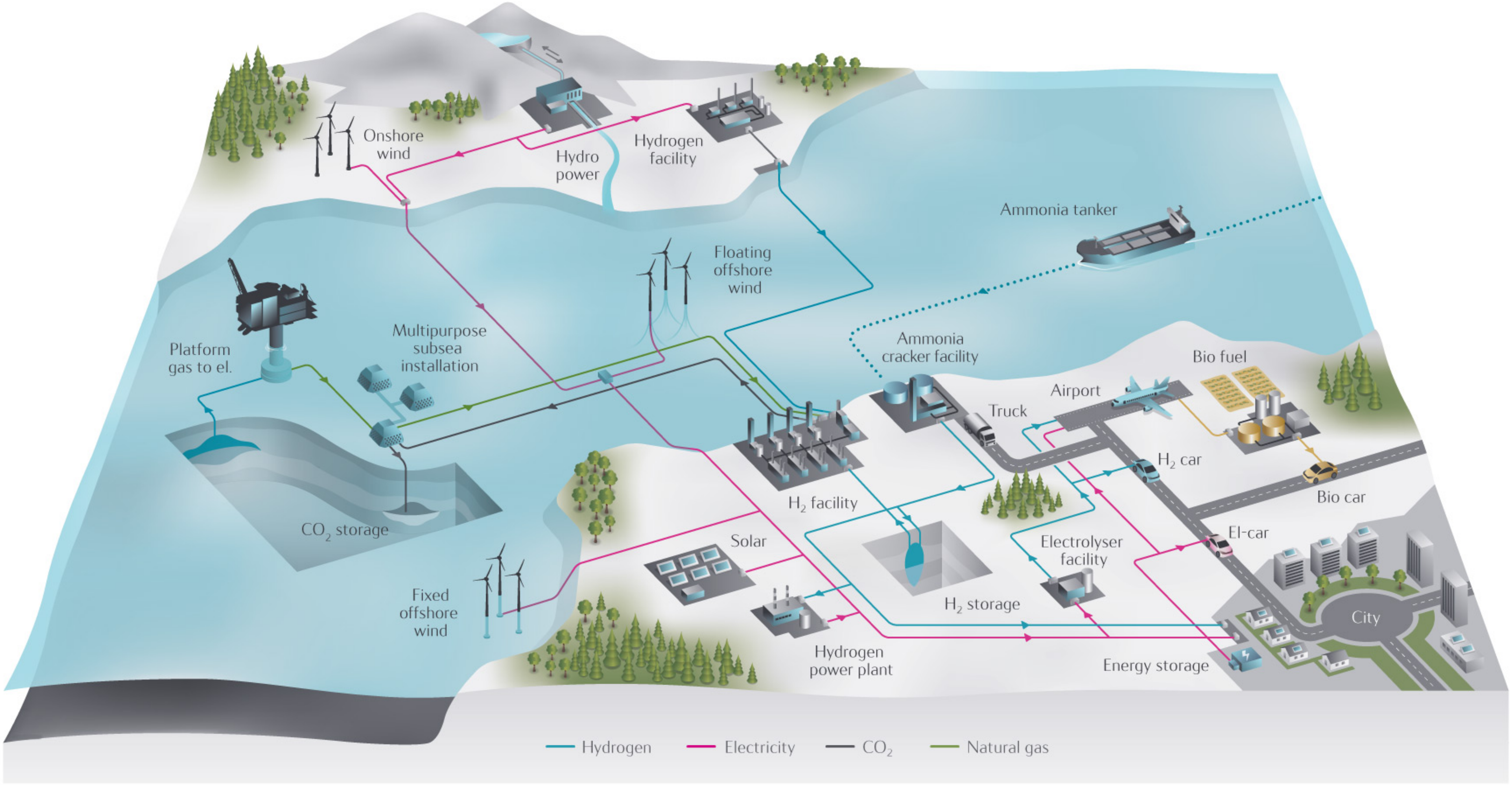
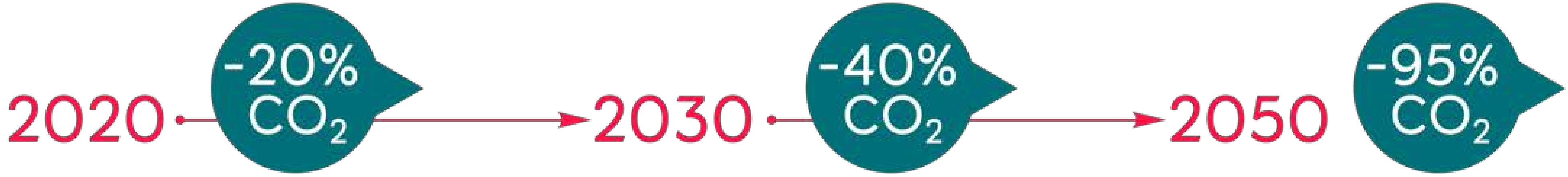
Low Carbon Solutions

Steinar Eikaas – Equinor



Gas is a cost efficient enabler

… to a carbon neutral energy system

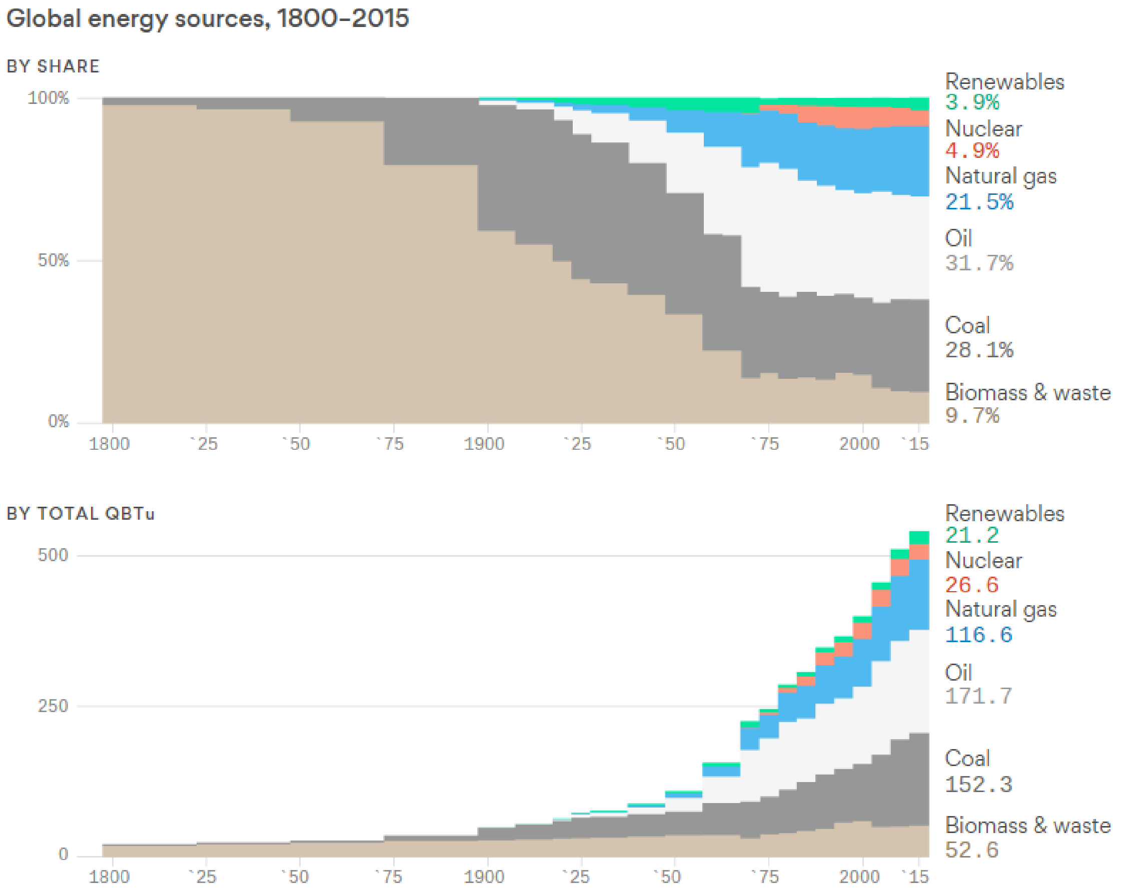


Gas displacing more carbon intense fuels in transport, heating and power

Gas combination with renewables (gas and electricity)

Hydrogen and renewable electricity smartly integrated

Despite new technology, there has never been an energy transition in the past…



Note: 1800–1900 data shown at 25-year intervals, 1900–1920 & 1930–1970 data shown at 10-year intervals, and 1920–1930 & 1970–2015 data shown at 5-year intervals. Data: Arnulf Grubler (2008), International Energy Agency (2017). Reproduced from charts by Richard Newell and Daniel Raimi. Chart: Axios Visuals

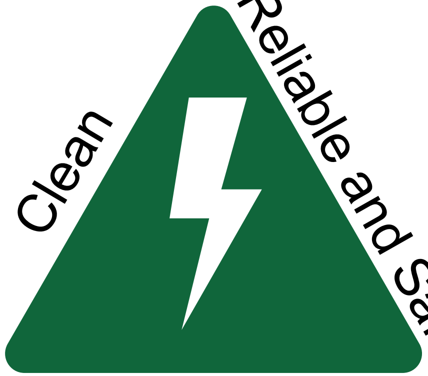
- Shifts in primary energy supply has taken decades in the past
- …but GROWTH in energy demand more than outweigh shift between supply sources
- To meet the 1.5 degree target, <u>all energy use has to be carbon neutral by 2050!</u>
- This cannot be solved by phasing in renewables only - it is currently a small fraction
- We need to use the entire toolbox to have the slightest chance of succeeding

The Challenge and the Tool-Box

equinor

Clean

Reliable and Safe

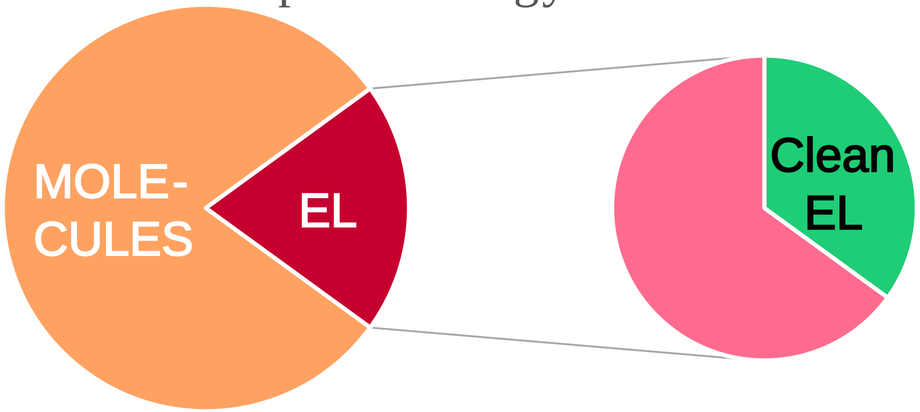


Affordable

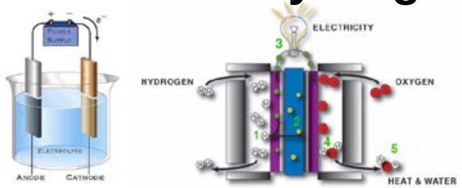
Cost Efficiency EL : MOL

Energy Transport 1 : 10
Long Term Storage 1 : 100

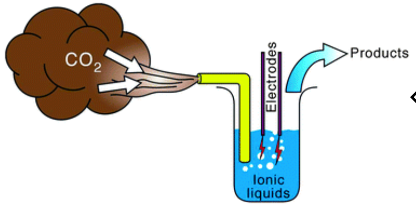
European Energy-Mix 2018



Green Hydrogen and Power to X



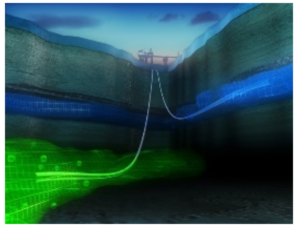
Electrolyser and Fuel Cell



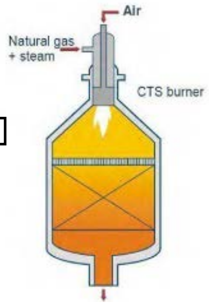
CCS

Hard-to-Decarbonize Industry

Blue Hydrogen

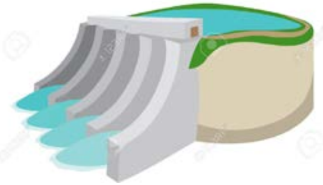


Permanent CO2 Storage (CCS)

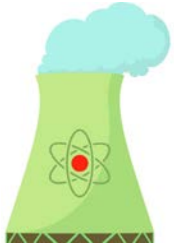


Gas Reformer w/CCS

Renewable EL



Zero Carbon EL



Nuclear

Hydrogen fired EL power

Improve Carbon Efficiency

Switch from Coal …

… to Natural Gas

Low Carbon Solutions portfolio
- building markets for CCS and clean hydrogen

CCS

2023

Northern Lights

- CCS for industry
- Transport of CO2 by ship

Hydrogen

2025

HyDemo Norway

- Liquid hydrogen for maritime
- Distribution of hydrogen
- Integration with existing onshore plants

2026

Zero Carbon Humber

- Hydrogen for industry
- Chemicals
- Synthetic fuels
- BECCS
- Hydrogen to power
- Blue Ammonia

2027/28

Clean Steel

- Hydrogen for industry (steel)

2027/28

H2 Magnum

- Hydrogen to power
- Hydrogen for industry
- Flexible back-up for intermittent renewable

Post-combustion

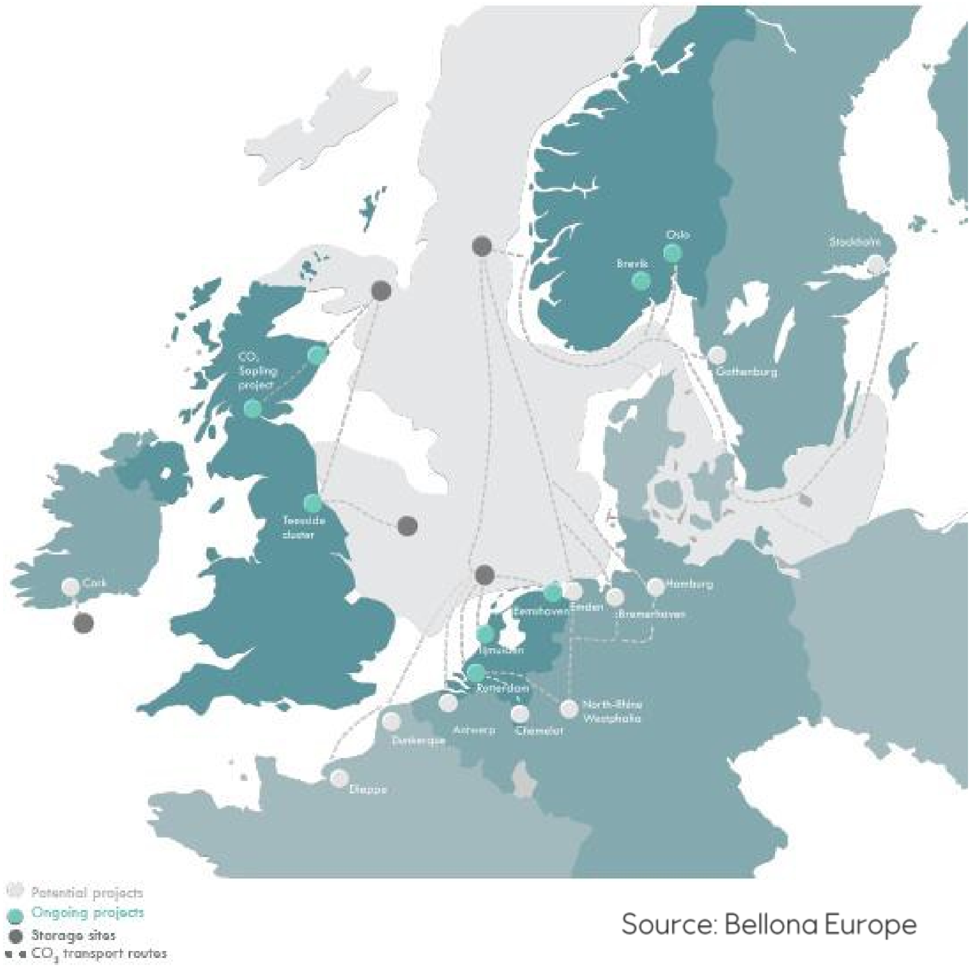
2026

Net Zero Tesside

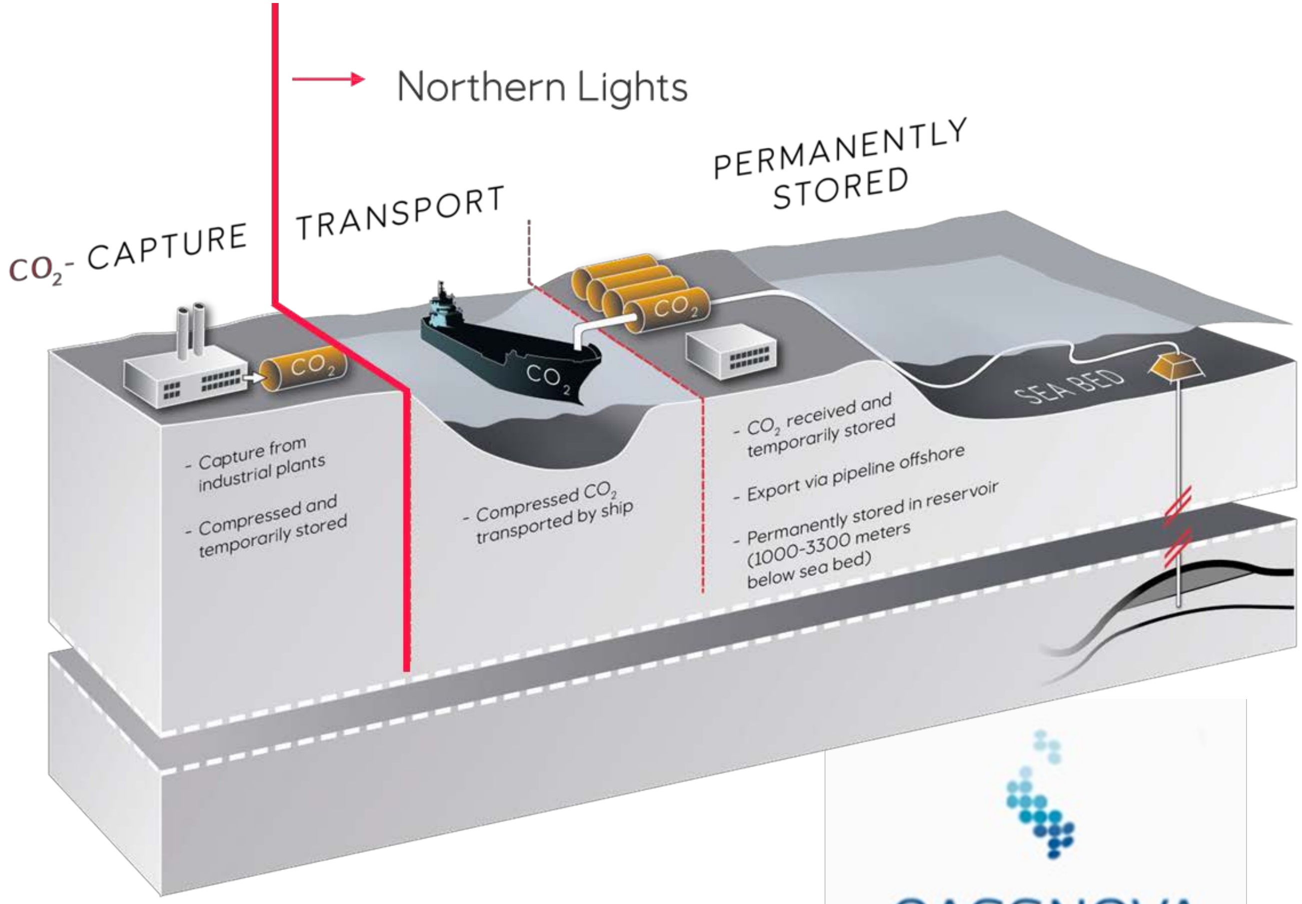
- Post-combustion CCS power generation
- CCS for industry
- BECCS
- Hydrogen production

A European “open source” network for CO2 removal

THE EUROPEAN CO_2 NETWORK



Source: Bellona Europe



GASSNOVA

Project status & future

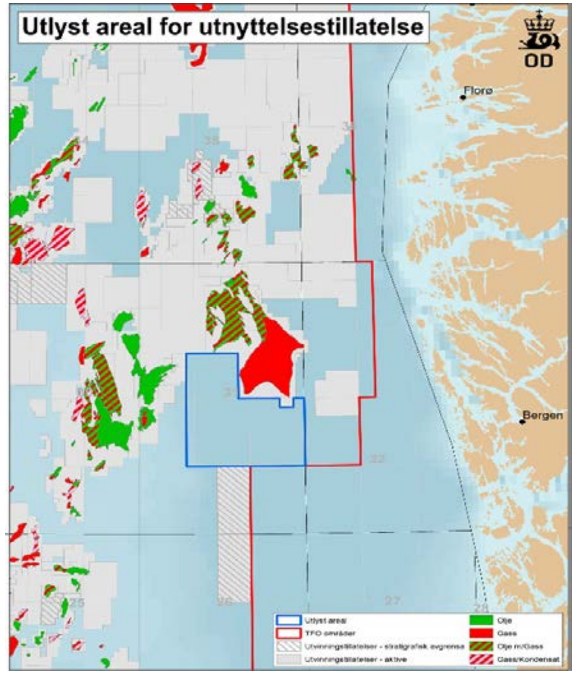
- **Transport, intermediate storage, pipeline**
  FEED to be delivered Q3 2019

- **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

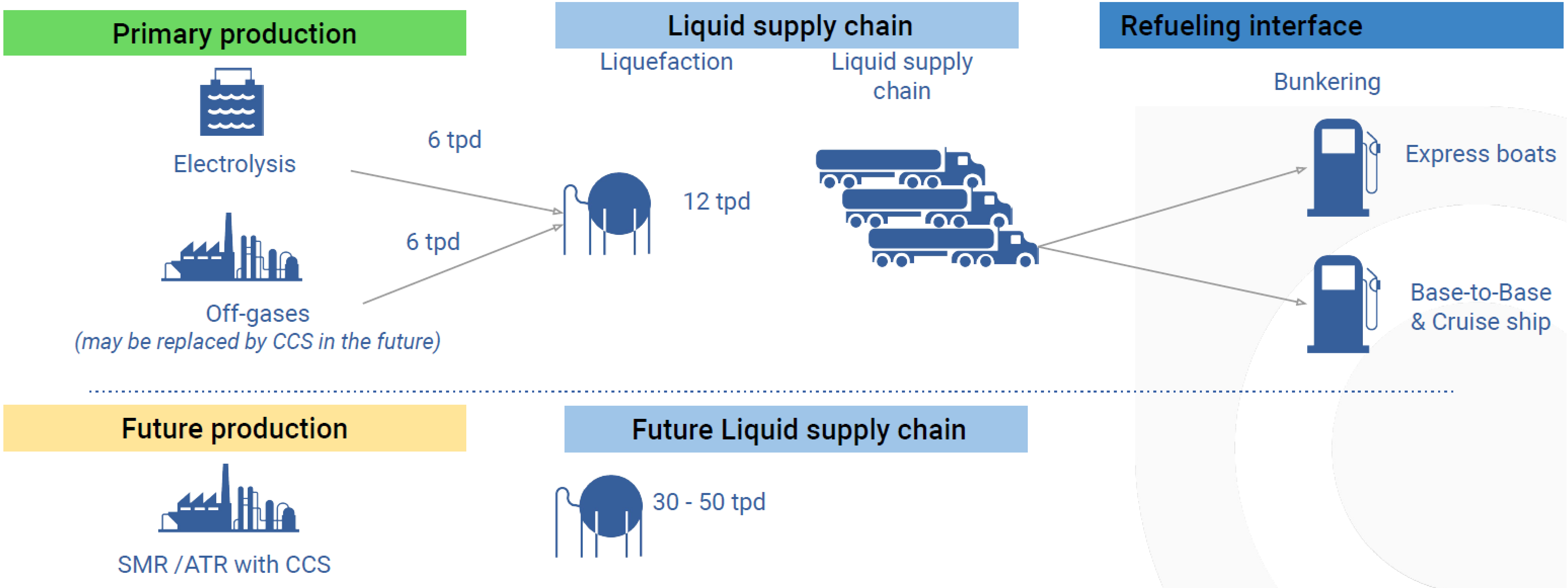
- **Investment decisions**
  Planned for December 2020 (State budget)

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

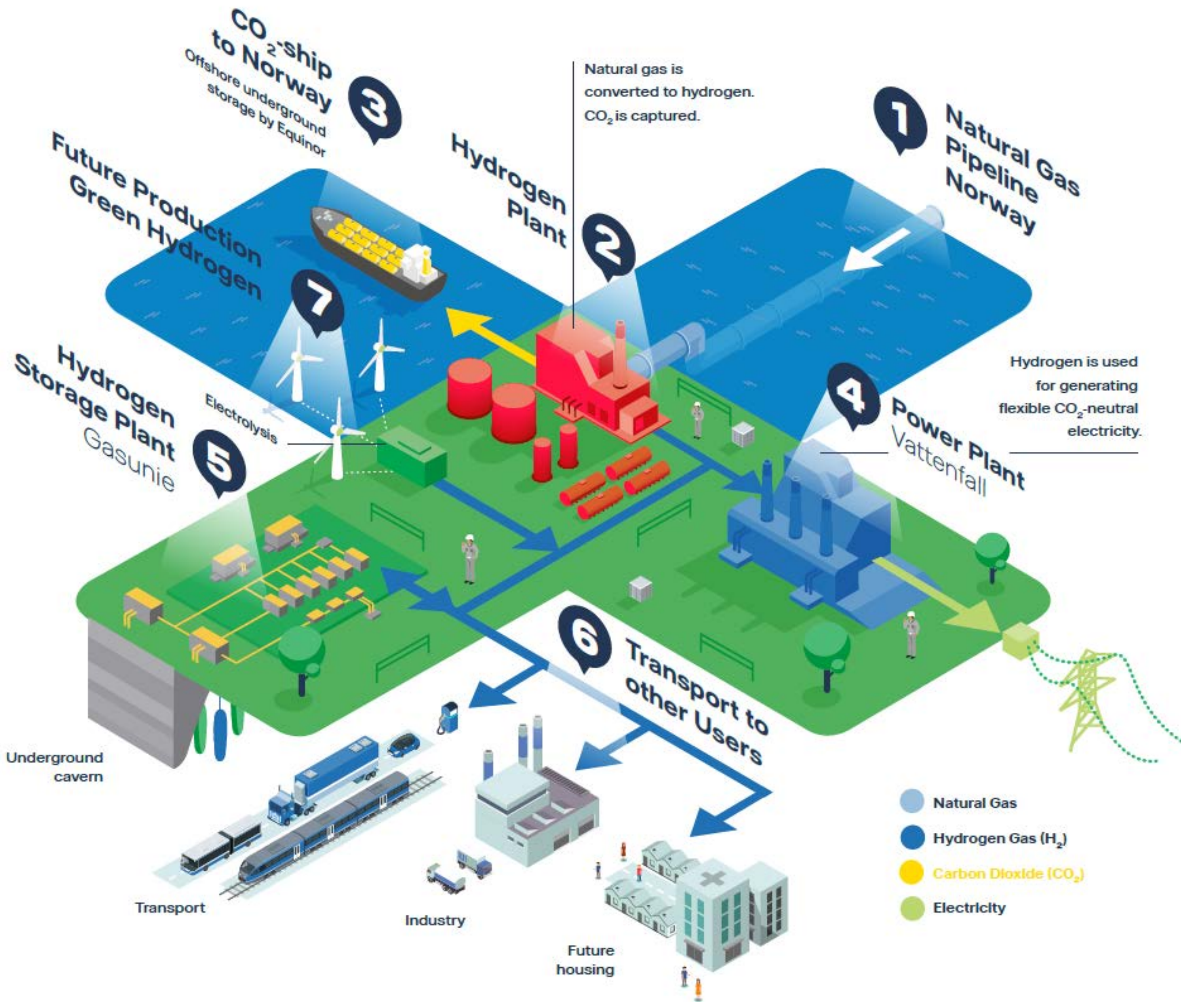


Open

Hydrogen to Maritime in Norway
Production concept development



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

Hydrogen to Steel ThyssenKrupp, Europe (video)

equinor

2018
The world premiere

The concept: CO_2 becomes raw materials. In September 2018, thyssenkrupp produced ammonia from steel mill gases for the first time at its Carbon2Chem® technical center in Duisburg.

From 2019
The test

Thyssenkrupp will gradually replace pulverized coal in one blast furnace (BF) with hydrogen (H_2).

From 2020
The industrialization

The pilot system at the Duisburg steel plant will use steel mill gases to produce base chemicals.

From 2022
The introduction phase

Step by step, all three blast furnaces (BF) will be transitioned to H2 injection.

From 2024
The milestone

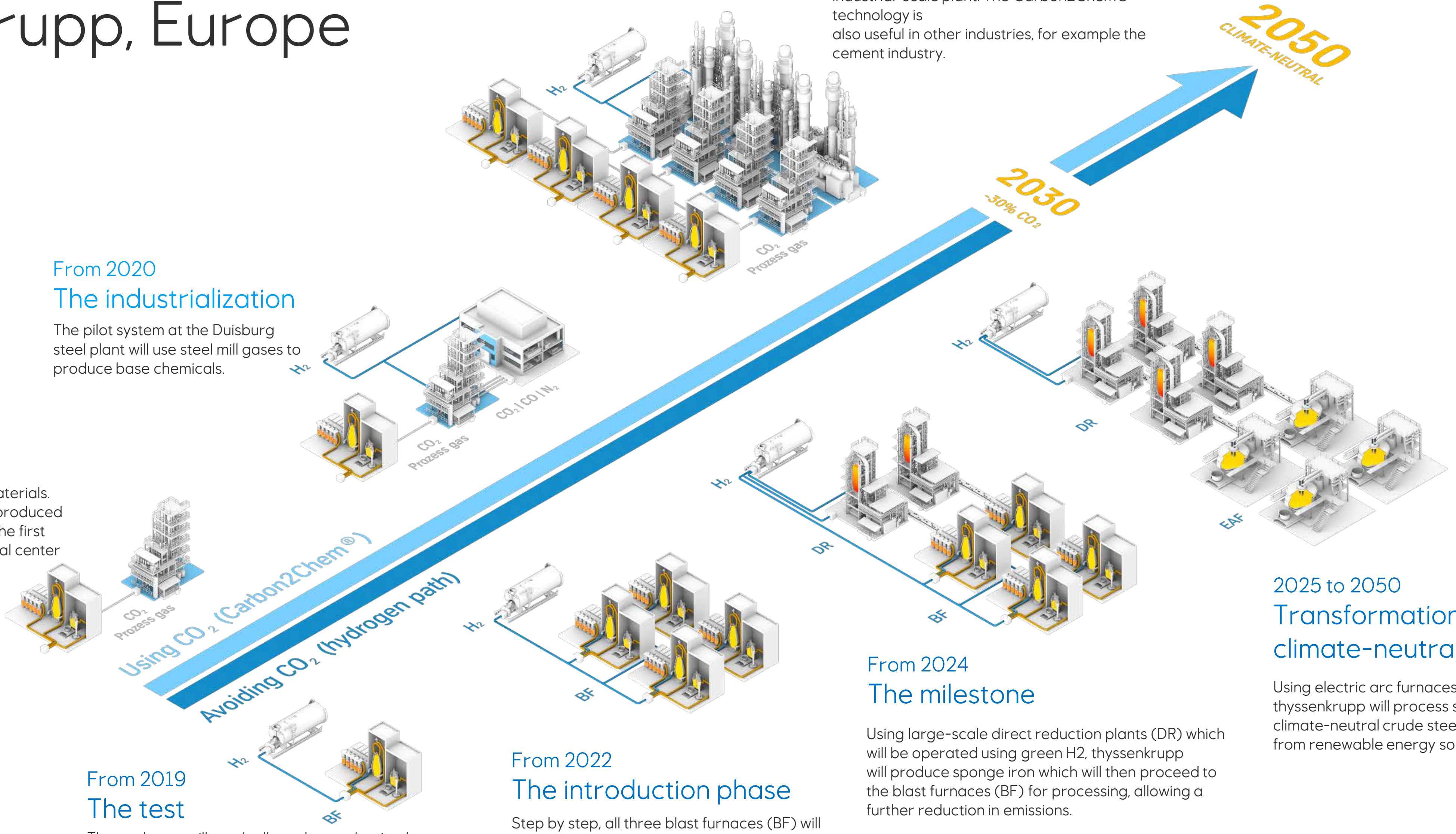
Using large-scale direct reduction plants (DR) which will be operated using green H2, thyssenkrupp will produce sponge iron which will then proceed to the blast furnaces (BF) for processing, allowing a further reduction in emissions.

From 2025
The breakthrough

CO_2 will be used as a raw material in an industrial-scale plant. The Carbon2Chem® technology is also useful in other industries, for example the cement industry.

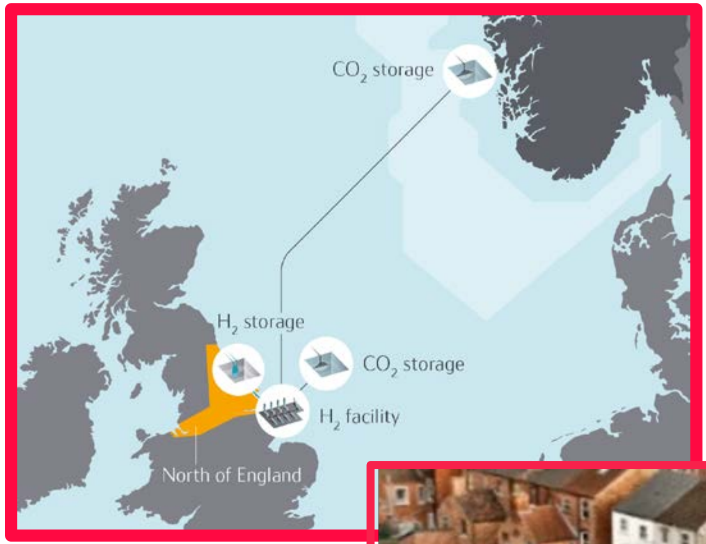
2025 to 2050
Transformation into a climate-neutral steel mill

Using electric arc furnaces (EAF), thyssenkrupp will process sponge iron into climate-neutral crude steel using electricity from renewable energy sources.



How it looks today – To become carbon neutral by 2050 by using hydrogen

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

CO_2 Storage

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

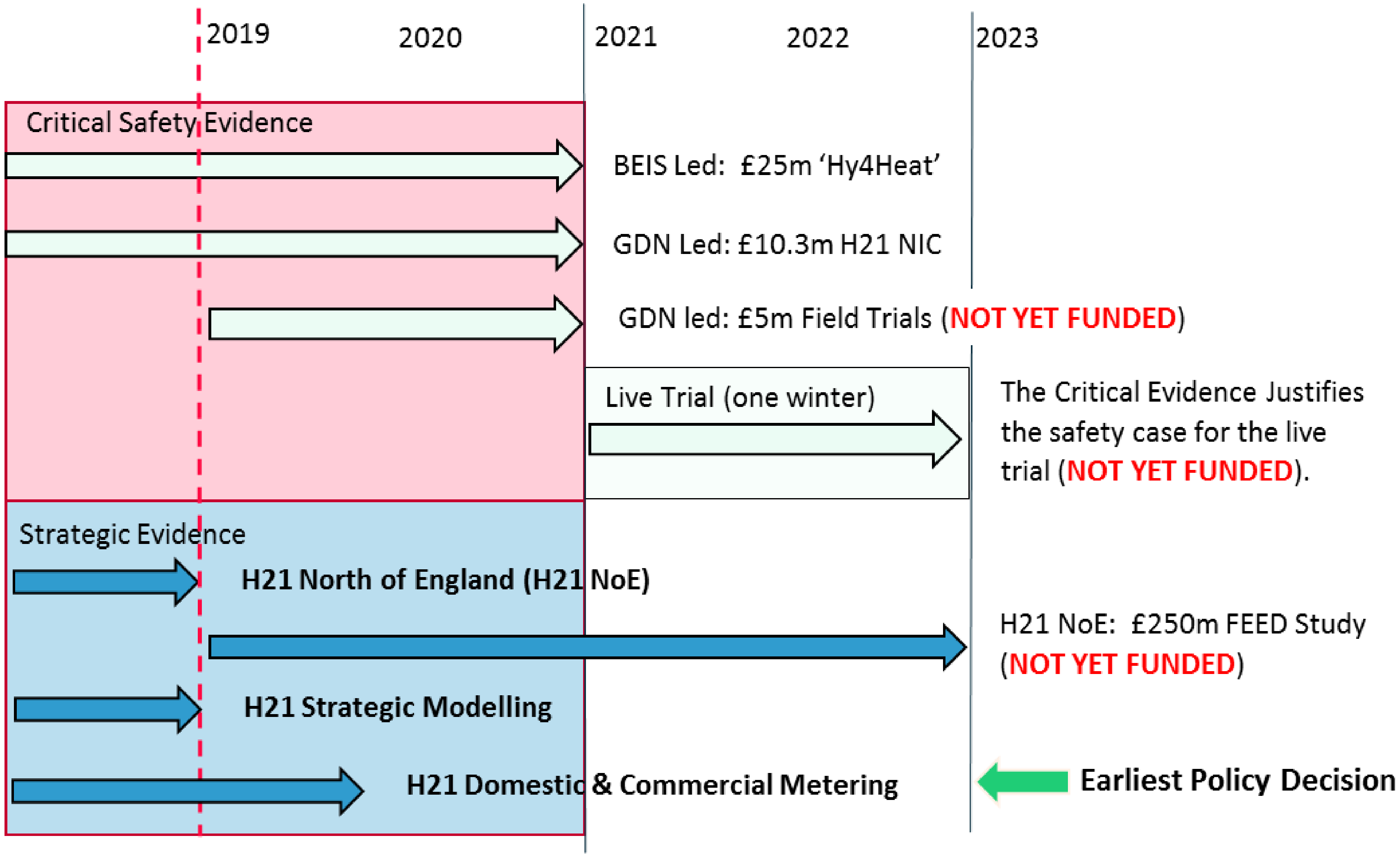
Open

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)

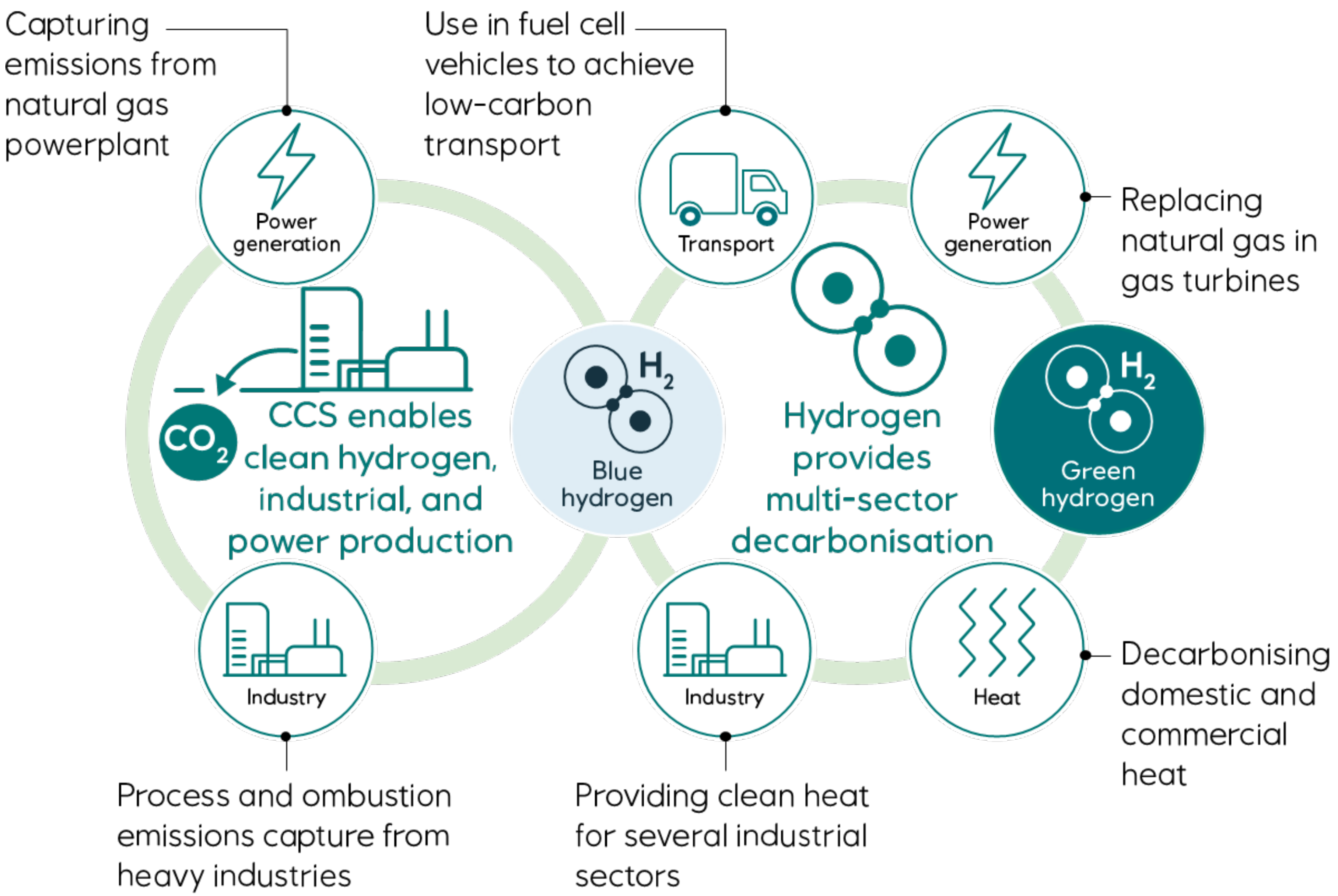
The next steps

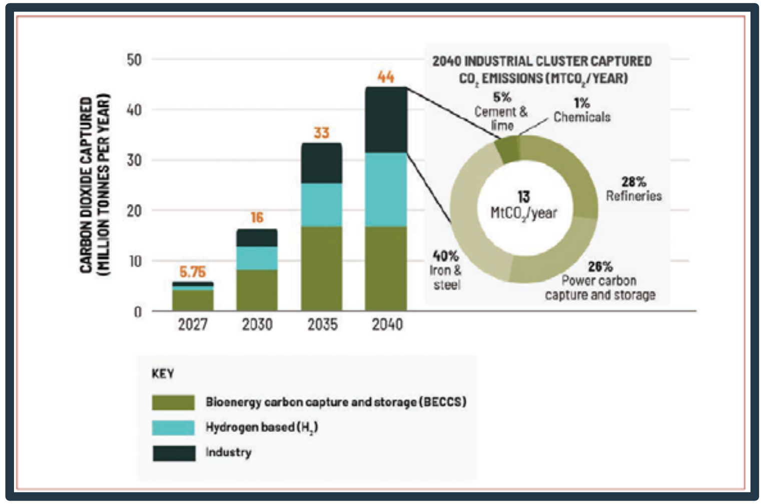


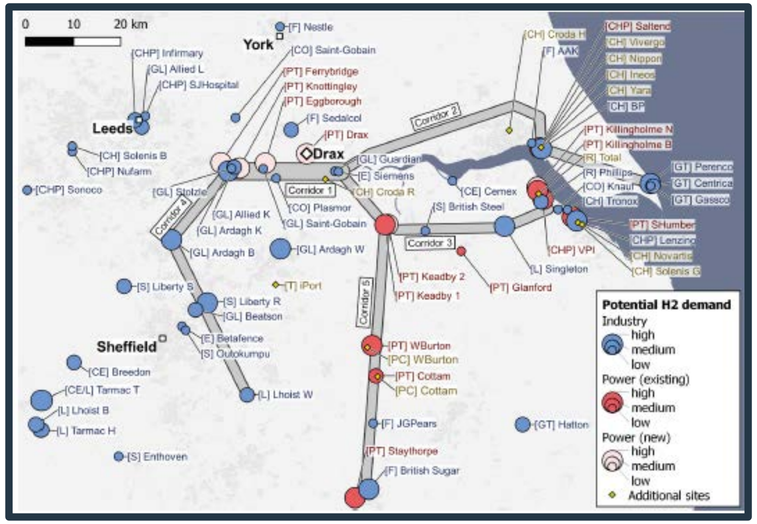
Open

The first step in UK: Zero Carbon Humber

- Aiming at decarbonizing the largest industrial cluster in UK by 2040







Decarbonising Energy Systems

Easy ⟵ complexity to decarbonise ⟶ Hard

Transport

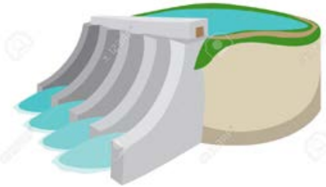
Battery (mostly) plus Hydrogen for Heavy Duty

Hydrogen Fuel-Cell Trains

Liquid Hydrogen and Fuel-Cells for long haul Big Ships

Power

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



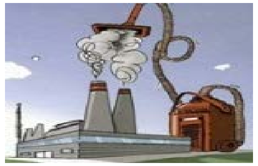
Hydro-Power as Battery for Small Scale Intermittency

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



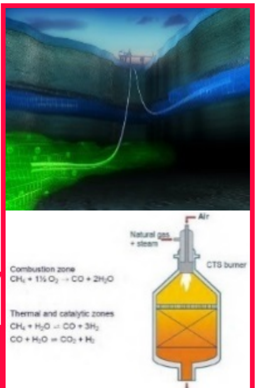
CCS for Industry without other Alternatives

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

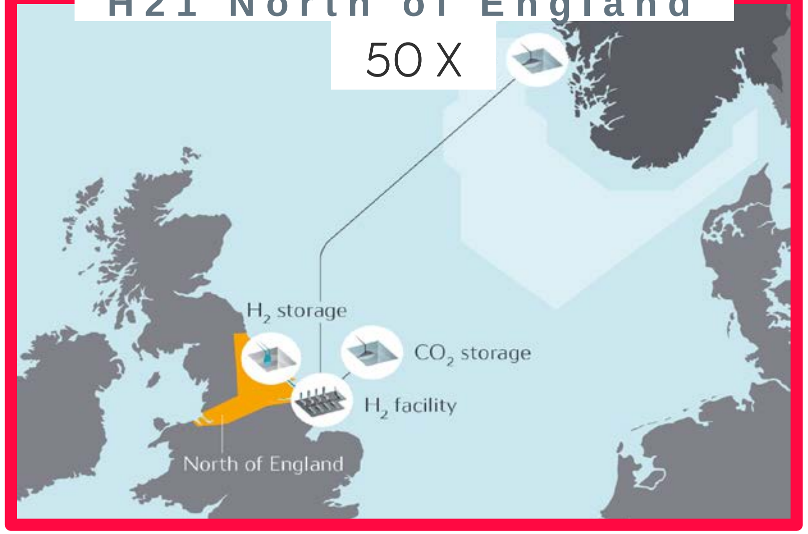
Understanding the Challenge

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

What is 1500 TWh?

H21 North of England

50 X



Vehicle

20 000 000 000 X

Battery park

11 600 000 X

Hydro

200 X

TESLA 75D Li-Batteries

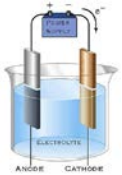
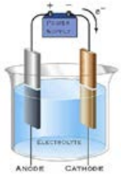
World largest battery park in Australia (129 MWh)

Norways biggest hydro electrical storage -Blåsjø equinor

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

… and What Will it Take?

- Policy leadership to design a financial framework to absorb the costs initially
- Industrial leadership to design credible anchor projects
- An outlook for a market willing to pay for zero carbon products

Steinar Eikaas