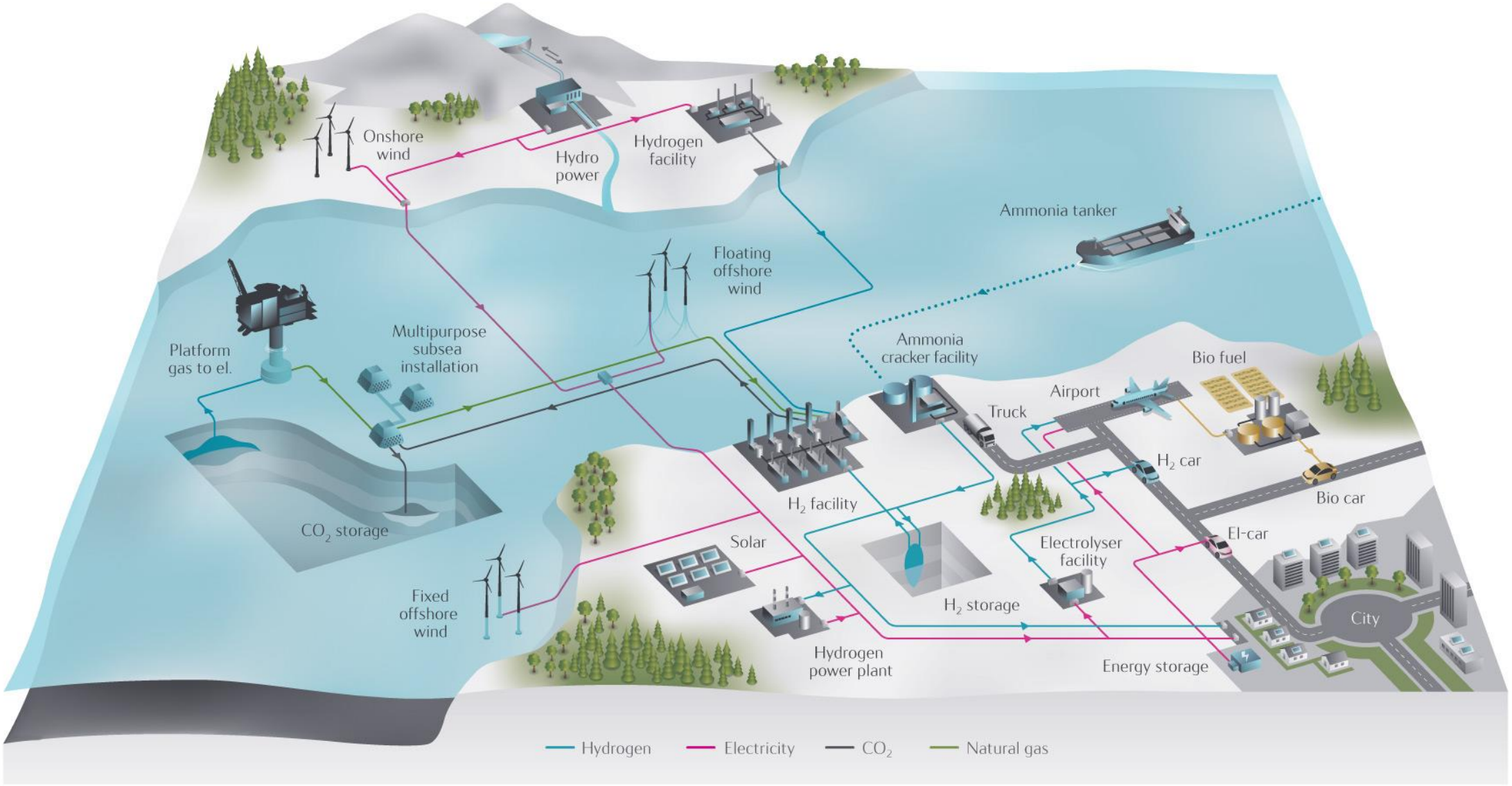
Low Carbon Solutions

Steinar Eikaas – Equinor



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)

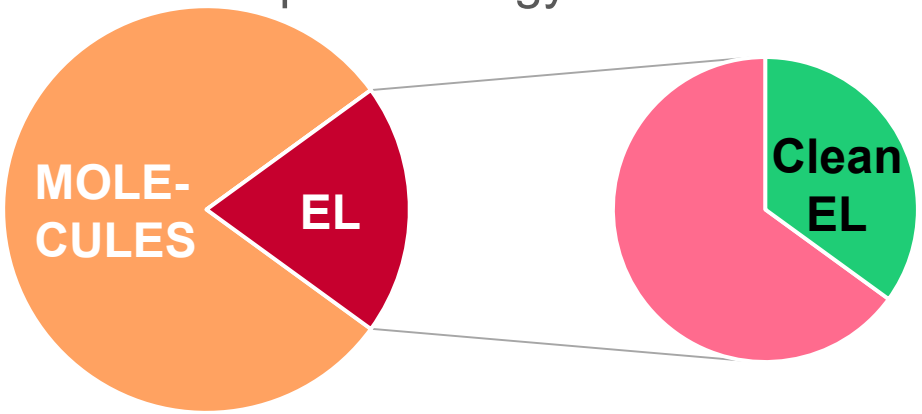
Hydrogen and renewable electricity smartly integrated

The Challenge and the Tool-Box

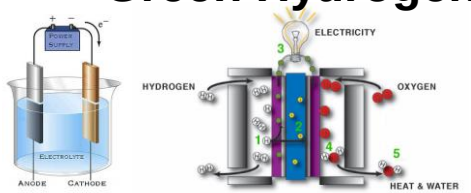
Cost Efficiency EL : MOL

Energy Transport 1 : 10
Long Term Storage 1 : 100

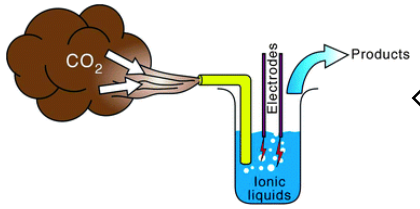
European Energy-Mix **2018**



Green Hydrogen and Power to X



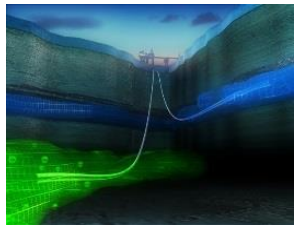
Electrolyser and Fuel Cell



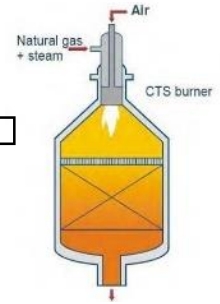
CCS

Hard-to-Decarbonize Industry

Blue Hydrogen

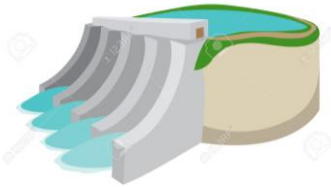


Permanent CO2 Storage (CCS)

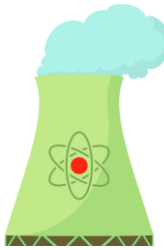


Gas Reformer w/CCS

Renewable EL



Zero Carbon EL



Nuclear

Hydrogen fired EL power

Improve Carbon Efficiency

Switch from Coal …

… to Natural Gas

CCS and Clean Hydrogen Portfolio

Market Build (2019 – First Operations)

2023

Northern Lights

Applications:
- CCS for industry

2026

HyDemo Norway

Applications:
- Hydrogen for maritime

2028

Clean Steel

Applications:
- Hydrogen for industry (steel)

2026

Zero Carbon Humber

Applications:
- Hydrogen for industry
- Chemicals
- Synthetic fuels
- BECCS
- Hydrogen power

2026

Clean Gas Project

Applications:
- Post-combustion CCS power generation
- CCS for industry
- BECCS
- Hydrogen production

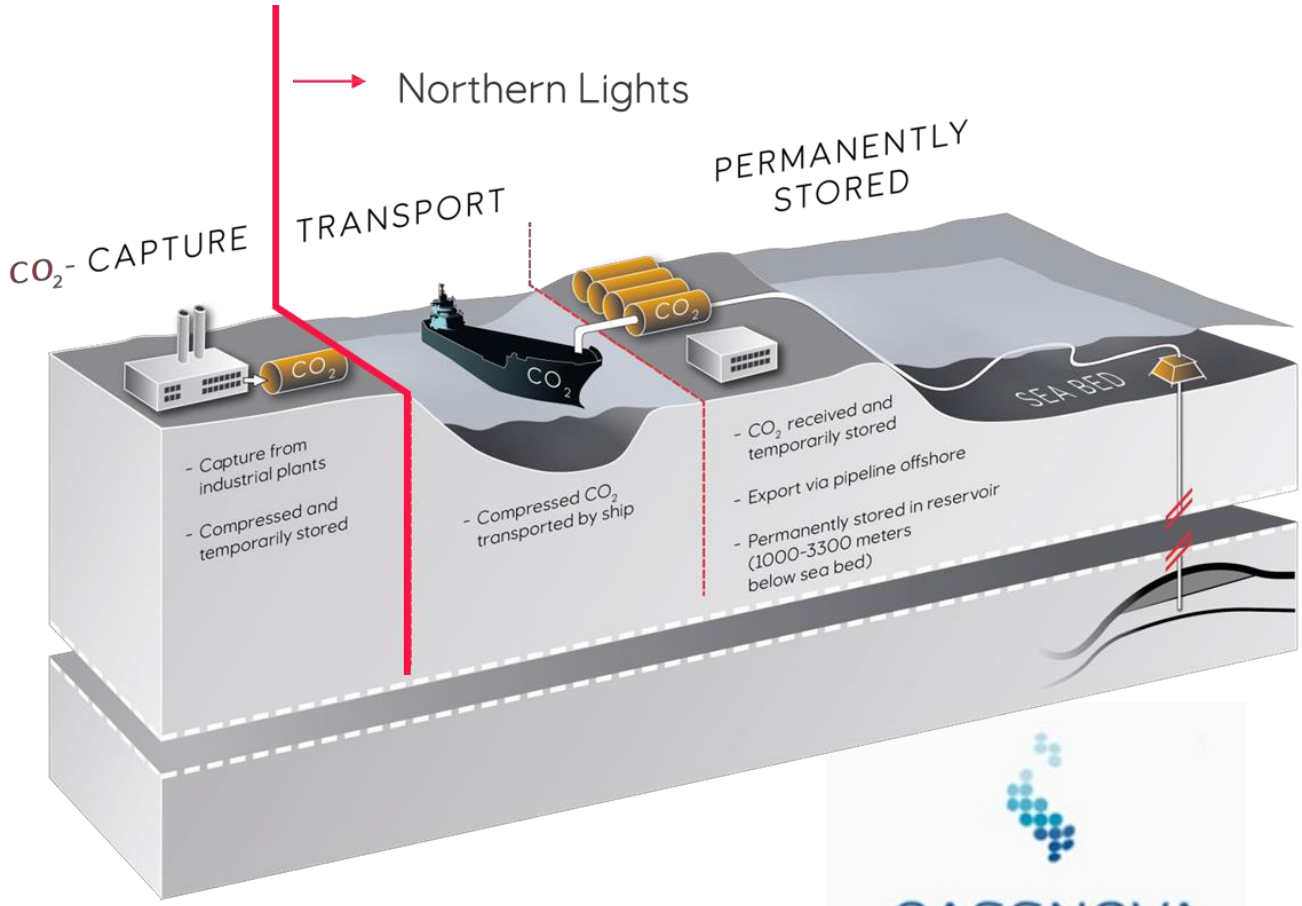
2027

H2 Magnum

Applications:
- Hydrogen power

A European “open source” network for CO2 removal

Source: Bellona Europe



GASSNOVA

Project status & future

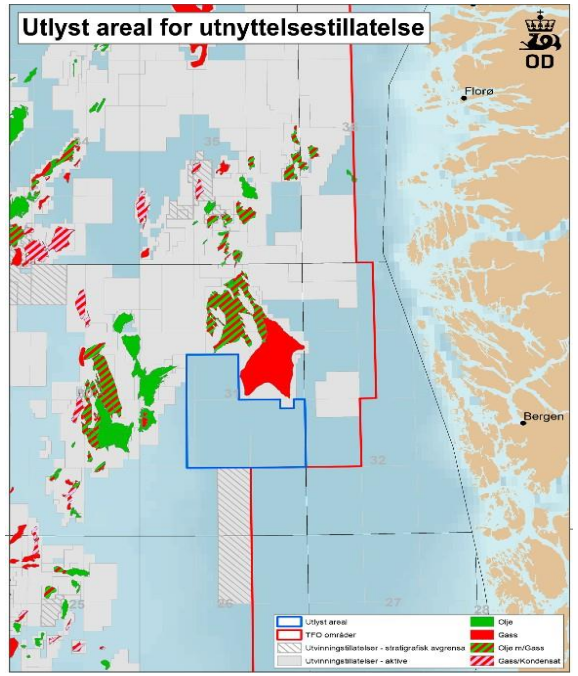
- **Transport, intermediate storage, pipeline**
  FEED to be delivered Q3 2019

- **Storage**
  - Use permission Nr 001 given for “Aurora” south of Troll
  - Confirmation well to be drilled November 2019, subsea equipment is being built

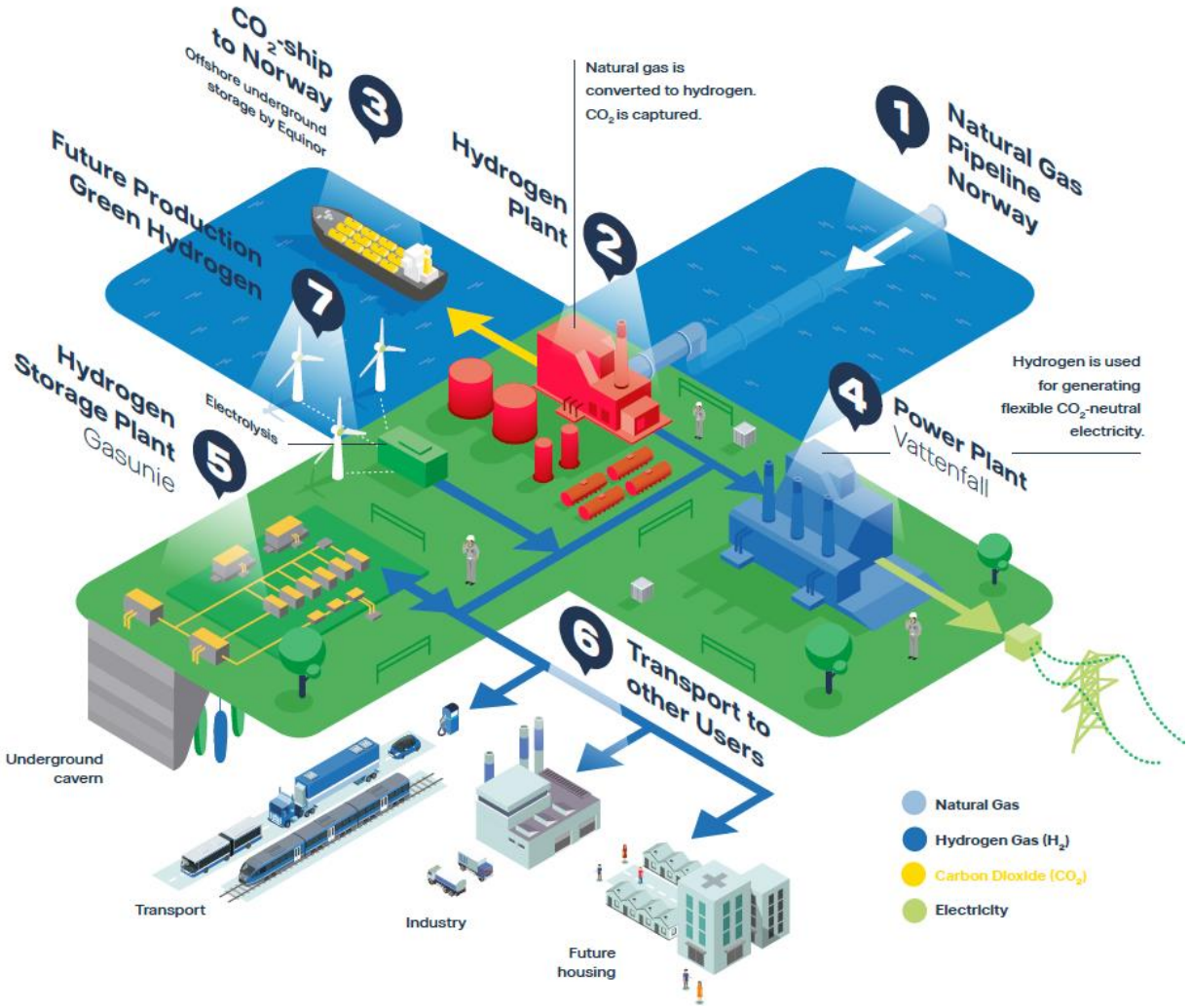
- **Potential beyond anchor customers**
  In dialogue with 15 possible users in 8 European countries

- **Investment decisions**
  Planned for December 2020 (State budget)

- **Operational 2023**
  Then all emitters have a storage solution – start capture!



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: gasunie & NUON VATTENFALL

Perfect fit of Offshore Wind and Hydrogen

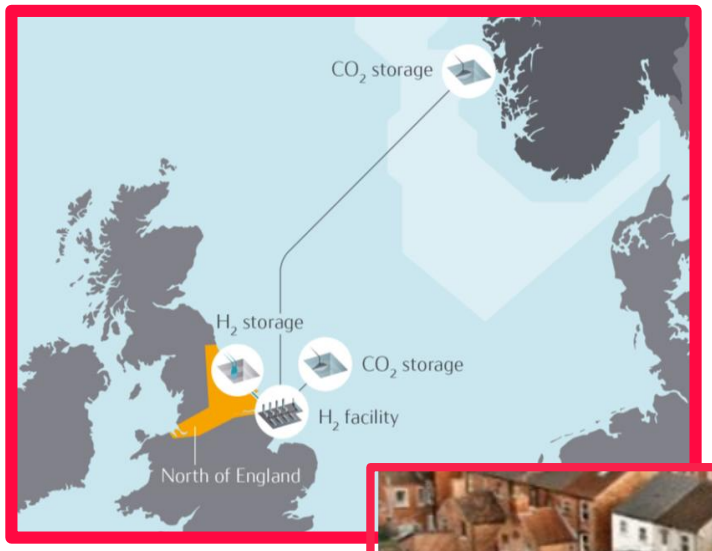
10 sec backup

360 MW

20.000 x 20ft (2,5 days backup)

440 Mw Unlimited, Clean Backup

H21 North of England



System approach to decarbonise residential heating and distributed gas

Energy: ~85 TWh (12.5% of UK population)

/ 12 GW hydrogen production

CO2 emissions reduction: 12,5 Mt CO2 pa

CO2 storage offshore UK / Norway

8 TWh (seasonal) hydrogen storage

CO2 footprint 14,5 g/KWh

Unlimited system coupling

CAPEX: £23 billion

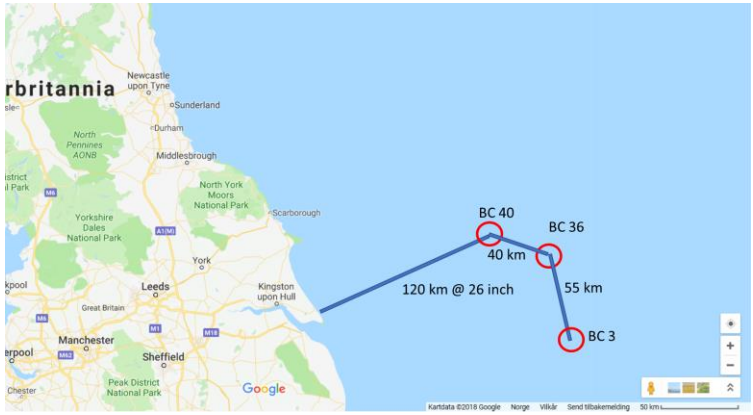
H21 NoE supply concept

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

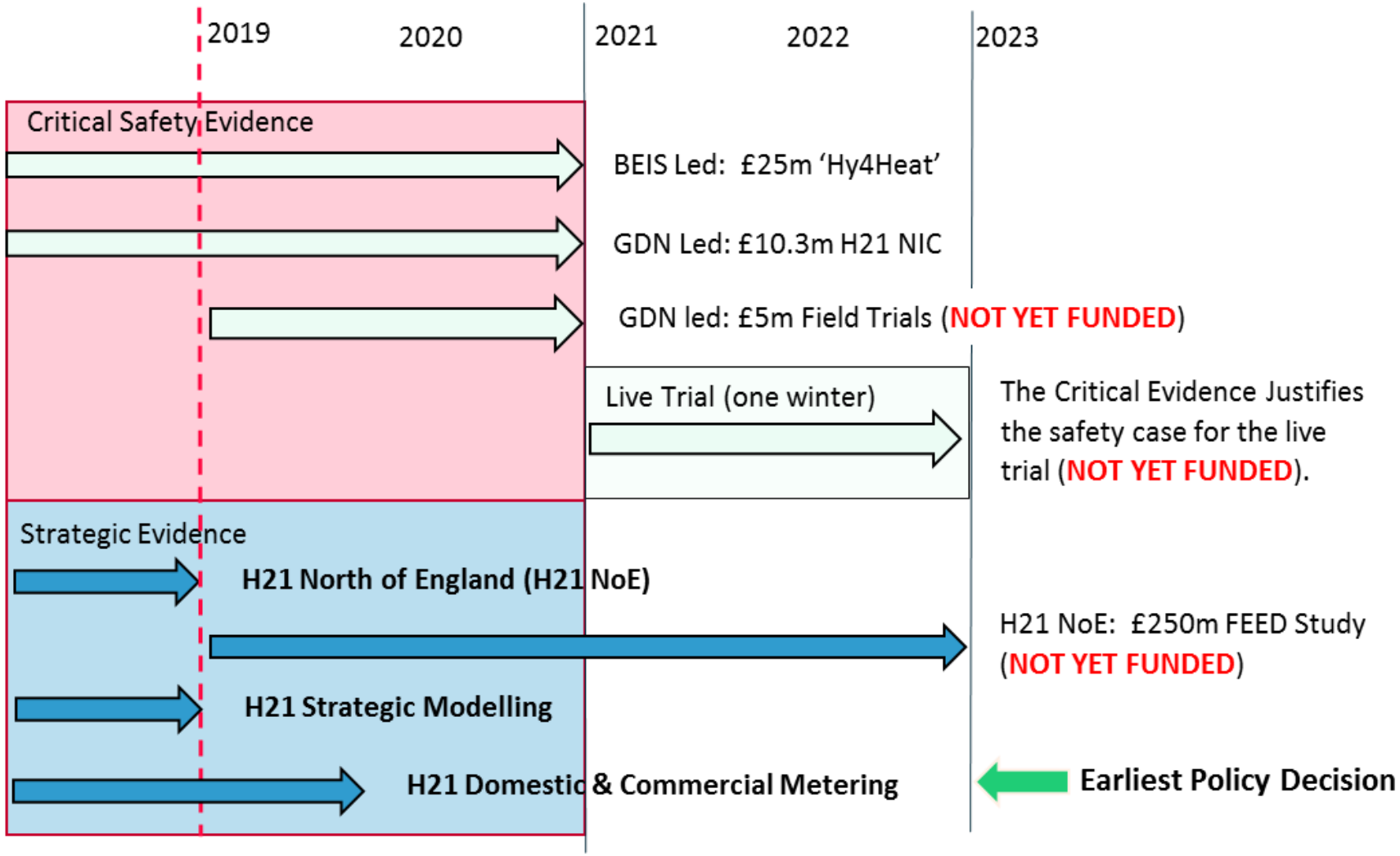
- Location: Bundter
- Capacity: +600 Million @ 17 mtpa
- Configuration: Saline aquifers

H21 - What will it cost?

2035 Residential Prices

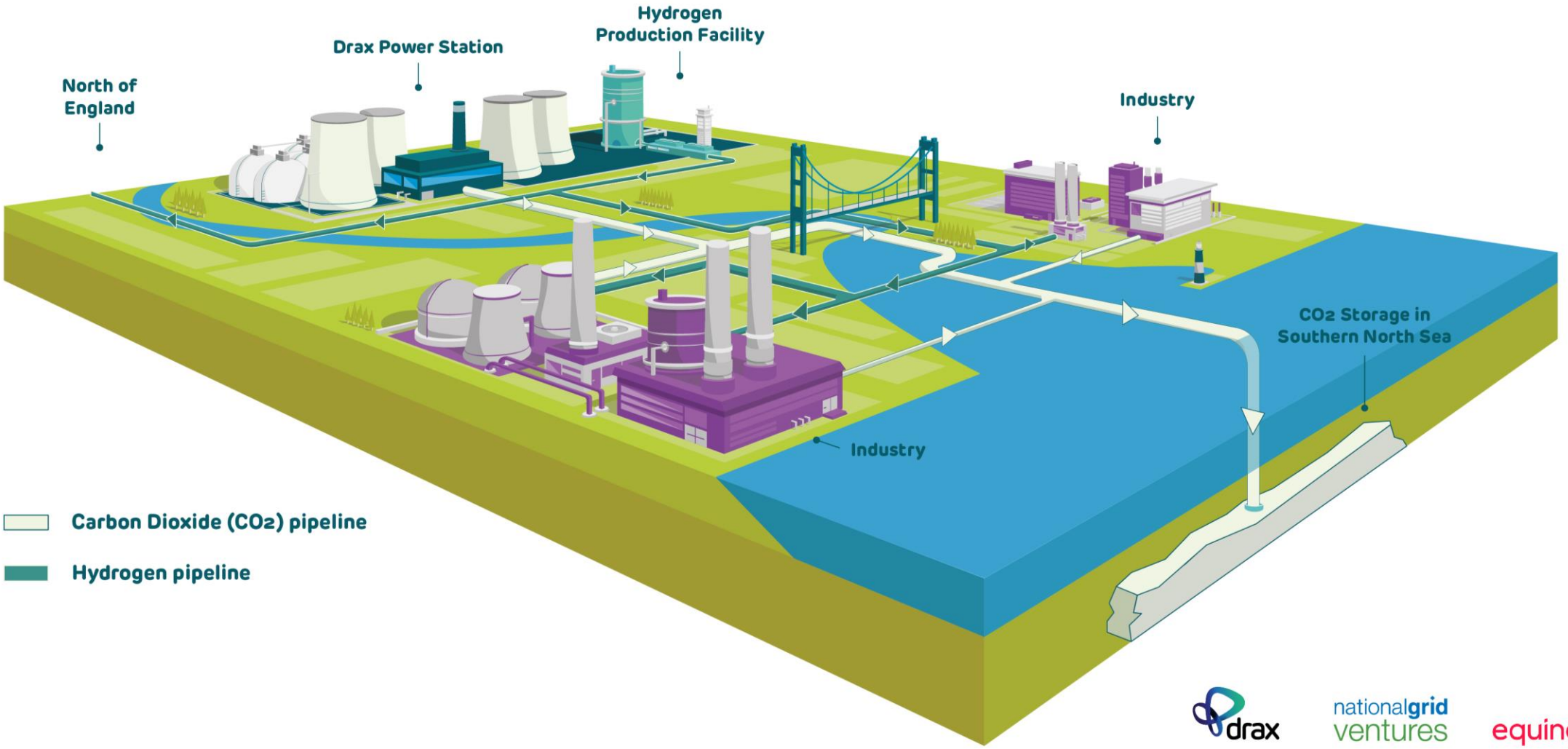
	2035 Residential Prices	CO2 Footprint
Electricity	£200/MWh (BEIS Projection)	50 g/KWh
Natural Gas	£50/MWh (BEIS Projection)	200 g/KWh
Hydrogen	£75/MWh (H21)	15 g/KWh (H21)

The next steps



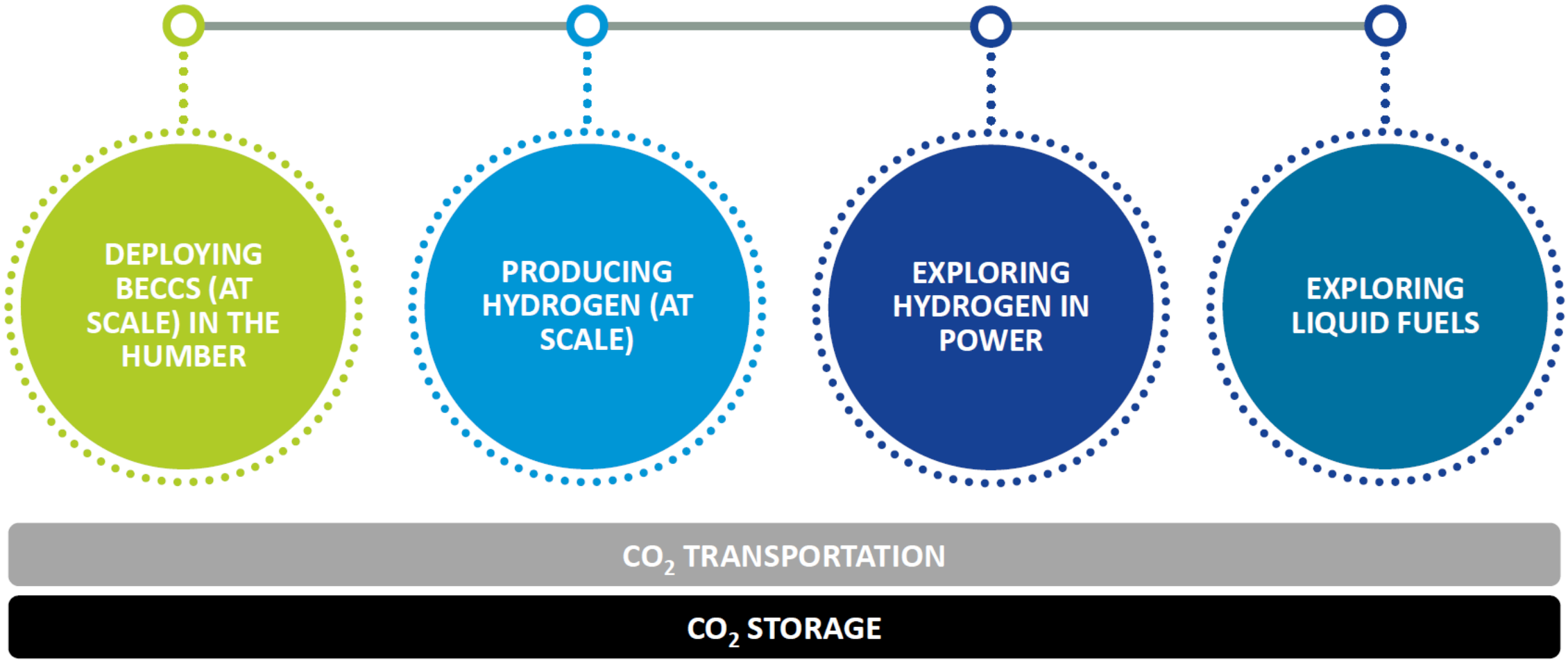
Zero Carbon Humber

Our vision



Overview of partnership

Areas of collaboration



Decarbonising Energy Systems

Easy ⟵ **complexity to decarbonise** ⟶ **Hard**

Transport

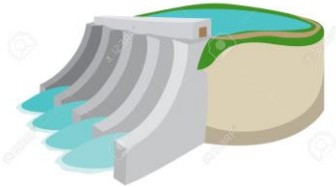
Battery (mostly) plus Hydrogen for Heavy Duty

Hydrogen Fuel-Cell Trains

Liquid Hydrogen and Fuel-Cells for long haul Big Ships

Power

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



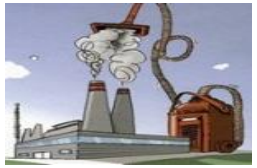
Hydro-Power as Battery for Small Scale Intermittency

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

Industry

Light Industry powered by Renewable

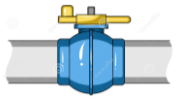
Heavy Industry powered by Hydrogen from Natural Gas + CCS



CCS for Industry without other Alternatives

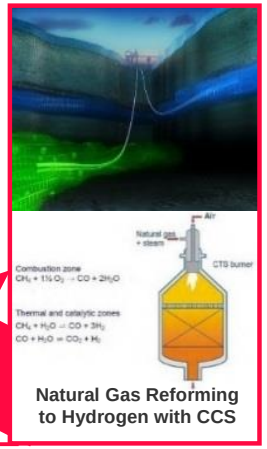
Heat

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



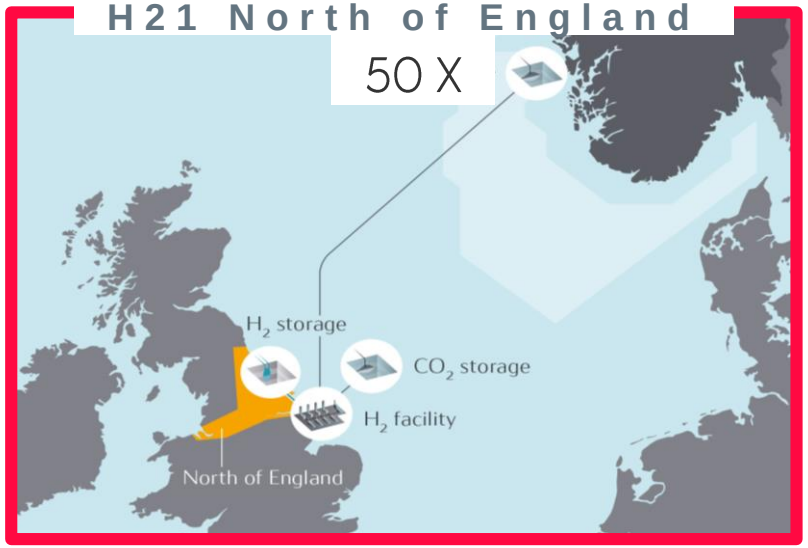
Natural Gas Reforming to Hydrogen with CCS

Multiple technologies to address the challenge

Understanding the Challenge

Natural Gas currently provides Europe with more than 1500 TWh of flexible energy.

What is 1500 TWh?



Vehicle

20 000 000 000 X

Battery park

11 600 000 X

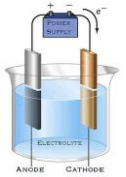
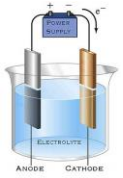
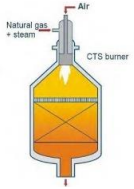
Hydro

200 X

Why Blue Hydrogen?

Europe currently consumes about 8000 TWh of Oil & Gas

How can half of that be converted to decarbonized Hydrogen?
(assuming all new renewable generation is channeled towards the remaining electricity sector)

REQUIREMENTS	Green Hydrogen	Blue Hydrogen
Energy Source	 x 150 New Plants	Already Exists (Natural Gas)
Hydrogen Capacity	 x 50.000 (10 MW units)	 x 500 (1 GW units)
vs.		
Existing Supply Chain *annual global deliveries*	 x 100 (10 MW units)	 x 100 (1 GW units) SMR, ATR, LNG

Blue Hydrogen – What Will it Cost?

Sector	Price Premium	Compared to …
Industry	+25%	Grey Hydrogen
Heat	+50%	Natural Gas
Power (on demand)	+100%	Natural Gas

Steinar Eikaas