GLEAM NETWORK

10 YEARS OF CATAPULT Offshore Renewable Energy

Manufacturing for Net-Zero

Wednesday 22nd November

ORE Catapult, Operations & Maintenance Centre of Excellence (OMCE), Grimsby

Delivered by University of Lincoln · BRIDGE · Greater Lincolnshire Local Enterprise Partnership · Business Lincolnshire The place to go for business growth

GLEAM NETWORK

Agenda

- 09.00: **Welcome Address**
  Craig Nicholls, Innovation Manager - Operations & Maintenance, ORE Catapult
- 09.15: **Introduction to GLEAM and the Bridge**
  Matthew Thornton, Commercial Manager, The Bridge, University of Lincoln
- 09.30: **Introduction to ORE Catapult, the OMCE and the Scale of Opportunity**
  Katharine York, OMCE Manager, ORE Catapult
- 09.45: **Opportunities in Fusion**
  Paul Goodwin, Group Lead for Manufacturing Technology & Equipment Qualification, UK Atomic Energy Authority
- 10.00: **The Role of Hydrogen in Net Zero**
  Cedric Hanson, Business Development Manager Applications, BOC Ltd.
- 10.15: **Hydrogen Sector Developments and Links with CCUS in the Humber**
  Ian Livingston, Project Manager – Humber Cluster, UK Low Carbon Solutions , Equinor ASA
- 10.30: **Opportunities for Rare Earths for EVs and Wind Turbines**
  William Izod, Chief Commercial Officer, Pensana
- 10.45: Refreshment break
- 11.00: Panel discussion and audience Q&A
- 11.30: Networking and tech demonstrations
- 12.00: Close and depart

GLEAM NETWORK

Creating a Manufacturing Community

GLEAM
NETWORK

- The Greater Lincolnshire Engineering And Manufacturing (GLEAM) Network is an initiative founded by the University of Lincoln, Greater Lincolnshire Local Enterprise Partnership (GLLEP), and Business Lincolnshire and managed by the Bridge.
- GLEAM provides a knowledge-intensive business corridor locally at the heart of the manufacturing business in Greater Lincolnshire and is open to all manufacturing businesses in Greater Lincolnshire. Members are able to join free of charge and gain access to a range of benefits, including Affiliate Partner Membership with Make UK.

Make UK Affiliate Membership Benefit

- Join Make UK as an Affiliate Member
- Make UK Affiliate Membership is open to members of Make UK partner organisations. You'll receive industry information and insight, contribute to Make UK's policy positions and have access to events, guidance and support on issues affecting our sector.
- To register for Affiliate Membership just complete the form at: https://www.makeuk.org/affiliate-member-registration

BRIDGING BUSINESS WITH INNOVATION

- Bridge operates from the University of Lincoln and has a dedicated team of R&D project specialists working alongside the University's academic community.
- We help businesses access technologies and methods at the forefront of research to create R&D solutions, and drive innovation.

UNIVERSITY OF LINCOLN

European Union
European Regional Development Fund

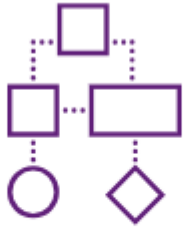
Greater Lincolnshire Local Enterprise Partnership
In partnership with
MIDLANDS ENGINE

BRIDGE

Bridge – Advanced Materials and Engineering R&D Centre

CONSULTATION AND 1-2-1 SUPPORT FOR BUSINESS DEVELOPMENT

Our process builds on an initial 1-2-1 consultation, roadmapping potential programmes from small-scale interventions to large-scale projects.



CREATION OF NEW PROCESS AND PRODUCT INNOVATION WITH OUR DEDICATED BRIDGE TEAM AND R&D PARTNERS

Bridge can address your advanced materials needs, assisting with new process creation and product innovation; providing access to world-class R&D at the interface of science and engineering through links to the University of Lincoln and a consortium of industry R&D partners.

MATERIALS RESEARCH AND INNOVATION

Bridge provides access to state-of-the-art instrumentation and laboratory workspaces. Our scientists and engineers are experienced in delivering cutting edge insight into materials

BRIDGE

Bridge – Advanced Materials and Engineering R&D Centre

EXPERT USE OF INSTRUMENTATION AND MATERIALS ENGINEERING LABORATORIES

Our dedicated team of specialists includes a community of expert Instrument Scientists. We can share that knowledge and help upskill your team by creating bespoke training packages.

BUSINESS NETWORKING AND COLLABORATION

Our dedicated innovation centre provides a quality environment for business interaction facilitating exchange of expertise and business opportunities. We host a range of networking events and seminars and our facilities are available for business-led events.

TRAINING AND PROFESSIONAL DEVELOPMENT

Bridge houses a dedicated training facility for on-site and remote learning alongside laboratory settings for at-instrument or in-lab training. Bridge gives you direct access to academic- and industry-experienced consultants to educate, develop and mentor your staff and they can upskill at our regular specialist courses.

BRIDGE

Bridge to…
Manufacturing Innovation

- With programmes designed to increase businesses' competitiveness, Bridge has delivered innovation to businesses and connected regional and international supply chains to cutting-edge materials science and engineering in the manufacturing and engineering sectors.
- Bridge has supported manufacturing businesses to access technologies at the forefront of research to deliver effective problem solving and to develop the workforce of tomorrow through accredited training.

BRIDGE

View the video at: https://youtu.be/MV4p10BIHJ0

- Visit our website for a virtual walkthrough of the Bridge at https://www.thebridge-lincoln.org/

- Follow us on:
  - https://www.linkedin.com/company/thebridge-lincoln
  - https://twitter.com/thebridge_linc
  - https://www.instagram.com/bridge_lincoln/

- E. mthornton@lincoln.ac.uk

BRIDGE

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Introduction to ORE Catapult, the OMCE and the Scale of Opportunity

Katharine York
OMCE Manager
ORE Catapult

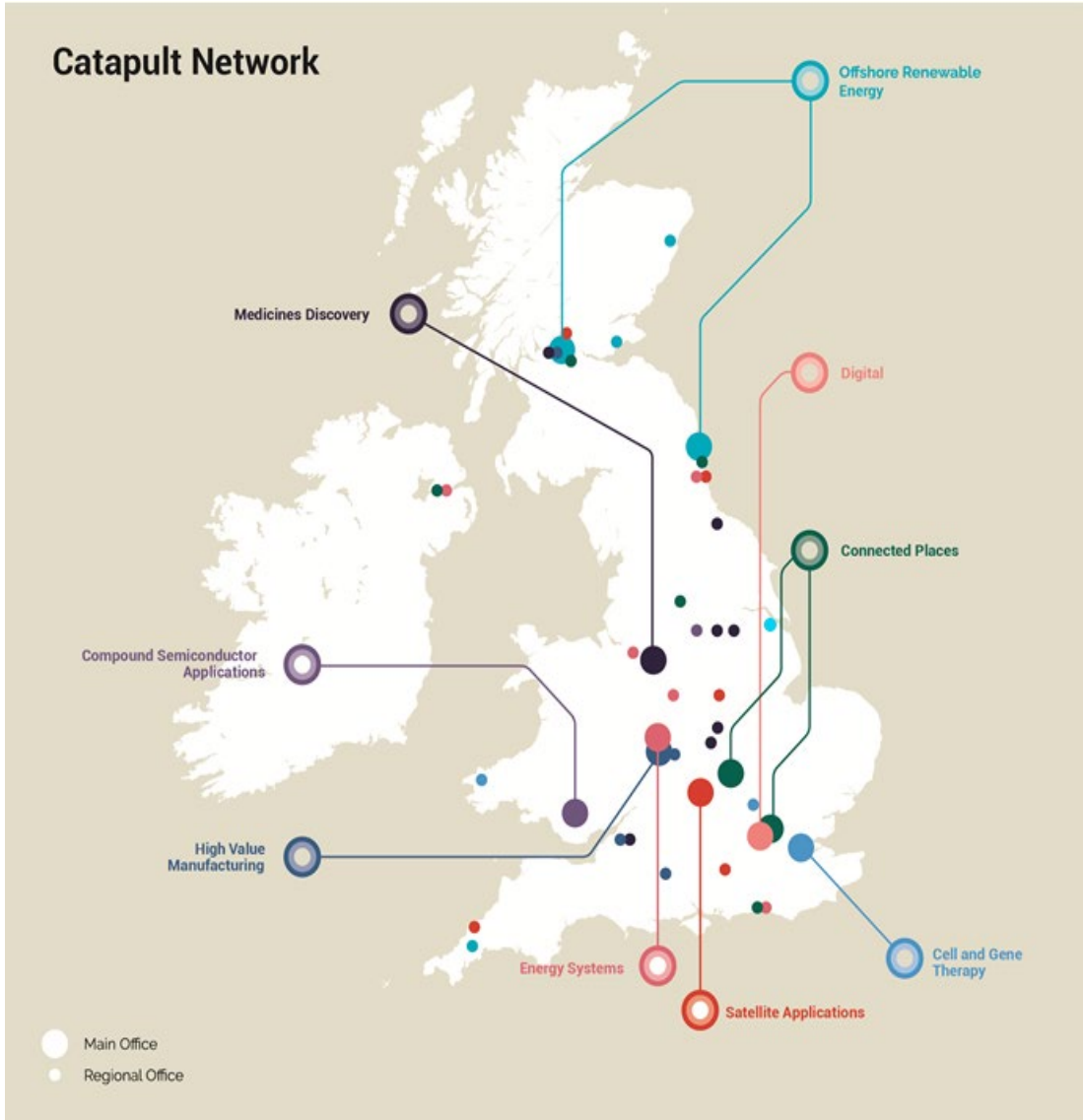
CATAPULT
Offshore Renewable Energy

Operations & Maintenance Centre of Excellence

Credit: Equinor Hywind Floating Offshore Wind Farm

Catapult Network – A National Capability

- Network of 9 world-leading technology innovation centres.
- Independent & not-for-profit.
- Goal is to transform the UK's capability for innovation – bridge the “valley of death” between research and industry.
- Physical centers, cutting edge R&D infrastructure, technical experts.
- Core grant leveraged with industry and other public funding.
- Catapult Network: https://catapult.org.uk/
- ORE Catapult: https://ore.catapult.org.uk/



UKRI Innovate UK

Offshore Renewable Energy Catapult

The UK's leading technology innovation and research centre for offshore renewable energy

Mission: to accelerate the creation & growth of UK companies in the offshore renewable energy sector.

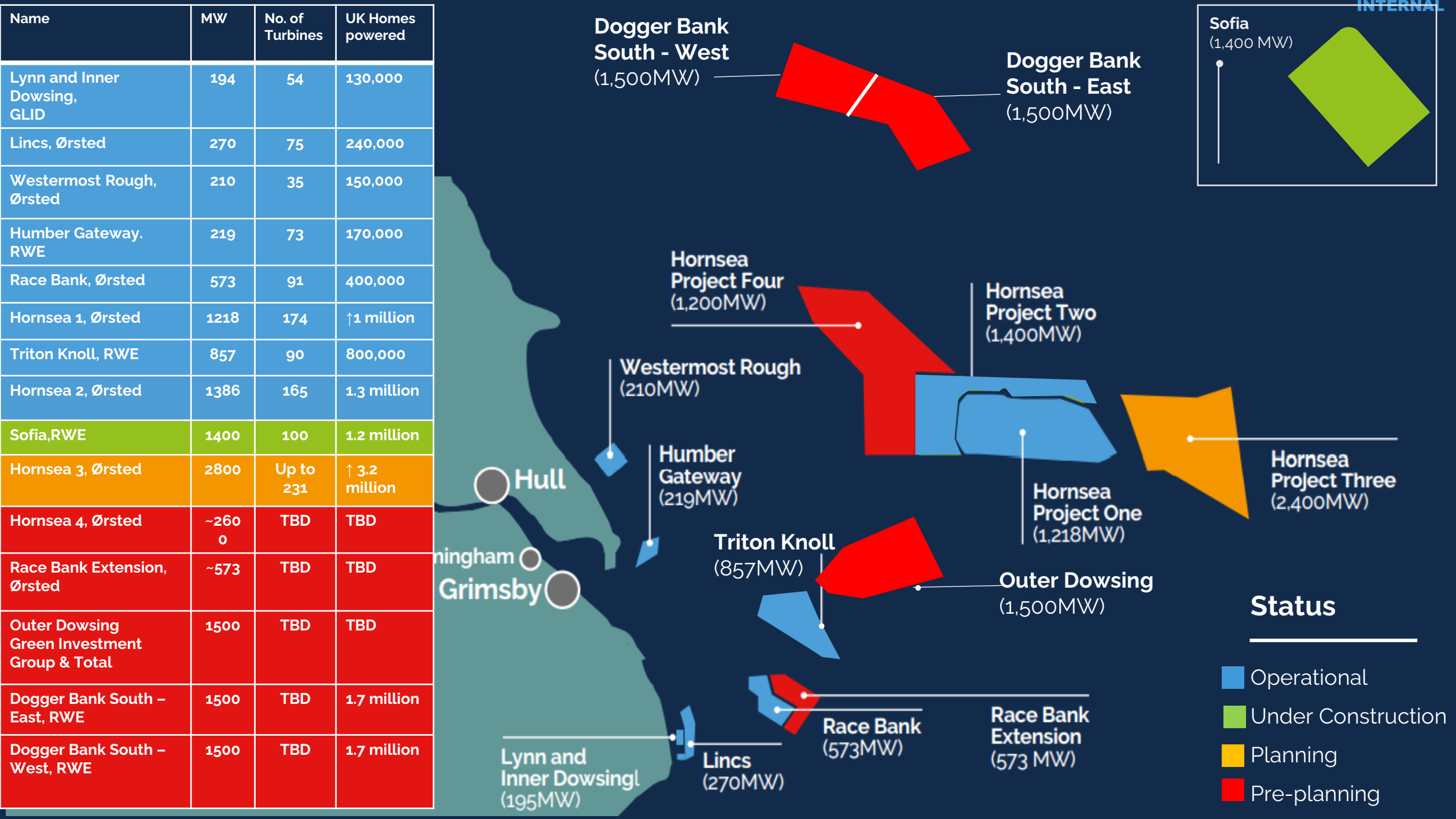
- Unique facilities, research & engineering capabilities
- Accelerating creation and growth of UK companies
- Reducing cost and risk in renewable technologies
- Growing UK economic value
- Enabling the transition to a low carbon economy
- Help the UK economy by enabling innovation

OMCE

At the entrance to Grimsby Docks

Grimsby – home to Operations & Maintenance

Name	MW	No. of Turbines	UK Homes powered
Lynn and Inner Dowsing, GLID	194	54	130,000
Lincs, Ørsted	270	75	240,000
Westermost Rough, Ørsted	210	35	150,000
Humber Gateway. RWE	219	73	170,000
Race Bank, Ørsted	573	91	400,000
Hornsea 1, Ørsted	1218	174	↑1 million
Triton Knoll, RWE	857	90	800,000
Hornsea 2, Ørsted	1386	165	1.3 million
Sofia,RWE	1400	100	1.2 million
Hornsea 3, Ørsted	2800	Up to 231	↑ 3.2 million
Hornsea 4, Ørsted	~2600	TBD	TBD
Race Bank Extension, Ørsted	~573	TBD	TBD
Outer Dowsing Green Investment Group & Total	1500	TBD	TBD
Dogger Bank South – East, RWE	1500	TBD	1.7 million
Dogger Bank South – West, RWE	1500	TBD	1.7 million



Key themes in O&M

Smarter

Data analysis, digital twins, solution simulation, economic analysis

Safer

Robotics and Autonomous Systems (RAS), advanced comms, remote sensors, AR, new tooling, advanced training

Greener

End-to-end Clean O&M: Clean Maritime, Circular Economy, Decommissioning

ADVANCED COMMS/5G

DATA & DIGITAL SERVICES

HUMBER OSW CLUSTER

Hull

GRIMSBY

Operations & Maintenance Centre of Excellence (OMCE)

CLEAN MARITIME

NET ZERO PORT

Link to wider transport network

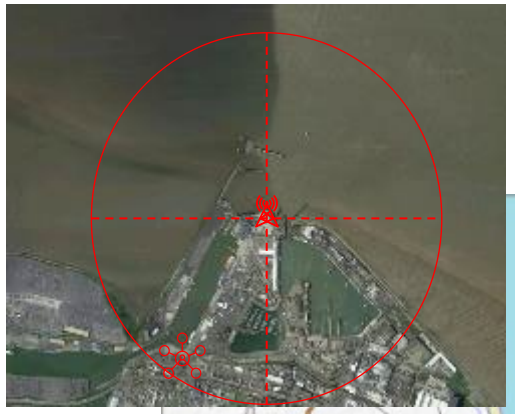
Partner Operational windfarm

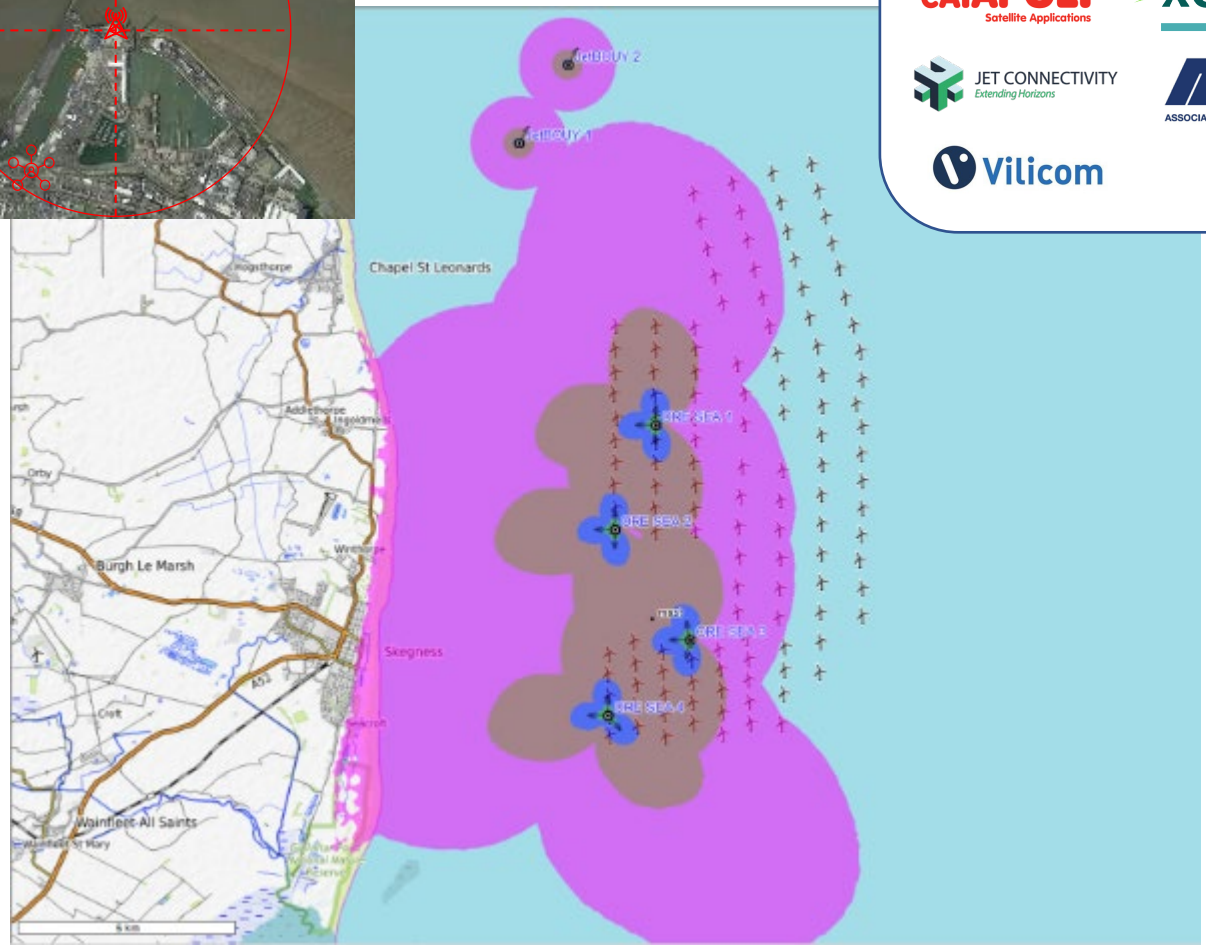
ROBOTICS & AUTONOMOUS SYSTEMS

Applied 5G testbed

Development, demonstration and test zone for:

- Robotics and Autonomous Systems (RAS)
- remote sensors
- Wearables
- advanced communication technologies
- zero emission vessels
- smart ports
- aquaculture…?





Led by: CATAPULT Offshore Renewable Energy

Working with: Microsoft, CATAPULT Satellite Applications, xceco, JET CONNECTIVITY Extending Horizons, ABP Associated British Ports, Vilicom

CONTACT US

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GLASGOW

BLYTH

LEVENMOUTH

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ABERDEEN

CHINA

LOWESTOFT

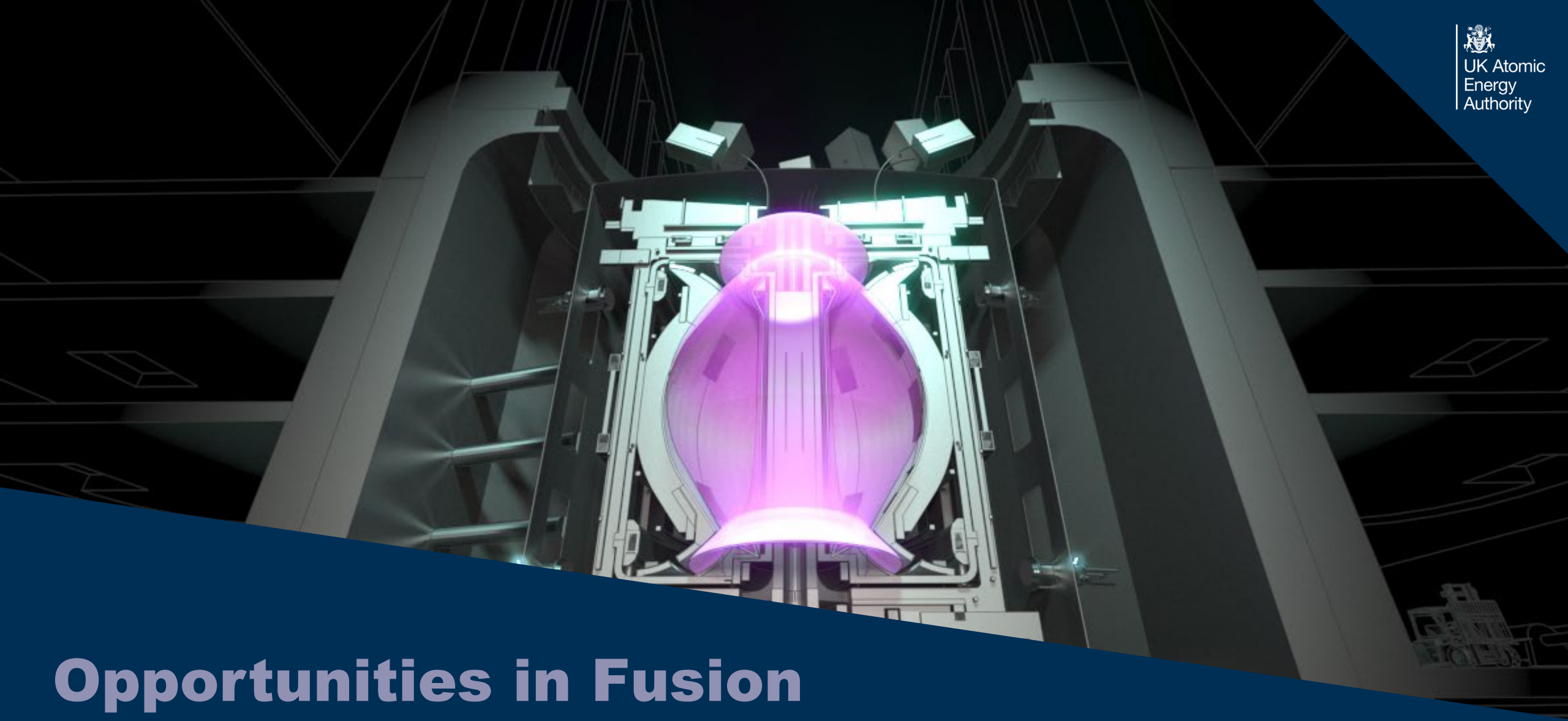
PEMBROKESHIRE

CORNWALL

CATAPULT
Offshore Renewable Energy

Opportunities in Fusion

Paul Goodwin
Group Lead for Manufacturing Technology & Equipment Qualification
UK Atomic Energy Authority



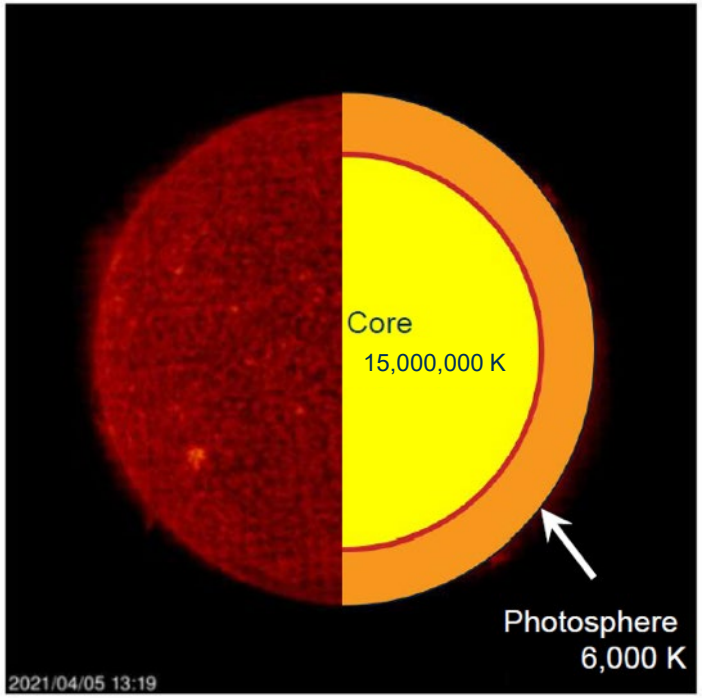
UK Atomic Energy Authority

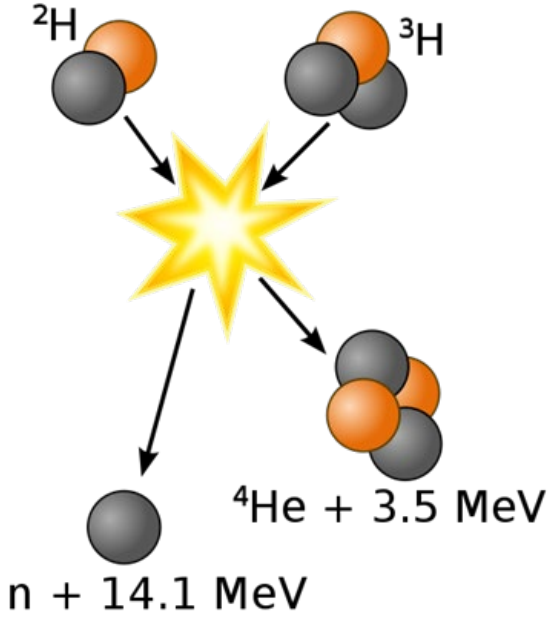
Opportunities in Fusion

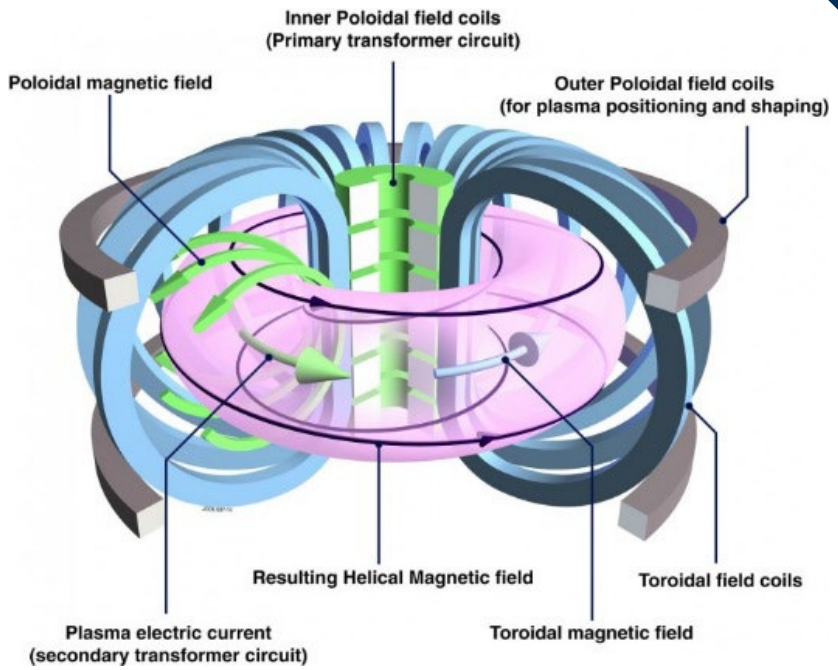
Paul Goodwin
MTEQ Group Lead, FT Division, UKAEA

GLEAM: Manufacturing Net-Zero
22nd November 2023

Fusion overview







In the sun:

- Core temperature of 15,000,000°C.
- Fuse hydrogen isotopes to form He.
- Uses gravity to enable fusion.

Combining small nuclei to release massive energy

In a fusion power plant (tokamak):

- Plasma at 150,000,000°C.
- Fuse hydrogen isotopes; deuterium and tritium.
- Generate 17.6MeV energy per fusion reaction.
- Use a combination of high temperature and magnetic confinement to enable fusion (other methods possible).

Designing a sustainable fusion reaction

UK Atomic Energy Authority

Coal-fired plant = 2.7 MT coal p/a

Fusion plant = 0.25 T DT p/a

- Abundance of deuterium in seawater.
- BUT Tritium is very limited (tens of kgs global supply, almost exclusively from CANDU reactors).

Abundant

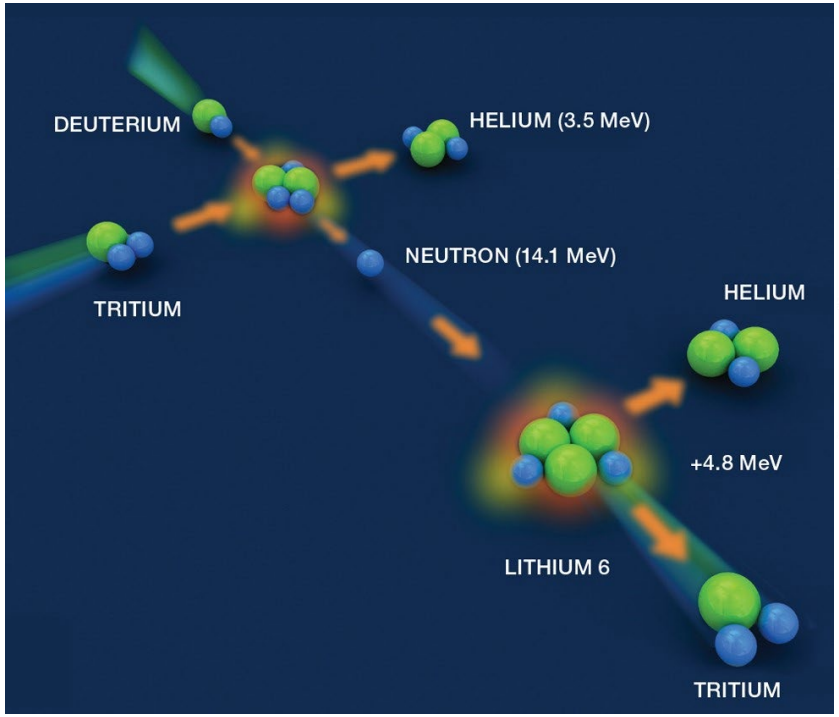
- **Raw fuel available in seawater**

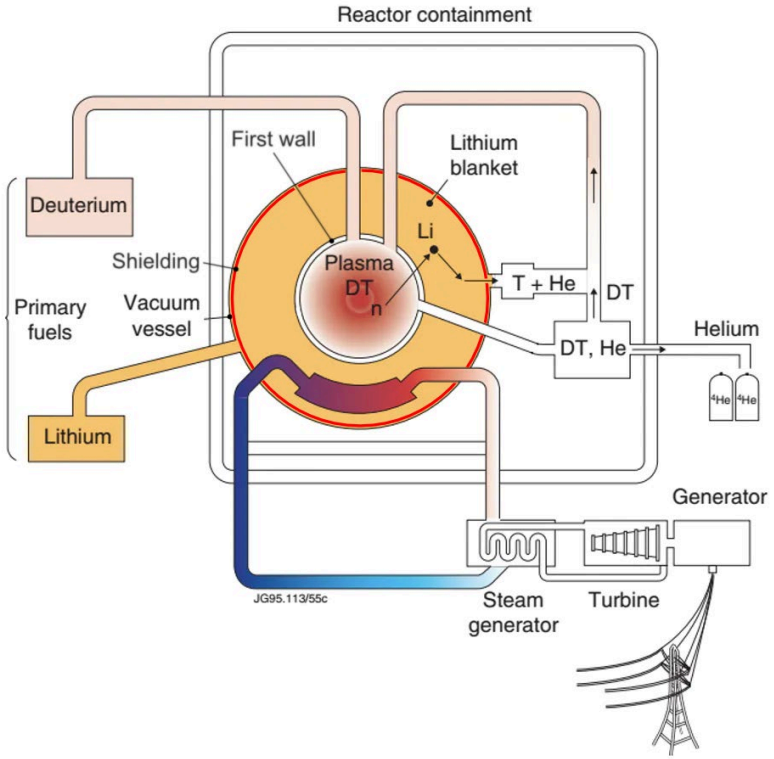
Clean

- **No carbon emissions**
- **No long term nuclear waste**

Safe

- **No chain reaction**
- **Small quantities of stored energy**



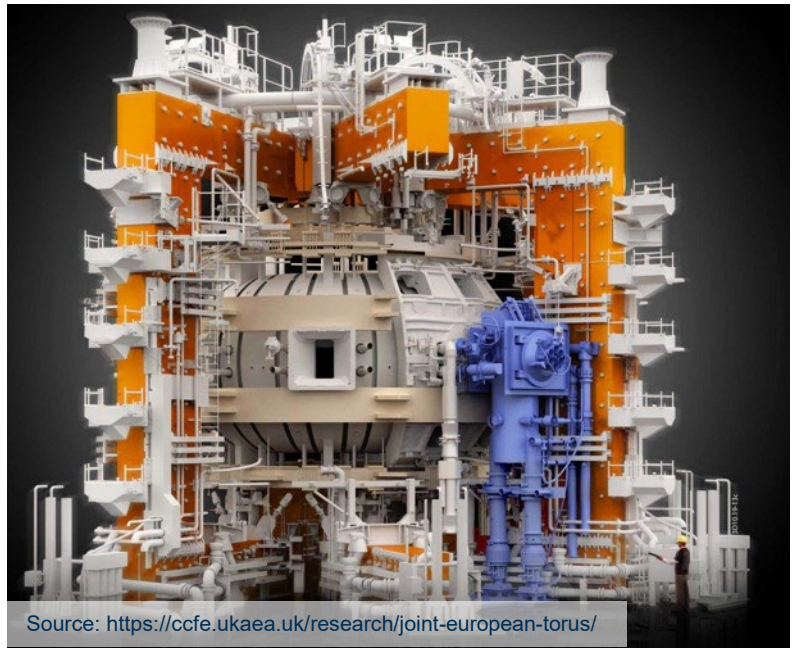


A sustainable tokamak design is required to breed more tritium than it consumes. The concept is to surround the reactor core with a breeder blanket containing Lithium 6 which the passing neutrons convert to helium + tritium (which is then collected and fed back in to the reaction).

Designing to contain a fusion reaction

UK Atomic Energy Authority

Joint European Torus (JET)



Source: https://ccfe.ukaea.uk/research/joint-european-torus/

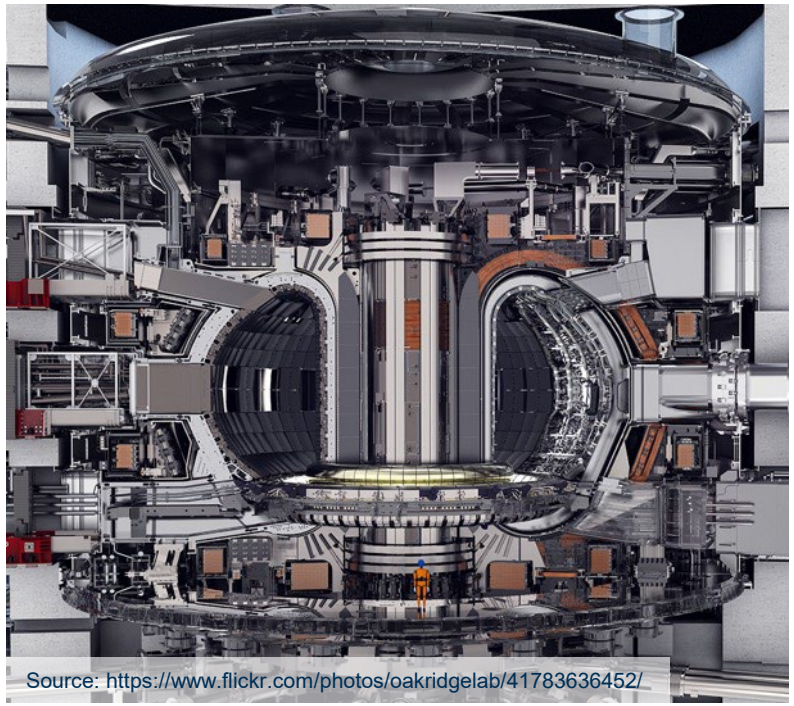
Q = 0.67 (1997 peak record)
Or; Q = 0.3 (2022, longest sustained pulse)

First plasma: 1983

Plasma volume = 100 m^3

No tritium breeding capability.

International Thermonuclear Experimental Reactor (ITER)



Source: https://www.flickr.com/photos/oakridgelab/41783636452/

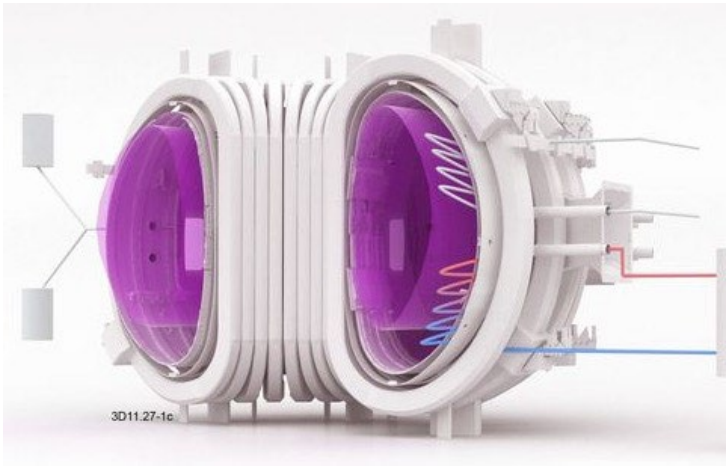
Q = 10

First plasma: ~~2025~~ 2027

Plasma volume = 830 m^3

Test blanket module (TBM), tritium breeding system test capability.

DEMOnstration power plant



Source: https://www.euro-fusion.org/news/2020/december/expert-panel-approves-next-demo-design-phase/

Q = 25

First plasma: ~2050

Plasma volume = 1500 - 2500 m^3

Full tritium breeding capability.

Commercial fusion power

UK Atomic Energy Authority

To lead the delivery of sustainable fusion energy and maximise the scientific and economic benefit.

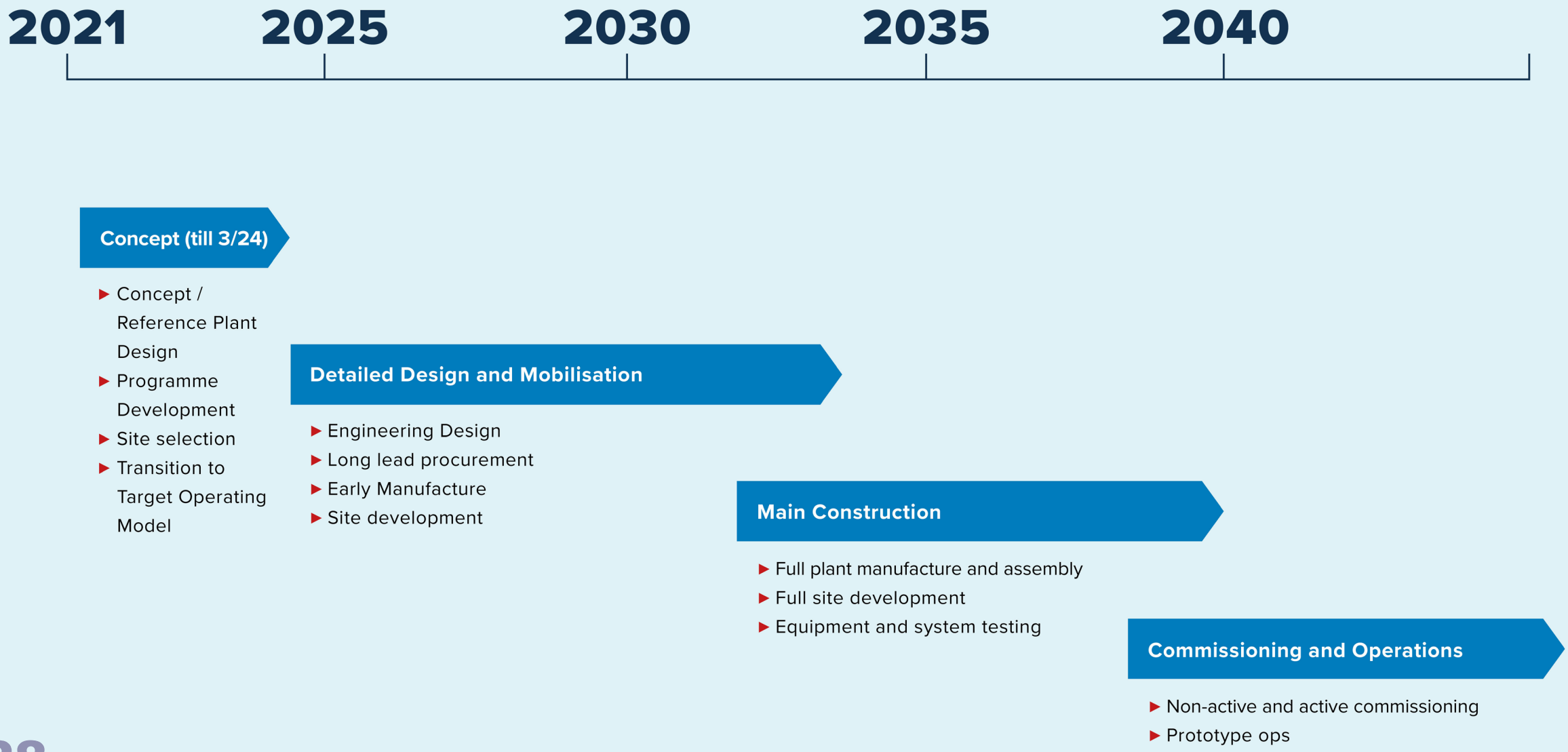
UKAEA mission

Deliver a UK prototype fusion energy plant, targeting 2040, and a path to commercial viability of fusion.

STEP mission

STEP high-level schedule

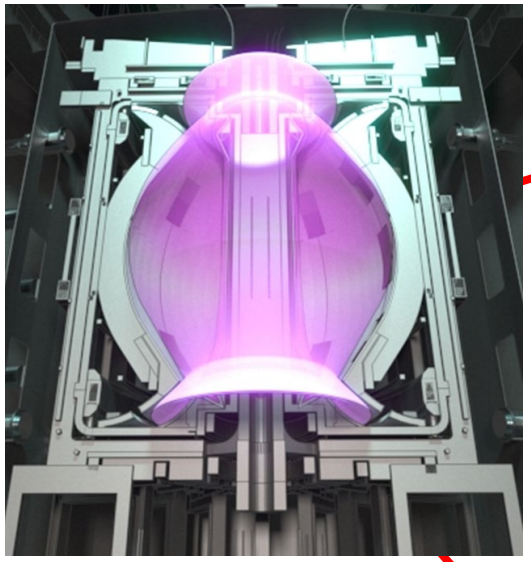
UK Atomic Energy Authority

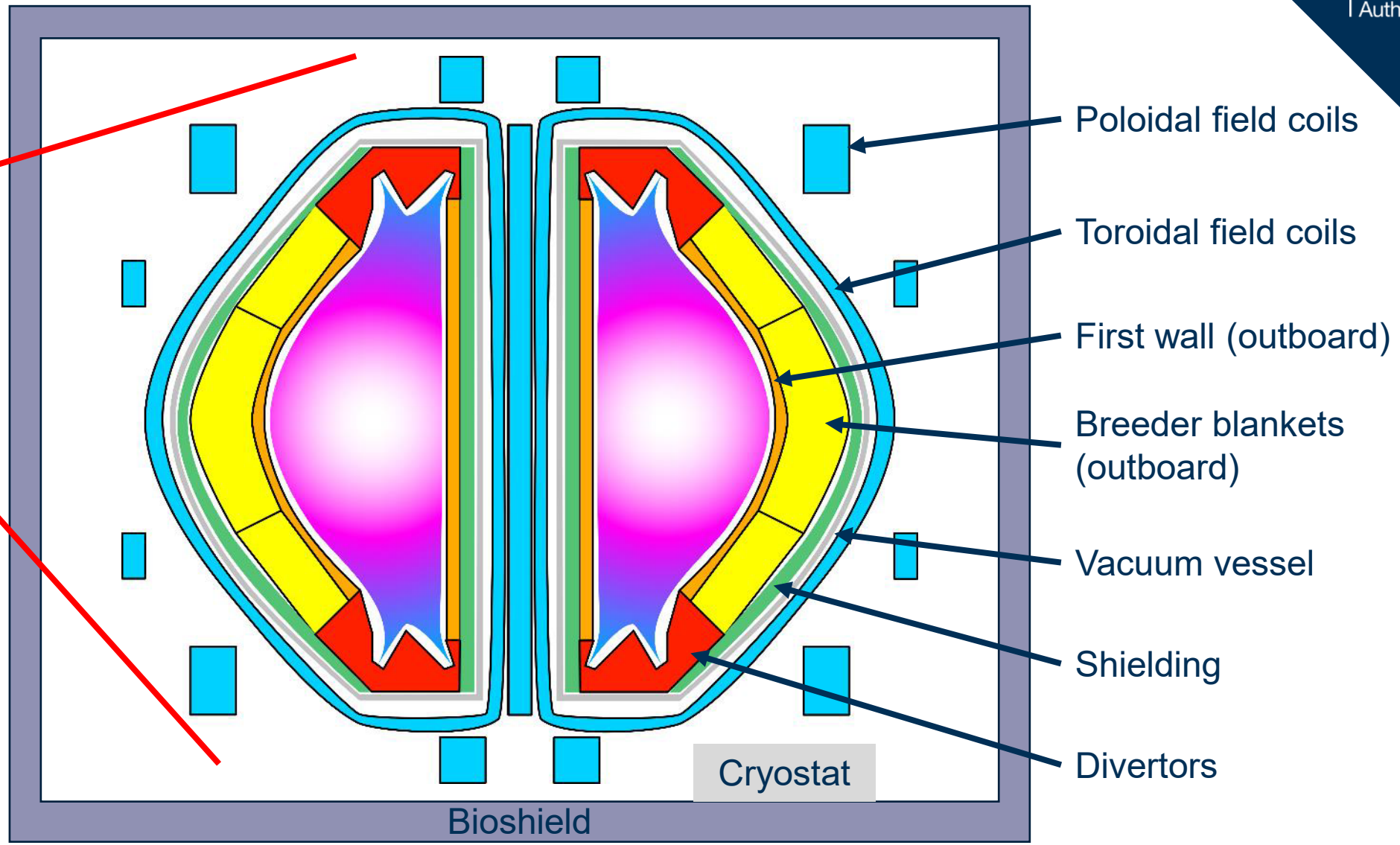


West Burton – the home for STEP

UK Atomic Energy Authority

Designing to contain a fusion reaction





Materials challenges

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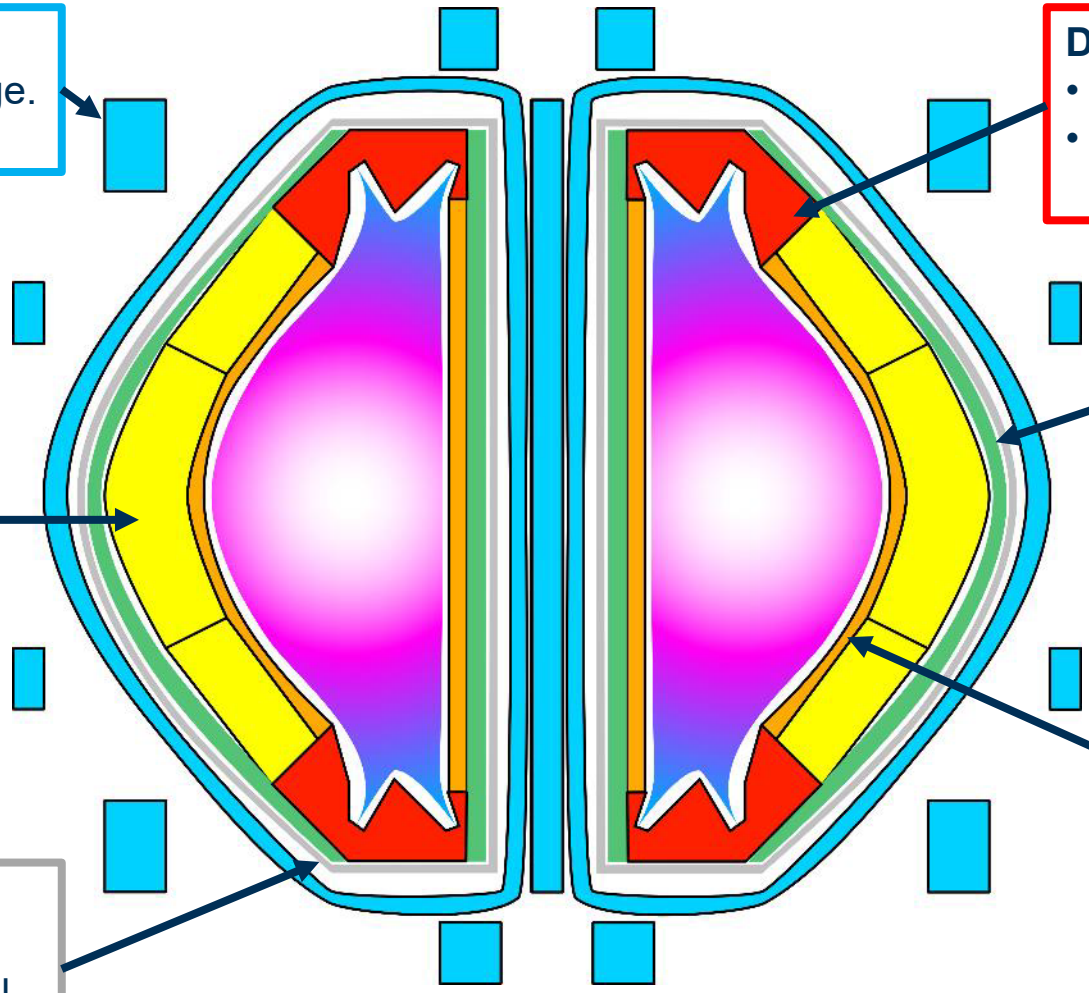
Magnets
- Very sensitive to neutron damage.
- Cooled to ~20K.

Blankets
- High temperatures (550°C+).
- Radiation damage (100's dpa) and transmutation effects.
- Corrosion effects.
- Creep effects.
- Limiting tritium ingress.
- Magnetic field interactions (magnetohydrodynamics).
- Waste considerations.

Vacuum vessel
- Maintain high vacuum.
- Maintain integrity – safety critical component.



Divertors
- Heat loads up to 20 MW/m^2.
- Plasma effects (erosion, sputtering…)

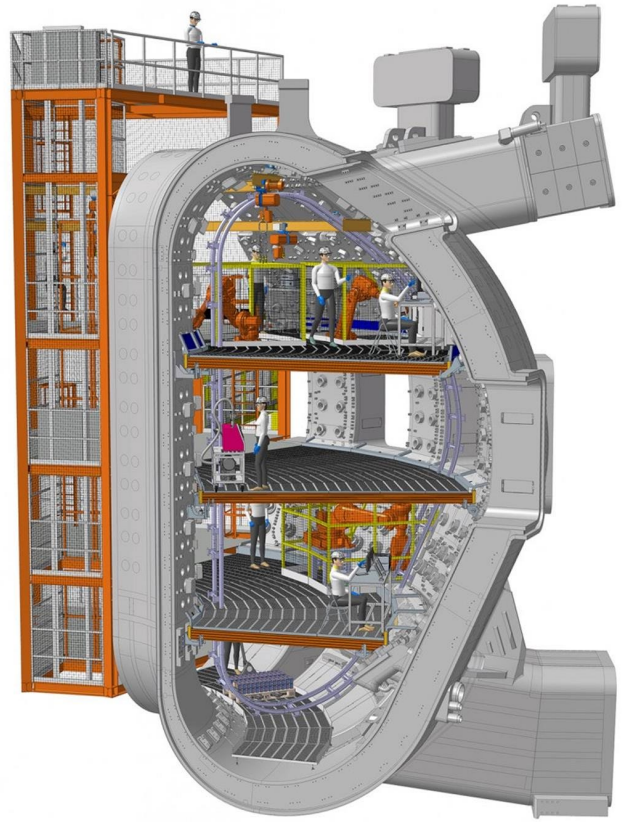
Shielding
- Protect the magnets from neutrons.
- Maximise efficiency in small volumes.
- Operate in temperatures of 1000°C+.

First wall / armour
- Protect underlying material from plasma.
- Heat loads up to 5MW/m^2.
- Plasma effects (erosion, sputtering…).

Challenge example: ITER Vacuum Vessel

UK Atomic Energy Authority

- Material manufacture
  - Over 5200 tonnes (nett after manufacturing) of nuclear grade steel
- Forming
  - Complex 3D geometries required
  - Large variance in size and geometry
  - Heavy plant required
- Welding
  - Over 15 km of full penetration EB and TIG welds
  - 25 tonnes of filler metal
  - ~150 coded welders working two daily shifts for four years
- NDE
  - 100% volumetric inspection of all welds



Component Manufacturing options

Drivers: ability to manufacture the design; desire to eliminate joints; desire for ‘near net shape’ components; desire to allow maintenance / repair to maximise plant availability, controlled costs

Forging + machining	conventional; understood; can be wasteful in material; long lead times
Advanced Casting	issues with defects; microstructure variations with cooling in different cross sections
Near net shape HIPing	moderate TRL; needs development; powder quality and handling; HIP facilities limited in size
Additive manufacturing	allows complex geometries; lower TRL; needs development; defect control required

Joining of dissimilar metals: steel / CuCrZr / W	without introducing weak weld zones; EB welding; friction welding; diffusion or HIP bonding

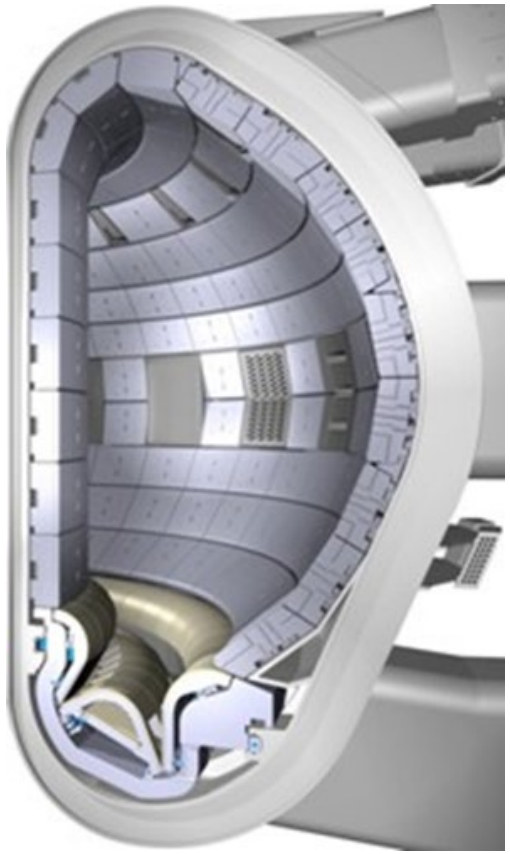
Component Manufacturing options

There is no ‘one size fits all’ manufacturing route and all may potentially have to be used in combination to manufacture the required tokamak components.

All offer potential benefits in terms of component performance, manufacturability, etc but have issues with:

- current MRL vs required MRL
- scalability
- cost to develop; time to develop
- supply chain maturity, viability and capacity
- cost of manufacture
- how to qualify manufacturing process and components for service

MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
Manufacturing feasibility assessed	Manufacturing concepts defined	Manufacturing concepts developed	Capability to produce the technology in a laboratory environment	Capability to produce prototype components in a production relevant environment	Capability to produce a prototype system or subsystem in a production relevant environment	Capability to produce systems, subsystems or components in a production representative environment	Pilot line capability demonstrated. Ready to begin low rate production	Low rate production demonstrated. Capability in place to begin full rate production	Full rate production demonstrated and lean production practices in place



Fusion - A major manufacturing challenge and opportunity

UK Atomic Energy Authority

The Role of Hydrogen in Net Zero

Cedric Hanson
Business Development Manager Applications
BOC Ltd.

The Role of Hydrogen in Net Zero

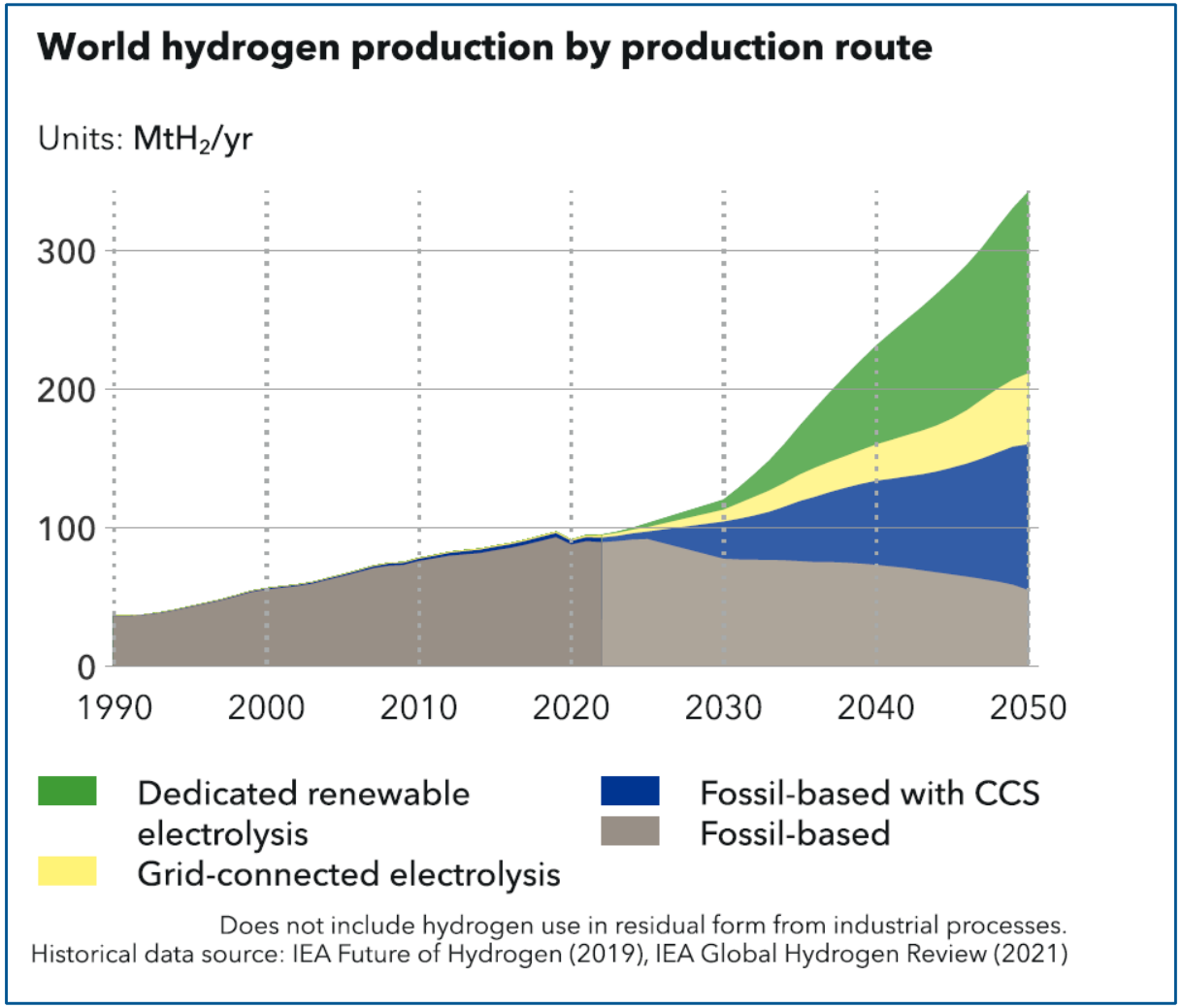
Cedric Hanson
Business Development Manager
BOC Ltd

Making our world more productive

World Production of Hydrogen 1990 - 2050

Low-carbon Hydrogen

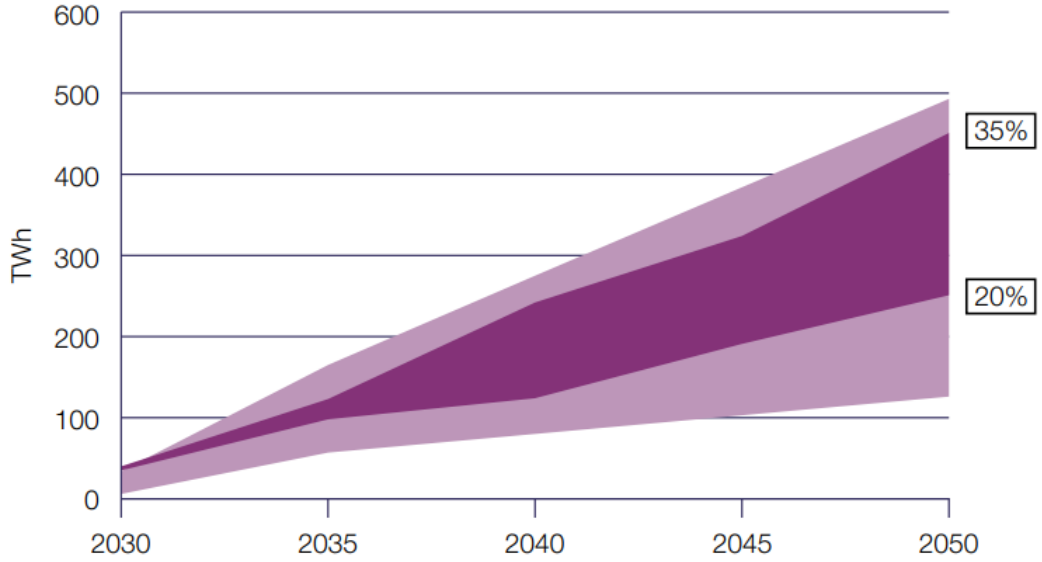
Early Days..



Only By Accelerating Access to Hydrogen Can we Unlock Net Zero

- Hydrogen can carry energy to hard-to-decarbonise sectors with no greenhouse gas emissions at point of use.
- Achieving the UK's ambitions to produce 10 GW (90TWh/year) of low-carbon hydrogen by 2030 will require significant and rapid advances in the scale of current capacity and end-uses.
- Low-carbon hydrogen will be **essential for**
  - Meeting the UK's CB6 target to reduce emissions **78 per cent on 1990 levels by 2035.**
  - **Achieving net zero by 2050**
- UK Gov analysis suggests **250-460TWh** of hydrogen could be needed in 2050
  - making up **20%-35%** of UK final energy consumption

Figure 1.2: Hydrogen demand and proportion of final energy consumption in 2050



% = hydrogen as proportion of total energy consumption in 2050

Source: Central range – illustrative net zero consistent scenarios in CB6 Impact Assessment. Full range – based on whole range from UK Hydrogen Strategy Analytical Annex. Final energy consumption from ECUK (2019).

Lsource: UK Hydrogen Strategy 2021; UK Hydrogen Strategy (publishing.service.gov.uk)

Climate Change Committee (CCC): Carbon Budgets

All six carbon budgets have been put into law and run up to 2037. The UK is currently in the third carbon budget period (2018 to 2022).

Budget	Carbon budget level	Reduction below 1990 levels	Met?
1st carbon budget (2008 to 2012)	3,018 $MtCO_2e$	25%	Yes
2nd carbon budget (2013 to 2017)	2,782 $MtCO_2e$	31%	Yes
3rd carbon budget (2018 to 2022)	2,544 $MtCO_2e$	37% by 2020	On track
4th carbon budget (2023 to 2027)	1,950 $MtCO_2e$	51% by 2025	Off track
5th carbon budget (2028 to 2032)	1,725 $MtCO_2e$	57% by 2030	Off track
6th carbon budget (2033 to 2037)	965 $MtCO_2e$	78% by 2035	Off track
Net Zero Target		At least 100% by 2050	

Advice on reducing the UK's emissions - Climate Change Committee (theccc.org.uk)

BOC Supporting Greater Lincolnshire and UK industry

BOC Scunthorpe Air Separation Plant

BOC Immingham Special Gases Plant

BOC's Hydrogen Plant, Teesside

The scale of the challenge – Fossil 80% Electric 20%

Gas Pipes

736 Twh

Electricity Pylons

275 Twh

Petroleum Pipes

634 Twh

Source:- C Stait form internet public domain information and calculation

Options in the future for Industry

Fuel Switch

Reheat furnace on hydrogen

Electrification

Induction melting

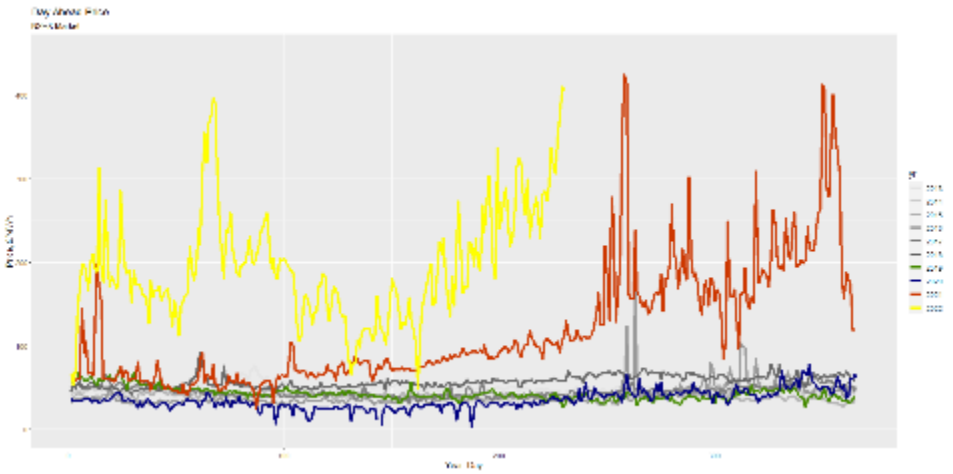
CCUS

Linde carbon capture plant

Today's Drivers

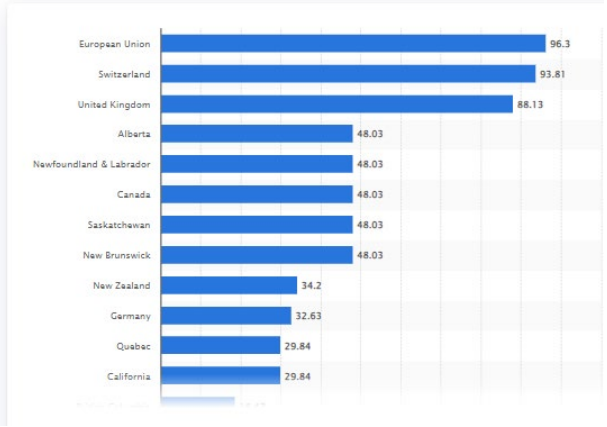
Price volatility

High energy price



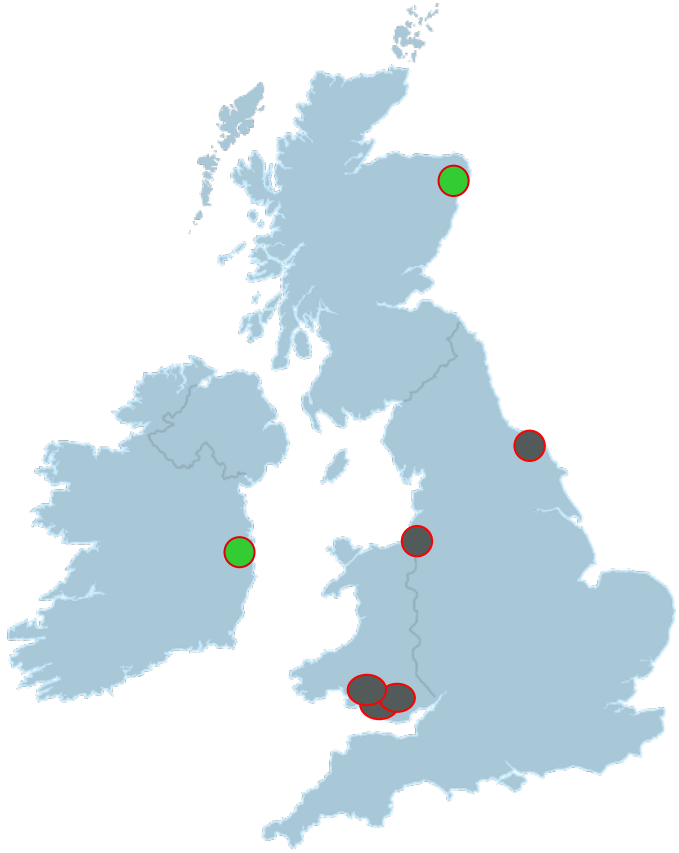
Carbon compliance

(in U.S. dollars per metric ton of CO_2 equivalent)



Prices of carbon trading worldwide 2023, by jurisdiction
Published by Ian Tiseo, Jul 6, 2023

BOC's Hydrogen Production Plants in the UK and Ireland



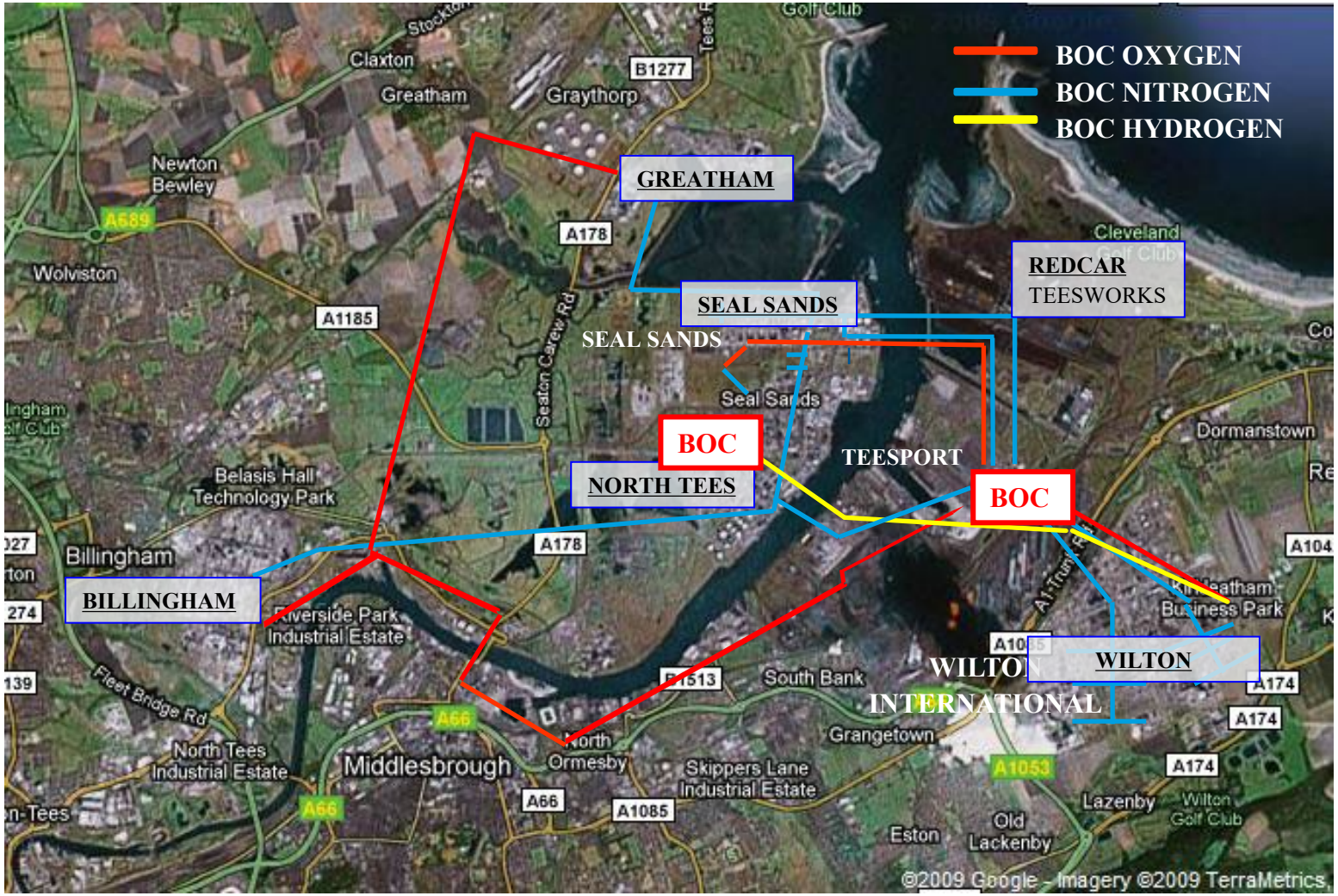
H2 production - electrolysis

H2 production – steam methane reforming

– 7 hydrogen production plants

BOC Middlesbrough, Teesside – Large Scale Hydrogen Example

Pipeline Grid Connecting Our Customers



Teesside Hydrogen

- One of the UK's largest Steam Methane Reformers (SMR) brought on stream in 2002
- **24/7/365** operation
- Manned by **single operator** with back up by BOC's **Remote Operating Centre at Sheffield**
- Hydrogen is supplied by **pipeline** to the Wilton International complex over 8 km away
- Hydrogen **trailer filling** is available for customers not connected to the pipeline and takes place at the air separation facility at Teesport

Teesside Hydrogen CO2 Capture

- The existing SMR is based on the SABIC North Tees site
- Our intention is to construct the **CO2 capture plant** in the area marked in **red.**
- Proximity to the proposed **Northern Endurance Partnership** CO2 capture pipeline routing is favourable
- If we are successful in obtaining funding under the Cluster Sequencing competition the installation of the capture facility will convert our hydrogen production from **grey to blue**
- Blue hydrogen is seen a key enabler in transitioning industry to a low carbon future

Post Combustion Capture Plant

- The **Post Combustion Carbon Capture plant** will be designed and constructed by BOC's sister company **Linde Engineering**
- Linde Engineering are one of the world's leading EPC contractors with many years of experience in constructing and commissioning capture facilities
- It is envisaged that the facility will capture over **200,000 tonnes of CO2 per year**
- In keeping with the Cluster Sequency Competition timeline, if BOC successful with our application the facility will be **onstream in 2027**

View of a typical PCC installation

Supporting the transition

Consumer Products

- **Hydrogen as a replacement fuel in a boiler**
- **Proving mixtures up to 100% hydrogen**
- **Safe and reliable operation of an industrial hydrogen fired boiler demonstrated**

Glass

- World first, successful production of float glass using hydrogen
- 100% Hydrogen firing achieved - Glass unaffected
- Customer – '**Demonstrate feasibility of Hydrogen Conversion**' – **Achieved**
- BOC – 'Demonstrate delivery of large scale H2 trial' – **Achieved**
- 8 x 2900Sm3 BOC tube trailers per day
- approx. 100 tube trailers supplied for project

Minerals

- **World First Net Zero Fuel mix for clinker production**
- **Up to 10 trailers per day**
- **Clinker production unaffected**
- **Max flow rate of ~3500+ Sm3/hr achieved (1 x trailer every 25 mins)**

Important Uses of Hydrogen: Chemicals

DRI Iron for Green Steel

The future is here – the world's first vehicle made with fossil-free steel

In a world-first, Volvo Group has unveiled the first vehicle made of SSAB's fossil-free steel. A load carrier for use in mining and quarrying represents the first leg of the journey towards a decarbonized future.

Read more

Breaking new ground in sustainable mining

Epiroc has developed the world's first underground mining truck with a dump box made from fossil-free steel.

Learn more

SSAB and TRIWA present the world's first consumer product made using fossil-free steel – a watch

The unique watch, named Time for Decarbonization, has been created using fossil-free steel powder.

Read more

Other High Heat Processes – Cement, Lime, Glass

Marine – as methanol or ammonia fuel

Jet Aviation

Trucks, Coaches, Rural Trains

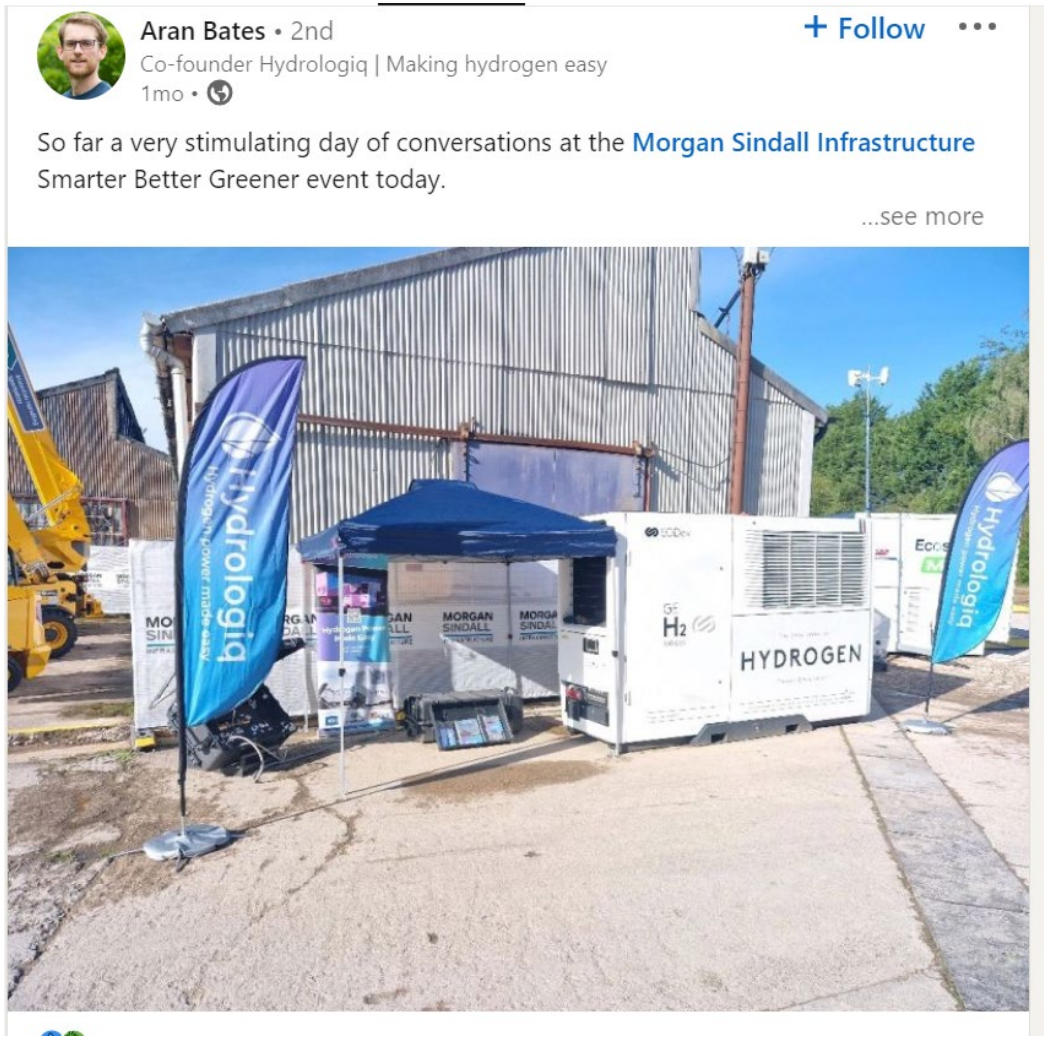
Non-Road Mobile Machinery

Mobile Generators

Image Credit: BOC

BOC's HYMERA is the world's first commercially viable, low-carbon, hydrogen fuel cell generator and offers a convenient alternative to diesel generators. Hydrogen Industry Leaders investigates why HYMERA is so essential and how it is powering narrowboats with hydrogen.

Providing up to 175 watts of peak power whenever and wherever it is needed, HYMERA is explained by BOC as incorporating ground-breaking hydrogen fuel cell technology, which produces electricity from the reaction between hydrogen and oxygen from the air.



Fusion Energy – Hydrogen and its Isotopes

The time to act is now..

The financial drivers to change to a decarbonized operation are here today and will get stronger

Hydrogen is a suitable fuel for the replacement of hydrocarbons in many processes

Process optimization & intensification will mitigate today's costs, ready for CCUS tomorrow

BOC can supply technology, assets and industrial gases to support your path towards decarbonisation

Thank you for your attention.

Cedric Hanson C.Eng, MBA, FIChemE - Business Development Manager Applications, BOC

cedric.hanson@boc.com

Heating Values of Various Fuels

- https://world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx

- Hydrogen 120-142MJ/kg
- Petrol 44-46MJ/kg
- Diesel 42-46MJ/kg
- Crude oil 42-46MJ/kg
- Hard Black Coal 23.9MJ/kg
- Bituminous 17.4-23.9 MJ/kg
- Brown Coal (lignite) <17.4MJ/kg

WORLD NUCLEAR ASSOCIATION

Heat Values of Various Fuels

The heat value of a fuel is the amount of heat released during its combustion. Also referred to as energy or ca value, heat value is a measure of a fuel's energy density, and is expressed in energy (joules) per specified amo (*e.g.* kilograms).

	Heat value
Hydrogen (H_2)	120-142 MJ/kg
Methane (CH_4)	50-55 MJ/kg
Methanol (CH_3OH)	22.7 MJ/kg
Dimethyl ether - DME (CH_3OCH_3)	29 MJ/kg
Petrol/gasoline	44-46 MJ/kg
Diesel fuel	42-46 MJ/kg
Crude oil	42-47 MJ/kg
Liquefied petroleum gas (LPG)	46-51 MJ/kg
Natural gas	42-55 MJ/kg
Hard black coal (IEA definition)	>23.9 MJ/kg
Hard black coal (Australia & Canada)	c. 25 MJ/kg
Sub-bituminous coal (IEA definition)	17.4-23.9 MJ/kg
Sub-bituminous coal (Australia & Canada)	c. 18 MJ/kg
Lignite/brown coal (IEA definition)	<17.4 MJ/kg
Lignite/brown coal (Australia, electricity)	c. 10 MJ/kg
Firewood (dry)	16 MJ/kg
Natural uranium, in LWR (normal reactor)	500 GJ/kg
Natural uranium, in LWR with U & Pu recycle	650 GJ/kg
Natural uranium, in FNR	28,000 GJ/kg
Uranium enriched to 3.5%, in LWR	3900 GJ/kg

Uranium figures are based on 45,000 MWd/t burn-up of 3.5% enriched U in LWR
MJ = 10^6 Joule, GJ = 10^9 J
MJ to kWh @ 33% efficiency: x 0.0926
One tonne of oil equivalent (toe) is equal to 41.868 GJ

Hydrogen Sector Developments and Links with CCUS in the Humber

Ian Livingston
Project Manager – Humber Cluster
UK Low Carbon Solutions
Equinor ASA

GLEAM NETWORK

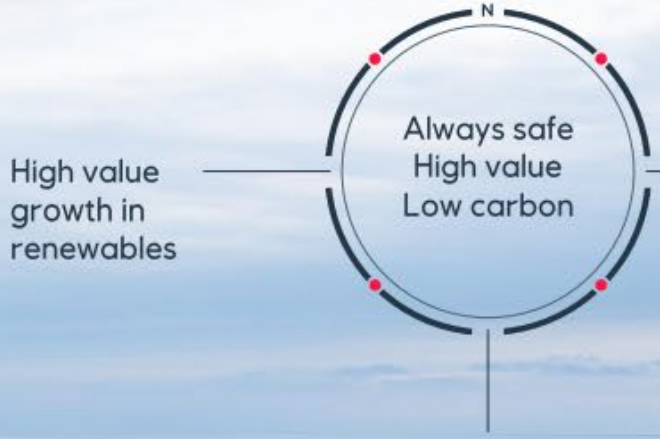
Building a Hydrogen Economy in the Humber

GLEAM Presents: Manufacturing for Net-Zero with ORE Catapult

22nd November 2023

Firm on our strategy

We are committed to turning natural resources into energy for people and progress for society



Shaping the future of CCS and low-carbon hydrogen

15-30 MTPA

CO_2 transport and storage capacity by 2035

Equinor share

>25%

CO_2 transport and storage market share in Europe by 2035

3-5 MAJOR INDUSTRIAL CLUSTERS

Clean hydrogen projects by 2035

>10%

Clean hydrogen market share in Europe by 2035

Equinor's CO_2 T&S, hydrogen and CCS post combustions portfolio

Transport & Storage (T&S)

2024>

Northern Lights

- CCS for industry
- Transport of CO2 by ship
- Open/ flexible

North Sea Basin

- In-house general screening
- Saline and depleted fields

Polaris

- Storage solution for Barents Blue
- Offshore off-loading concept

2026

Northern Endurance Partnership

- Pipeline transport
- Storage for Humber and Teesside
- Potential scale-up opportunities identified

2029

Tri-State

- Supply hydrogen and collect CO_2 in a large US industrial area
- Offer geological CO_2 storage for industrial decarbonisation

Blue/green H2 and low carbon power

2025

Hydrogen Norway

- Liquid hydrogen for maritime
- Distribution of H2
- Integration with existing onshore plants
- H2/Ammonia – Barents Blue

2026

Zero Carbon Humber

- Hydrogen for industry/power
- Blue Ammonia

Post-combustion portfolio

CCGT with CCS for industry

- Net Zero Teeside
- SSE Peterhead
- SSE Keadby 3

2027/28

NW Europe

- Hydrogen for industry (H2morrow steel)
- Hydrogen to power/industry (Magnum)
- Flexible back-up for intermittent renewable
- Market based H2 approach

2027

NorthH2

- Hydrogen production from offshore (wind) renewable
- H2 for industry
- Back-up renewable intermittence

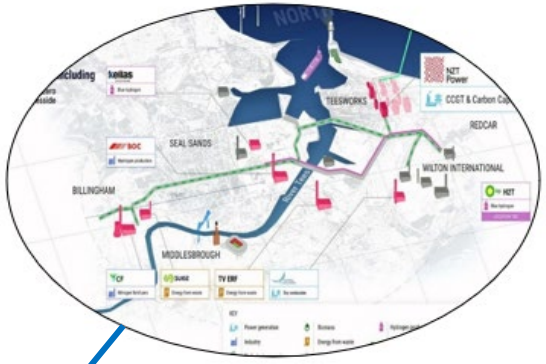
Progressing where advanced CCS/H2 policies | Require large CO_2 storage capacity

Industrial Cluster Projects

UK Research and Innovation

Scotland Net Zero Infrastructure

(onshore & offshore)

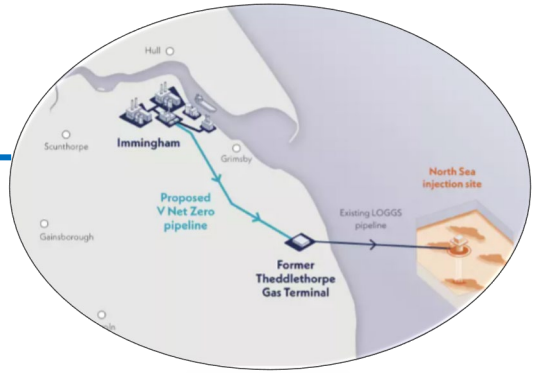


Net Zero Teesside

Northern Endurance Partnership

HyNet North West

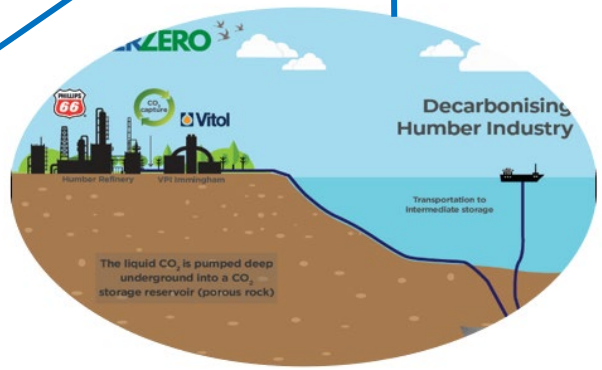
(onshore & offshore)



VikingCCS

Viking CCS pipeline

SWIC
South Wales Industrial Cluster



HUMBERZERO

ZEROCARBON HUMBER

EAST CO_2AST CLUSTER

NORTH SEA

Northern Endurance Partnership

145km

103km

REDCAR

MIDDLESBROUGH

DARLINGTON

HULL

YORK

GRIMSBY

SCUNTHORPE

LEEDS

SHEFFIELD

KEY
Phase 2 shortlisted projects

PROJECTS IN TEESSIDE	UP TO 10 MTPA CO_2 CAPTURED

INDUSTRIAL CARBON CAPTURE
- CF Fertilisers Billingham Ammonia CCS
- Norsea Carbon Capture
- Redcar Energy Centre
- Tees Valley Energy Recovery (TVERF)
- Teesside Hydrogen CO2 Capture
- Lighthouse Green Fuels
- STV 1+2 Energy from Waste Carbon Capture
- STV 3 Energy from Waste Carbon Capture
- Teesside Green Energy Park Limited

HYDROGEN
- bpH2Teesside
- H2NorthEast

POWER
- Net Zero Teesside Power
- Whitetail Clean Energy
- Alfanar CCGT Teesside

PROJECTS IN THE HUMBER	17+ MTPA CO_2 CAPTURED

BIOENERGY WITH CCS
- North Yorkshire Power Station

INDUSTRIAL CARBON CAPTURE
- Humber Zero - Phillips 66 Humber Refinery
- Prax Lindsey Oil Refinery Carbon Capture
- ZerCaL250
- Altalto Immingham waste to jet fuel
- North Lincolnshire Green Energy Park
- Saint-Gobain Glass Carbon Capture

HYDROGEN
- Hydrogen to Humber (H2H) Saltend
- Uniper Humber Hub Blue Project

POWER
- Keadby 3 Power Station
- C.GEN Killingholme
- VPI Humber Zero

H2H Saltend

- 600 MW blue hydrogen plant
- Minimum 95% CO_2 capture (~0.9 MTPA)
- Location in Saltend Chemicals Park in Hull, UK
- Target start-up in 2028, pending access to CO_2 T&S
- FEED and EPC option awarded to Linde Engineering. 4-year O&M by BOC
- Decarbonising offtakers within power, chemicals, feedstock and heat
- Steppingstone towards UK target of 10 GW H_2 deployed by 2030
- Potential public private partnership through funding. Due diligence ongoing
- CO_2 Transport & Storage by Northern Endurance Partnership (NEP)

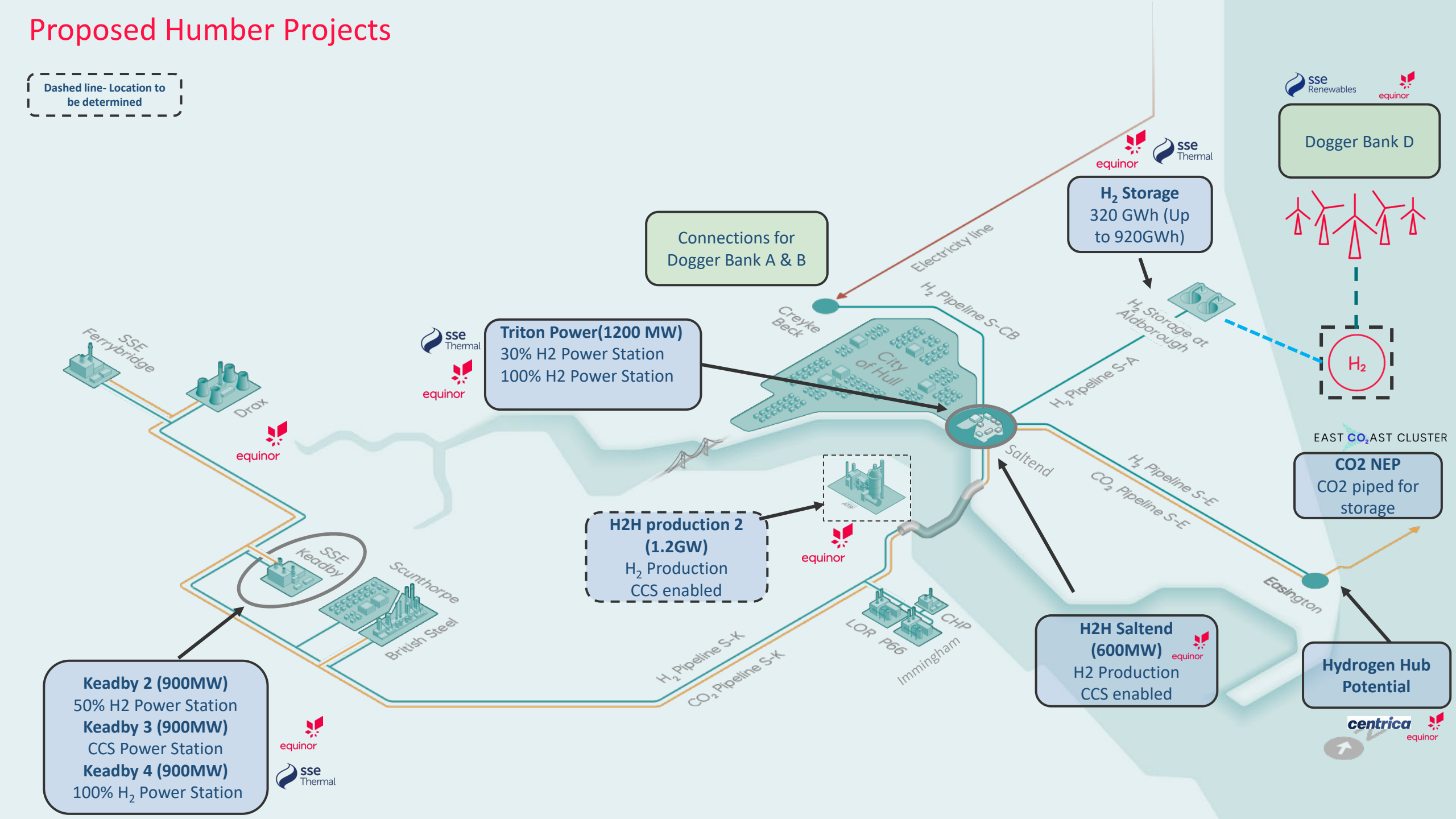
FEED / EPC / O&M Contract

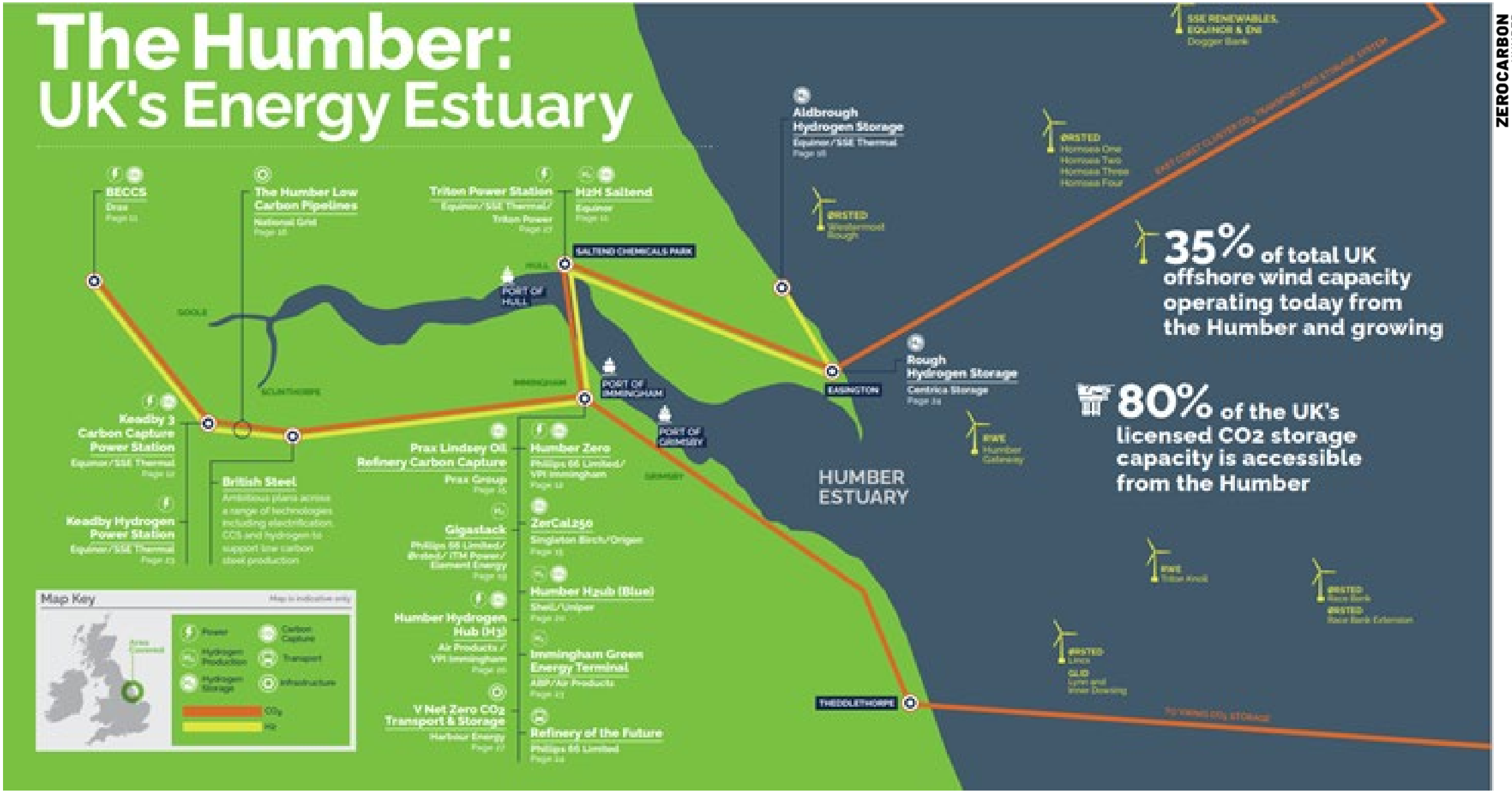
Linde

BOC
Member of The Linde Group

JM Johnson Matthey
Inspiring science, enhancing life

Proposed Humber Projects





https://investhumber.com/documents/HED-Brochure.pdf

Open

Opportunities for Rare Earths for EVs and Wind Turbines

William Izod
Chief Commercial Officer
Pensana

Developing an independent and sustainable supply of magnet metals in support of Net-Zero

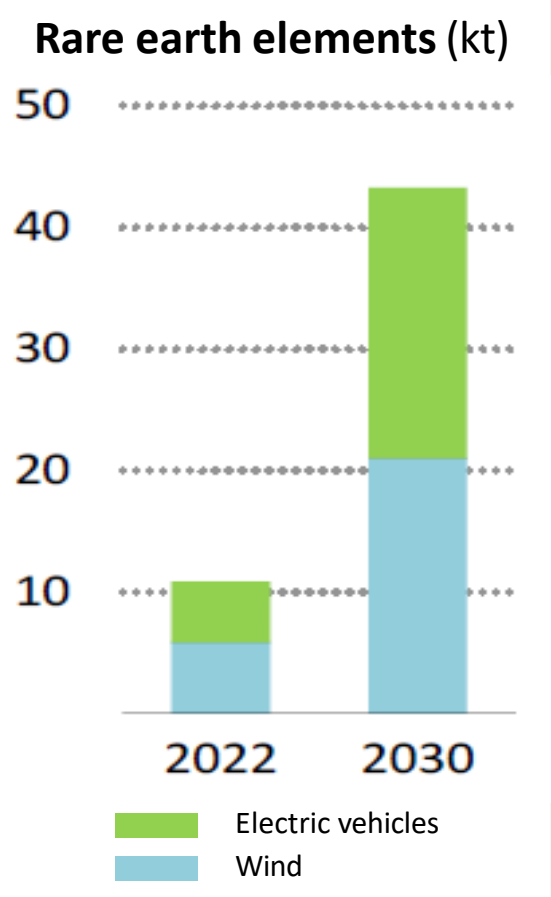
November 2023 | **LSE:PRE**

IEA World Energy Outlook 2023: Electric Vehicles to increase 10-fold by 2030 amid ‘unstoppable’ net zero shift

The transition to clean energy is happening worldwide and it’s unstoppable. Electric vehicles are now expected to have a global market share of 38% of new sales by 2030.

Rapid uptake in EVs in recent years with projections now showing more than 220 million passenger cars on the road in 2030, a 20% increase in the 2020 outlook.

Long lead times for mines and the associated infrastructure mean that scaling up supplies takes time, raising the risk of supply bottlenecks.



Demand for rare earths expected to increase by almost 400% by 2030 under IEA APS

Source: International Energy Agency: World Energy Outlook 2023

PENSANA Plc

Establishing a magnet metal supply chain to support automotive Electronic Drive Unit (EDU) and offshore wind manufacture in the UK

Saltend Chemicals Park, Humber Freeport

Fully engineered and permitted downstream UK Separation Facility.

Strategically located within Humber Freeport and powered by low-cost offshore wind

Designed to produce 12,000 tonnes of TREO and 4,400 tpa of NdPr oxides equivalent to ~5% of world demand.

Will create 450 jobs during construction and 150 high-value full-time jobs.

Looking to Establish an Independent Downstream Supply Chain

Mine & Processing

- 40,000 tpa MREC
- Offtake underway
- Capex stage 1 US$200m
- Capex stage 2 US$105m
- Financing: ABSA, FSDEA & multilaterals

Saltend Chemicals Park

- 12,500 tpa TREO
- 4,400 tpa NdPrO
- Fully Engineered & Permitted
- 25% Japan Offtake
- Capex US$250m
- Proposed Finance: ABGSC Green Bond, recently announced ATF grant.

Yorkshire Energy Park

- 4,000 tpa NdPr alloy
- Low electricity cost
- Offshore Wind zero carbon PPA from UK Gov.
- Scoping Study underway
- Capex US$80 million

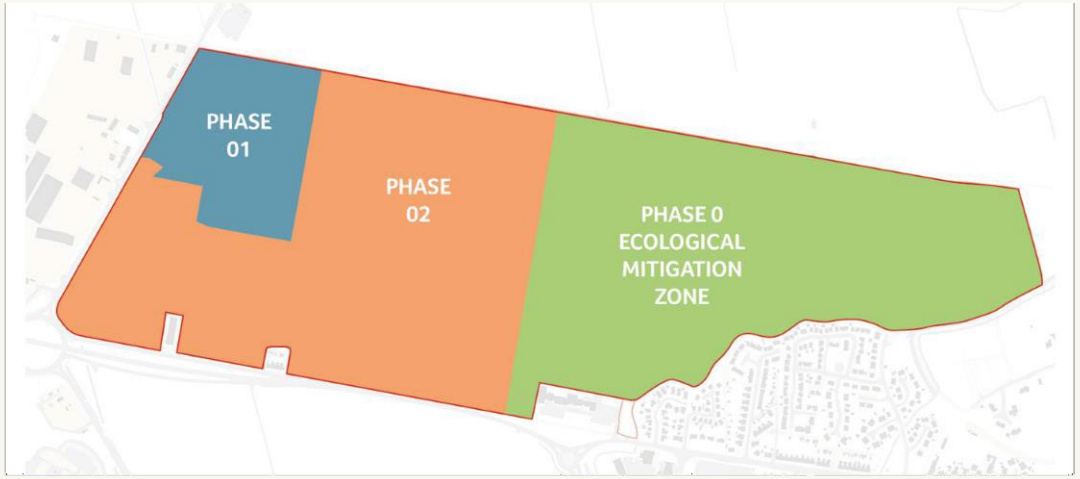
- UK/Europe location
- Japanese Partner /Customer

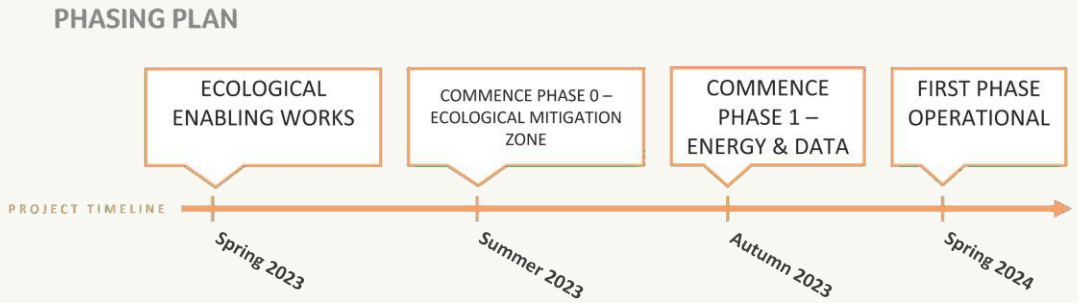
China controls **91%** of Refining, **87%** of Separation and **94%** of Magnet Production

Source: Wall Street Journal - The U.S. Wants a Rare-Earths Supply Chain. Here's Why It Won't Come Easily. - WSJ

First magnet metal production facility powered by offshore wind delivering sustainability to the automotive sector

Yorkshire Energy Park





Situated 50m north of the separation facility and providing up to 50MW of on-site generation of green electricity and electricity from the grid.

UK Gov low cost, zero carbon PPA based on Energy Intensive Industry and British Industry Supercharger Schemes.

Interest from Automotive based in the UK, Ford/JLR.

Siemens Gamesa adjacent blade factory.

R&D facilities and training centre.

Minister confirms that Saltend is of strategic importance to the UK and awards ATF Grant Funding

By 2030 the UK is expected to transition from being a major producer of internal combustion engines to a world leader in electric drive units (EDUs), producing three million EDUs annually, with a large proportion for export.

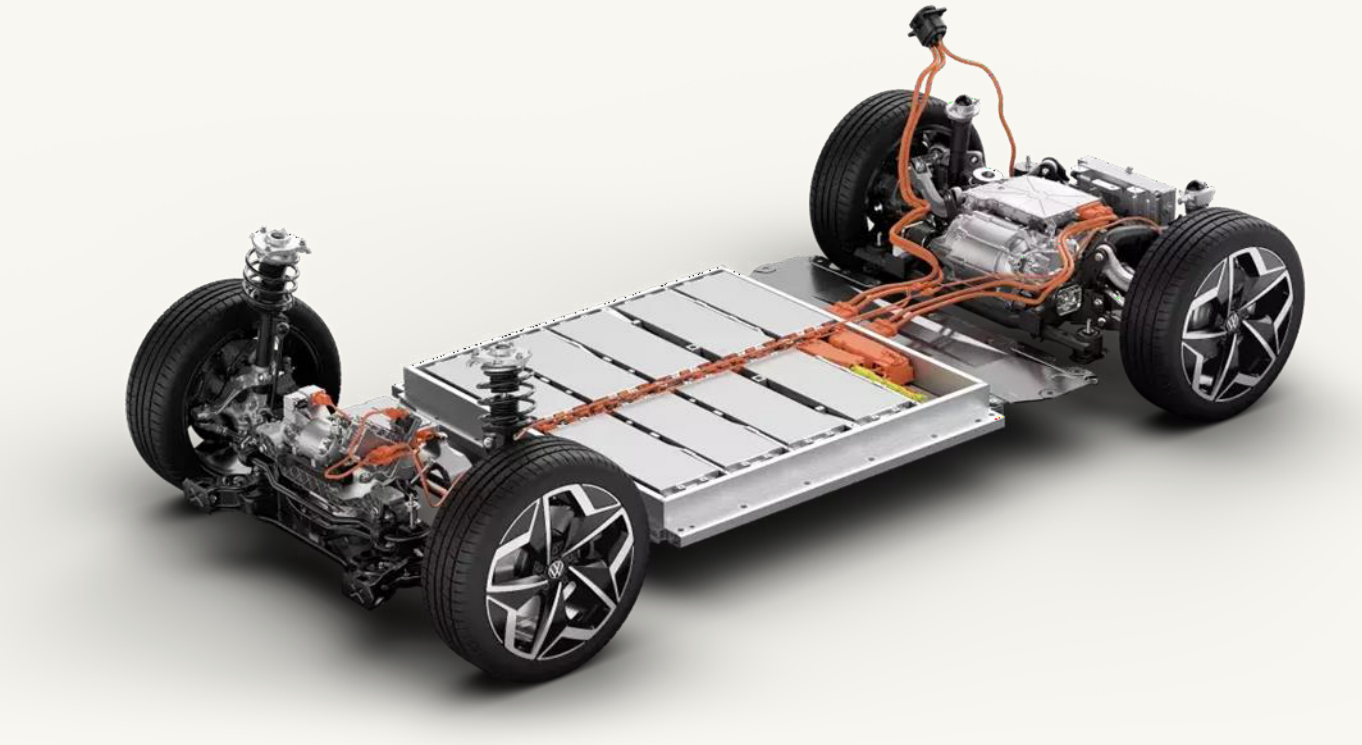
Without a secure magnet metal supply chain this is under threat.

Nusrat Ghani, Minister of State at the Department for Business and Trade and Cabinet Office, highlighted that the Saltend project would be an important step in supporting the UK automotive industry which employs 780,000 people.

Pensana has been nominated by the UK Government as a partner under the Minerals Security Partnership (MSP) between the US and its international allies.

Secretary of State for Business and Trade has offered a £4,000,000 Grant towards the funding required to build the Saltend rare earth separation facility.

The UK is currently a net exporter of automotive engines but needs a magnet metal supply chain to convert to electronic drive units (EDUs)



The UK's current manufacturing facilities are planned to be converted to EDU (electronic drive unit) manufacture with an estimated 2-3 million units being produced in the future with a large export component.

The UK also has a high-level of EDU technology which is being acquired by automotive OEM's (eg: Mercedes buys UK Start-up Yasa) and it is hoped that this production will be maintained in the UK.

This will only happen if the supply chains for these are established in the UK. HMG is already working on electrical grade steels and rotor manufacture but needs to secure a magnet metal supply chain, such as the Saltend rare earth processing facility.

HMG wishes to utilise Pensana's relationship with the world's largest magnet manufacturer with a view to bringing their next investment to the UK.

Wind turbine nacelles is the other market the UK government is strategically interested in, however, without the supply chain of permanent magnets, this is likely to be lost to Europe and elsewhere.

Saltend's Importance as an Independent and Sustainable Supplier

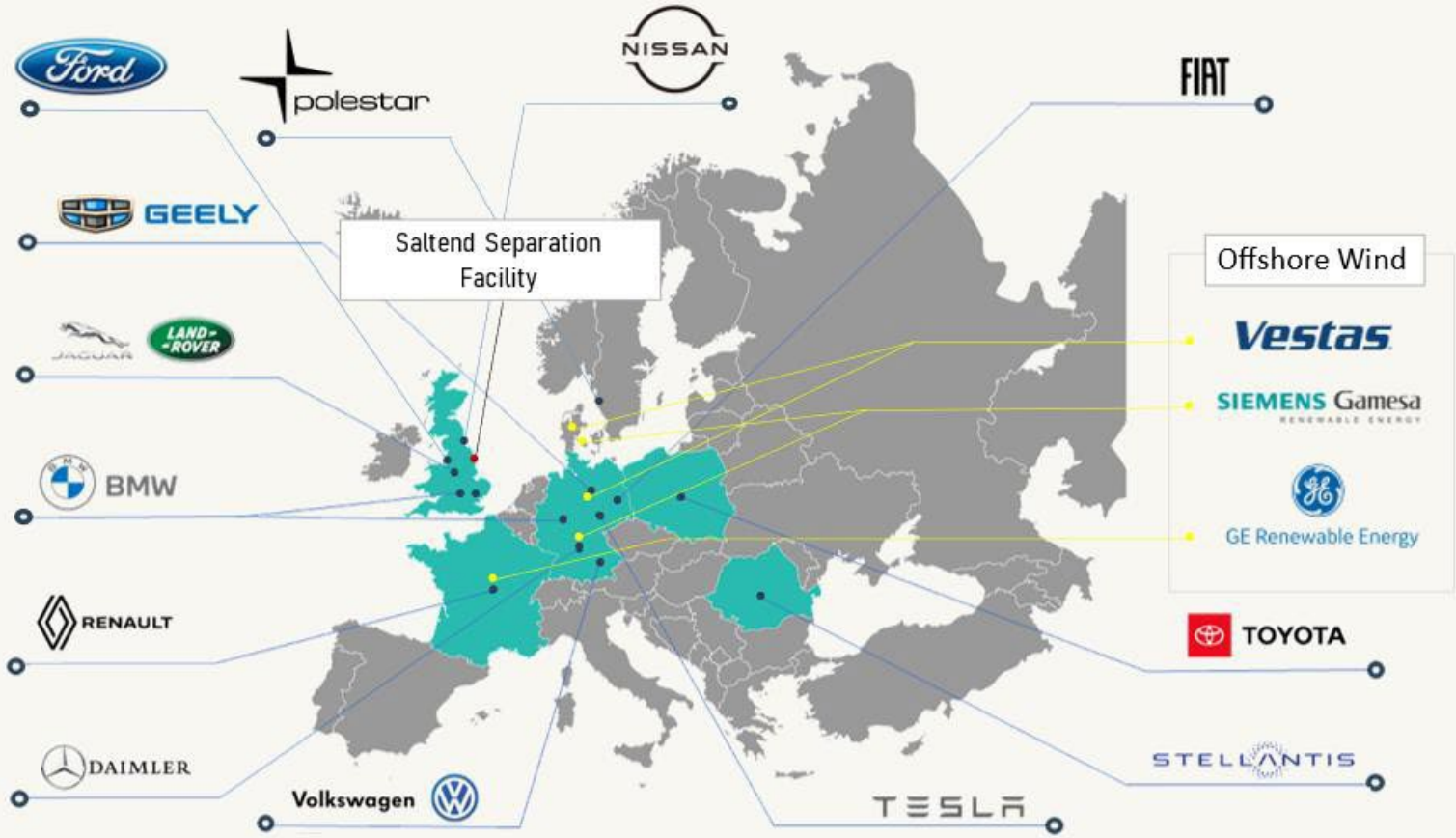
European and UK electric vehicle industry

The UK will produce 2- 3 million Electric Drive Units (EDU's) annually from 2030.

Exporting around the world supporting the burgeoning demand for electric vehicles globally.

The UK and Europe remain committed to the Automotive sector and governments continue to offer support.

Highlighting Saltend's growing importance as an independent and sustainable supplier and critical supporting supply chain for the Auto industry.



PARTNERING WITH POLESTAR

Pensana is partnering with Polestar (Nasdaq: PSNY) on its moon-shot goal of creating the first truly climate-neutral car by 2030.

The scope of the Polestar 0 project is to identify and eliminate all greenhouse gas emissions from the extraction of raw materials to when the car is delivered to the customer and onwards to the end of vehicle life.

Chairman Paul Atherley with Hans Pehrson Project Lead, at the Stockholm launch of Polestar's moon-shot climate-neutral car.

Cooperation Agreement with Equinor to Recycle Offshore Wind Turbine Magnets using Low Carbon Hydrogen

Pensana Chairman Paul Atherley with Equinor President and CEO Anders Opedal

Pensana is partnering with leading energy provider, Equinor, to develop a low-energy method for recycling end-of-life wind turbine magnets using low-carbon Hydrogen produced from Equinor's Hydrogen to Humber (H2H) at Pensana's Saltend Rare Earth processing hub.

Strong Independent Board and Experienced Executive Management Team

PAUL ATHERLEY
CHAIRMAN

Mr. Atherley is an experienced mining executive and is the founder of the Company. Previously Executive Director of the investment banking arm of HSBC. He has completed numerous successful acquisitions and financings of resource projects in Europe, China, and Australasia. He is a supporter of Women in STEM.

RT HON BARONESS NORTHOVER
NON-EXEC DIRECTOR

Baroness Northover was the Prime Minister's Trade Envoy to Angola (2016- 2020), Zambia (2017-2020) and Minister in the Department for International Development ("DFID") 2011-15, including serving as Parliamentary Under Secretary and Africa Minister, 2014-15.

ROBERT KAPLAN
FINANCE DIRECTOR

Mr Kaplan is a Chartered Accountant with over 20 years' operating experience in the African mining sector. He brings a broad skill set in both the UK and sub-Saharan corporate finance together with experience in mining operations in Angola, South Africa and Tanzania.

ALISON SAXBY
NON-EXEC DIRECTOR

Alison is an industry-leading expert with over 35 years of experience in industrial minerals and metals. She was previously a Managing Director at metals consultancy Roskill and was recently appointed as Research Director of Project Blue. Alison is the author of numerous publications on critical and other minerals and was originally trained as a mineral engineer.

STEVE SHARPE
NON-EXEC DIRECTOR

Mr Sharpe is a highly experienced natural resources financier. He is an Executive Board Member of EIT Raw Materials. Previously, he was Chair of AME Group, Managing Director at Canaccord Genuity, Managing Director at Endeavour Financial and held senior positions at Standard Bank and NM Rothschild.

ROCKY SMITH
CHIEF OPERATIONS OFFICER

Rocky Smith is a highly experienced Chemical Engineer with 35 years' rare earths experience. He was Managing Director of Molycorp's Mountain Pass rare earth project in California, US, which is now owned by New York Stock Exchange listed MP Materials.

JEREMY BEETON
NON-EXEC DIRECTOR

Former Director General of the 2012 London Olympic and Paralympic Games, Principal Vice President of Bechtel, Advisory Board of PWC, and Non-Exec of SSE Plc. Currently also a Non-executive Director of John Laing.

TIM GEORGE
EXEC DIRECTOR/ CEO

A Minerals Engineer, Mr. George leverages over 30 years of experience in the mining and engineering sectors, with a broad experience in mining project development throughout Sub-Saharan Africa.

WILLIAM IZOD
CHIEF COMMERCIAL OFFICER

William Izod has extensive experience in managing and developing rare earth supply chains, including 10 years working with large multi-national companies, including managing a Motor and Powertrain supply chain controlling £1bn of annualised spend.

CONTACT

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Pensana Plc

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Refreshments and Networking

Back at 11.00

Panel Discussion and Q&A

Katharine York	Paul Goodwin	Cedric Hanson	Ian Livingston	William Izod
ORE Catapult	UKAEA	BOC	Equinor ASA	Pensana

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