

Natural gas as an enabler to a carbon neutral energy system – CCS and hydrogen

equinor

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Our vision

Shaping the future of energy

- Competitive at all times
- Transforming the oil and gas industry
- Providing energy for a low carbon future



Equinor is shaping the future of energy in a low carbon future

A **low CO₂ footprint** is a competitive advantage

Evaluating **CCS and clean hydrogen** in the transition to a low carbon society

Exploring **several business opportunities** by reforming natural gas to clean hydrogen, while capturing and storing the CO₂

Meet future climate targets in **power, industry, transportation and heating**



New Energy Solutions – strategic objectives



Build a profitable renewable business



Develop new lower-carbon business opportunities for Equinor's core products

Gas is a cost efficient enabler ... to a carbon neutral energy system



Gas displacing more carbon intense fuels in transport, heating and power

Gas combination with renewables (gas and electricity)

Hydrogen and renewable electricity smartly integrated



Decarbonising energy systems

Easy ← complexity to decarbonise → Hard

Transport

Battery (mostly) plus Hydrogen for Heavy Duty

Hydrogen Fuel-Cell Trains

Liquid Hydrogen and Fuel-Cells for long haul Big Ships

Power

Large Battery Systems for Daily Swing (night-to-day)

Hydro-Power as Battery for Small Scale Intermittency

Hydrogen fired CCGTs Clean Back-Up Power for Large Scale Intermittency

Industry

Light Industry powered by Renewable

Heavy Industry powered by Hydrogen from Natural Gas + CCS

CCS for Industry without other Alternatives

Heat

Heat Pumps For Efficient Use of Electricity in Homes

Hydrogen for Efficient Transfer of Energy from Production to End-Users

Hydrogen for Large Scale Seasonal Storage

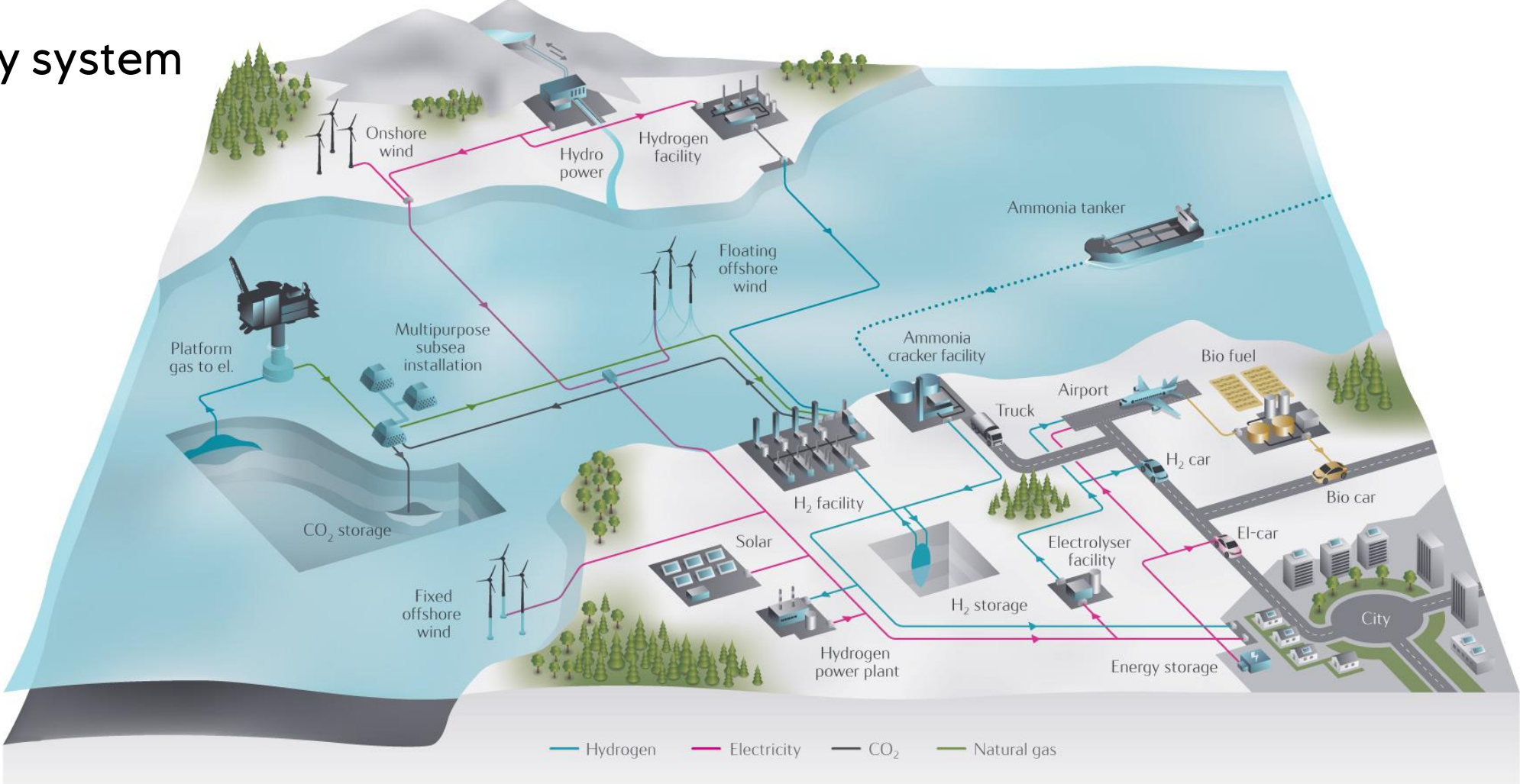
Natural Gas Reforming to Hydrogen with CCS

Combustion zone
 $CH_4 + 1.5 O_2 \rightarrow CO + 2H_2O$

Thermal and catalytic zones
 $CH_4 + H_2O \rightarrow CO + 3H_2$
 $CO + H_2O \rightarrow CO_2 + H_2$

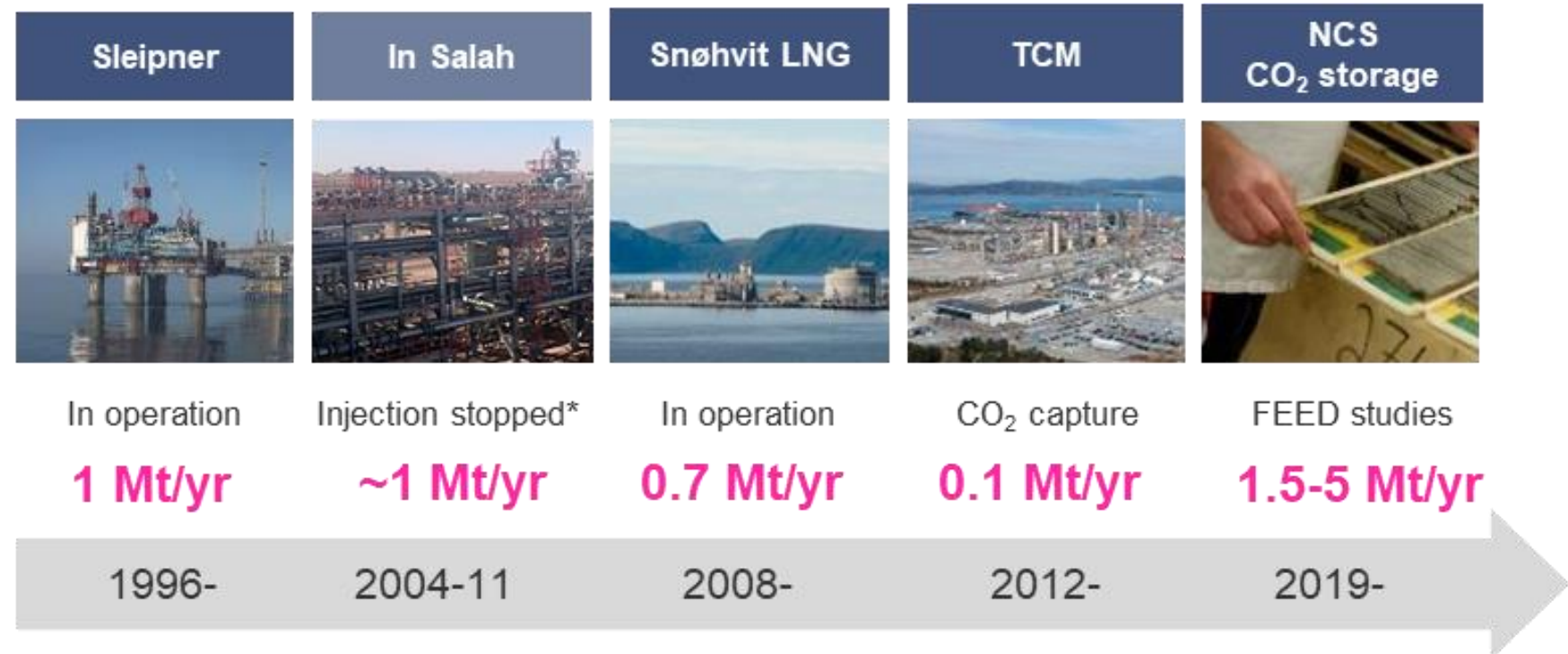
Multiple technologies to address the challenge

Future energy system

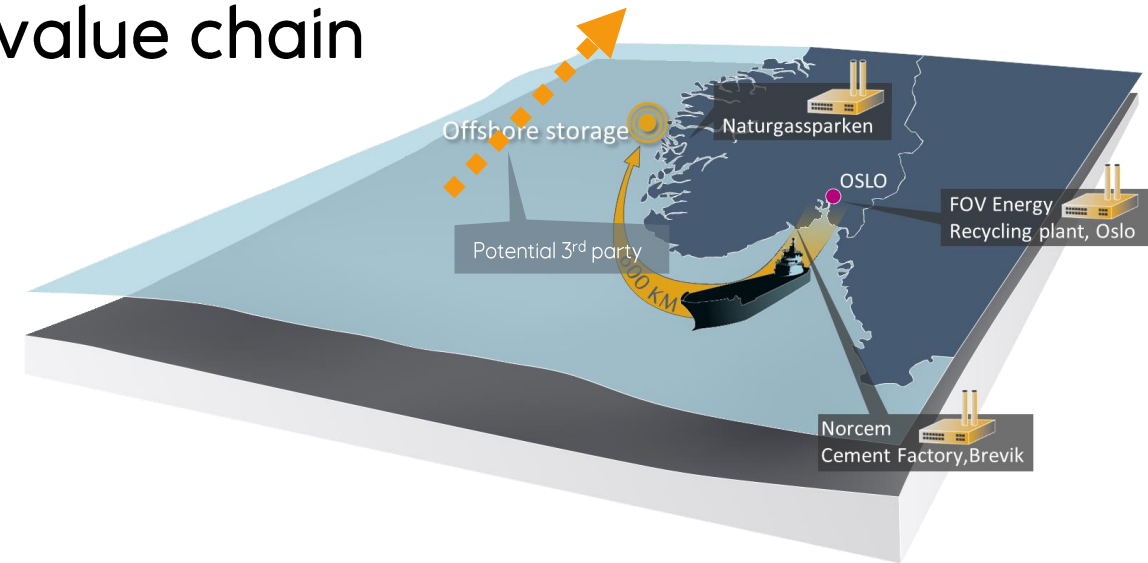
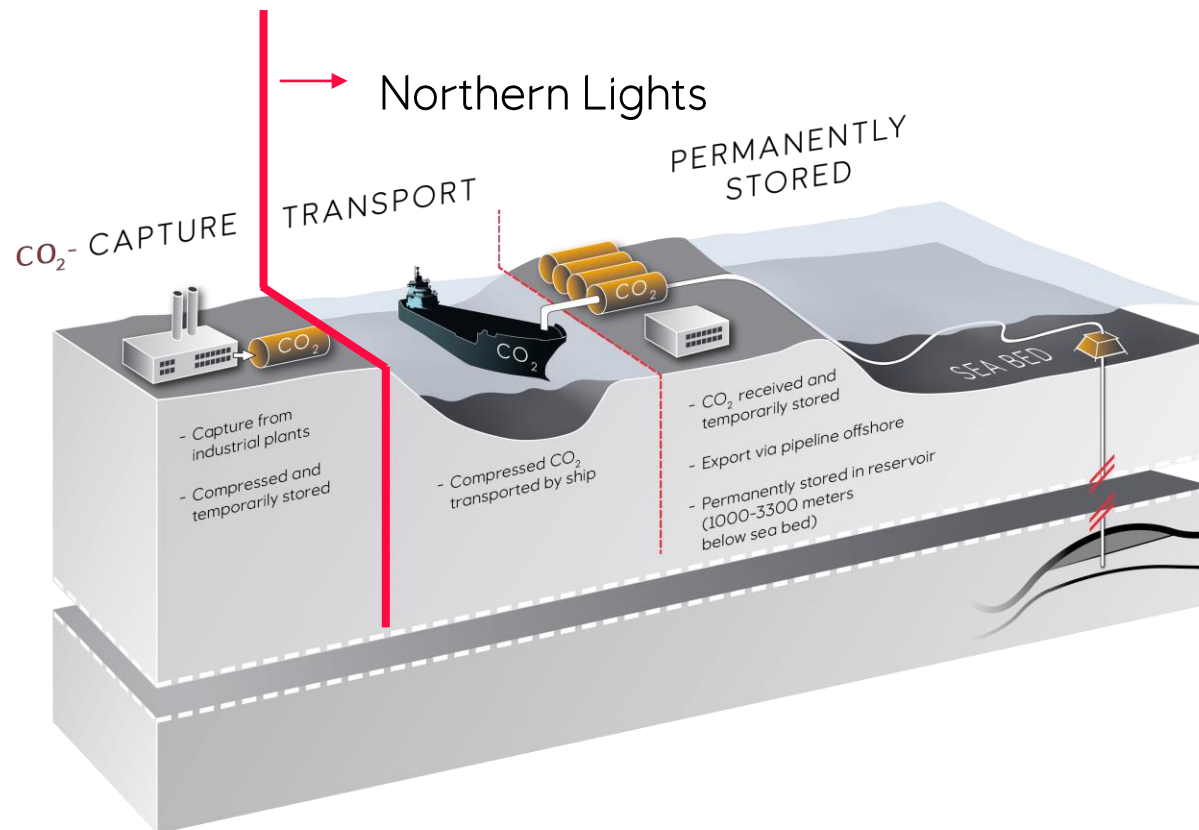


Equinor CCS entrepreneur; proven technology - developing commerciality

- Equinor operates some of the world's largest CCS projects
- More than 20 year experience of safe storage
- Capturing up to 1.8 Mt/yr ~850 000 cars/yr



Northern Lights: Part of the full CCS value chain



Norway full-scale CCS project combines industrial sources of CO₂ from Norway and other countries with safe storage on Norwegian continental shelf

Equinor's approach - clean (blue) hydrogen

Commercial dimension

- Identify markets suitable for switching to hydrogen
- Partner with large customers who are pioneers in pursuing low carbon solutions
- Develop real, tangible and sizable projects
- Approach authorities to design suitable financial support solutions

Infrastructure dimension

- Build on the massive existing natural gas network
- Produce hydrogen at large scale from natural gas
- Capture the CO₂ in the process and send it to permanent offshore storage









Equinor's hydrogen portfolio

Power generation

- Utilise existing gas power-plants
- Switch fuel from gas to hydrogen
- Clean baseload electricity
- Clean back-up for solar and wind
- Launch large-scale H₂ economy
- Enables H₂ to other sectors later



Heat

- Large energy sector in UK
- Difficult (and expensive) to de-carbonise with electricity
- Utilise existing gas network
- Synergies with industry/power gen
- Enables H₂ to transport later



Maritime

- Battery solutions not available
- Compressed or Liquefied H₂
- Utilise existing gas processing plants to provide low cost H₂
- FC efficiency -> CO₂ reductions
- Centralise CO₂ emissions which provides CCS optionality



Other

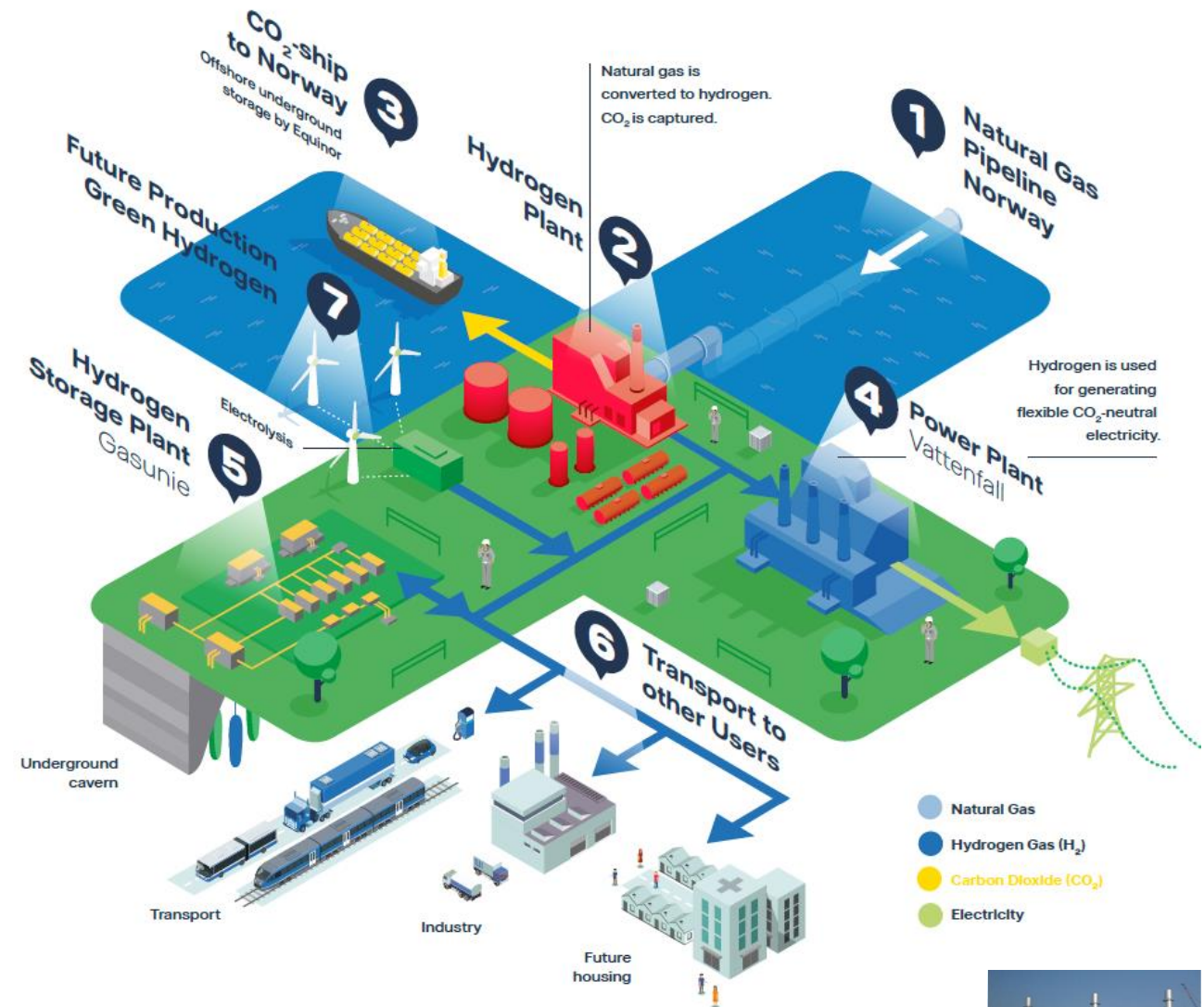
- Industry in Germany
- Industry in France
- Japan - potential hydrogen market
- UK CCUS clusters
- Norwegian projects



H2M – Magnum, Netherlands

- Energy: 8-12 TWh
- CO₂ emissions reduction of 2 Mton/year
- Utilise existing gas power plants and gas infrastructure
- Switch fuel from natural gas to clean H₂
- Clean, flexible electricity as back-up for solar and wind
- Launch large-scale H₂ economy

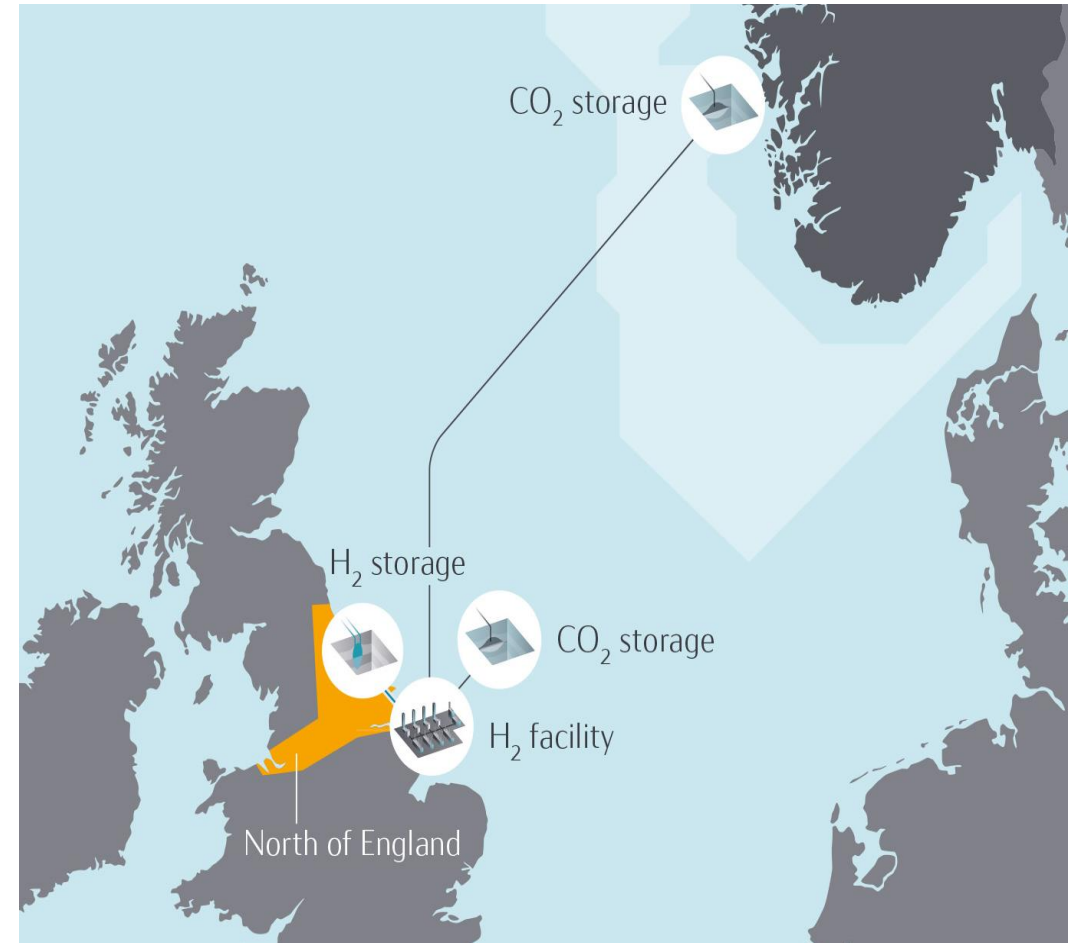
• Partners:  & 



H21 North of England

- System approach to decarbonise residential heating and distributed gas use (fuel switch from natural gas to clean hydrogen)
- Large-Scale: 12.5% of UK population , ~85 TWh
- 17-18 Mtons CO₂ reduction per year
- Continued use of existing infrastructure
- Security of supply - copes with seasonal (winter) peak demand
- Offshore CO₂ storage in either UK or Norway
- Facilitating unlimited system coupling between gas and electricity

- Partners:  & 
Your Gas Network

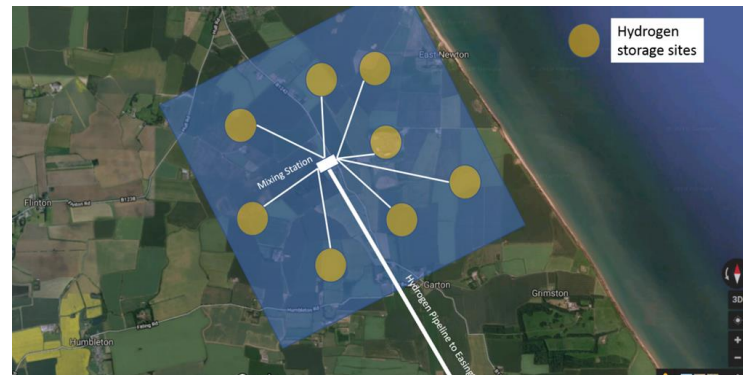


H21 NoE supply concept – illustration



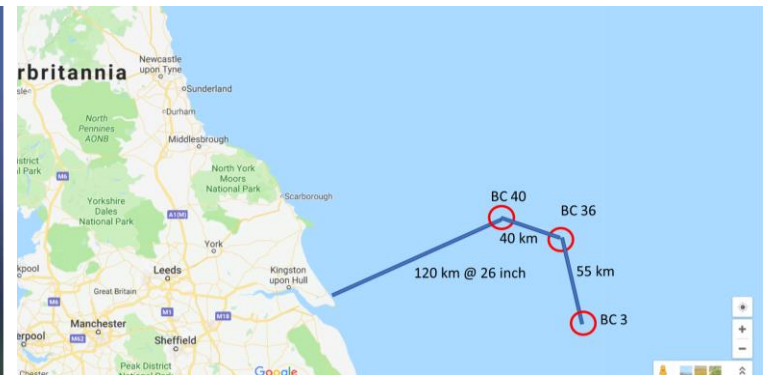
Greenfield hydrogen facility

Location: Easington
 Capacity: 12 GW
 Configuration: Multi train, self- sufficient with power



Hydrogen storage

Location: Aldbrough
 Capacity: 8 TWh
 Configuration: 56 caverns at 300,000 m³



CO₂ storage

Location: Bundter
 Capacity: +600 Million @ 17 mtpa
 Configuration: Saline aquifers

Key messages and take-away

- Decarbonising Europe towards 2050 is a major challenge
- Renewable solutions are perfect for the carbon-light sectors
- Heavy industry, heat and flexible power generation require large-scale solutions on which we need to start working today
- Hydrogen from natural gas with permanent offshore storage of CO₂ offers:

Low cost
Low technical risk
A clean value chain
Large scale

Gas reforming is the most cost effective hydrogen pathway
 Proven technology in H₂ production and CO₂ storage
 The CO₂ is returned to permanent offshore storage
 The industry has demonstrated a track-record of mega projects

- Hydrogen from natural gas with CCS will establish a robust hydrogen infrastructure that green hydrogen can utilise

Low Carbon Solutions

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