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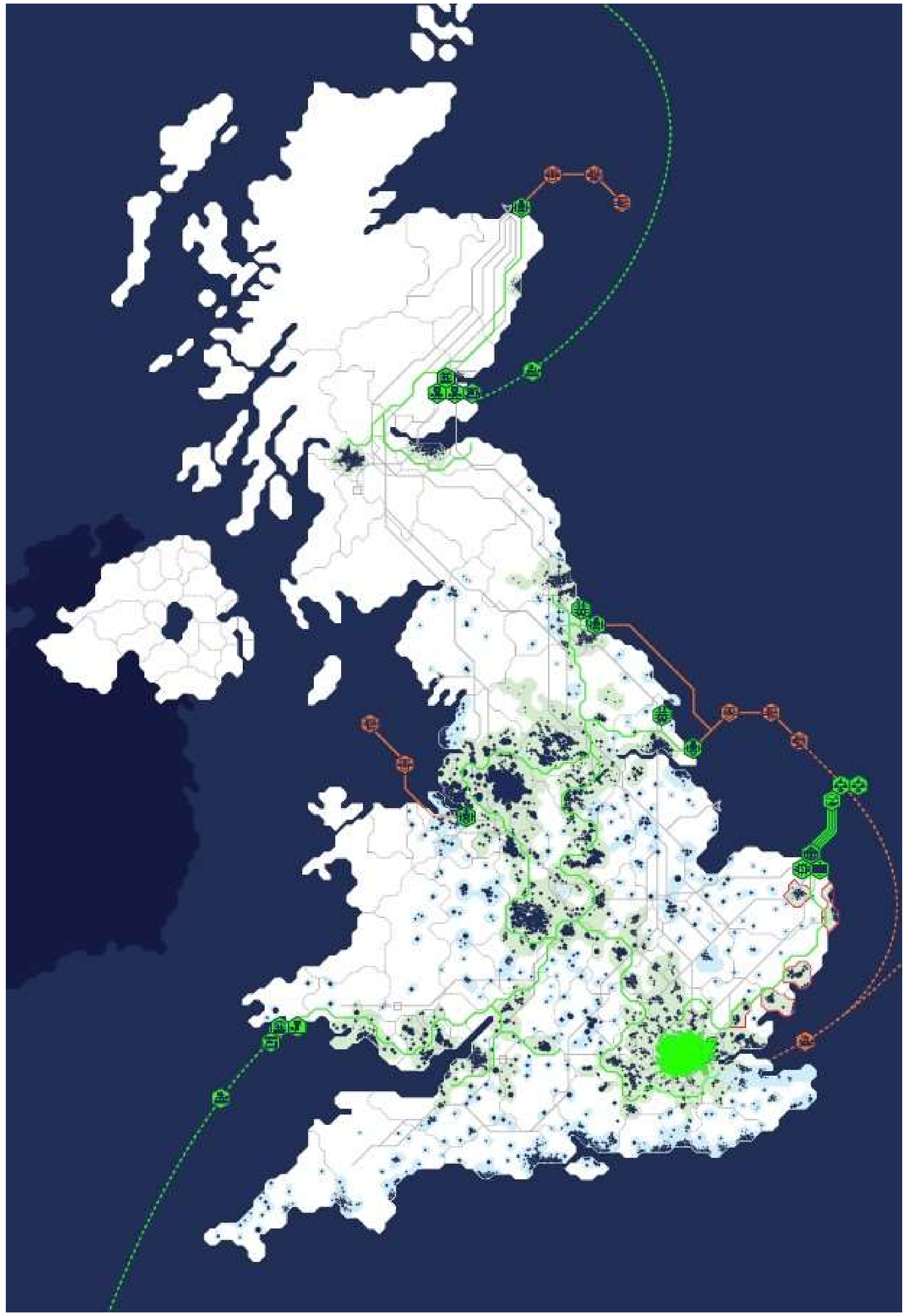
Dimensioning the storage concepts for H21

… potentially the world's largest clean energy project …

Rune Thorsen, Bamshad Nazarian, Philip Ringrose, Lars Hagesæther, Torgeir Melien & Henrik Andersen

Equinor ASA

TCCS10 Conference 2019



Northern Gas Networks

Cadent
Your Gas Network

Our vision

Shaping the future of energy

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

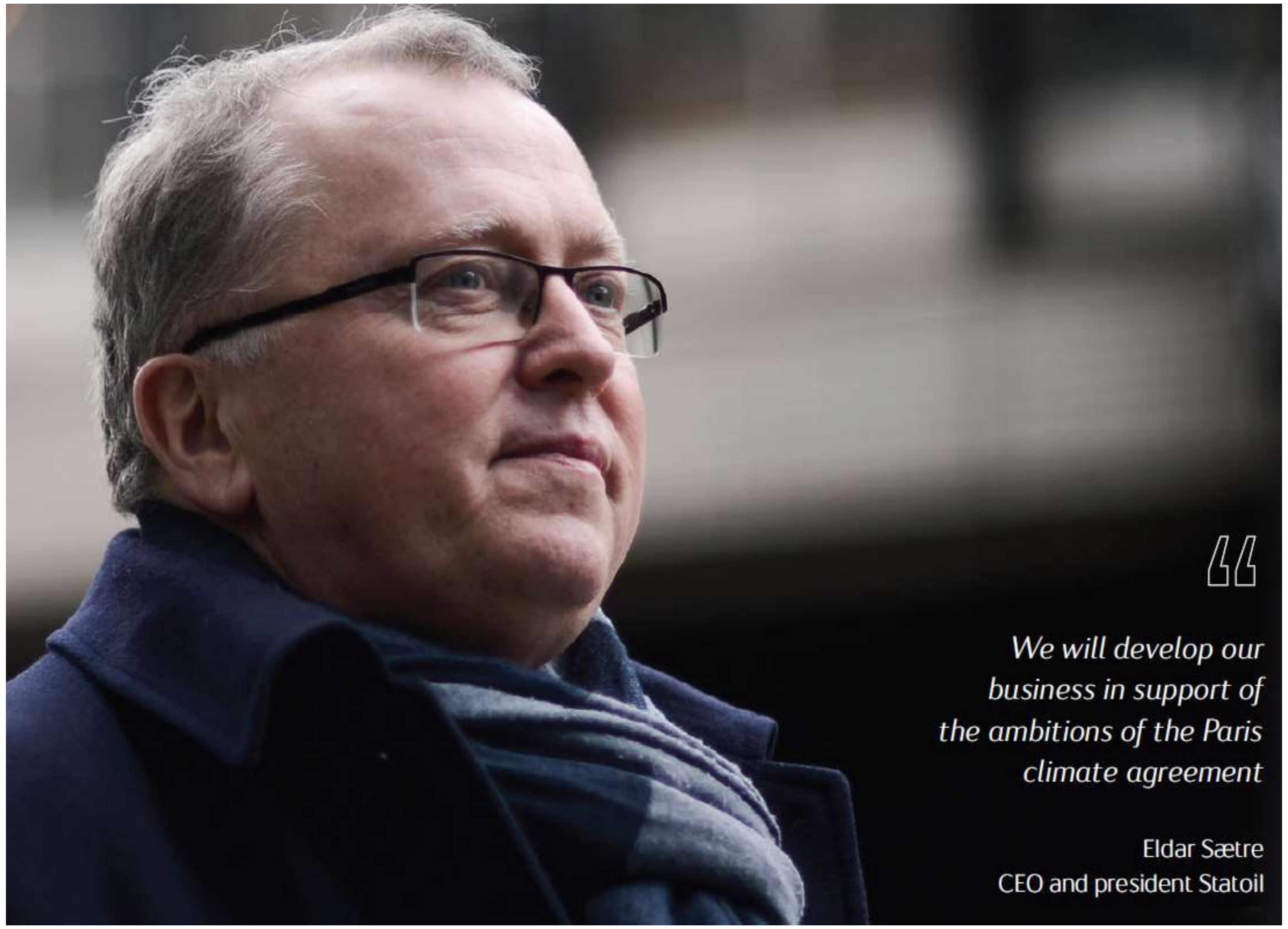
Shaping the future of energy in a low carbon world

A **low CO_2 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 CO_2

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



Gas is a cost efficient enabler

… for 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

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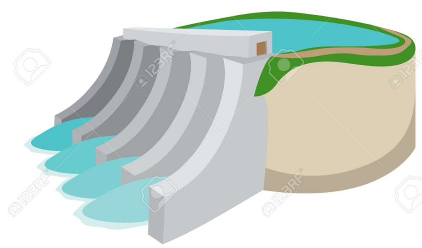
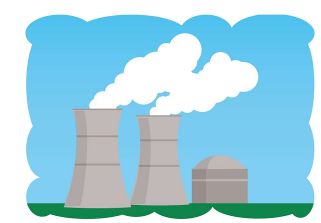
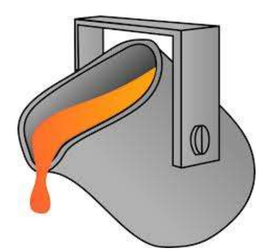
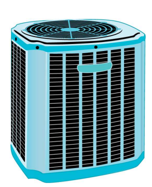
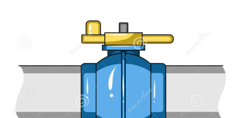
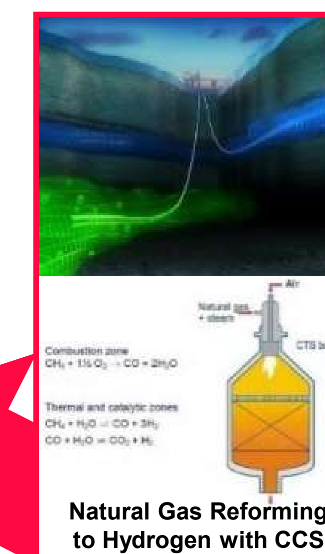
Decarbonising energy systems

	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



Multiple technologies to address the challenge

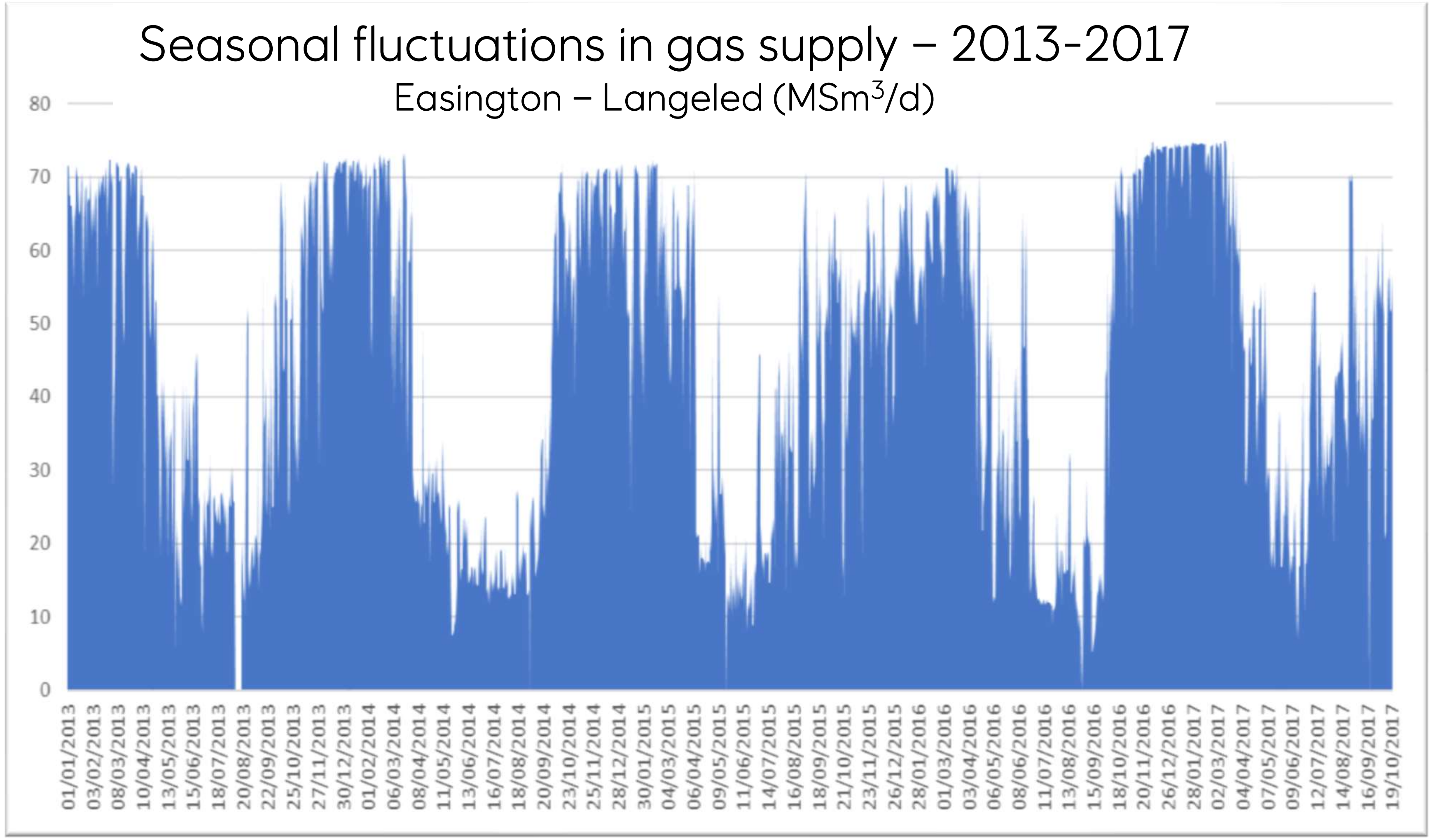
UK Energy markets:
Huge Seasonal Variations

UK Energy

- Gas dominated – 800 TWh
- CO2 emission from gas = 160 mtpa
- Seasonal variations in heat only require 60-80 TWh storage/ flexible supply

Gas Power

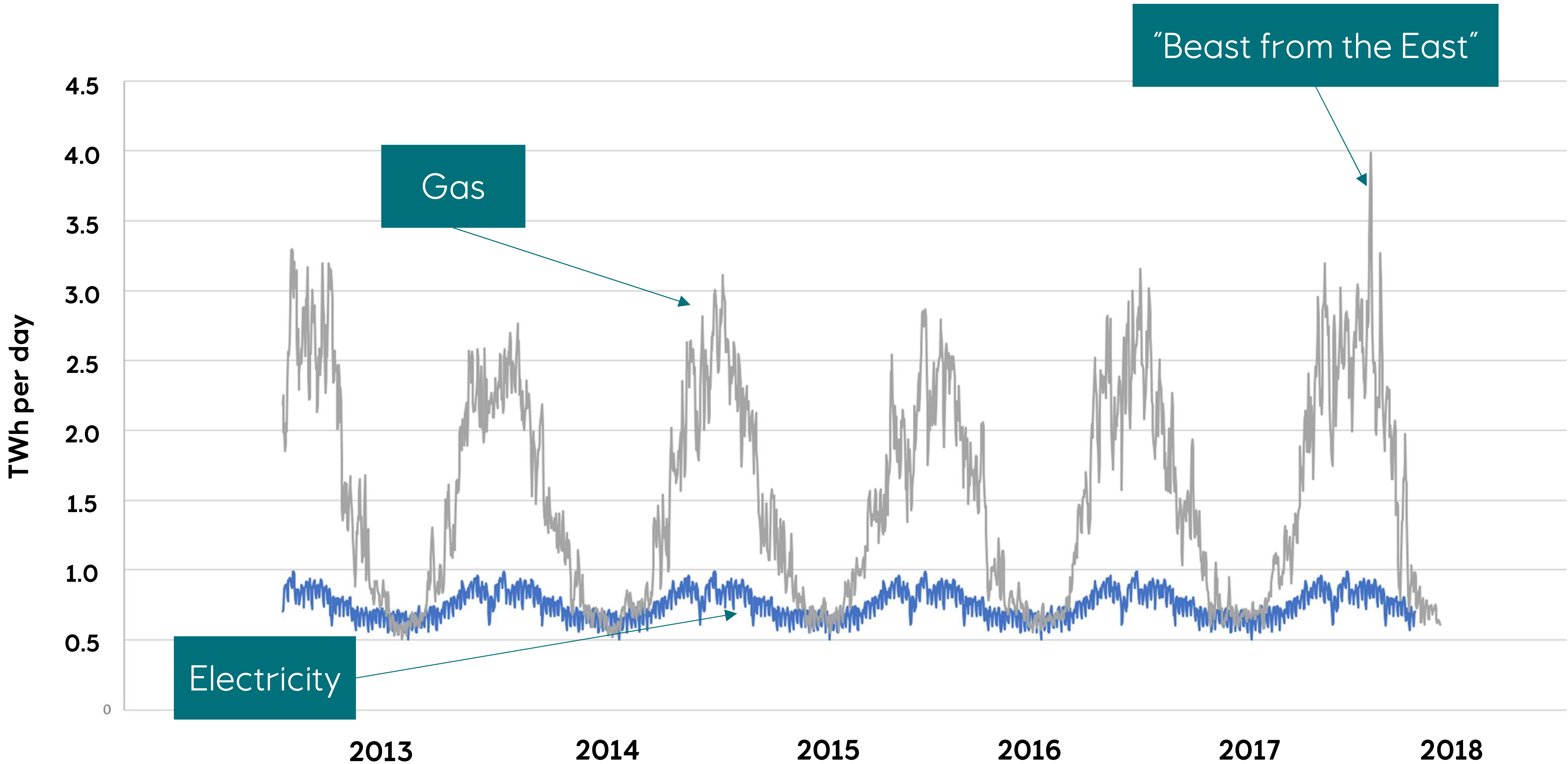
- 20-25 GW installed capacity
- Majority are swing producers
- Increases with phase out of coal



Norwegian Gas to UK

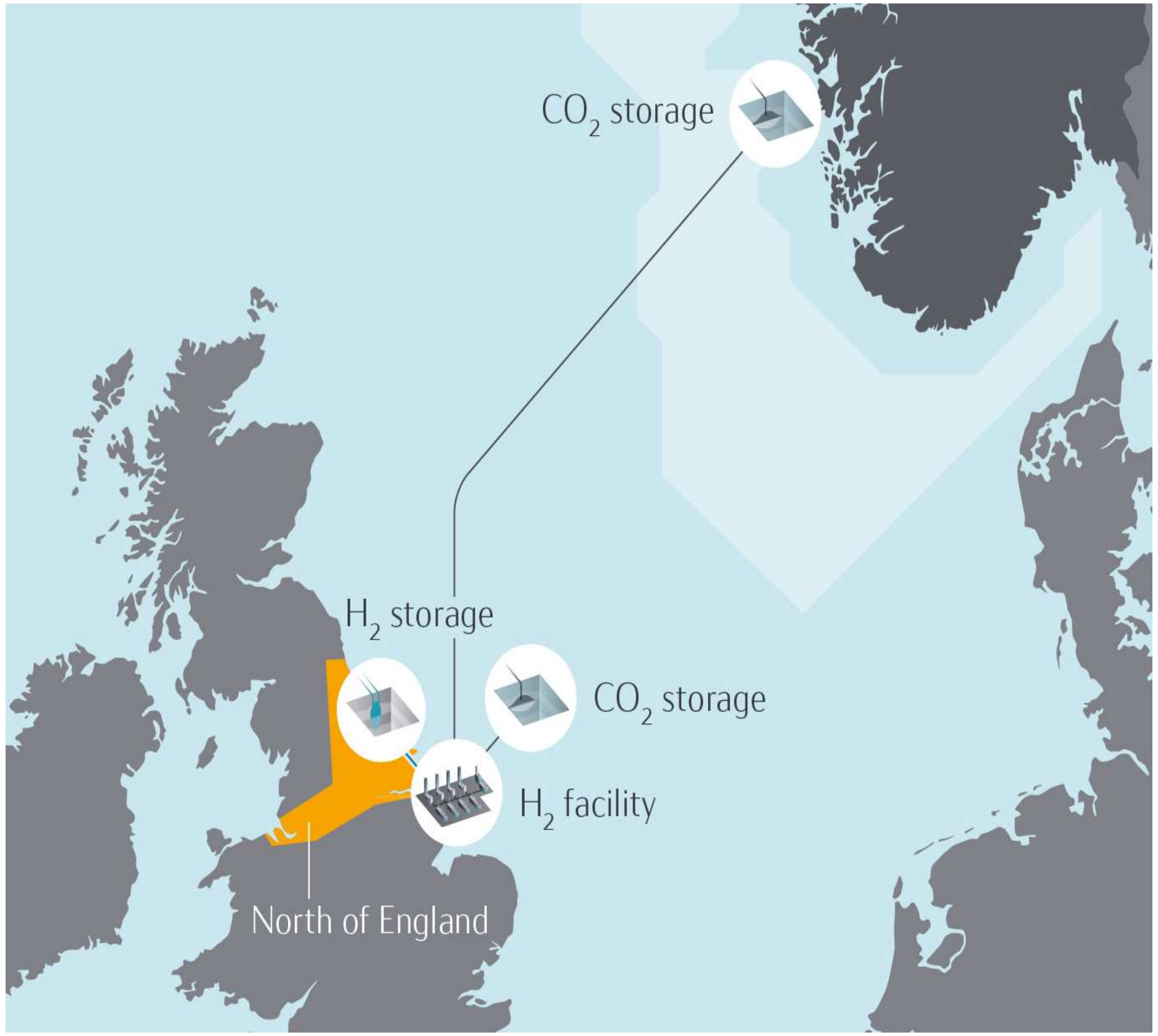
- Functions as the UK «energy storage»
- 40% of Norwegian gas export
- Norway total gas export = 1100 TWh

Non-transport energy use (UK)



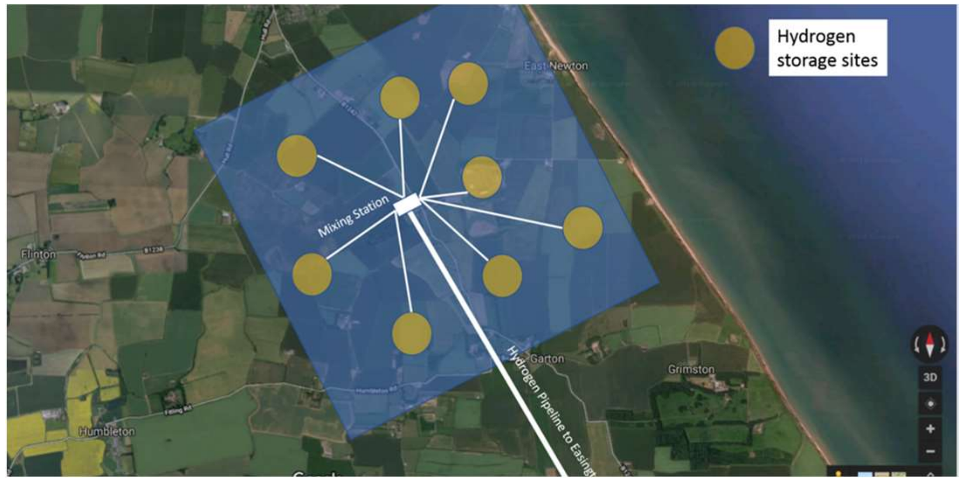
H21 North of England

- System approach to decarbonise residential heating and distributed gas use (fuel switch from NG to H_2)
- Large-Scale: 12.5% of UK population, ~85 TWh
- Conversion starts 2028 with stepwise expansion to 2035 replacing more than 3.7 million appliances
- 17-18 Mt CO_2 reduction per year
- Continued use of existing infrastructure
- Security of supply - copes with seasonal demand
- Offshore CO_2 storage in either UK or Norway
- Facilitating unlimited system coupling between gas and electricity
- UK-Norway partnership



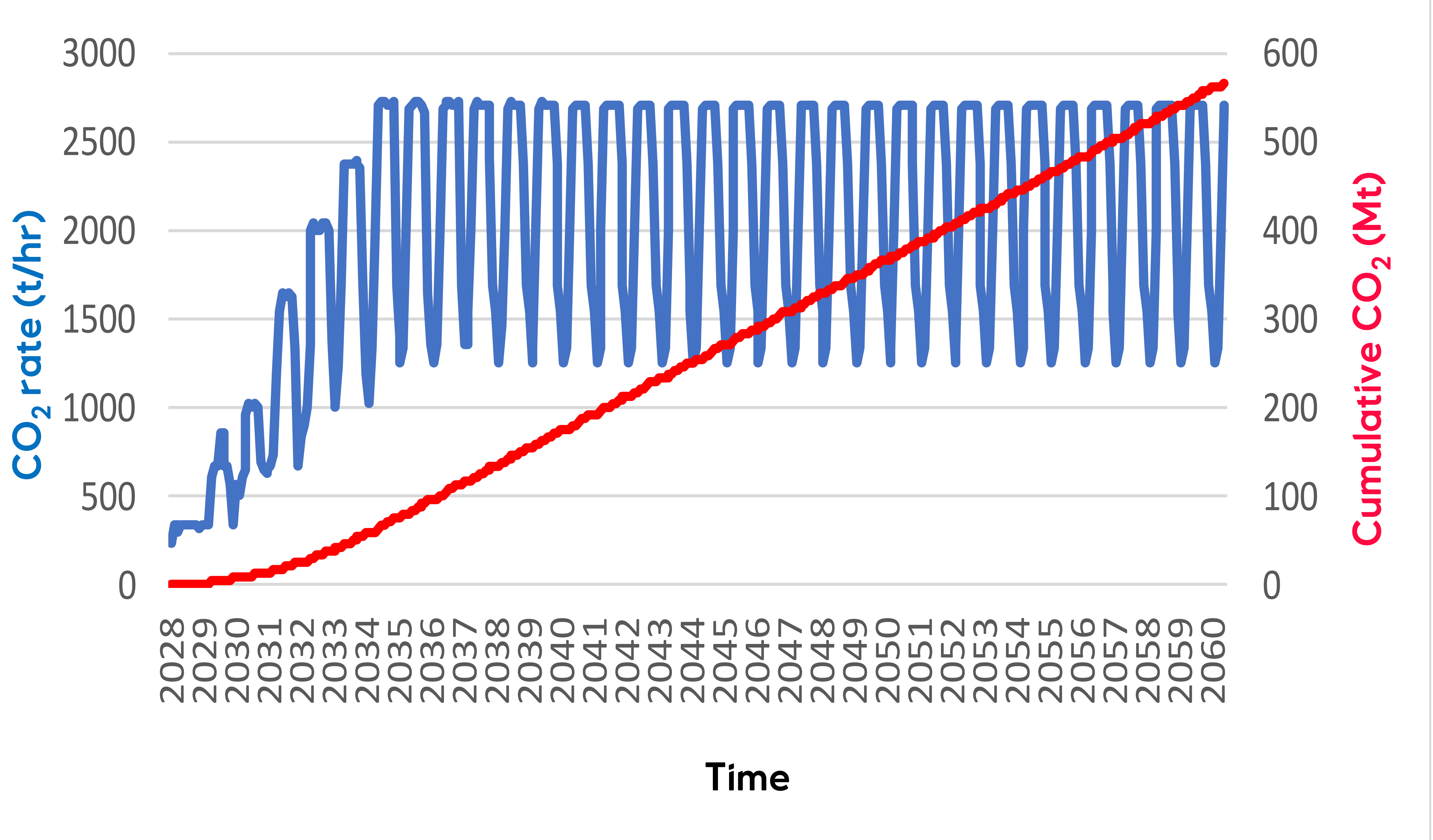
Full report at https://northerngasnetworks.co.uk/h21-noe

H21 supply concept – illustration



Greenfield hydrogen facility	Hydrogen storage	CO_2 storage
Location: Easington	Location: Aldbrough	Location: UK or Norway
Capacity: 12 GW	Capacity: 8 TWh	Capacity: +600 Mt @ 17 mtpa
Configuration: Multi train, self-sufficient power	Configuration: 56 caverns (of 300,000 m^3)	Configuration: Saline aquifers

Storage demand – large seasonal swing



Screening of storage sites

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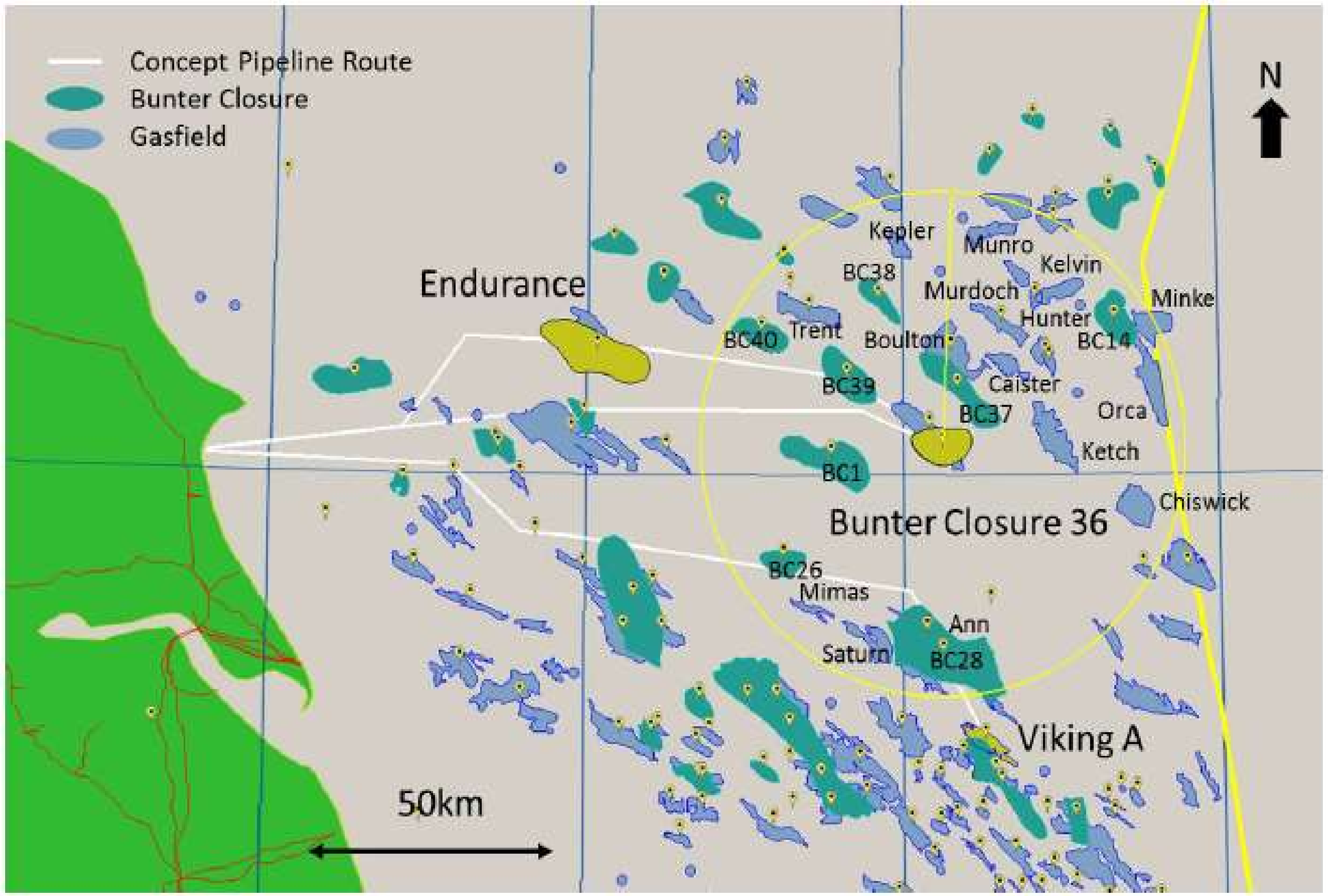
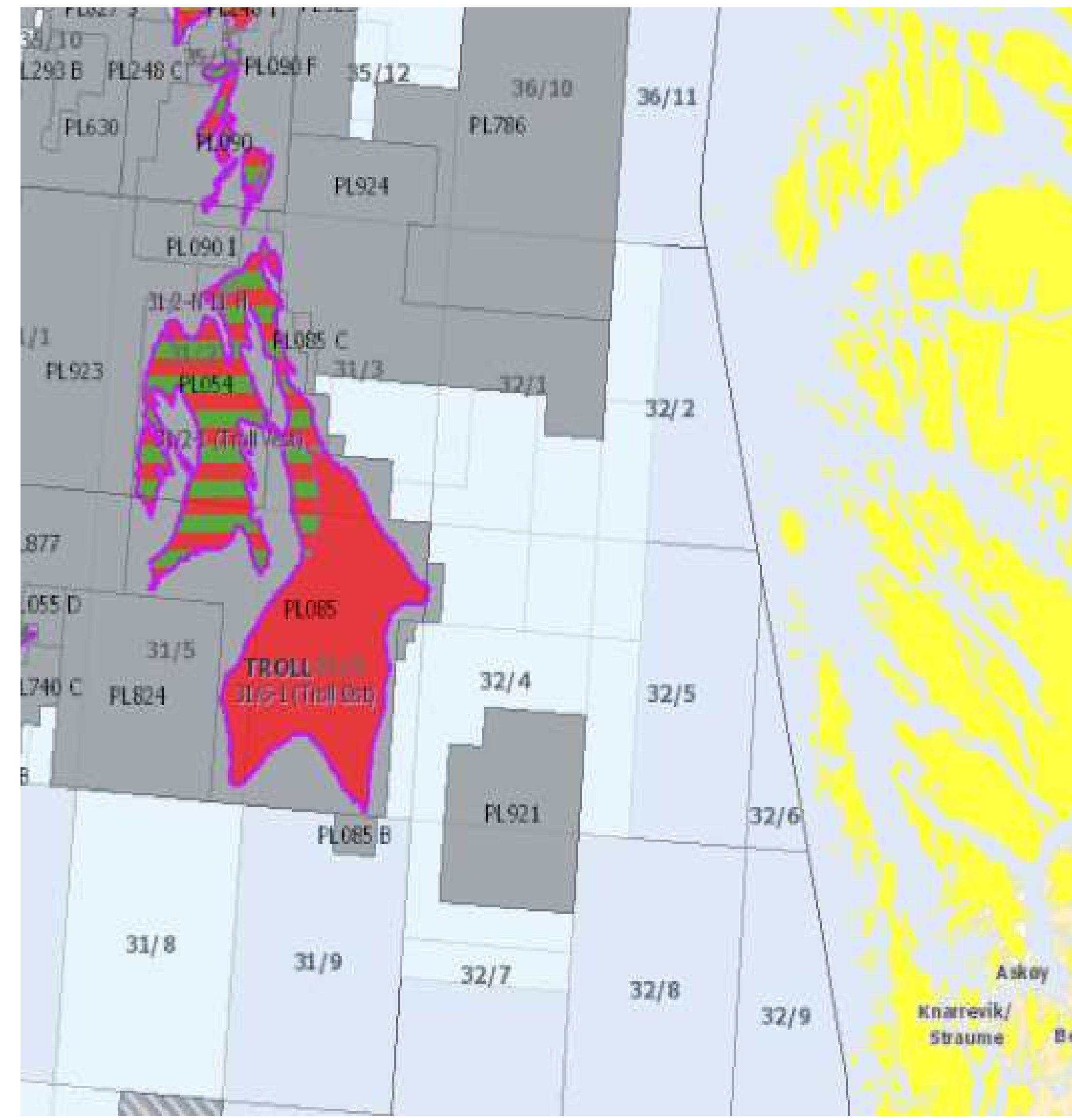
UK SNS



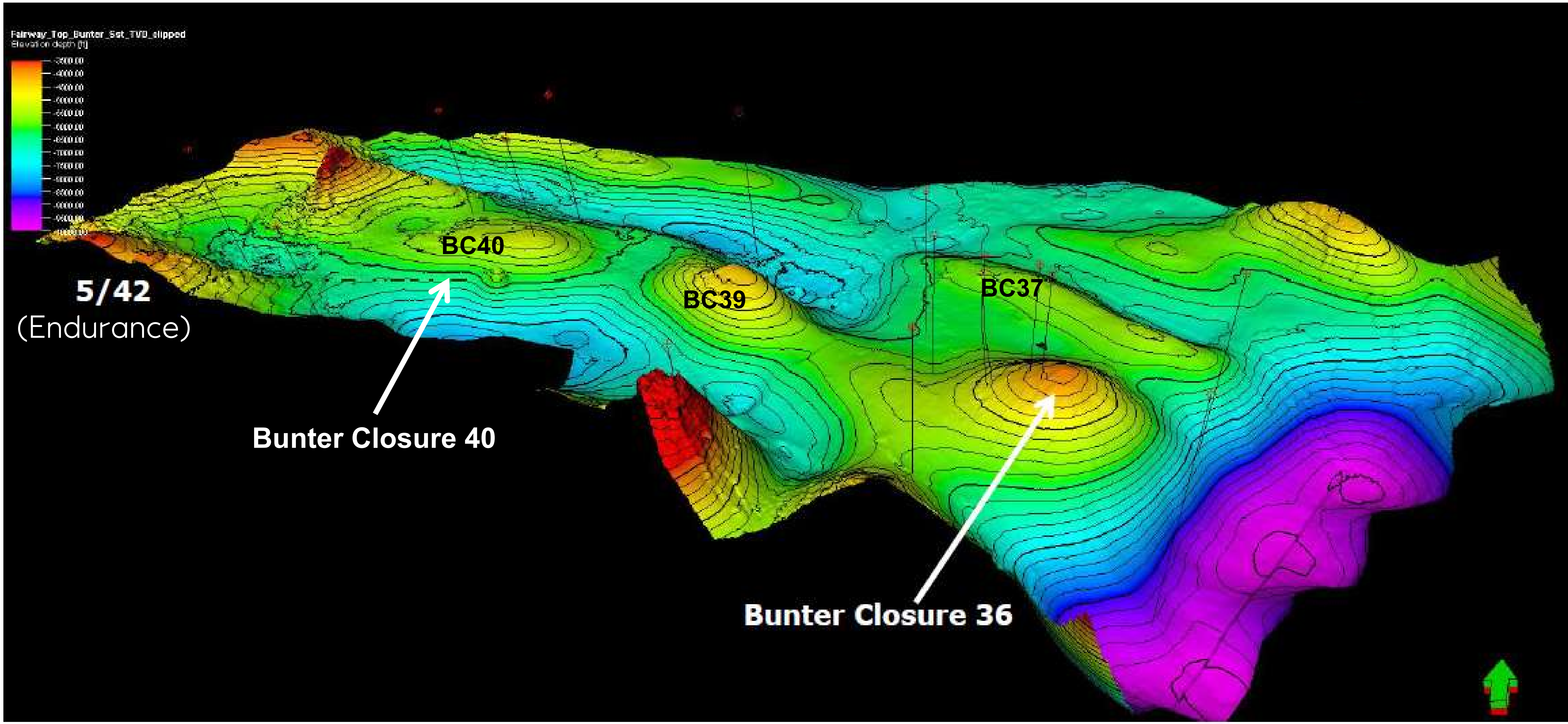
Norway – Horda Platform



Pale Blue Dot.

AXIS WELL TECHNOLOGY
FROM CONCEPT TO COMPLETION

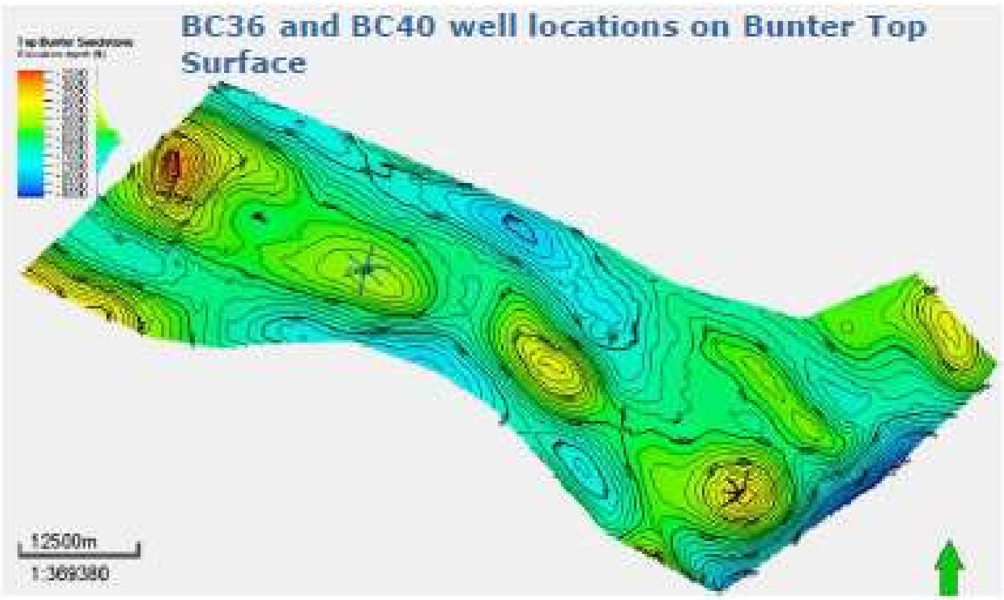
‘Worms eye’ view of the structures

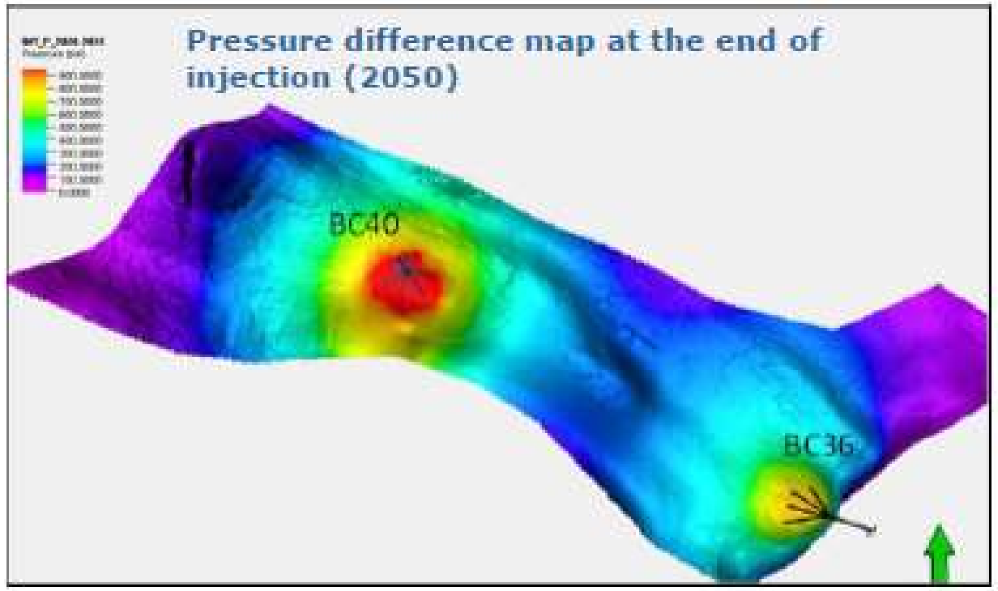


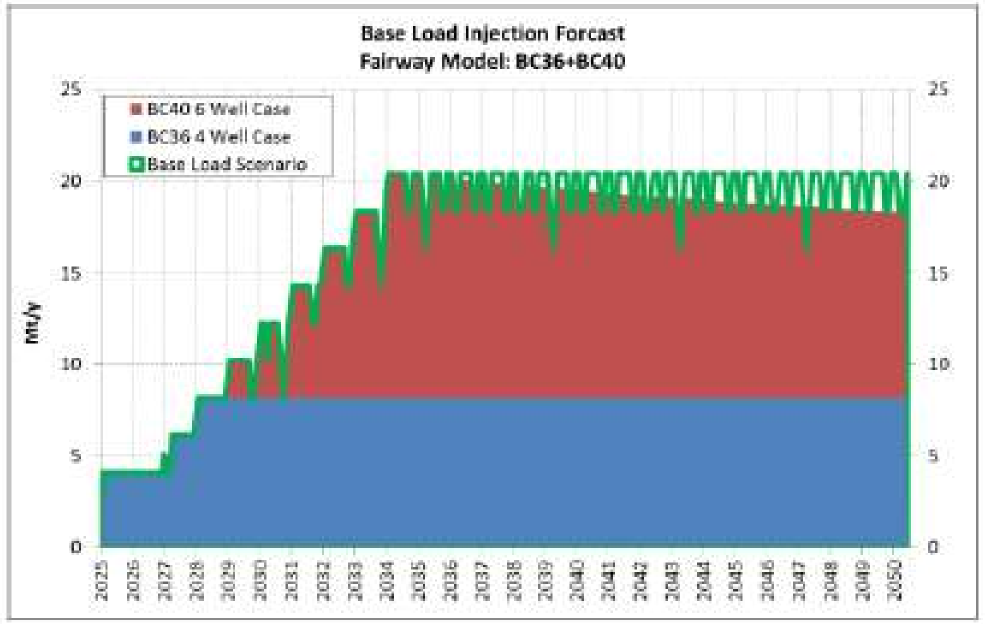
Derisking Northern Sites

- The Northern sites might accommodate a 15 Mtpa scenario, but struggle with the full Base Load or Seasonal CO_2 inventory (max injection rate 2700 t/hr ~24 Mtpa)
  - BC36 & BC40 performing better than expected (cf. CO2Stored database)
  - Pressure interference will be key

Northern cluster is the most promising



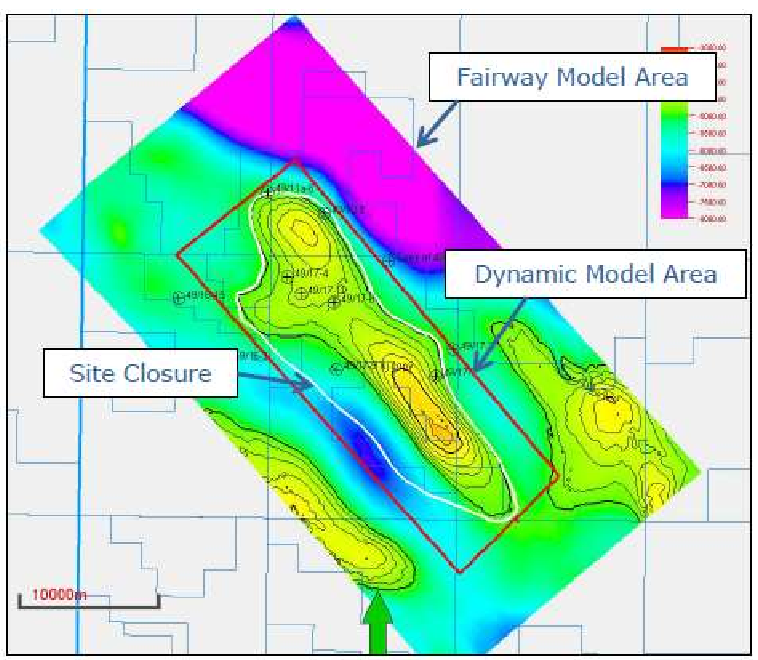


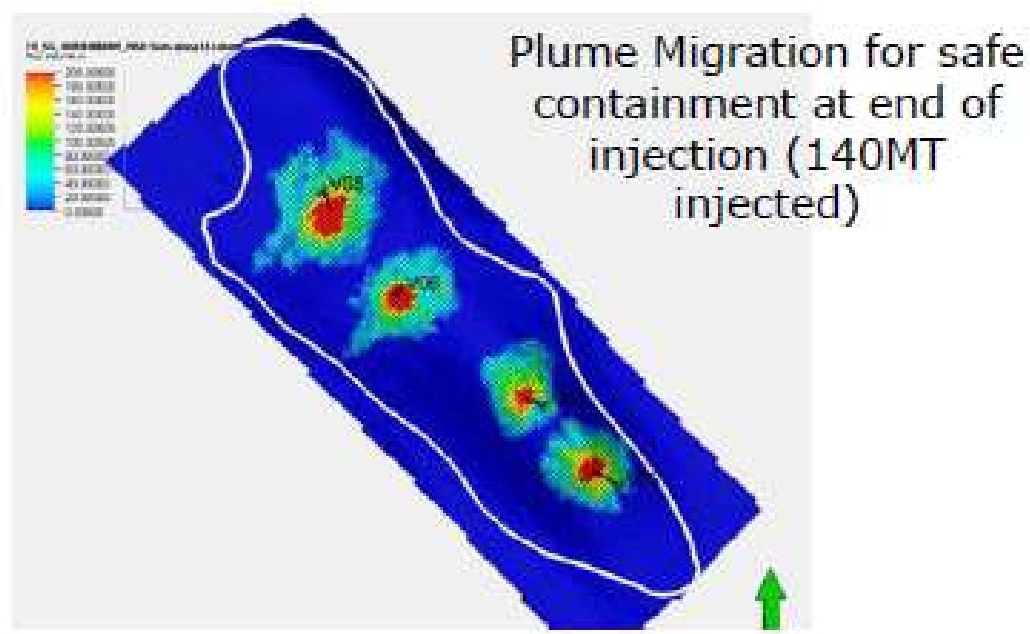


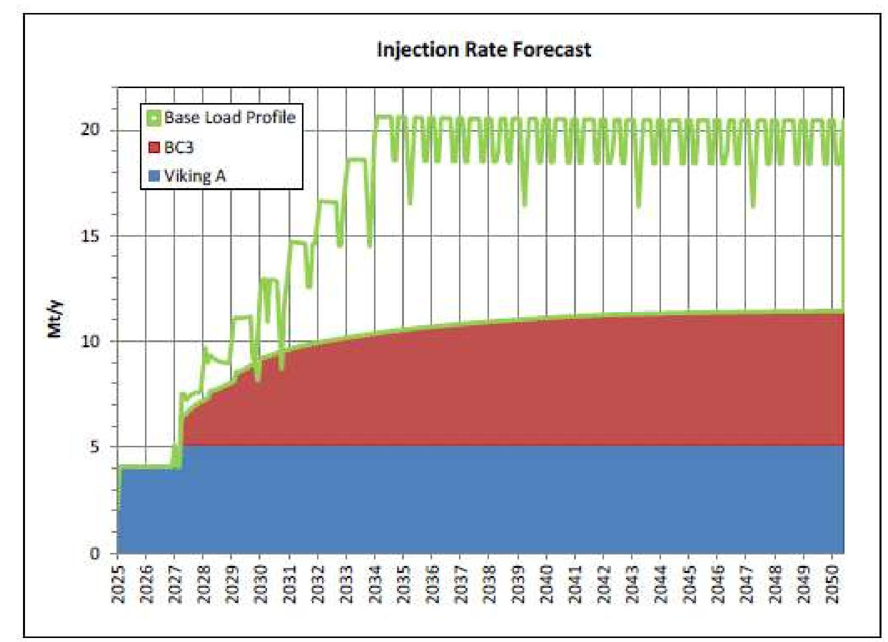
Derisking Southern sites

- The Southern sites unlikely to be able to accommodate the full baseload CO_2 inventory without further development of adjacent sites
  - Both Viking A and BC3 provide useful storage resource

Co-development of depleted and normally pressured reservoirs is more complex

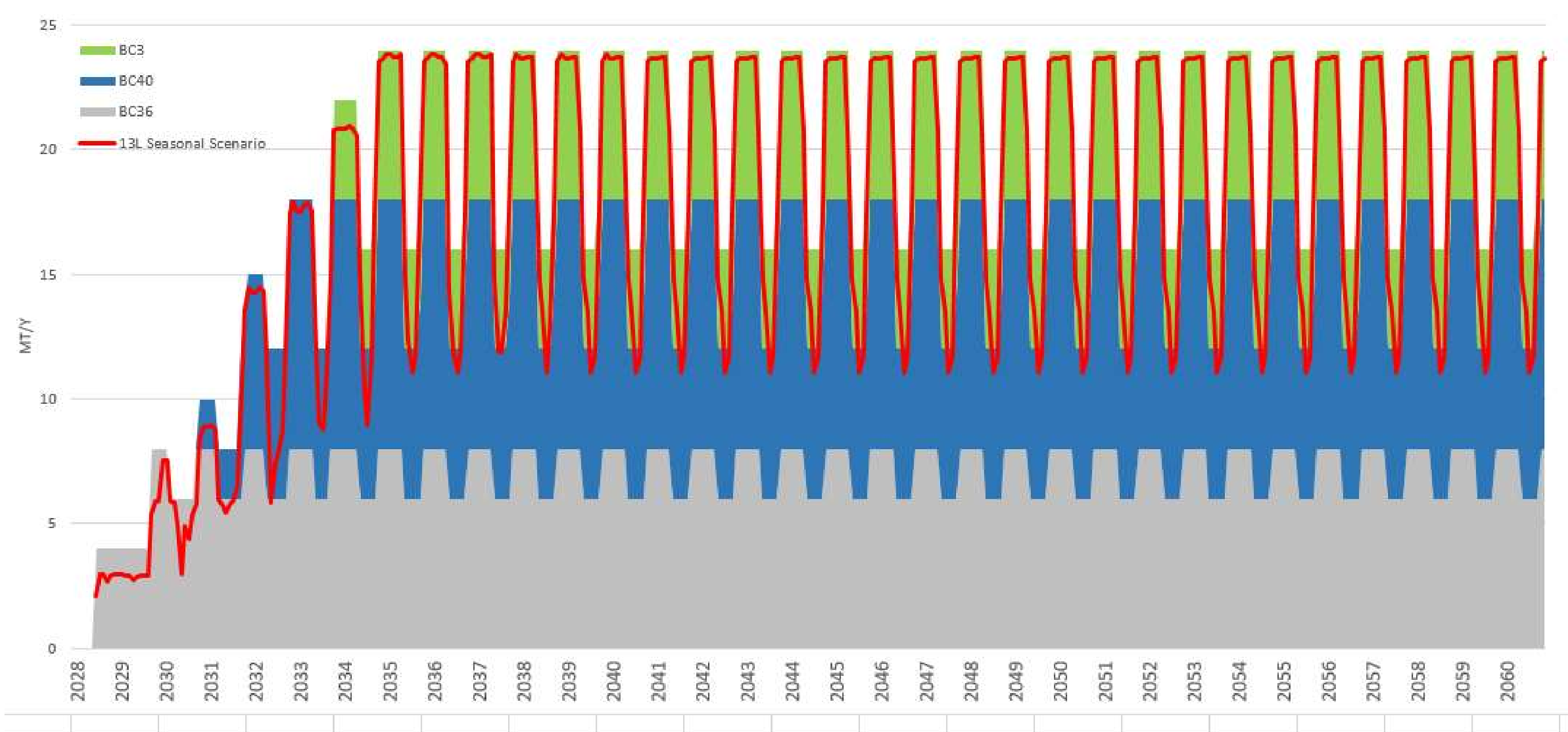


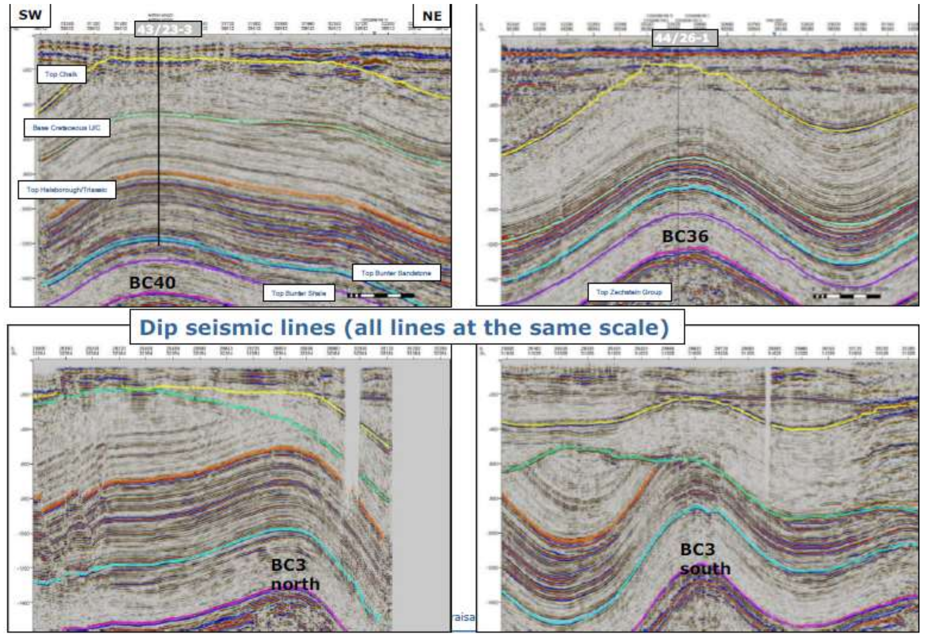


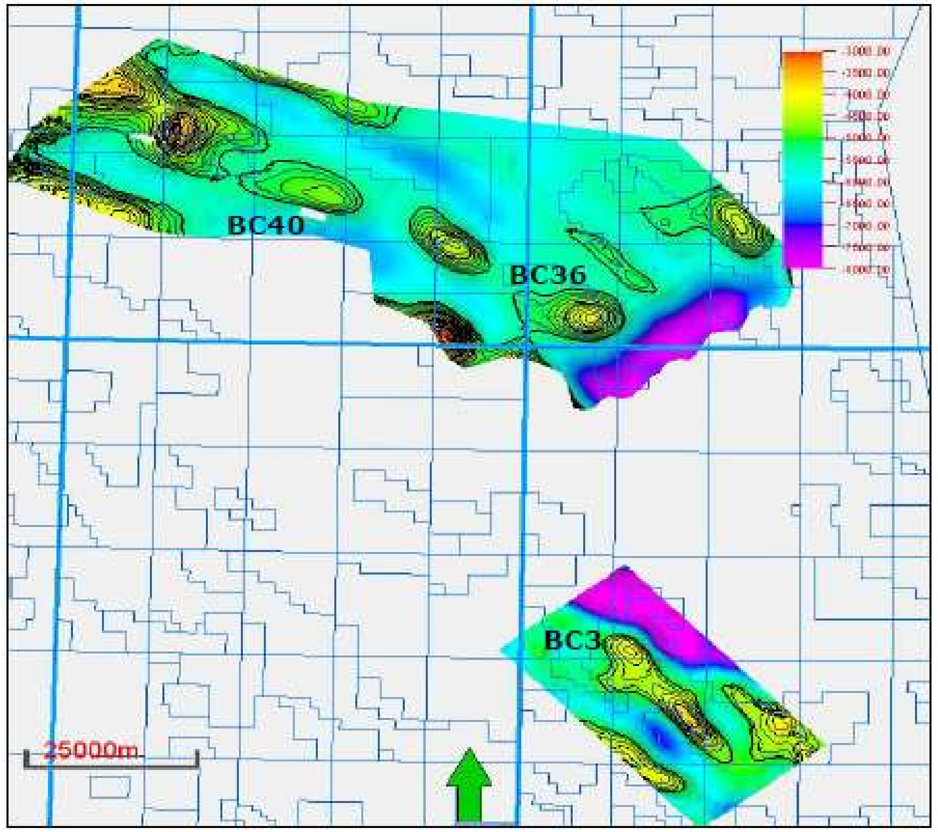


Meeting the full storage demand

- Will need three structures for storage
- Performance of the three Bunter closures (36, 40 and 3) are very different from each other
    - Will need careful engineering design on rates and well placement



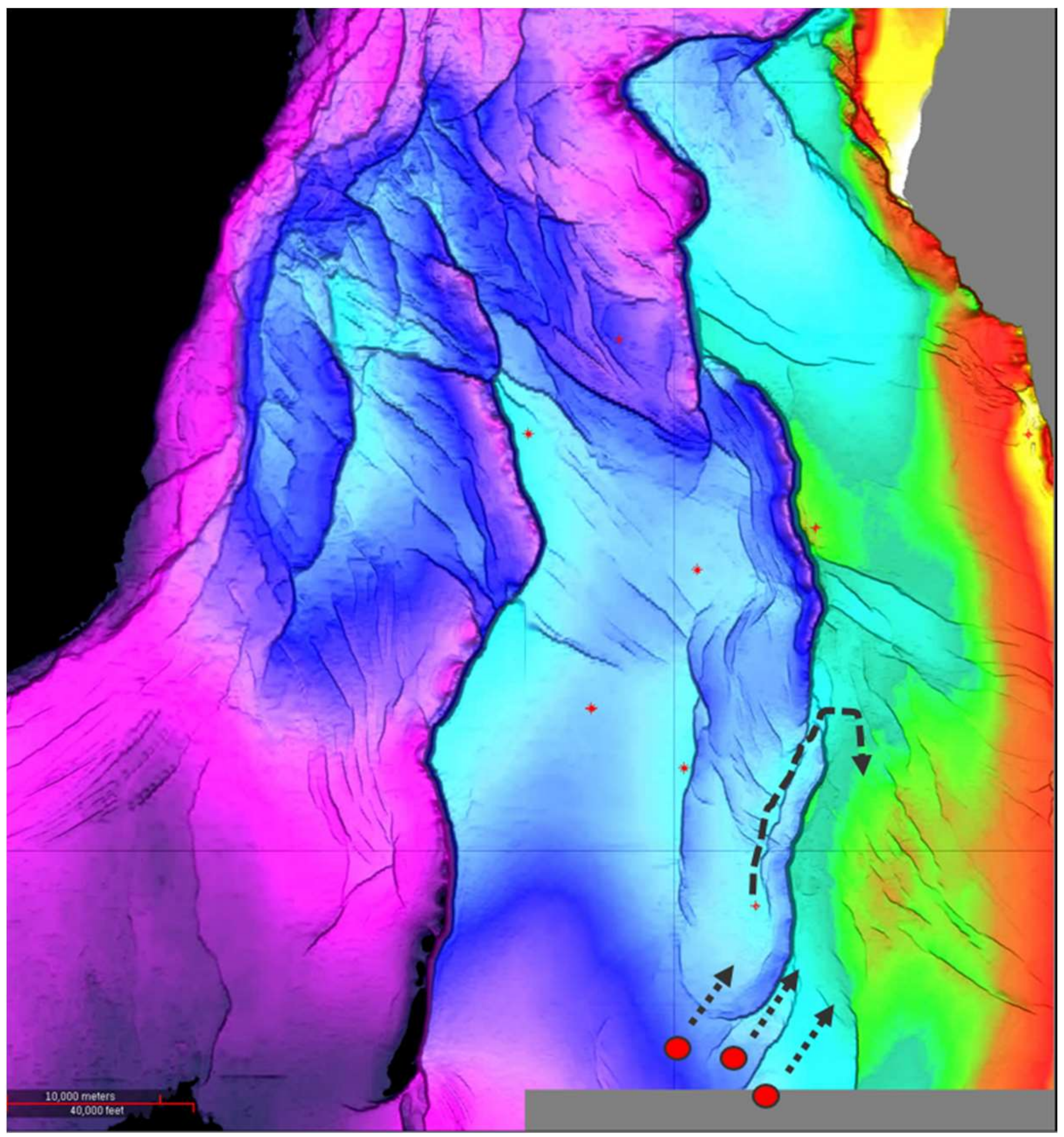




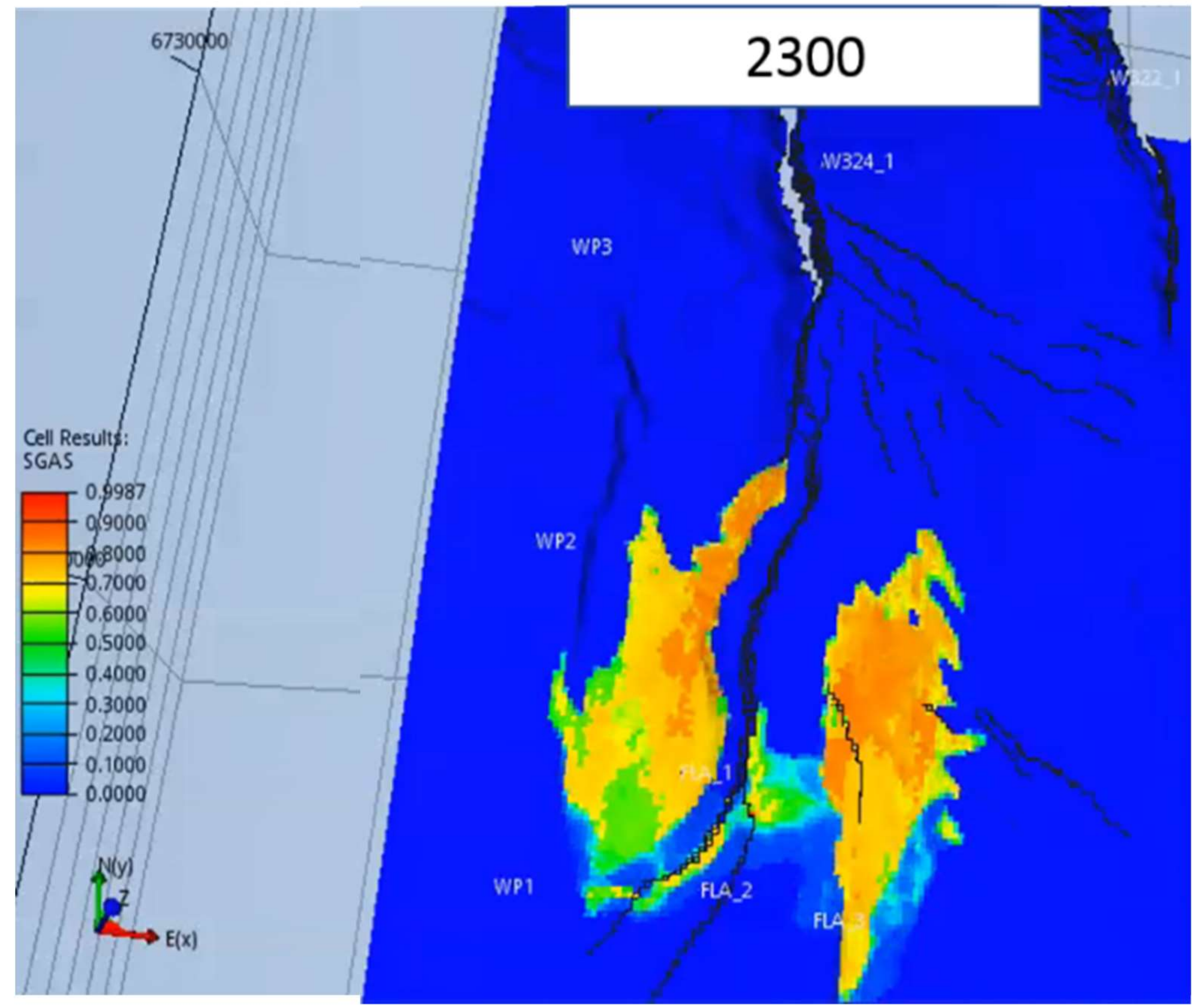
 Open 19 June 2019

Derisking Norwegian site(s)

Structural de-risking at Smeaheia / Horda



Scoping simulations of 600 Mt of CO_2 storage

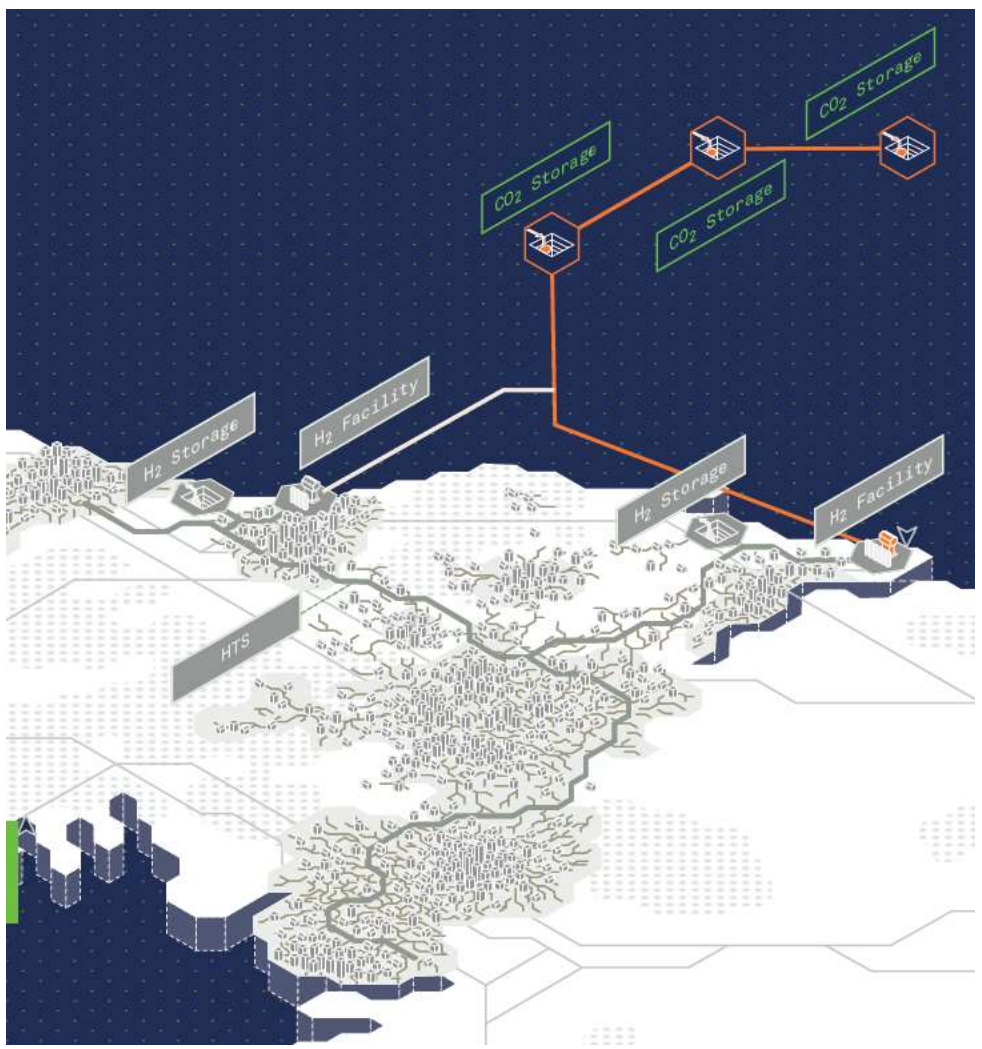


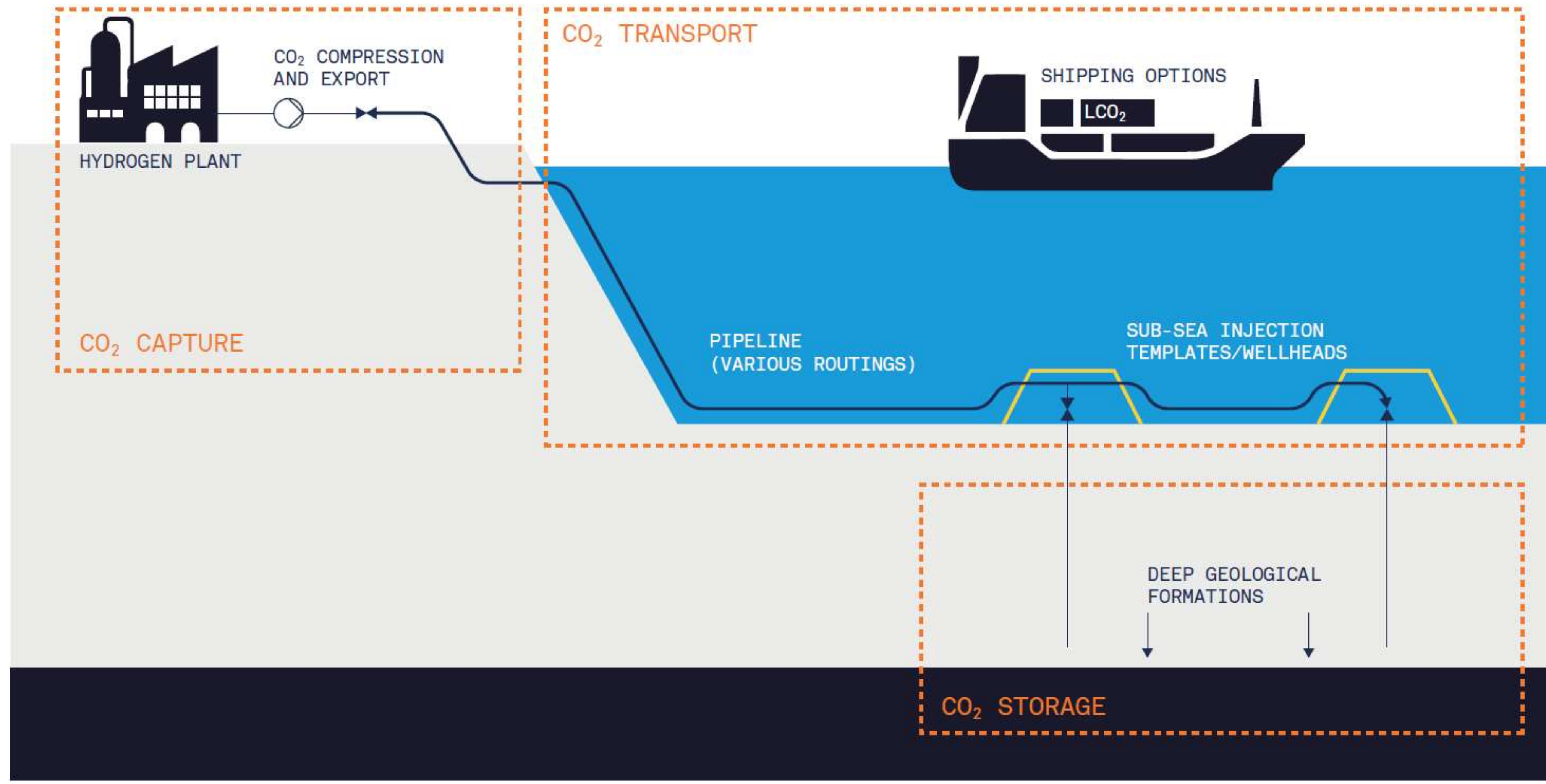
 Open

H21: Facilities concept

Facilities concept is focused on a sub-sea development (with shipping options)

- **UK solution:** 12 sub-sea wells drilled from 4 templates / 120 km pipe (26")
- **Norway option:** 6 sub-sea wells from 3 templates / 845 km pipe (32")





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Key messages

- 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 energy solutions**
- Hydrogen from natural gas with permanent offshore storage of CO_2 offers:

Low cost pathway

Low technical risk

Low carbon value chain

- Gas reforming is the most cost effective hydrogen pathway
- Proven technology in H_2 production and CO_2 storage
- The CO_2 is returned to permanent offshore storage
- The industry has a track-record of mega projects

Can be integrated with Renewable Electricity supply and ´green hydrogen´ feed-in

Low Carbon Solutions