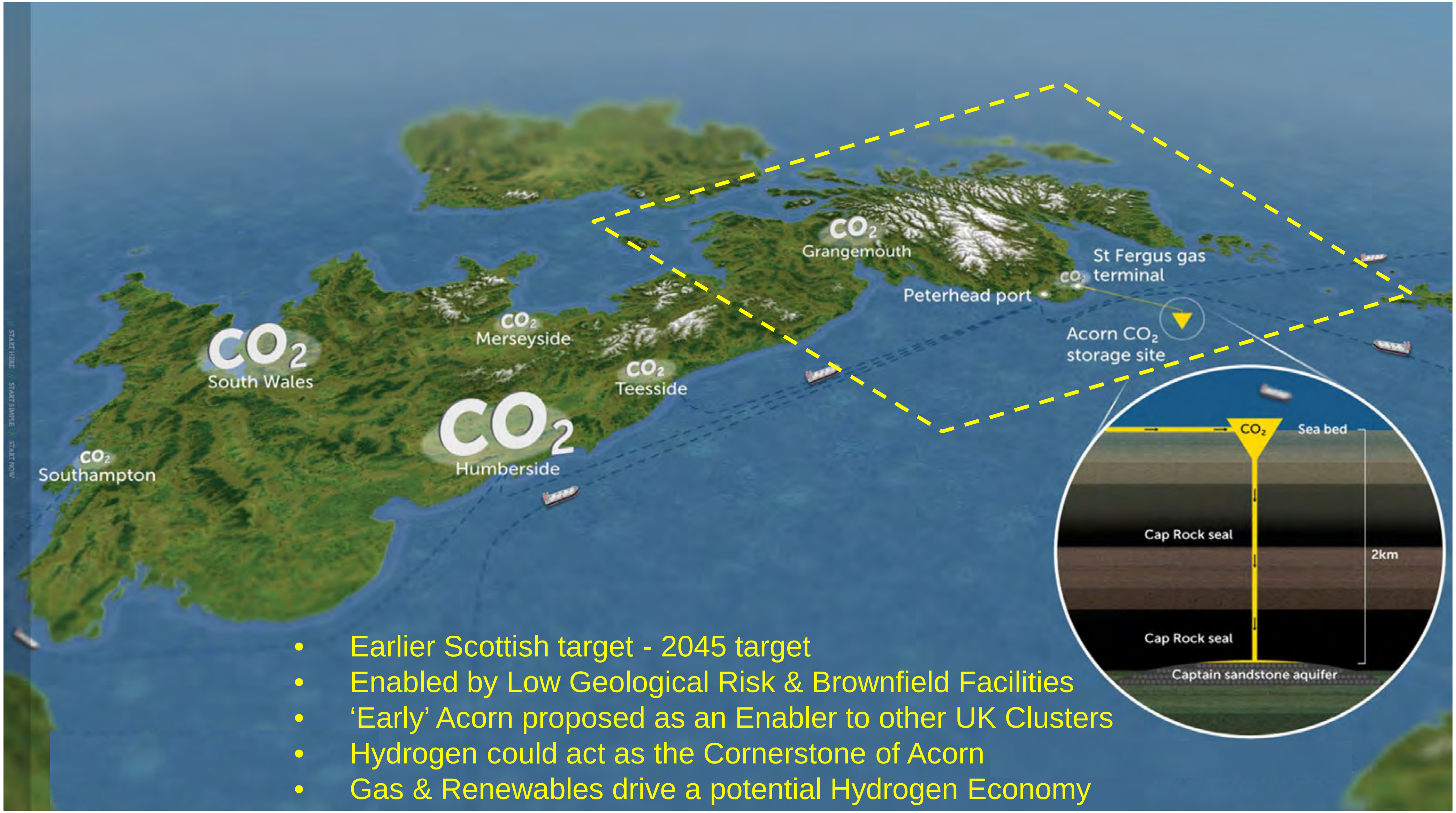




Gas is a crucial energy vector in UK.
Decarbonising heat is arguably the greatest challenge in meeting 'net-zero' targets.

TOTAL

UK "INDUSTRIAL" CLUSTERS → WHY SCOTLAND?

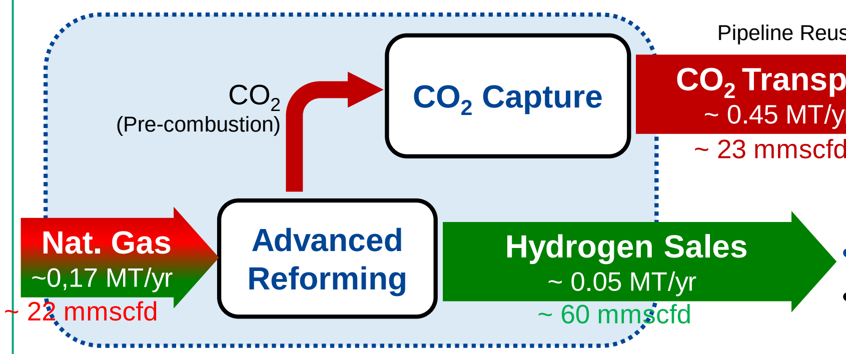


- Earlier Scottish target - 2045 target
- Enabled by Low Geological Risk & Brownfield Facilities
- 'Early' Acorn proposed as an Enabler to other UK Clusters
- Hydrogen could act as the Cornerstone of Acorn
- Gas & Renewables drive a potential Hydrogen Economy

‘ACORN’ – HYDROGEN (& CCS) PROJECT

DECARBONISING NATURAL GAS IN NORTH-EAST SCOTLAND

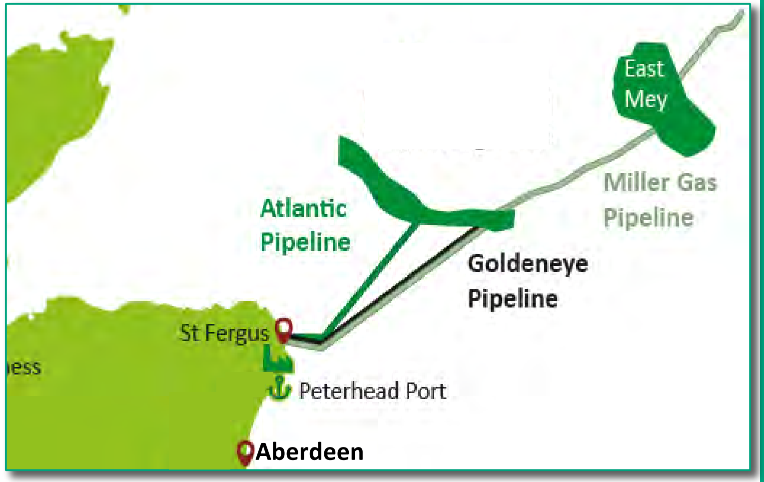
St Fergus Area: New H_2 Reforming & CCS



- **Phase 1 : Goldeneye**
- Storage build-out :
  - *Atlantic / Cromarty*
  - *East Mey*

- **Phase 1 : Blend up to 2% (vol) Hydrogen into nat. grid**
- Hydrogen sales build-out :
  - *National Grid: > 2% H_2 blend*
  - *Aberdeen: up to 100% H_2 local blend + transport*

- Supply build-out: Modular expansion of H_2 plant
  - *CO_2 import - Peterhead Port (Shipping)*
  - *CO_2 import - Grangemouth (FEEDER10 pipe)*



- Pale Blue Dot Energy & Total study under HSC-1 funding. Shell & Chrysaor joining under HSC-2
- Advanced reforming technology to generate Hydrogen from natural gas (Nat. Grid / St Fergus Terminals)
- Pre-combustion (higher efficiency) capture of by-product CO_2
- Transport using existing pipelines + offshore storage

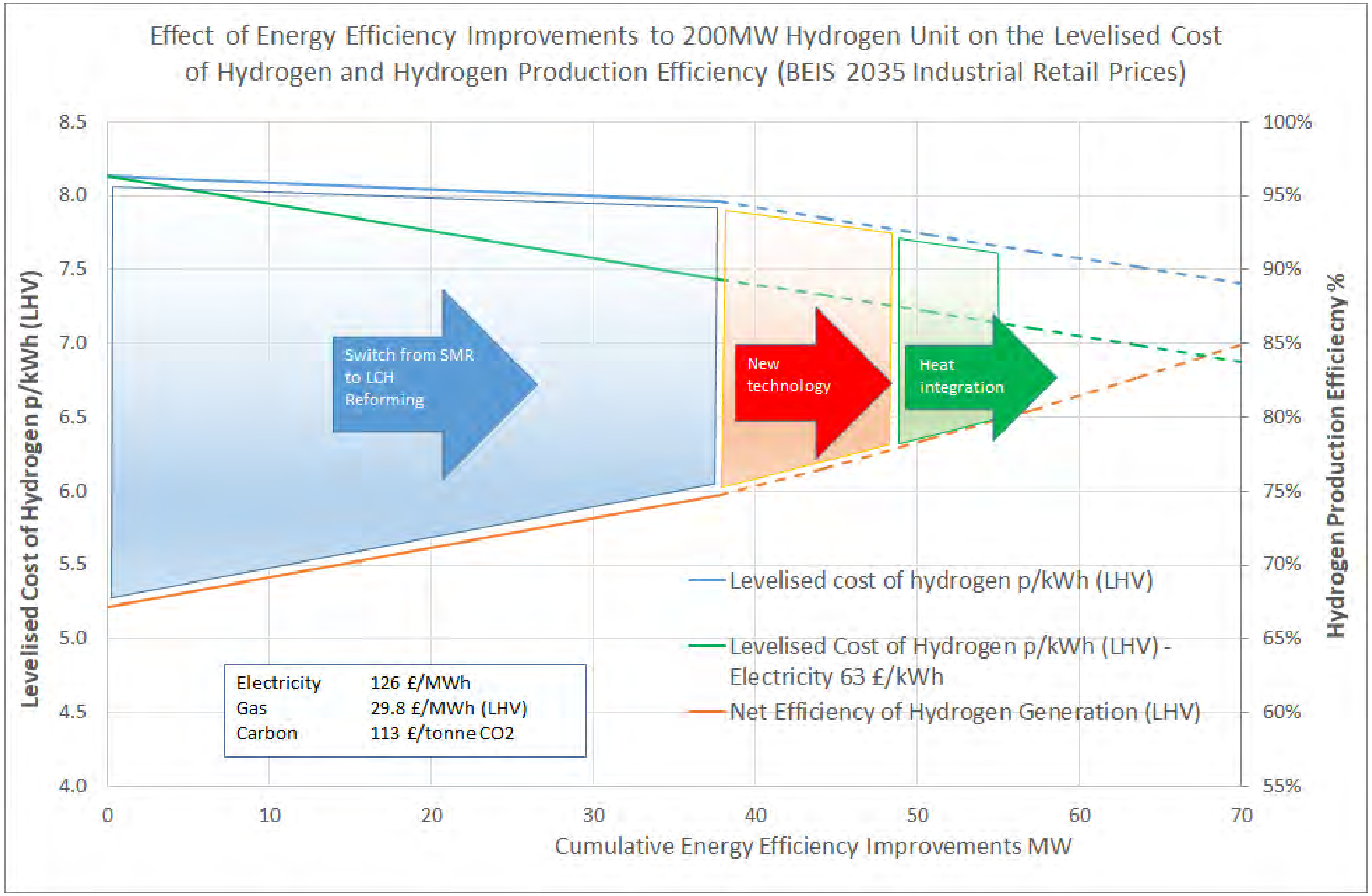
BEIS Hydrogen Supply Competition Phase 1 - Delivery September 2019

KEY OBJECTIVES

1. Evaluate the potential of different flow schemes for the production of low-carbon H_2
2. Reduce energy requirements and cost of low-carbon H_2
3. Maximize H_2 and CO_2 purity/recovery
4. Launch strategic research partnerships to drive forward the development of technologies
5. Identify the most promising technologies for scaling-up
6. Establish a low-carbon Hydrogen Business Model

H2 GENERATION CONCEPT

BEIS Counterfactual Assumptions



Identify the most promising technologies for scaling-up

ACORN = 200MW (LHV): 67 KNM^3 H_2/hr ≈ 144 TH_2/day

✓ Enough to power ~470k FCEVs - Toyota Mirai
(15k km/year @ 0.76 kgH_2/100 km*)

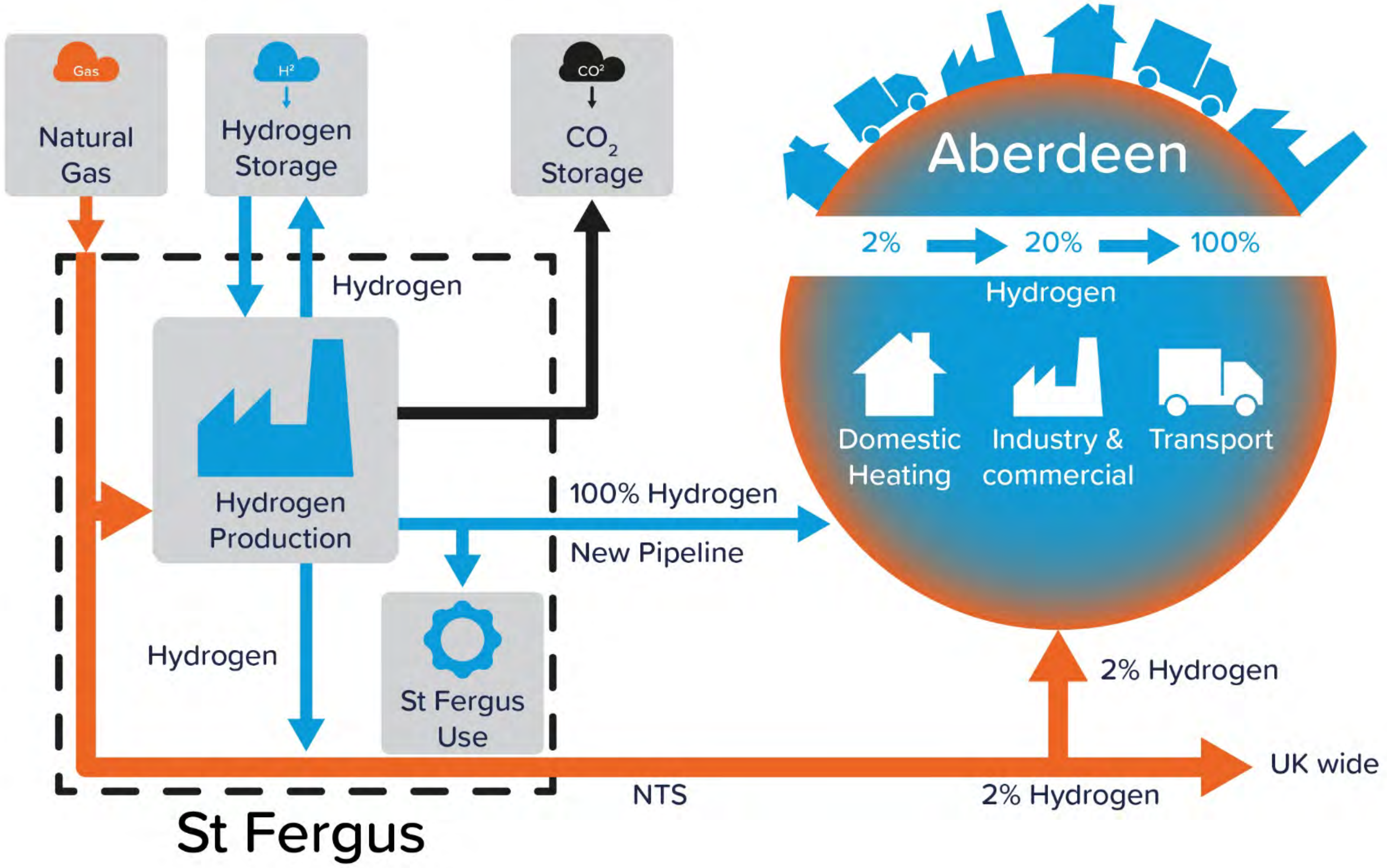
✓ 365 days of production adds up to a total of 1.7 TWh (LHV), or ~3.7% of total electricity production in Portugal in 2017 (Total = 47.66 TWh**)

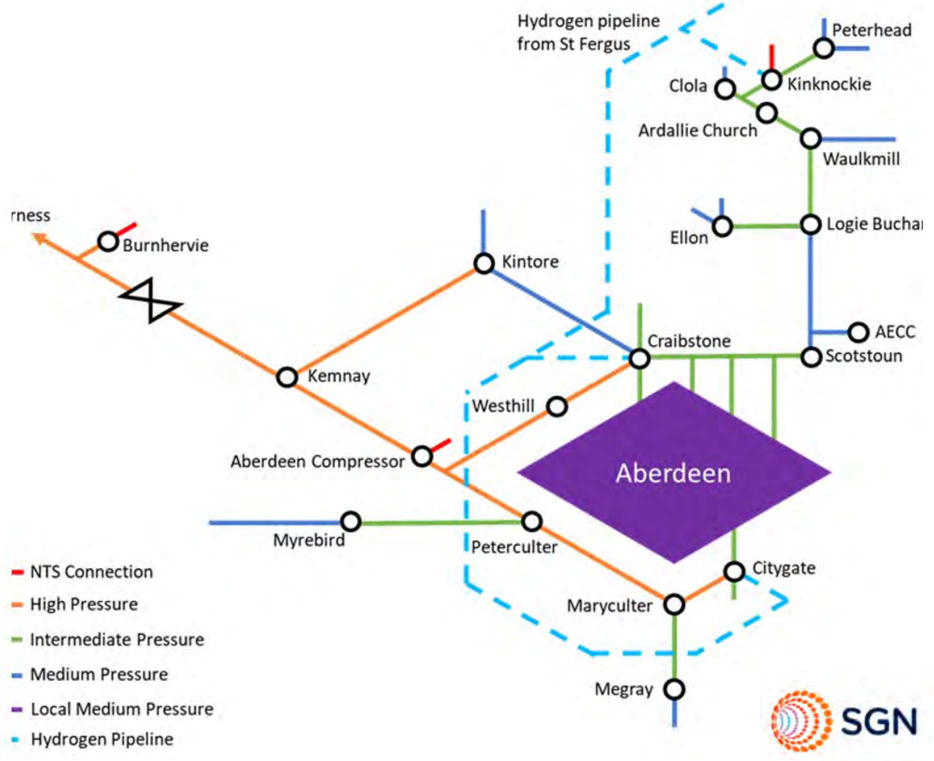
✓ Equivalent to ~13k "Mega Batteries"

< 0.1% of the total Hydrogen demand projected for Europe in 2050
(Total = 2252TWh, 2-degree scenario in Hydrogen Roadmap for Europe 2019)

* Combined fuel consumption for 154 hp/113 kW 2019 model, https://www.toyota-europe.com/new-cars/mirai/index/specs
** https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

ACORN H_2 → BUILD OUT





Hydrogen Blend (by vol)	Average Reform (MW)	CO_2 Captured (Mte/yr)
2%	172	0.378
10%	913	2.008
20%	1,976	4.347

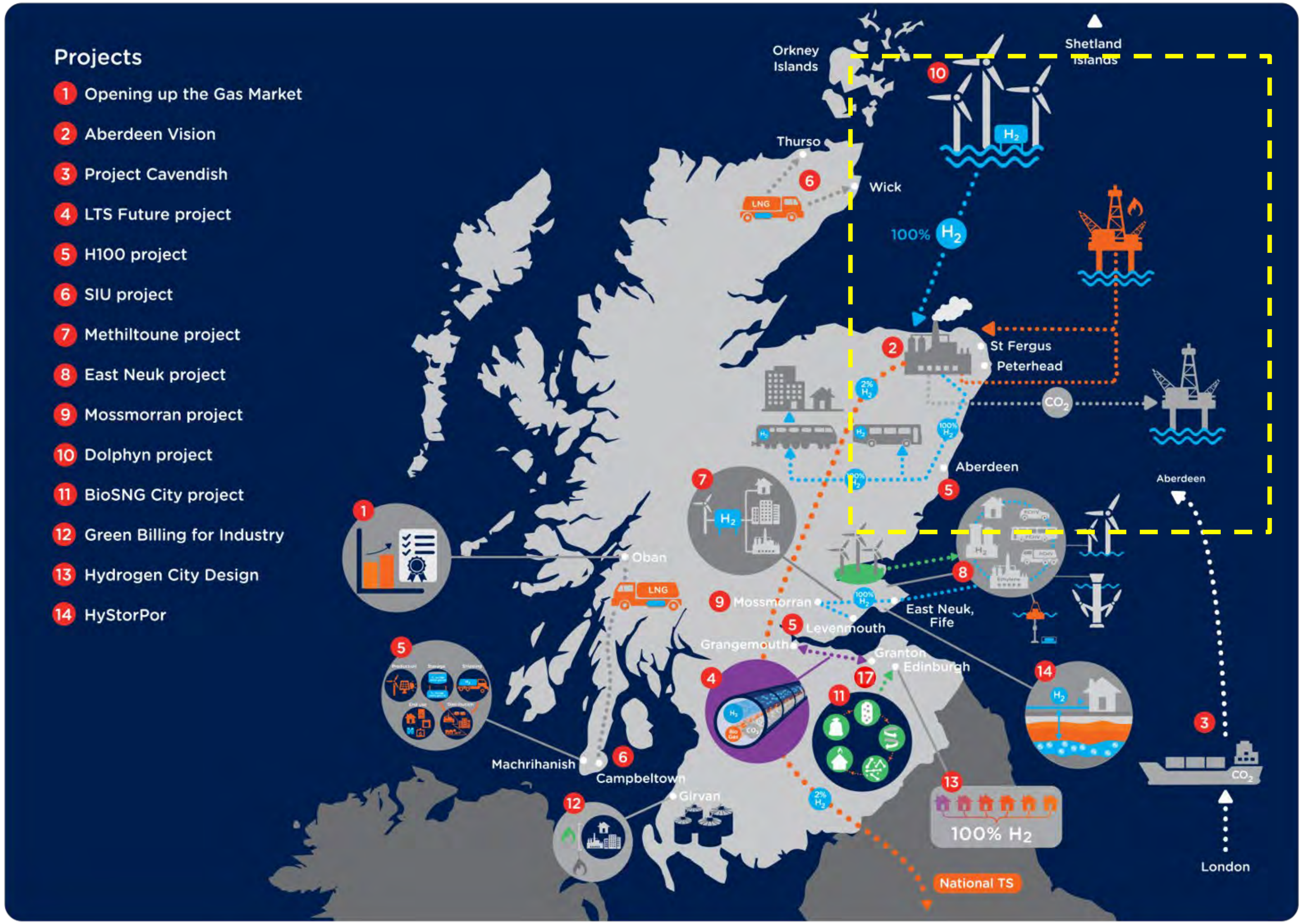
Hydrogen Generation Requirements for St Fergus NTS Blending

>30% of the UK Gas Consumption passes through St Fergus

TOTAL

SUMMARY

- Committed to Energy Transition
- Already Integrating climate into strategy – taking into account anticipated market trends
- Evaluate the potential for the production of low-carbon H_2
- North Sea Region already offers significant potential
- Must Understand and Establish Energy Price Points, before Scale Up
- Unlikely to be a single solution



Courtesy of SGN

Offshore Power To Hydrogen

Speaker: Molly Iliffe, ERM

> Back to contents

Offshore Power to Hydrogen

Molly Iliffe, ERM

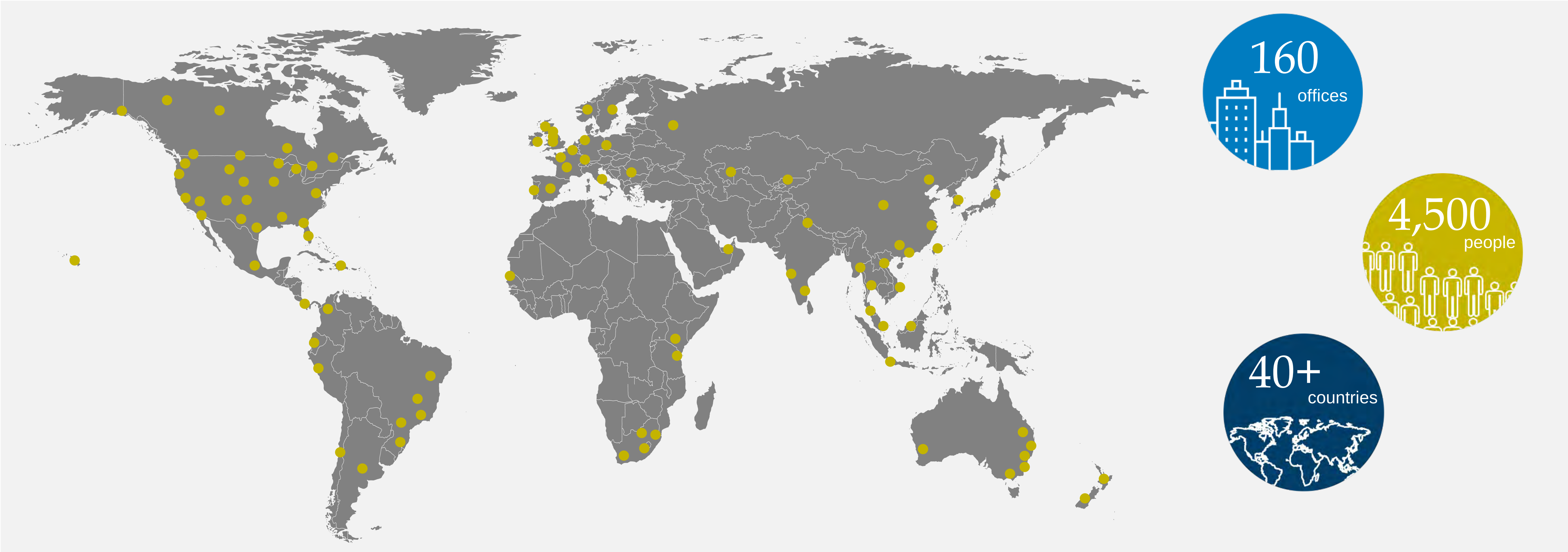
October 2019

The business of sustainability

ERM

About ERM

Environmental Resources Management (ERM) is a leading global provider of environmental, health, safety, risk, social consulting services and sustainability related services. ERM is committed to providing a service that is consistent, professional and of the highest quality to create value for our clients. We have worked with many of the Global Fortune 500 companies delivering innovative solutions for business and selected government clients helping them understand and manage the sustainability challenges that the world is increasingly facing.

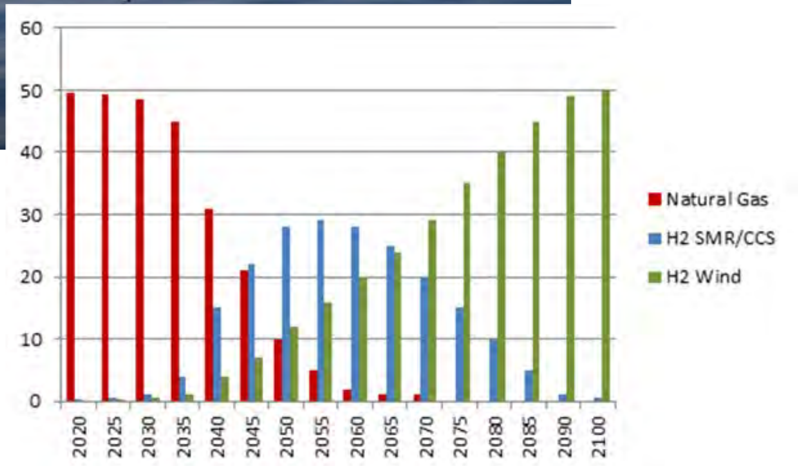


ERM's Hydrogen Expertise

- **Techno-economic feasibility** including detailed cost estimates, financial modelling, and technical concept select for new projects.
- Future **scenario development** for the energy transition, including development of hydrogen demand and supply scenarios.
- Development and analysis of **strategic responses** to climate change and the energy transition.
- Hydrogen **hazard assessment and risk assessment** (hydrogen production facilities and pipelines).
- **Stakeholder engagement** (technical and non-technical).
- **Safety & environmental consent** delivery for projects.
- **Lifecycle assessment**

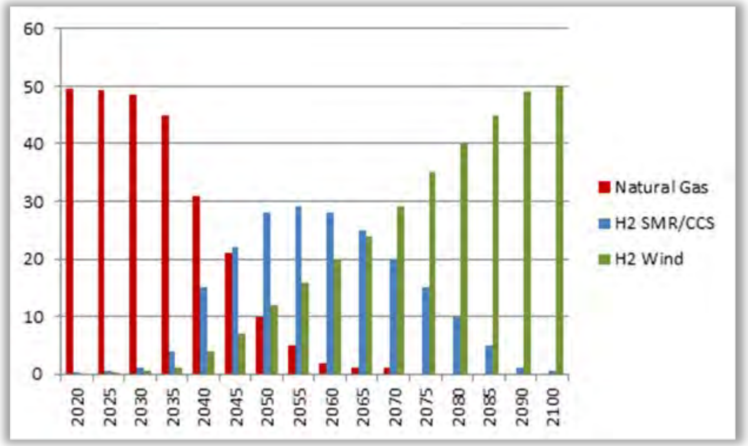
Feasibility Study of Large Scale Hydrogen Production from Offshore Wind in the UK

- Commissioned by **Offshore Wind Innovation Hub**, with **ORE Catapult** as key delivery party.
- Review of likely scenarios for implementation of hydrogen production.
- Estimation of macroeconomic benefit including:
  - **Job creation and GVA**
  - **Supply chain readiness**
  - **Policy requirements**
- Provides a case for government investment.
- Work completed July 2019. Will be published in combined OWIH study later this year.



Business case underpinned by robust analysis

Estimate hydrogen demand → Installed capacity of floating wind required → Capex, Opex and Decex



Complementary role for green and blue hydrogen.

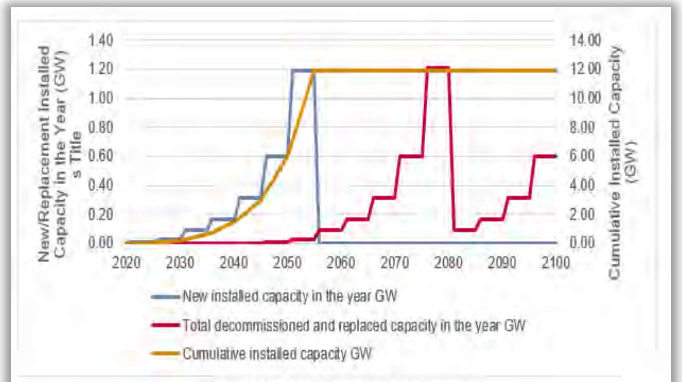


Figure 12. Installed Capacity: 20% Scenario

Development of floating wind at deep water sites to meet demand.

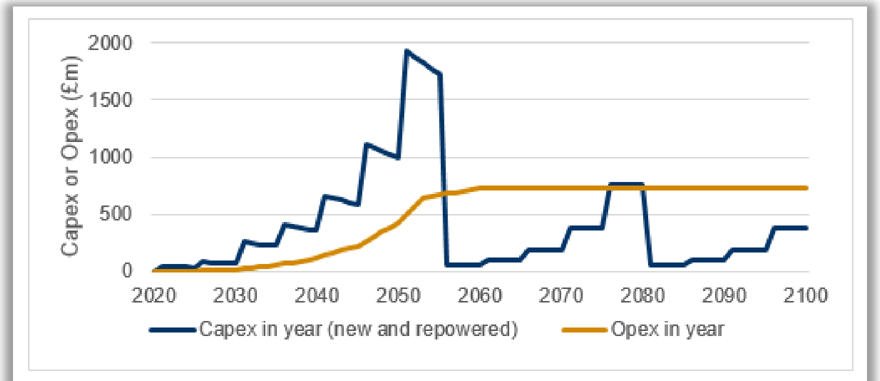


Figure 14. Capex and Opex in year: 20% scenario (£m)

Learning rates applied based on historic comparable industry trends.

Business case underpinned by robust analysis

UK supply of Capex, Opex and Decex.

Size of export market.

Apply GVA and employment multipliers

Return on government investment

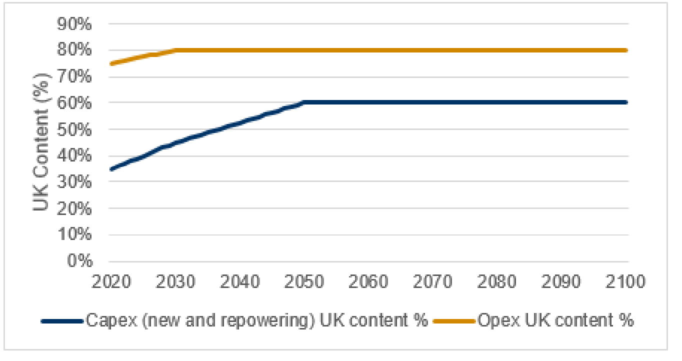


Figure 15. UK Content (%)

% of worldwide hydrogen market that the UK could realistically capture.

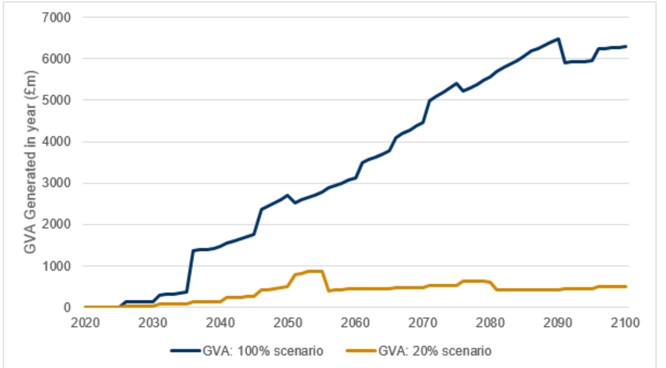


Figure 17. GVA generated in year (£m)

Economic benefit in terms of:

- Gross value added (GVA)
- Job creation

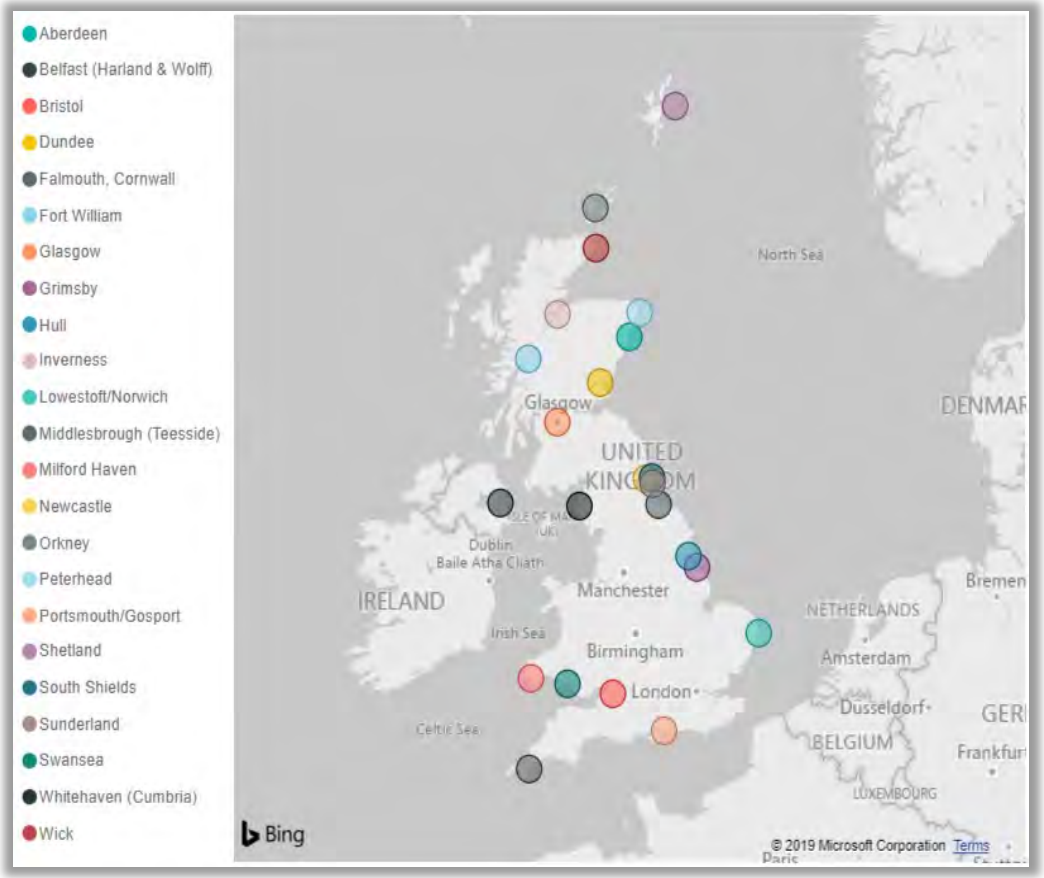
Table 5. Return on Government Investment

20% hydrogen blended into gas network		100% hydrogen in gas network by 2100	
Government investment required £bn	ROI £ GVA for each £1 gov investment	Government investment required £bn	ROI £ GVA for each £1 gov investment
1.4	3.6 in Year 2050	1.4	22.4 in Year 2050
	20.5 in Year 2100		180.9 in Year 2100

- New employment of over 8.4 million FTE years cumulatively to 2100.
- Delivery of cumulative GVA of £270bn to 2100.

The results demonstrate a clear business case for large scale deployment of hydrogen from floating wind

- Transition **opportunity** for the **UKNS oil and gas industry**.
- Production of hydrogen at scale, comparable to current wholesale **price** of natural gas.
- **Investment in UK ports** and traditional areas of **manufacturing** (particularly UK East Coast).
- Delivery of UK's **carbon emissions reduction** target by 2050.
- **Energy security**: no future reliance on gas imports.
- Potential to **export** UK hydrogen technology and services to the rest of the world.
- Delivery of cumulative **GVA of £270bn** to 2100.
- New employment of over **8.4 million FTE years** cumulatively to 2100.



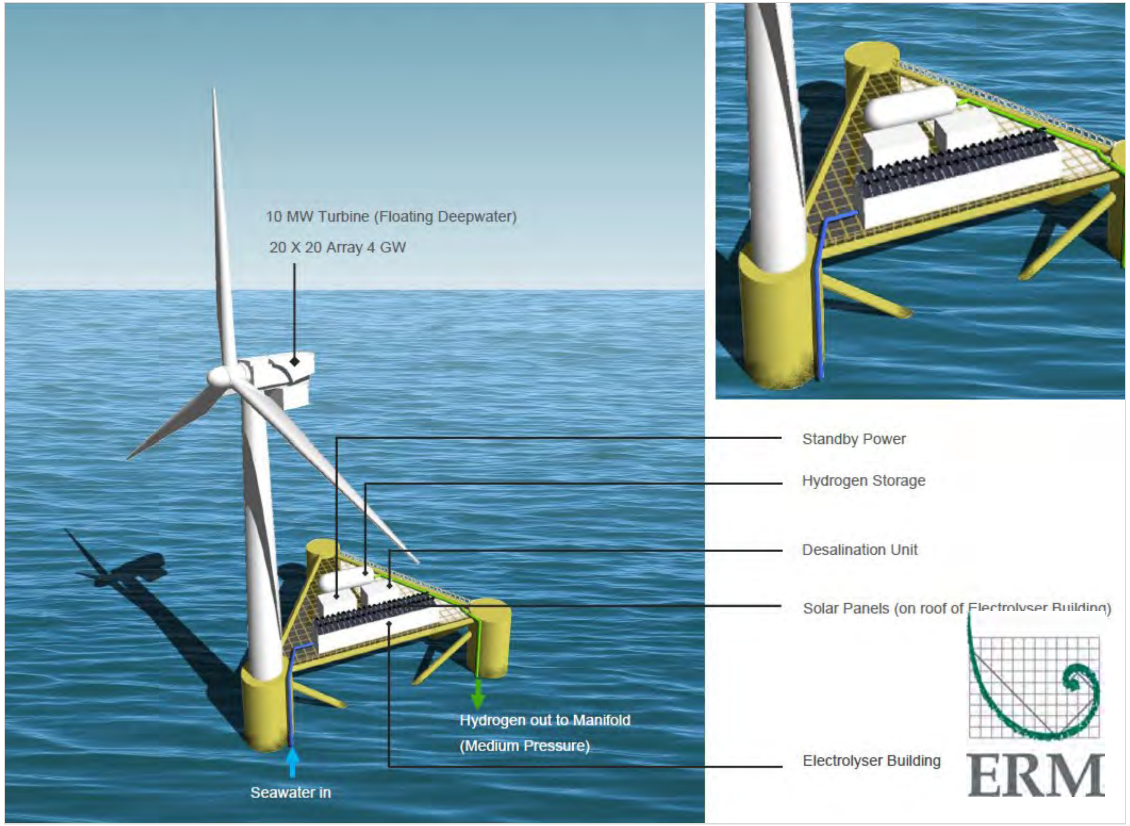
Potential UK Ports benefitting from offshore floating wind for hydrogen

Key enablers to capture this opportunity

- Creating the **market conditions** for hydrogen to be blended into the UK gas network to kick-start the hydrogen market at scale.
- A **Government long term commitment** to transition from natural gas to 100% hydrogen in the UK gas network.
- Making available **seabed rights** for development of floating wind sites. These could include areas that have already been evaluated as not suitable for electricity generation, but may still be viable for floating offshore hydrogen using new or existing pipeline infrastructure.
- Long term sustained investment and regeneration of **port assets, infrastructure, fabrication yards and UK manufacturing** value chain.
- Removal of regulatory restrictions in a number of related **regulations** (e.g. Gas Safety (Management) Regulations; and Gas (Calculation of Thermal Energy) Regulations)
- ***Short and medium term investment in floating hydrogen production through pilot and pre-commercial projects through to the first commercial hydrogen wind farm.***

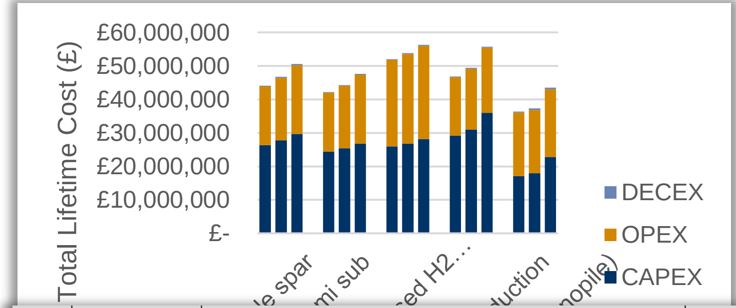
DOLPHYN: Example green hydrogen concept to capture the opportunity

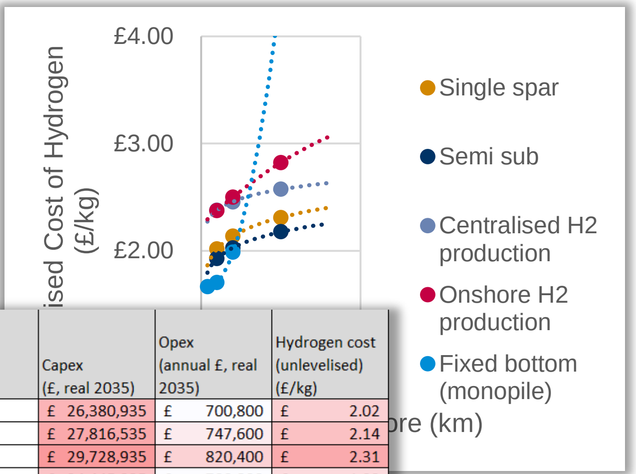
- ERM original design for production of 'green' hydrogen at scale from offshore wind.
- Floating semi-submersible (floating platform) design with integrated wind turbine, PEM electrolysis and desalination facilities.
- Enable the best UK offshore wind resources to be accessed in deep water at distances from land up to several hundred kilometres.
- Single 10MW unit will produce in excess of 800 Te of hydrogen per year, exported back to shore via a pipeline.
- Design has been taken through inception, definition, early technoeconomic feasibility, concept selection, and FEED.



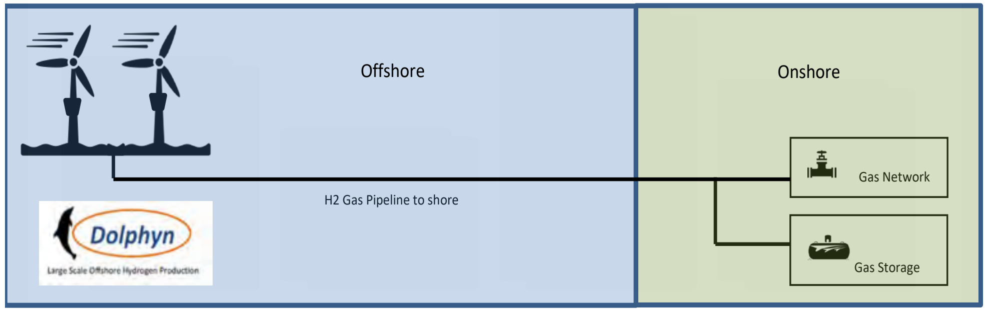
Development of optimal design, to ensure cost parity with "brown" options

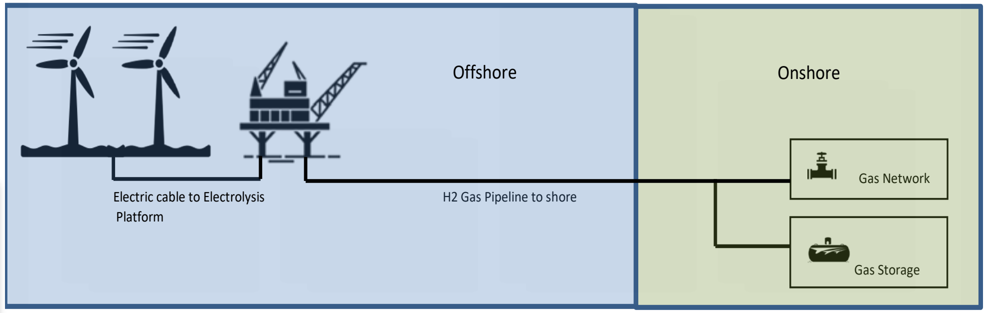
- Design has been developed through a detailed technical and financial evaluation process to achieve the lowest predicted cost for producing hydrogen from renewables at scale in the UK.
- Concept selection included modelling of Capex, Opex, Decex, hydrogen production, losses and construction schedule in order to compare potential project designs.

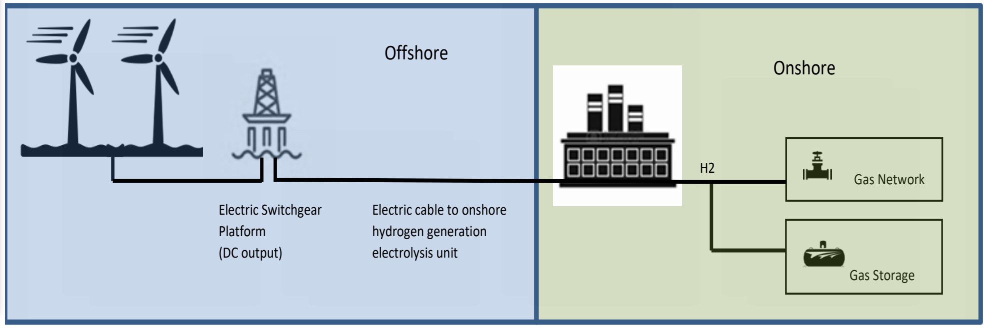




Option ID	Sub-structure options for Dolphyn	Offshore layout options	Distance offshore	Capex (£, real 2035)	Opex (annual £, real 2035)	Hydrogen cost (unlevelised) (£/kg)
1A	Single spar	ERM Dolphyn Concept: Offshore hydrogen production, with desalination and electrolysis integrated with wind turbine to enable local production of hydrogen and pipeline export	50km	£ 26,380,935	£ 700,800	£ 2.02
2B			100km	£ 27,816,535	£ 747,600	£ 2.14
3C			250km	£ 29,728,935	£ 820,400	£ 2.31
4A	Semi sub	ERM Dolphyn Concept: Offshore hydrogen production, with desalination and electrolysis integrated with wind turbine to enable local production of hydrogen and pipeline export	50km	£ 24,445,935	£ 700,800	£ 1.93
5B			100km	£ 25,386,535	£ 747,600	£ 2.02
6C			250km	£ 26,798,935	£ 820,400	£ 2.18

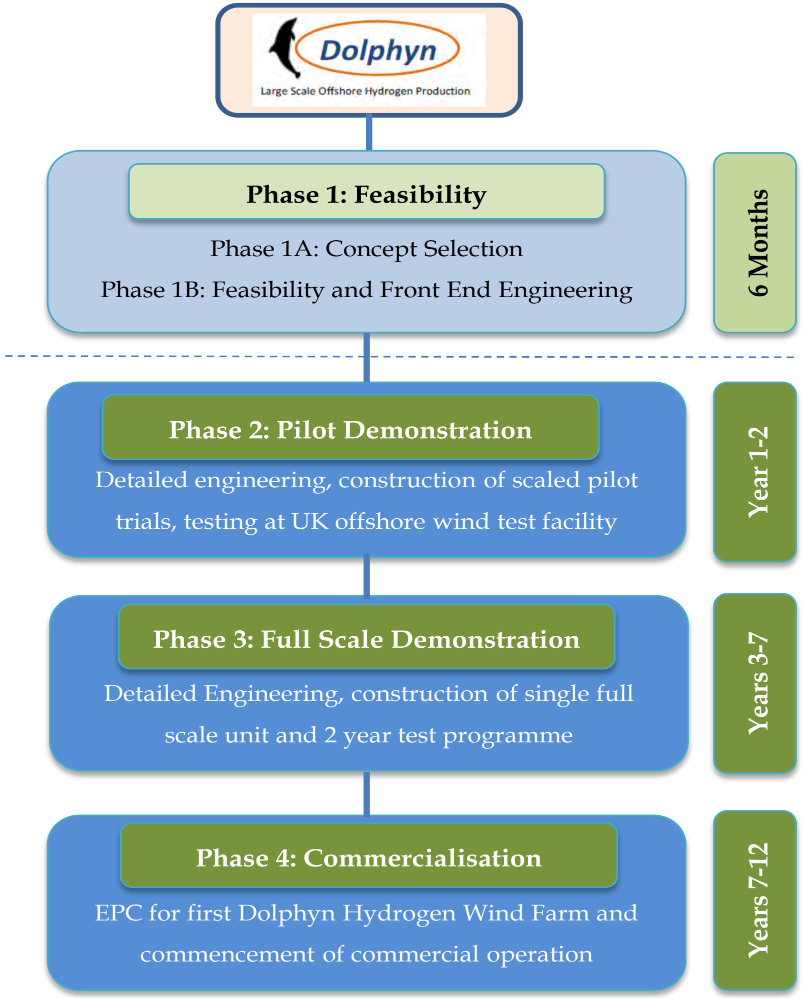






Next Steps – A collaborative approach is key to success

- The Front End Engineering work is now complete and the project will move forward to detailed design stage, with a view to making a final investment decision on a 2MW prototype facility by March 2021.
- Target date for the operational start-up of the 2MW prototype facility of Summer 2023.
- A 10MW full scale pre-commercial facility is planned to follow by 2026.
- **Continue to work with partners developing complementary projects in the emerging hydrogen economy** including blue hydrogen/CCUS, transportation of hydrogen, end users (transportation, industry, heating). **Collaboration is key to success!**



Thank you

Molly Iliffe
Senior Consultant
Energy and Climate Change
Molly.iliffe@erm.com
Edinburgh, UK

Aberdeen Vision Project

Speaker: Charlotte Hartley, Pale Blue Dot

> Back to contents

Charlotte Hartley
charlotte.Hartley@pale-blu.com

This year marks the fifty-year anniversary of the first person to land on the moon so I would like to open my presentation with a quote from John F Kennedy's 1962 speech 'We Choose to go to the Moon'.

We meet at a college noted for knowledge, in a city noted for progress, in a State noted for strength, and we stand in need of all three, for we meet in an hour of change and challenge, in a decade of hope and fear, in an age of both knowledge and ignorance. The greater our knowledge increases, the greater our ignorance unfolds.

Today, we meet in a city noted for oil and gas production, in a State (country) noted for ambitious climate change mitigation targets. Like in 1962, we meet in an hour of change and challenge, in a decade of hope and fear. It may seem strange to apply this statement to climate change when it was originally describing the Cold War, but it describes the challenge of decarbonisation quite aptly.

The Aberdeen Vision Project, which we have heard about briefly a few times earlier in the day, is designed to build upon the phased transition to enable a managed implementation of the energy system towards hydrogen. It builds upon other hydrogen transformation projects (H21, HyNet, H100) and links with other decarbonisation projects (Cavendish, Methiltoune). The focus is the transport and use of hydrogen produced from reformed natural gas from St Fergus in North East Scotland. Much of the material is regionally specific and linked to other facilities and projects in the region, particularly the Acorn Project.
The project is based upon hydrogen production from advanced steam methane reforming (SMR) technology located at the St Fergus Gas Terminal, with associated CO2 capture and CO2 transport and storage through the Acorn CCS project.

It is a collaborative project between SGN, National Grid and ourselves, Pale Blue Dot Energy.