The Equinor way; natural gas reforming and carbon capture and offshore storage (CCOS)

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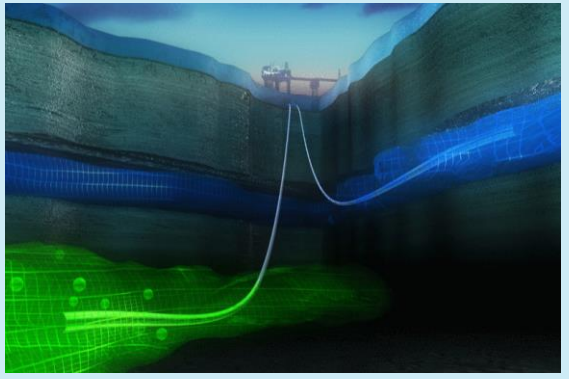
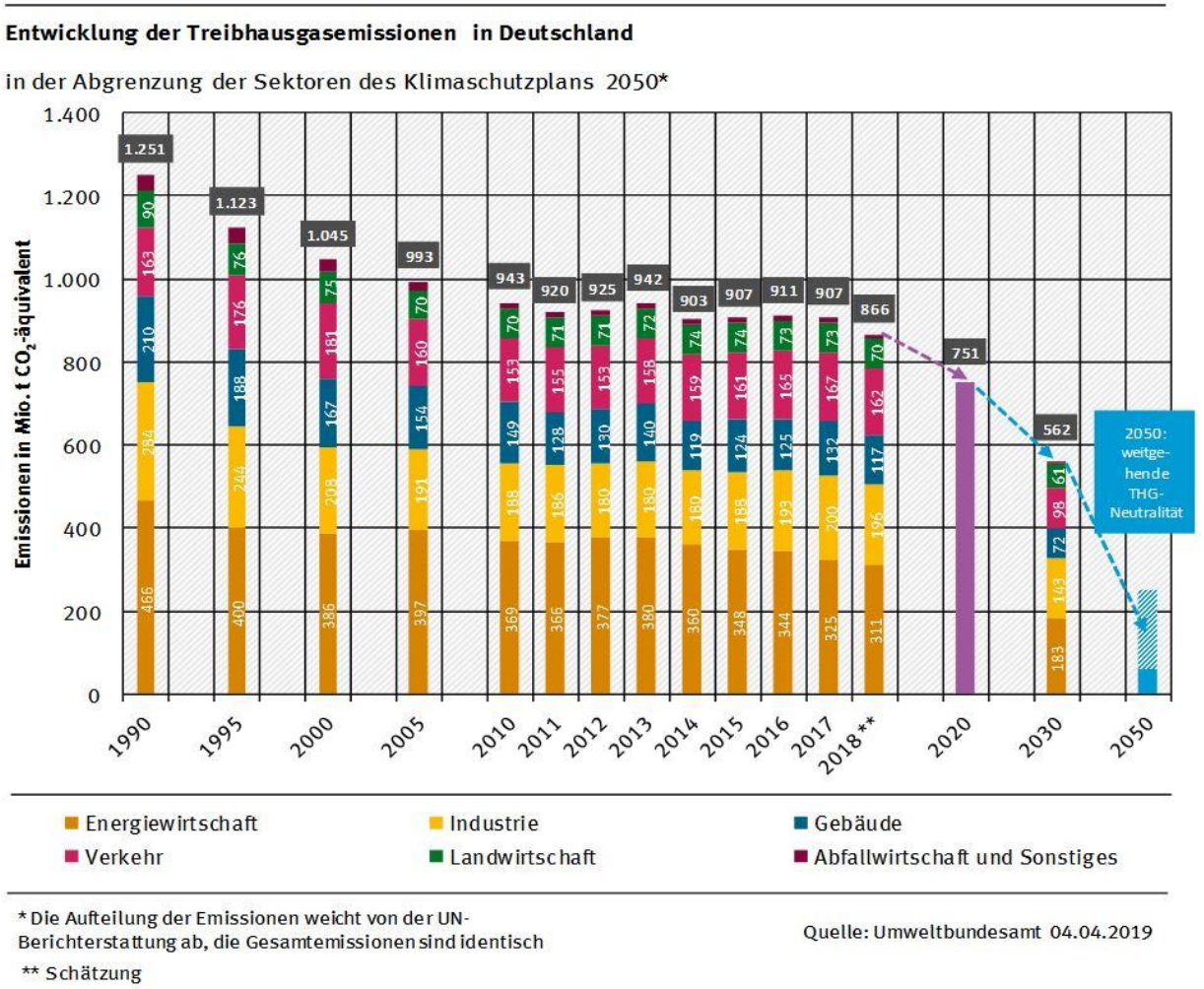
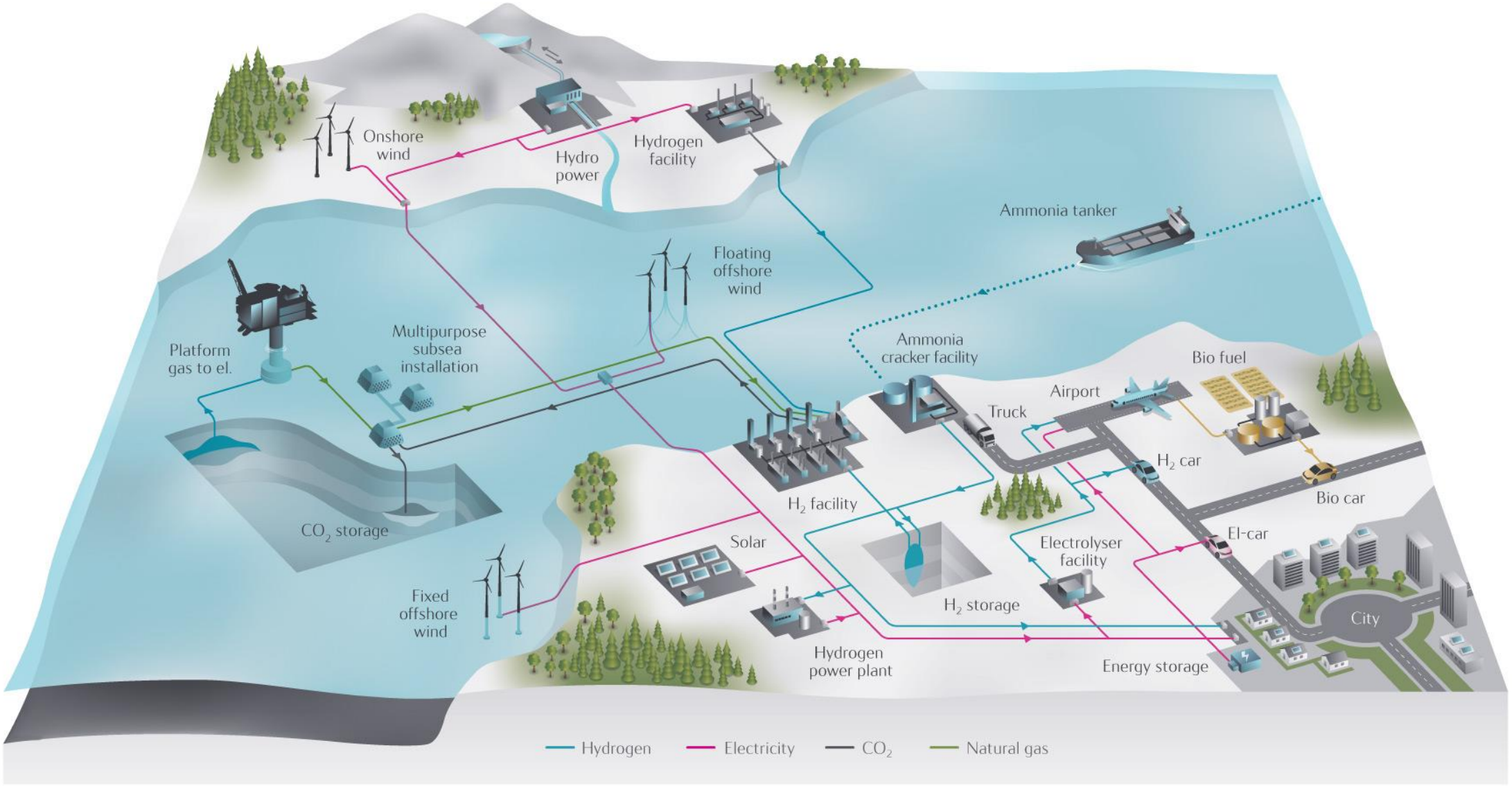
EU-RU GAC WG2
Berlin, October 21, 2019


Climate-neutrality 2050: GHG emissions reduction in Germany



Low Carbon Solutions



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)

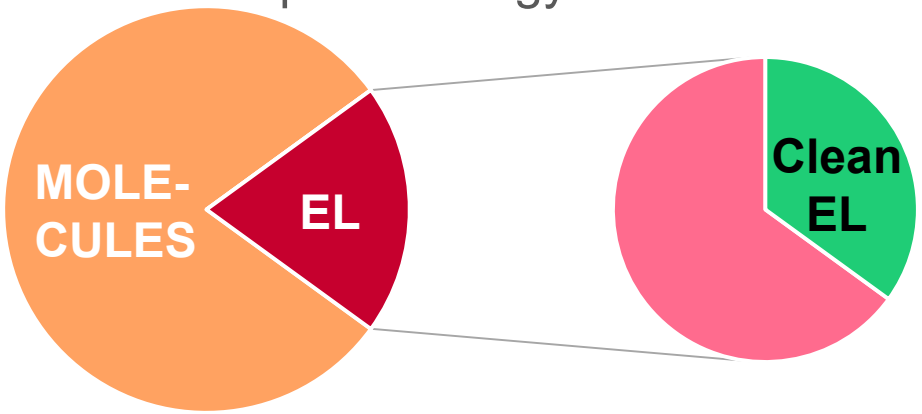
Hydrogen and renewable electricity smartly integrated

The Challenge and the Tool-Box

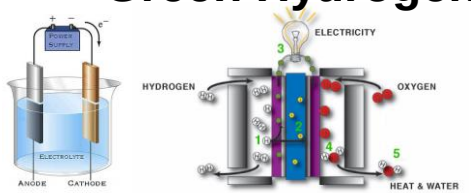
Cost Efficiency EL : MOL

Energy Transport 1 : 10
Long Term Storage 1 : 100

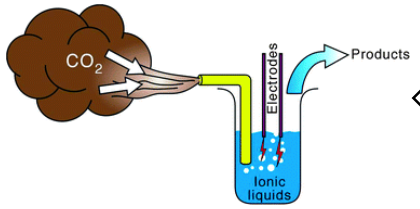
European Energy-Mix **2018**



Green Hydrogen and Power to X

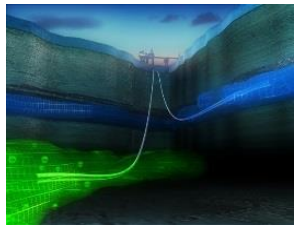


Electrolyser and Fuel Cell



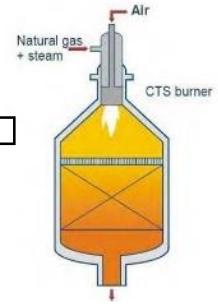
CCS

Hard-to-Decarbonize Industry



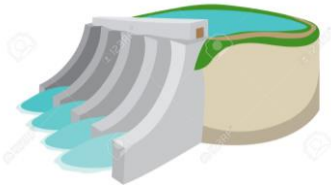
Permanent CO2 Storage (CCS)

Blue Hydrogen

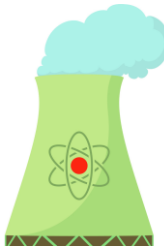


Gas Reformer w/CCS

Renewable EL



Zero Carbon EL



Nuclear

Hydrogen fired EL power

Improve Carbon Efficiency

Switch from Coal …

… to Natural Gas

CCOS 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

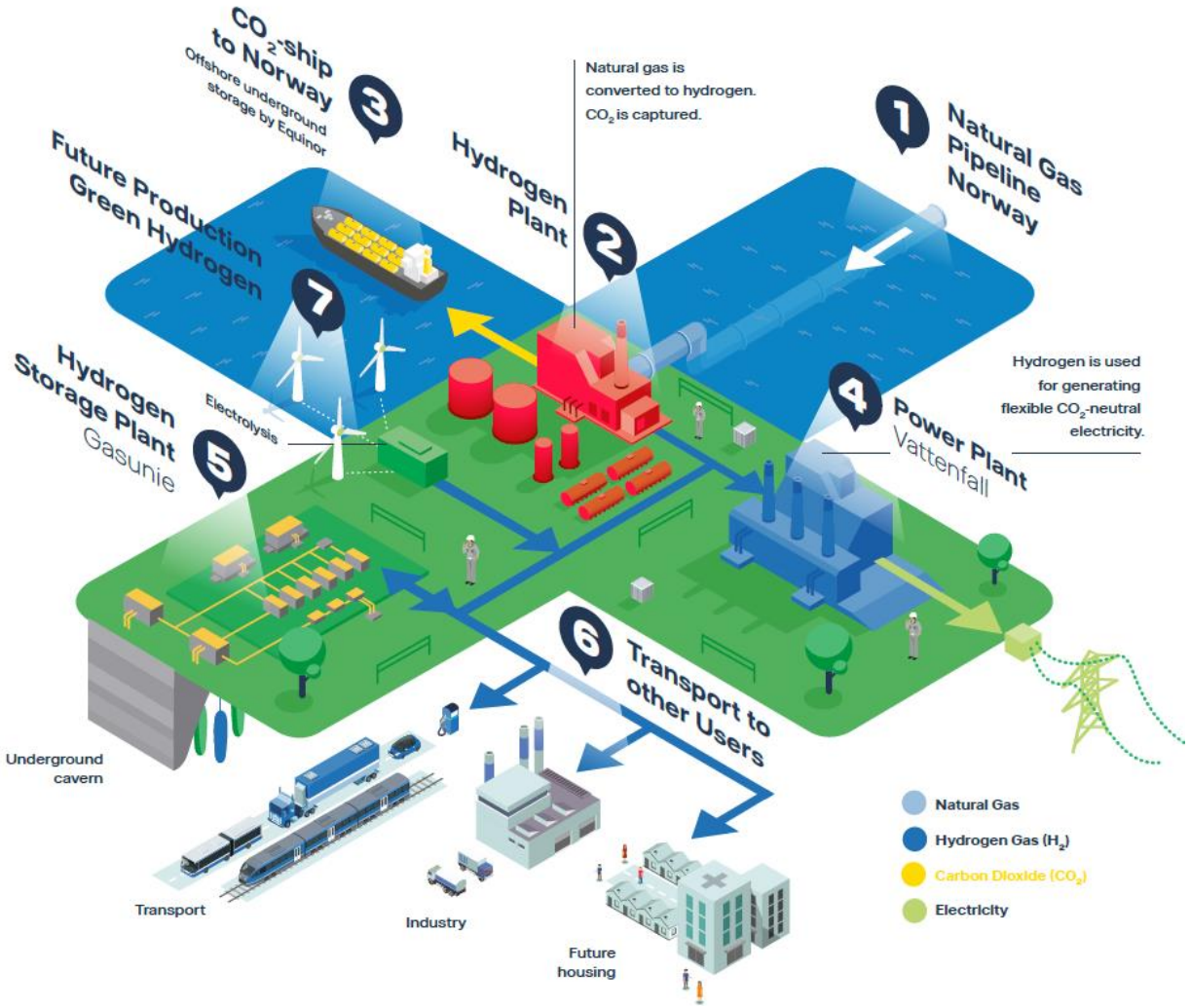
H2 Magnum

Applications:
- Hydrogen power

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

H2M – Magnum, Netherlands



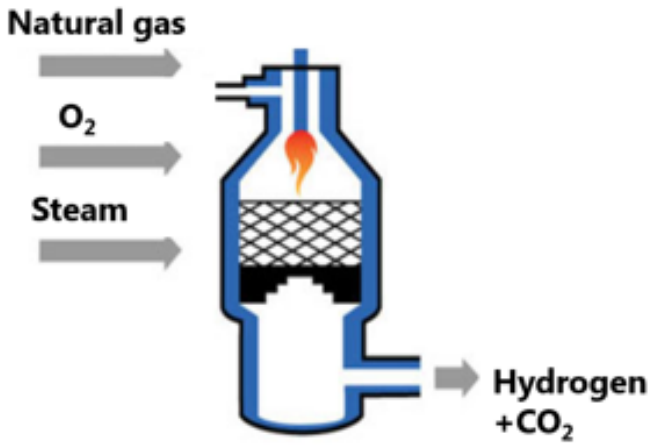
- Energy: 8-12 TWh
- CO2 emissions reduction of 2 Mton/year
- Utilise existing gas power plants and gas infrastructure
- Switch fuel from natural gas to clean H2
- Clean, flexible electricity as back-up for solar and wind
- Launch large-scale H2 economy

- Partners: gasunie & NUON VATTENFALL

Autothermal reforming – an efficient means of hydrogen production

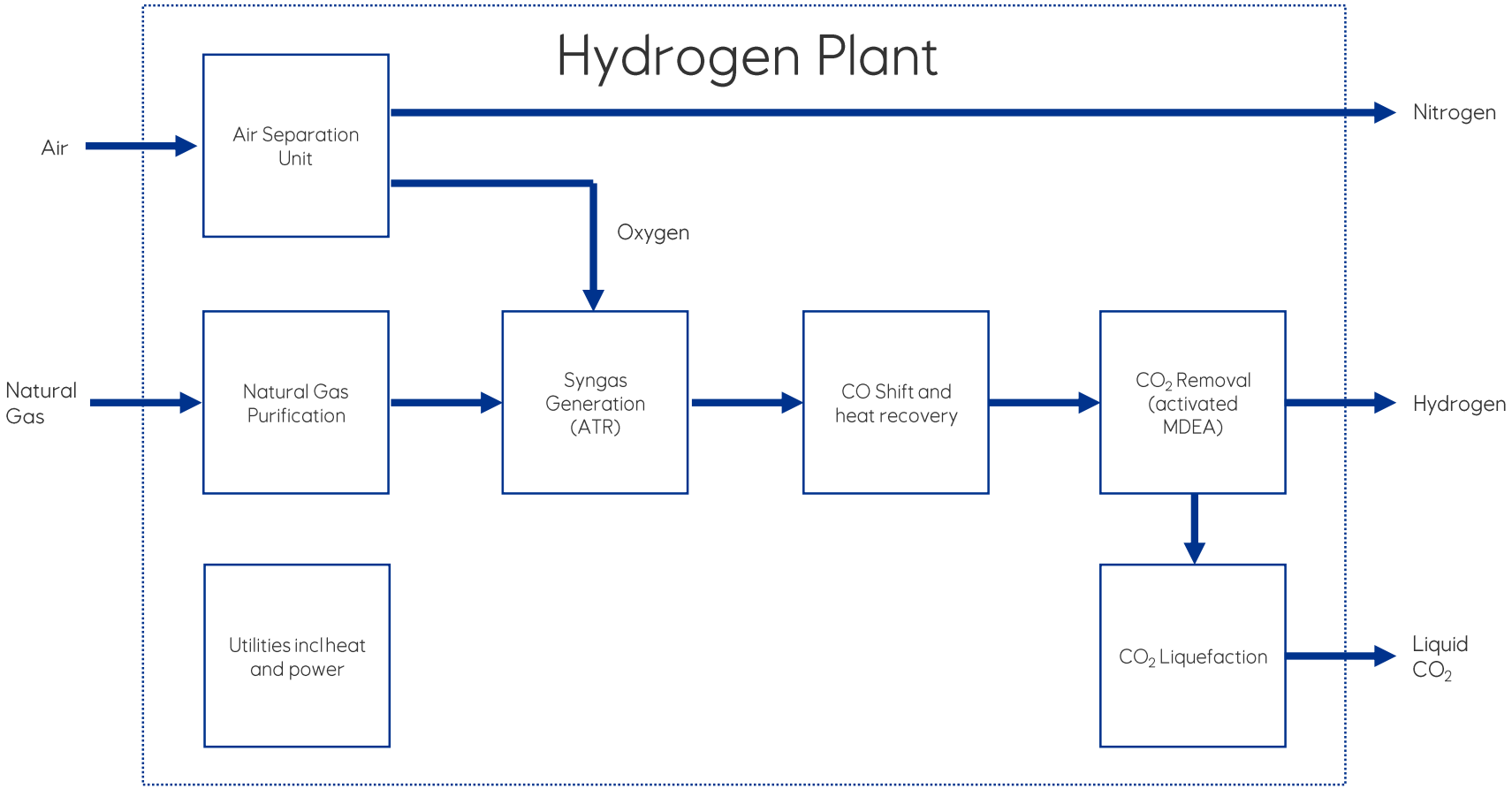
Autothermal reforming (ATR) is a well-established process for large-scale industrial production of hydrogen based on natural gas.

- In this process, the carbon dioxide is put under high pressure. This allows **separation rates up to 94%**
- ATR has **optimized efficiency** due to the combined advantages of two processes: Oxidation (providing energy from heat) and steam reforming (high hydrogen yield) complement each other very well
- Autothermal reformers **take up less space** than steam reformers

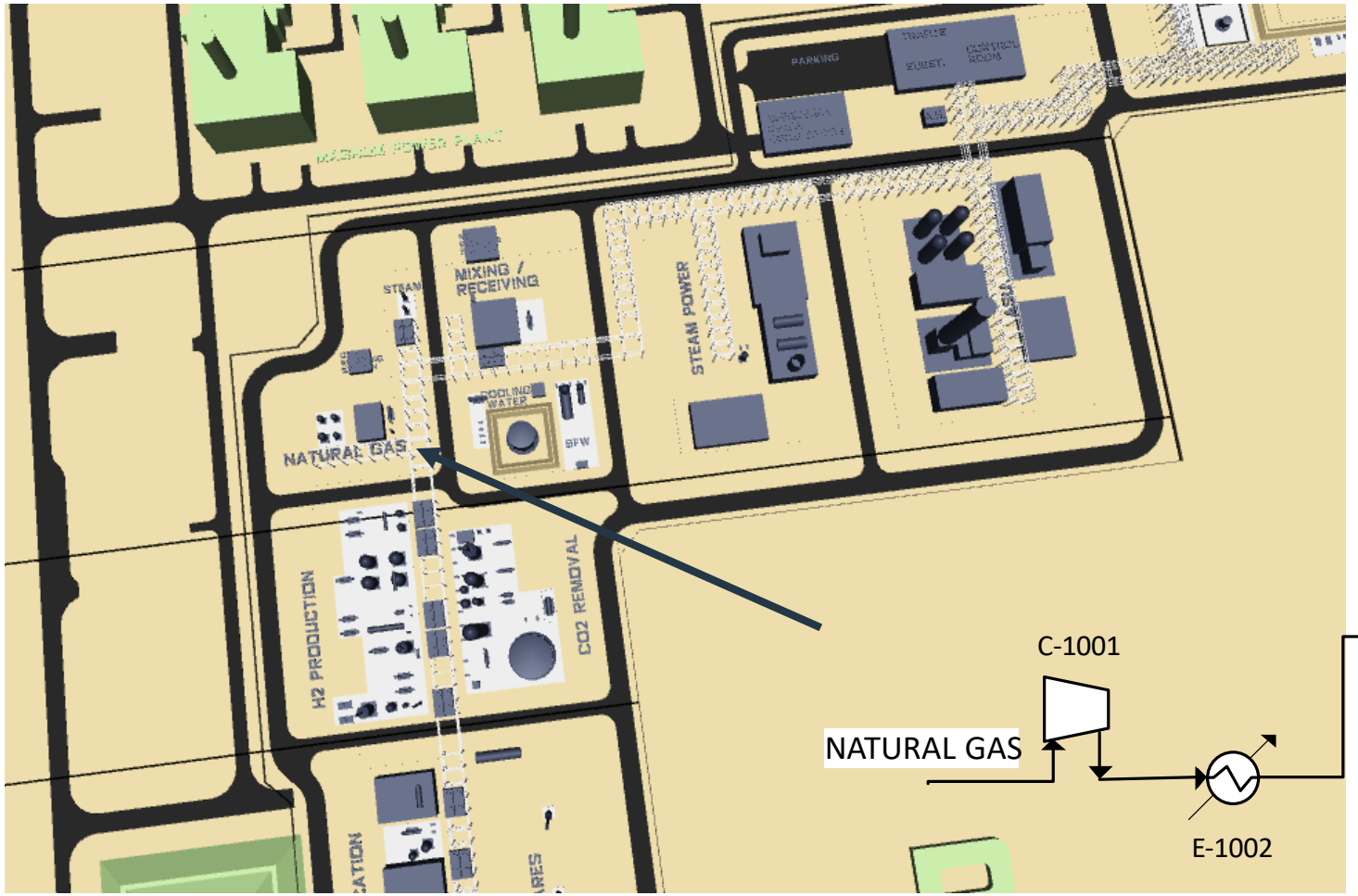


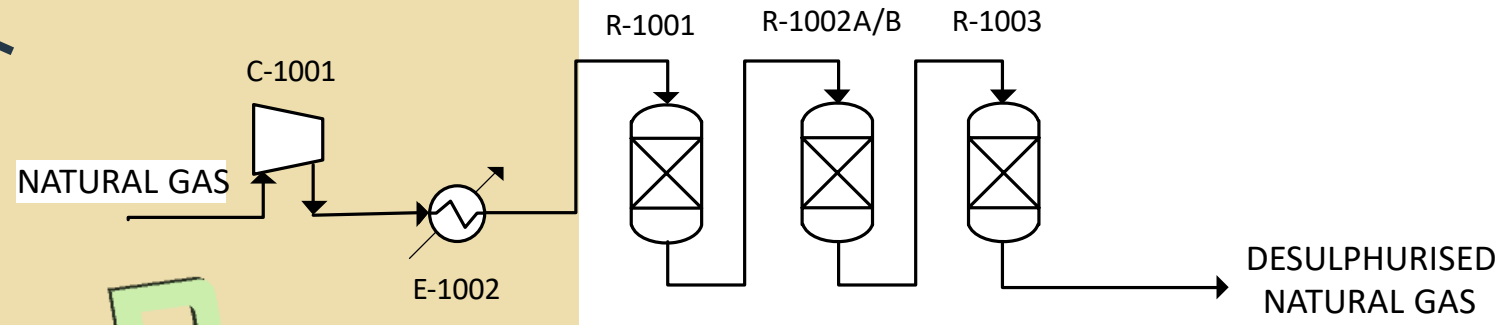
Decarbonization Process - Selected Technologies

ATR and Amines



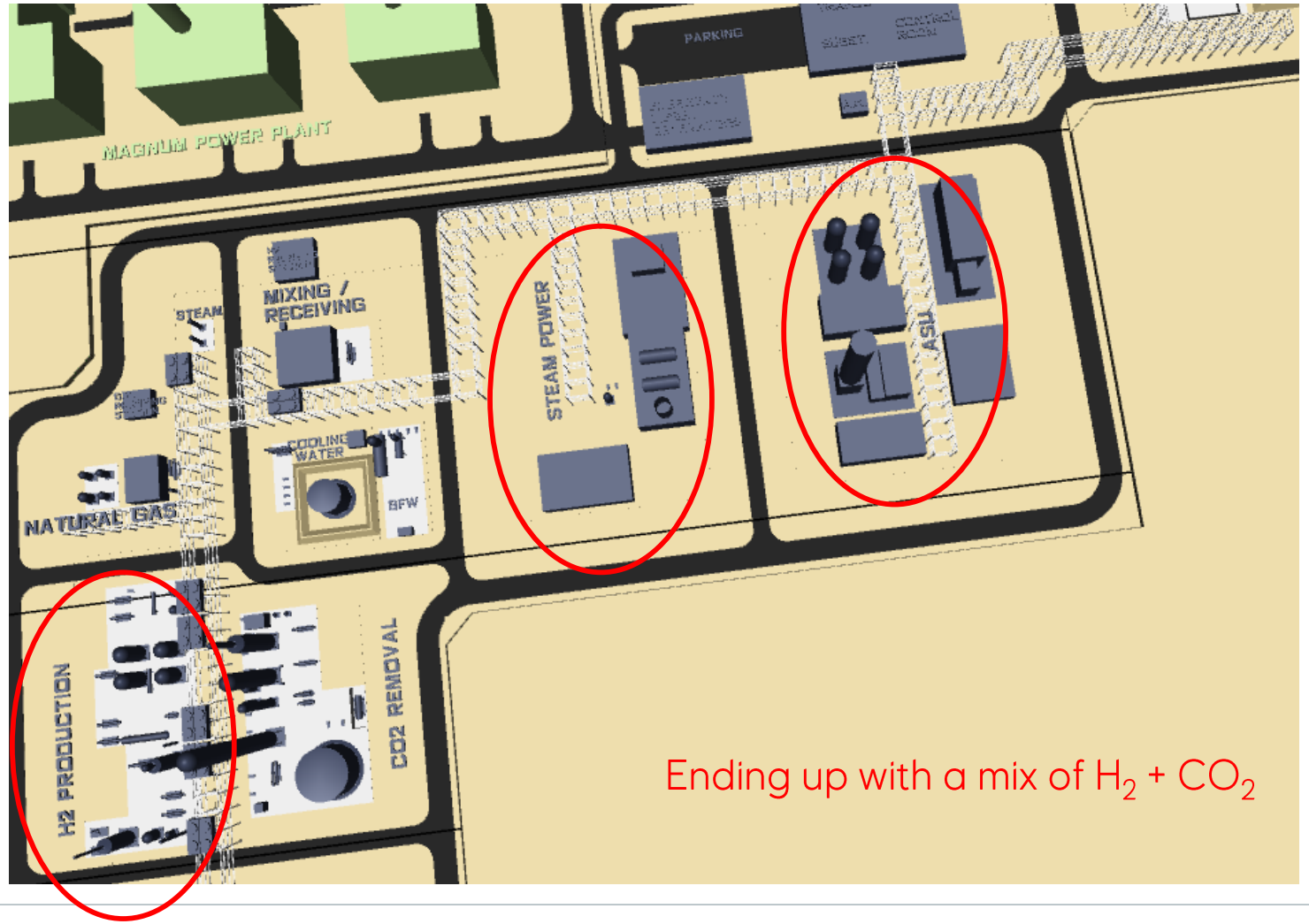
Natural Gas Compression and Desulphurisation





- Increasing the gas pressure to meet H_2 delivery pressure
- Cleaning out impurities from the gas that will harm the process

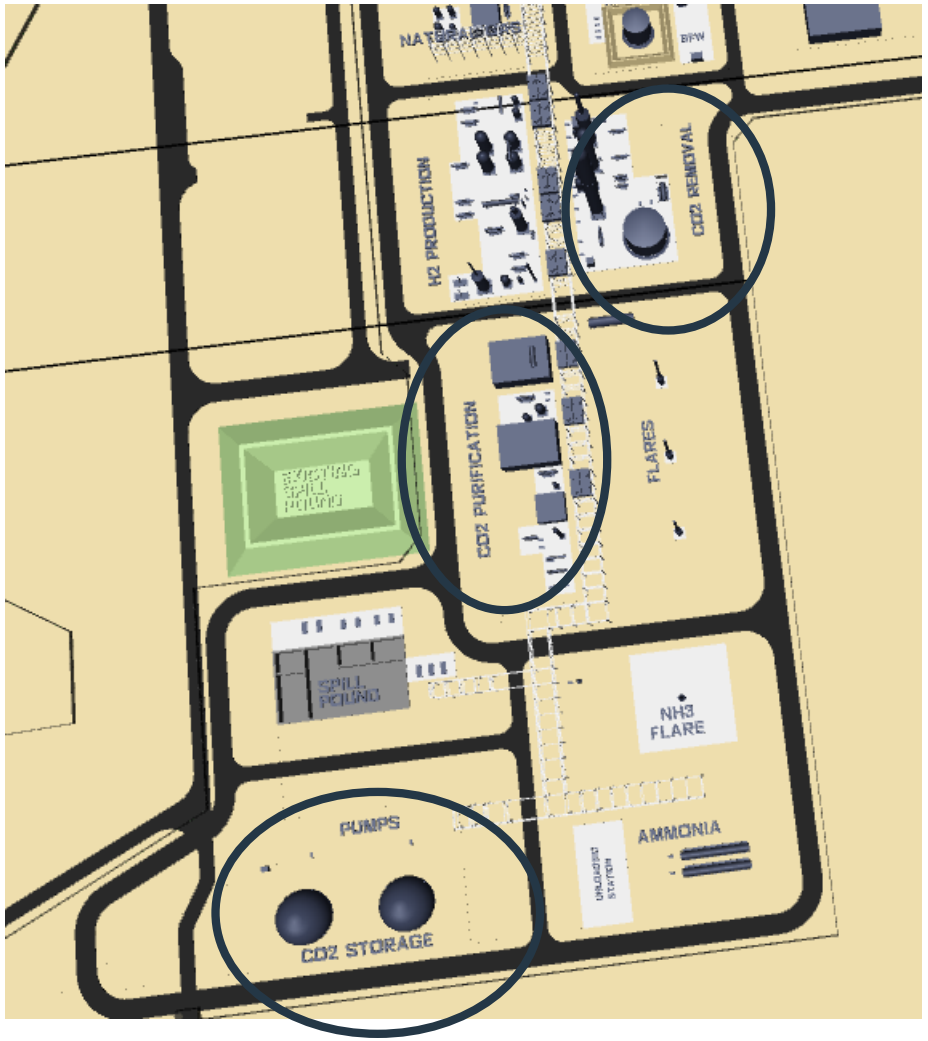
ATR - Reforming process (Syngas generation)



H_2 production:

- Natural gas, steam and Oxygen reacts forming Syngas ($CO+H_2$)
- Followed by CO conversion to CO_2 and H_2 and heat recovery (steam)
- ASU – Air Separation Unit (Oxygen and Nitrogen) – high power demand
- Steam is used for power generation

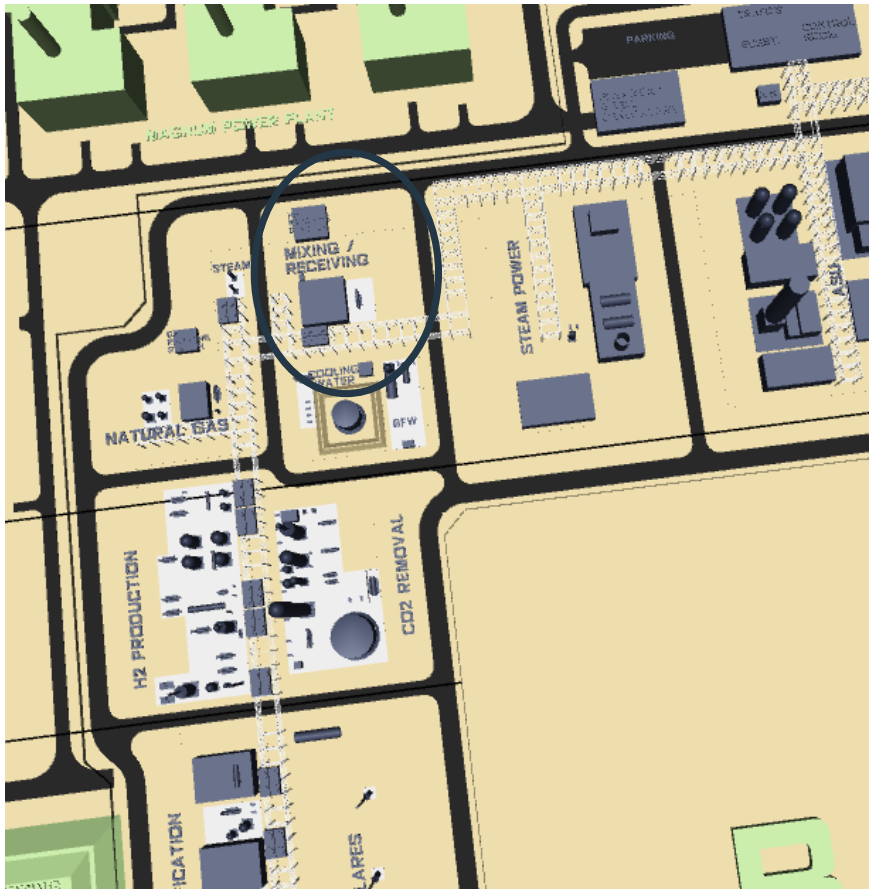
CO_2 Removal and CO_2 Liquefaction



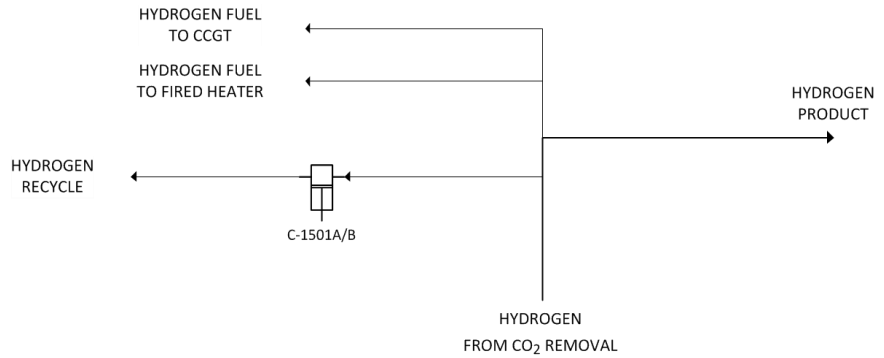
Separate the CO_2 from H_2:

- Amine CO_2 removal technology uses an amine based solvent to absorb CO_2 from the process gas
- The CO_2 is recovered and sent to the CO_2 liquefaction unit meeting the transport specification before going into storage waiting for transportation

Hydrogen Distribution and Export



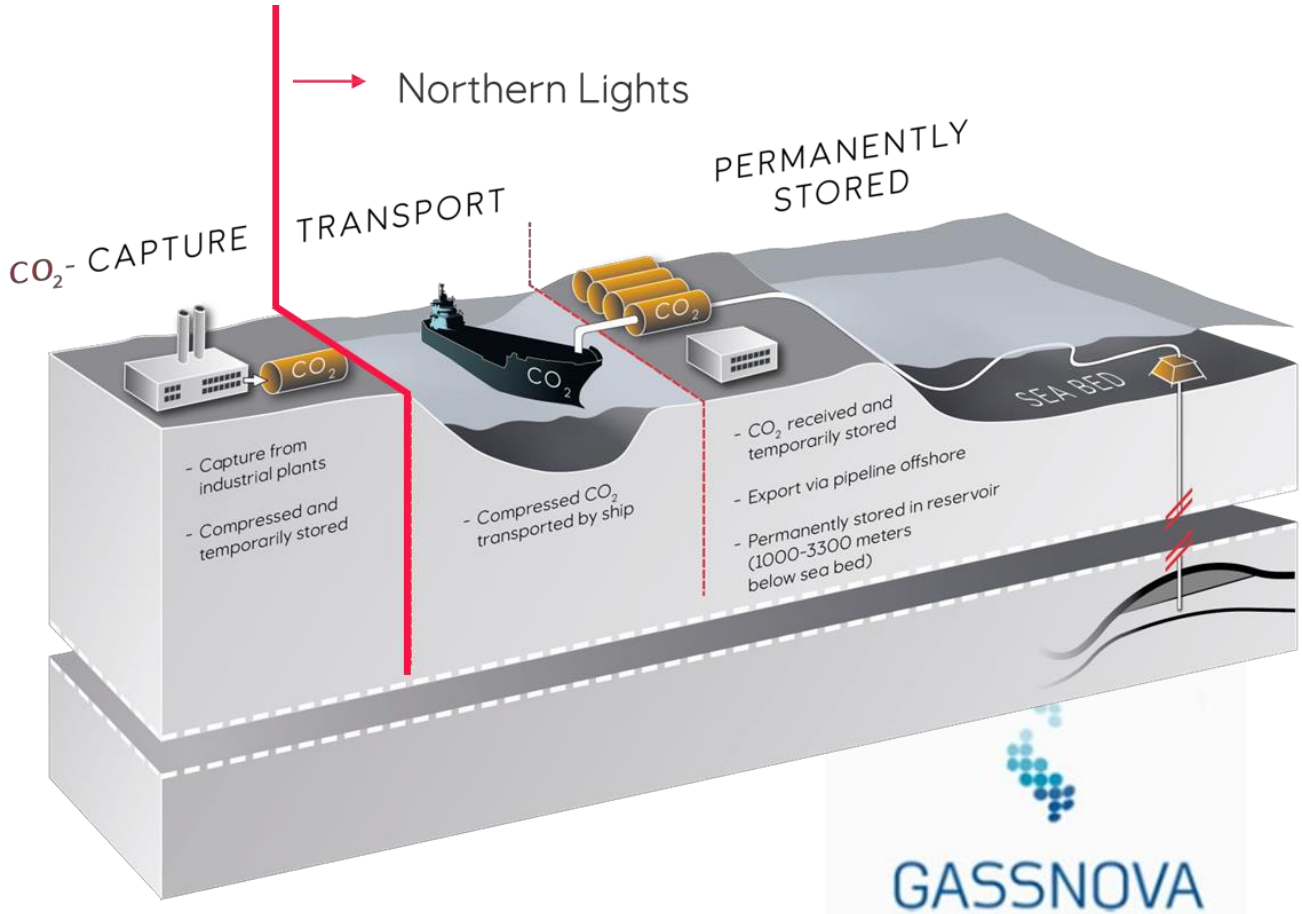
- Hydrogen used in the hydrogen plant to produce heat and power and for process recycle



- Hydrogen to "Gasunie" for further distribution to Magnum and/or pipeline to cavern and 3rd party

Norther Lights - a European “open source” network for CO2 removal and permanent offshore storage

Source: Bellona Europe



Northern Lights - Project status & future

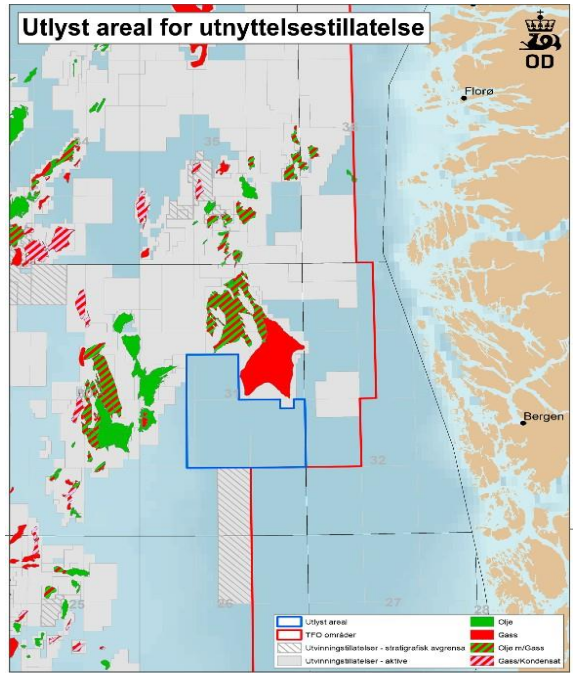
- **Transport, intermediate storage & pipeline**
  FEED to be delivered Q3 2019

- **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!

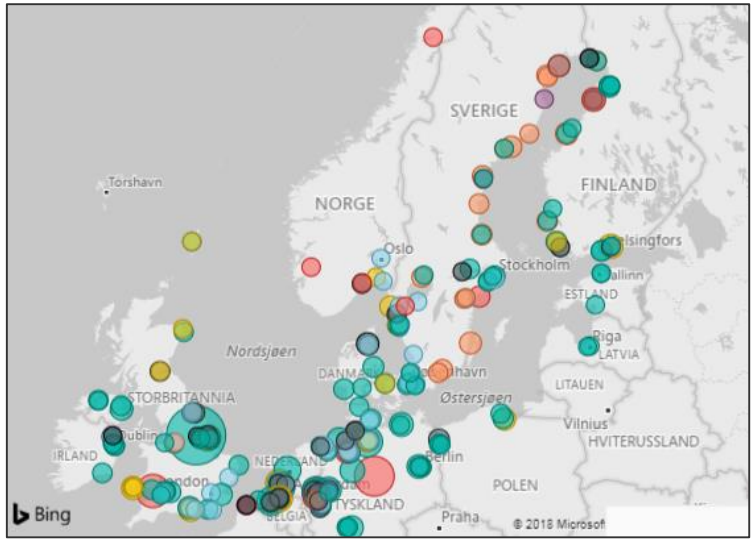


Northern Lights: a solution for European heavy industry

Large potential in energy-intensive industrial sectors:

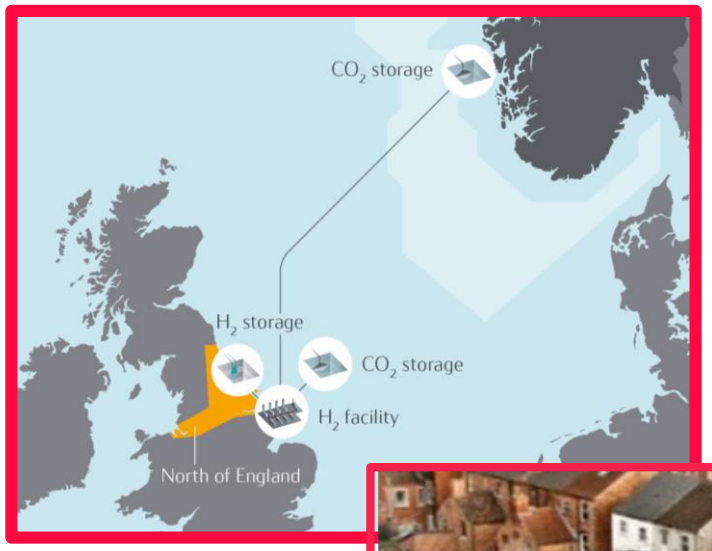
- Hydrogen and power from natural gas
- Waste incineration
- Cement
- Biomass and biofuel
- Steel
- Refinery

Equinor and Heidelberg Cement: signing of the Northern Lights MoU



→ Northern Lights is within reach of about 350 of the most 'attractive' European facilities amounting to 300 million tons of CO2

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

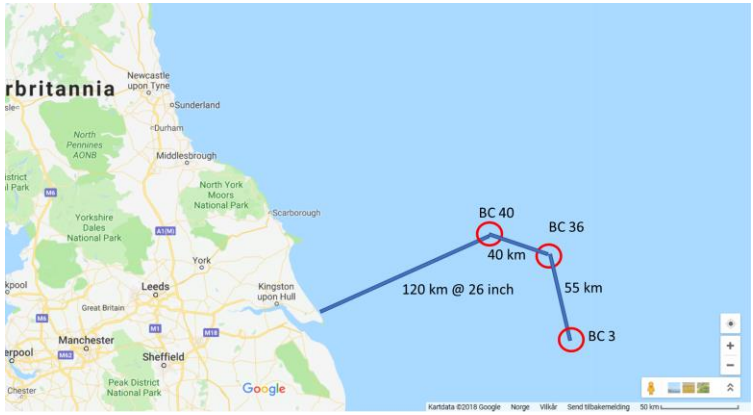
H21 NoE supply concept

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

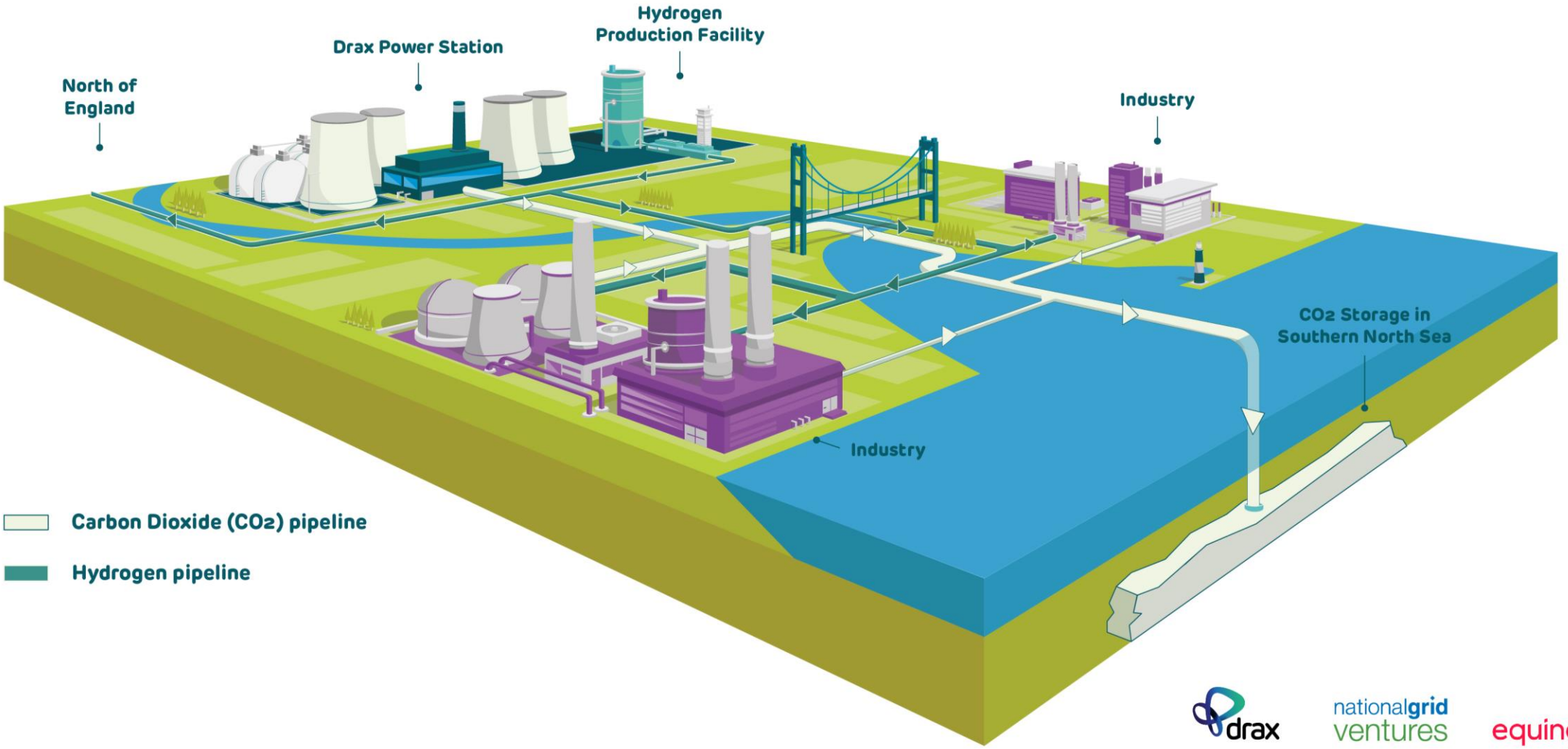
H21 - What will it cost?

2035 Residential Prices

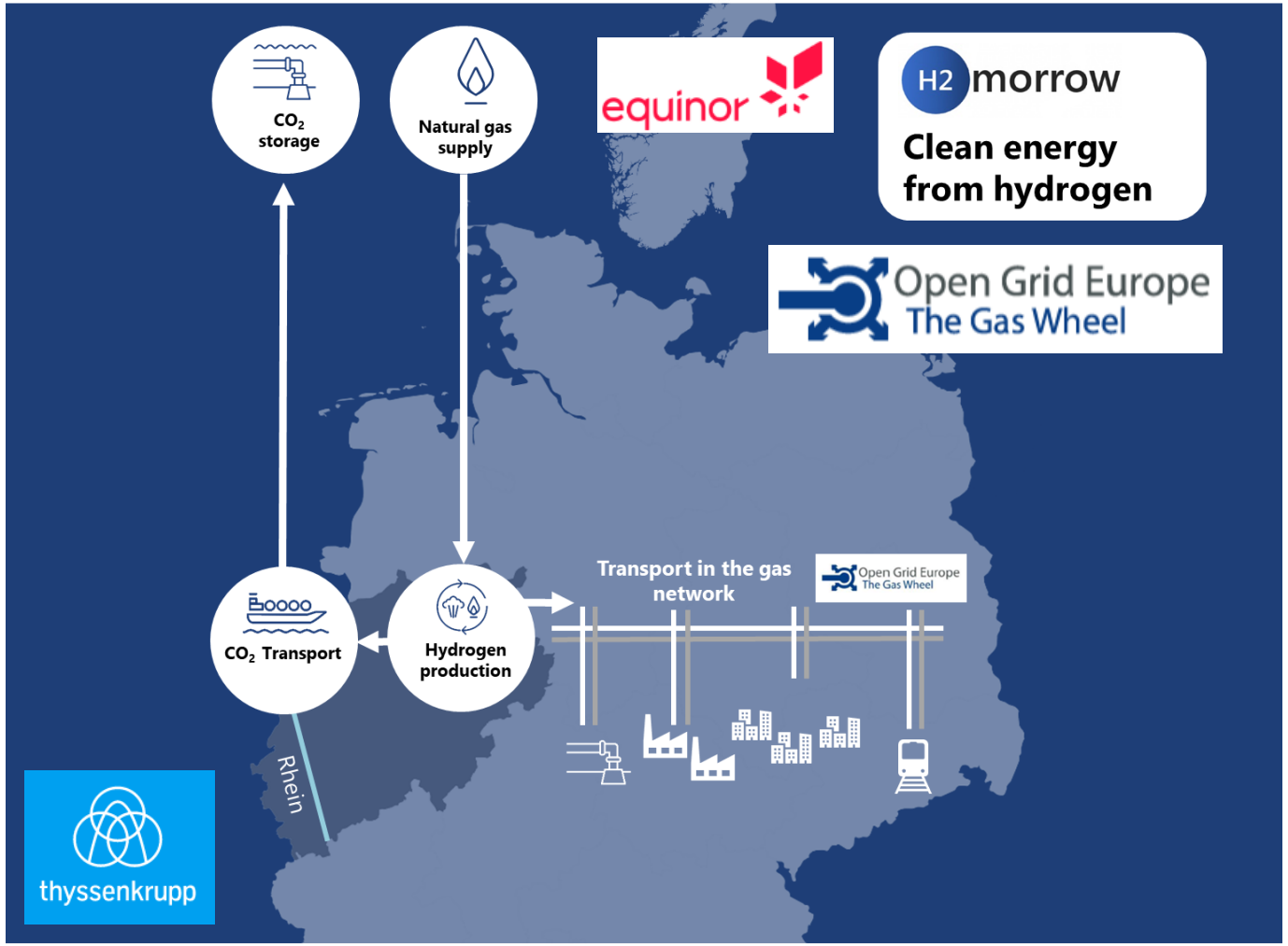
	2035 Residential Prices	CO2 Footprint
Electricity	£200/MWh (BEIS Projection)	50 g/KWh
Natural Gas	£50/MWh (BEIS Projection)	200 g/KWh
Hydrogen	£75/MWh (H21)	15 g/KWh (H21)

Zero Carbon Humber

Our vision



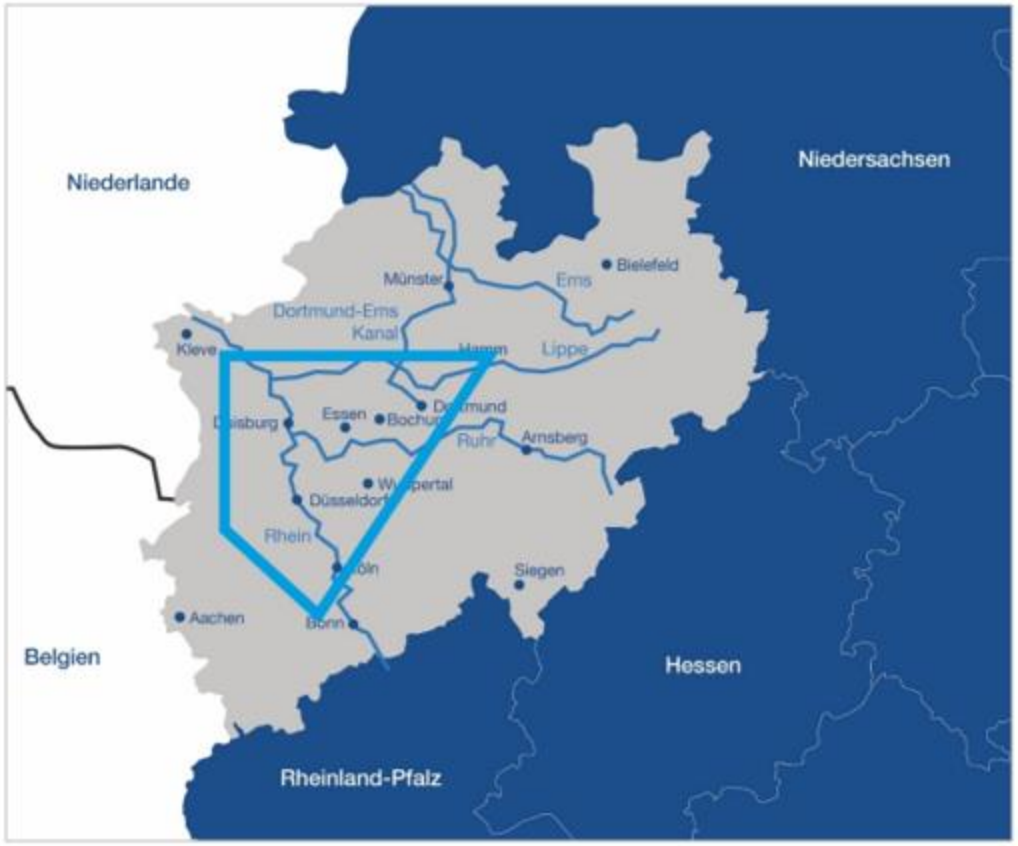
H2morrow: Building a platform for clean hydrogen in Germany



H2morrow pilot region

Why Nordrhein Westphalen?

- Well developed gas infrastructure
- Parallel L-gas and H-gas piplelines
- Available salt caverns for storage
- The Rhein with access to the North Sea
- Industrial heartland of Germany
- Industry well aquainted with H2
- Already a large market for grey H2
- Large CO2 emissions to be abated
- Strong will to retain industry & jobs
- Huge H2 market potential in other sectors
- More that 10 million people in pilot region
- Vantage point for further expansion to the south and southeast



CCS Projects:

Northern Lights - Decarbonising industry
H21 North of England – Decarbonising heat
H2M-Magnum – Decarbonising electricity
Zero Carbon Humber - Decarbonising industry
H2morrow – Decarbonising the Ruhr area

Steinar Eikaas/Bjarne L. Bull-Berg