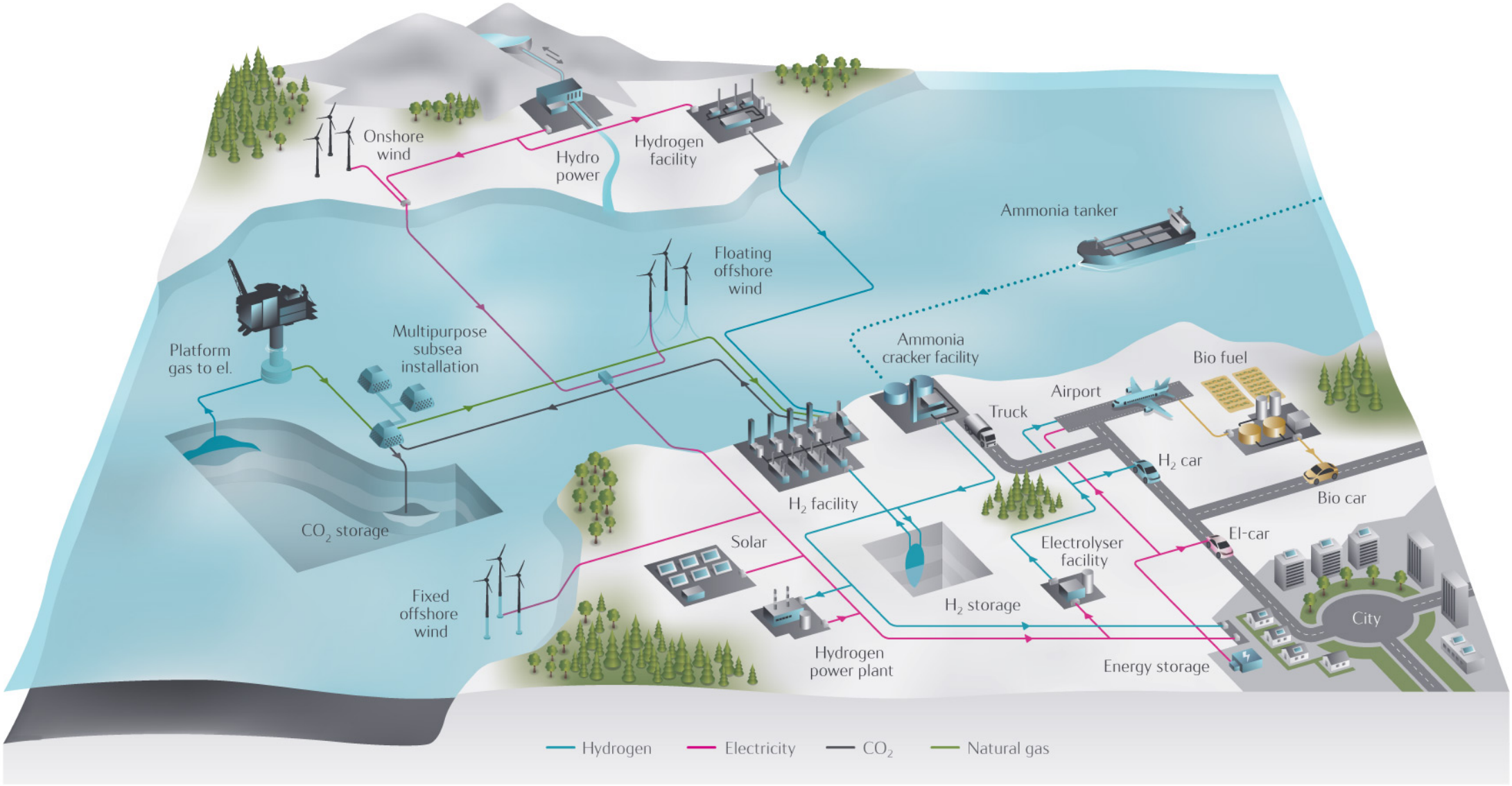
Low Carbon Solutions

Steinar Eikaas – Equinor



Gas is a cost efficient enabler

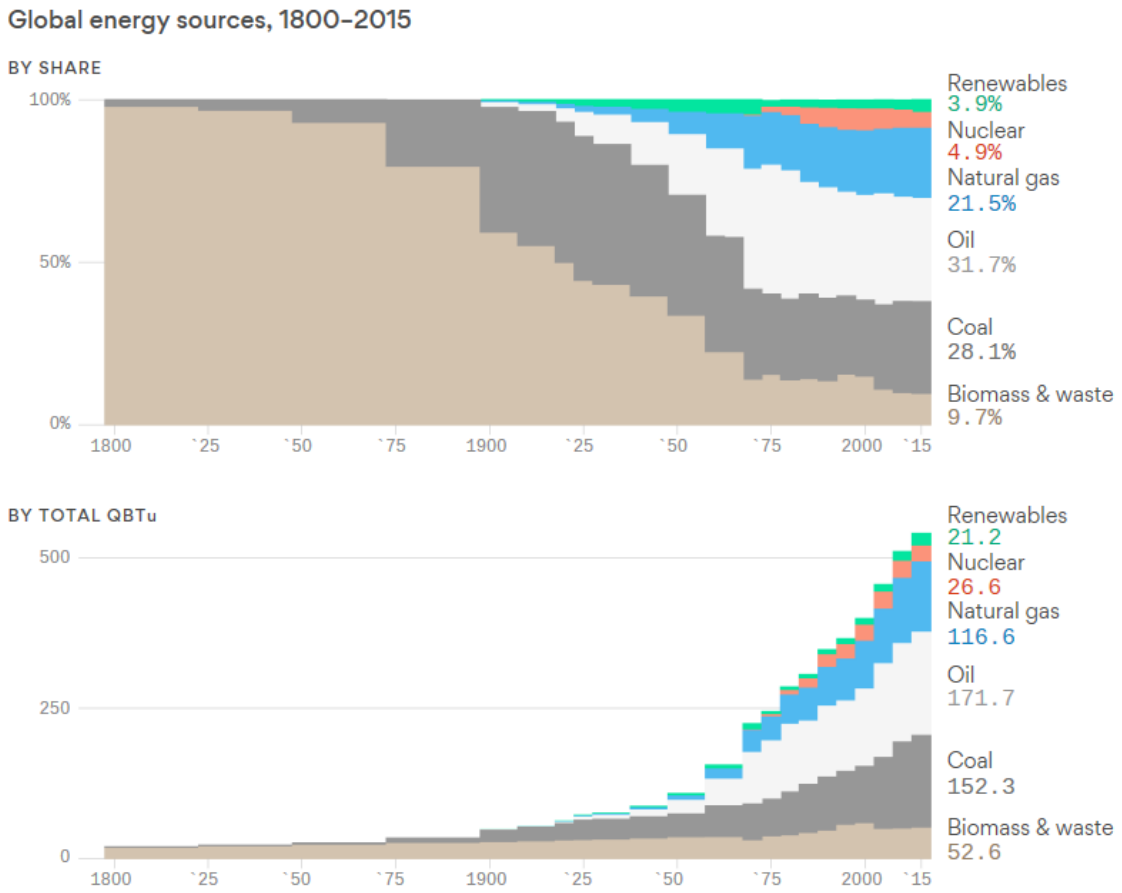
..to a carbon neutral energy system

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

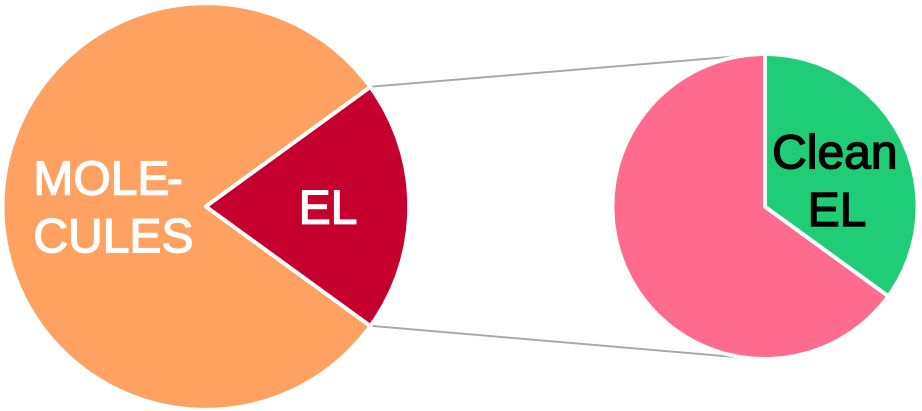
- Shifts in primary energy supply has taken decades in the past
- …but GROWTH in energy demand more than outweigh shift between supply sources
- To meet the 1.5 degree target, <u>all energy use has to be carbon neutral by 2050!</u>
- This cannot be solved by phasing in renewables only - it is currently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

The Challenge and the Tool-Box

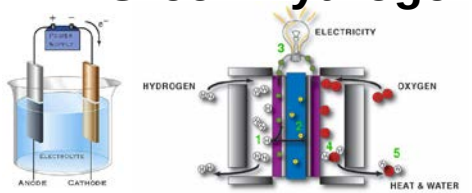
Cost Efficiency EL : MOL

Energy Transport 1 : 10
Long Term Storage 1 : 100

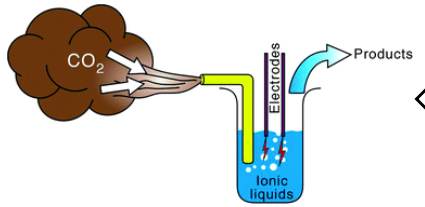
European Energy-Mix 2018



Green Hydrogen and Power to X

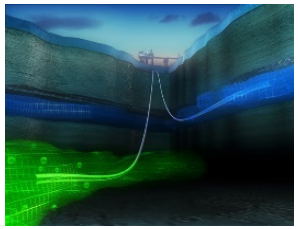


Electrolyser and Fuel Cell



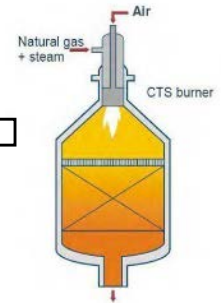
CCS

Hard-to-Decarbonize Industry



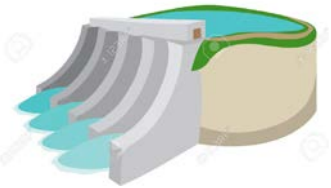
Permanent CO2 Storage (CCS)

Blue Hydrogen

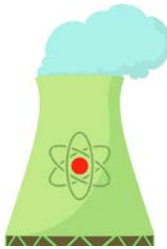


Gas Reformer w/CCS

Renewable EL



Zero Carbon EL



Nuclear

Hydrogen fired EL power

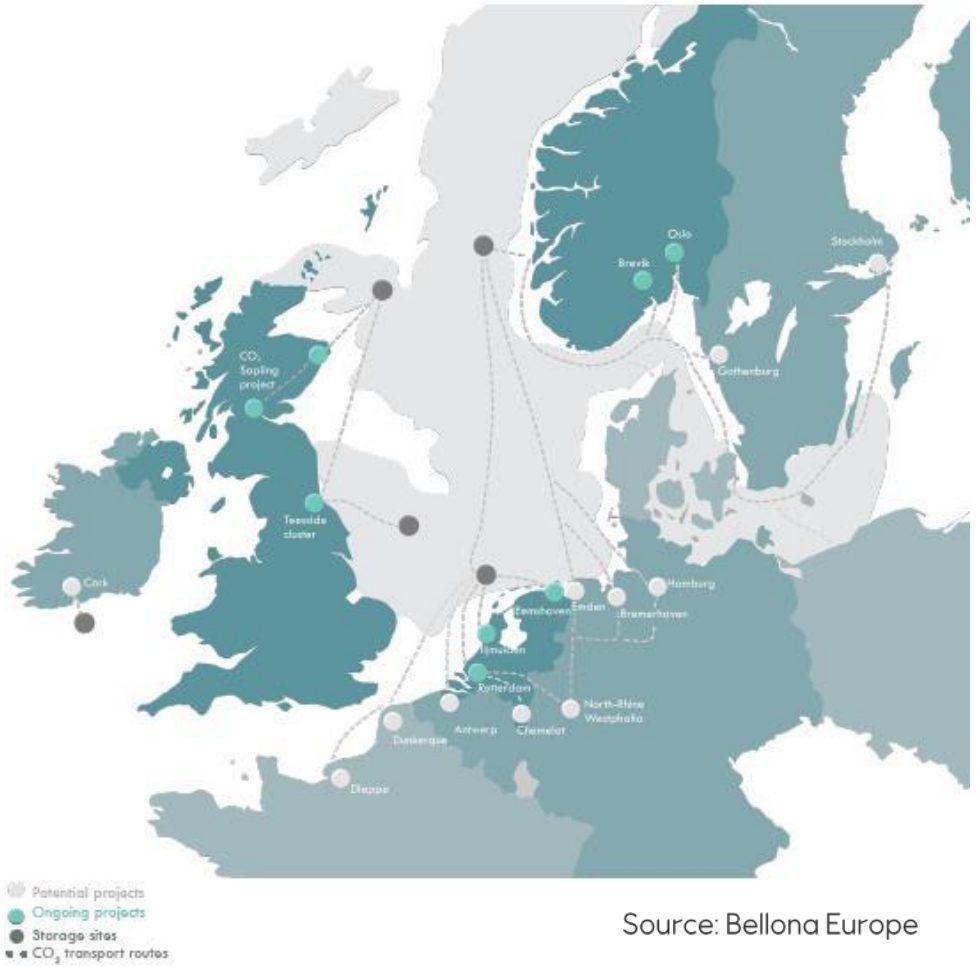
Improve Carbon Efficiency

Switch from Coal …

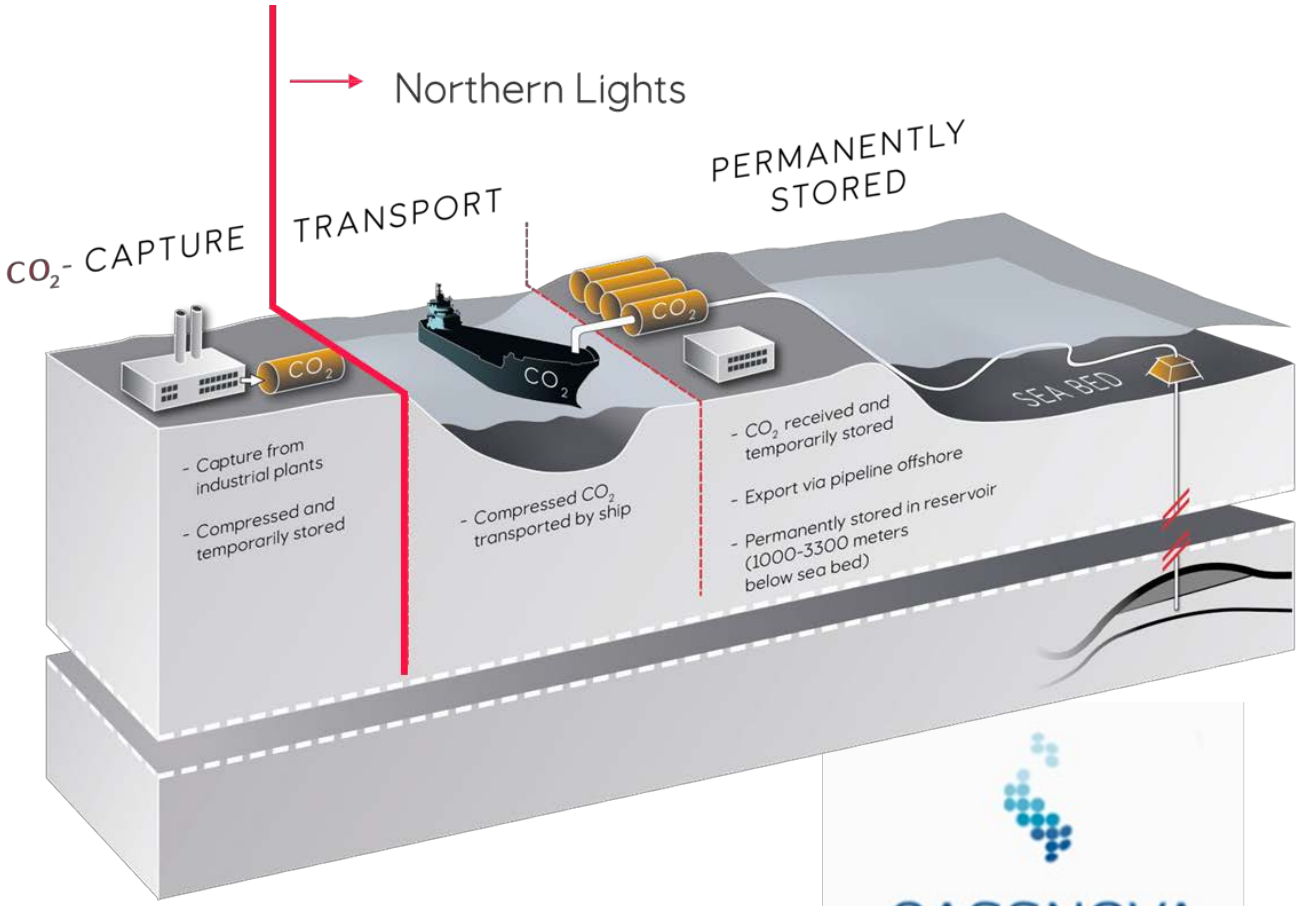
… to Natural Gas

Northern Lights
– Full Scale CCS Infrastructure

THE EUROPEAN CO_2 NETWORK



Source: Bellona Europe



GASSNOVA

Project status & future

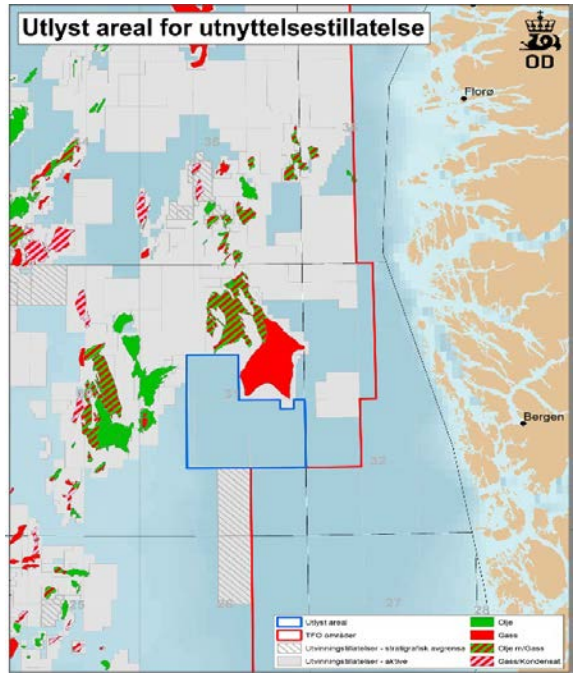
- **Transport, intermediate storage, pipeline**
  FEED to be delivered Q3 2019

- **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



Equinor Hydrogen Portfolio

H2M - Magnum

- Energy: 8-12 TWh
- Utilise existing gas power plants
- Switch fuel from natural gas to clean H2
- Clean electricity
- Clean back-up for solar and wind
- Launch large-scale H2 economy
- Partners: Nuon and Gasunie

H21 North of England

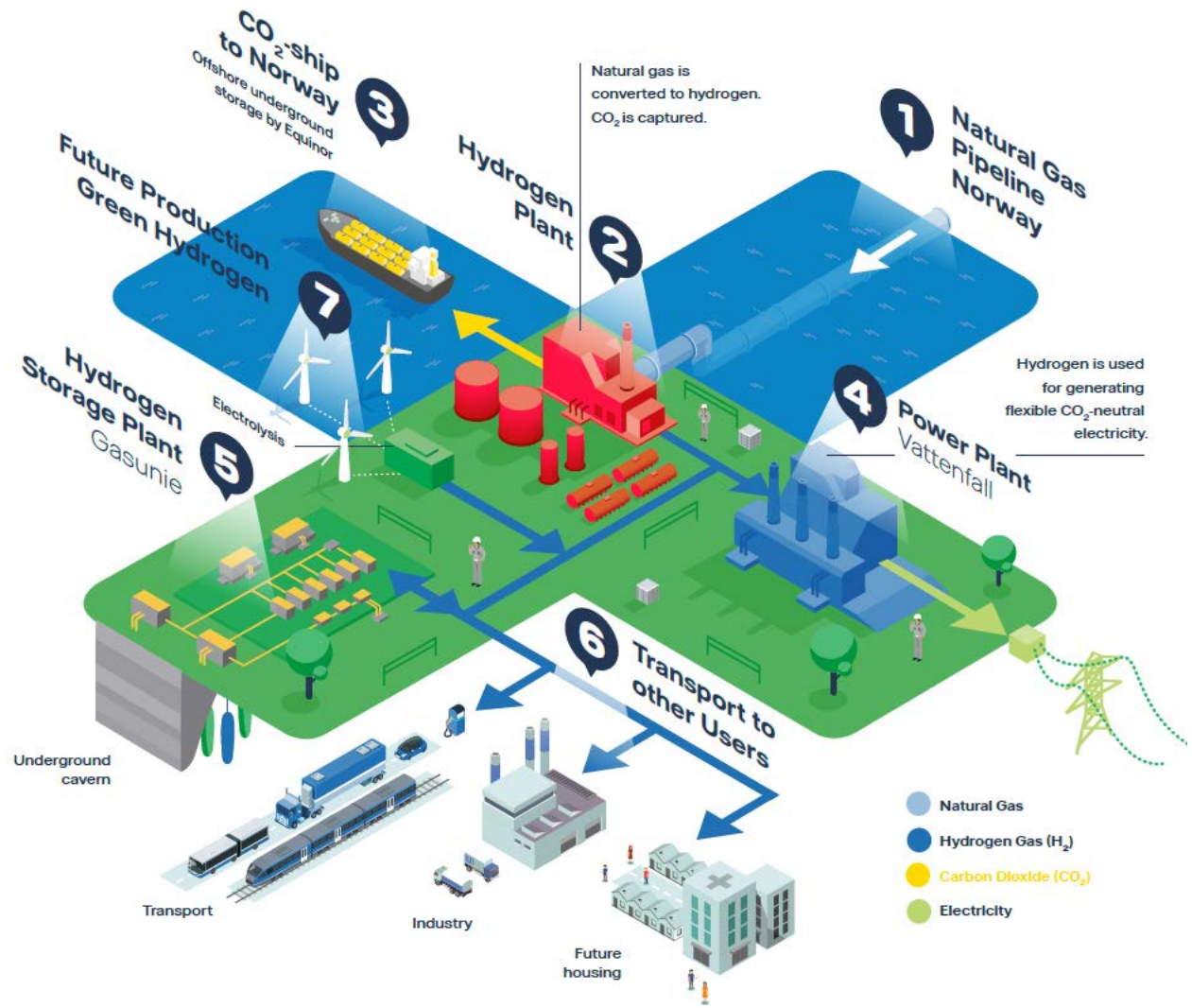
- Energy: 75-85 TWh
- Domestic heating in UK
- Utilise existing gas network
- Synergies with industry/power generation
- Enables H2 to transport later
- Partners: Northern Gas Network and Cadent

New Projects

- Maritime transport – Norway
- Clean Hydrogen Pilot - Norway
- Ammonia to Power – Japan (6-7 TWh)
- Power and Industry – France with GRT Gaz
- Heat and power – Germany with OGE
- Hydrogen CCU – UK (80-90 TWh)
- Power and Industry – NL (12-20 TWh)

H2M – Magnum, Netherlands

equinor



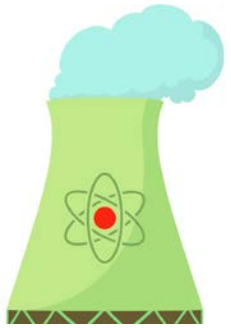
- Energy: 8-12 TWh
- CO2 emissions reduction of 2 Mton/year
- Utilise existing gas power plants and gas infrastructure
- Switch fuel from natural gas to clean H2
- Clean, flexible electricity as back-up for solar and wind
- Launch large-scale H2 economy
- Partners: NUON & gasunie

Demand for Clean and Flexible Power Expected to go up

Baseload

Coal

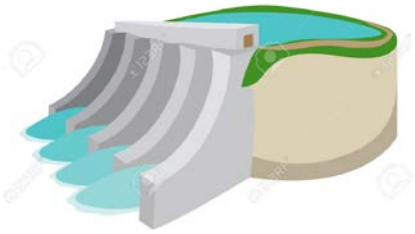
Phase Out



Nuclear

?

Flexible



Hydro

Limited Growth

Gas –> Clean Hydrogen

Strong Growth

Balance
Supply
&
Demand

Intermittent

Wind

Strong Growth

Solar

Strong Growth

Perfect fit of Offshore Wind and Hydrogen

10 sec backup

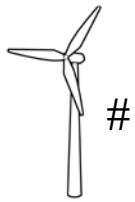
360 MW

20.000 x 20ft (2,5 days backup)

440 Mw Unlimited, Clean Backup

Wind Intermittency Managed via Blue or Green Hydrogen

Simplified concepts



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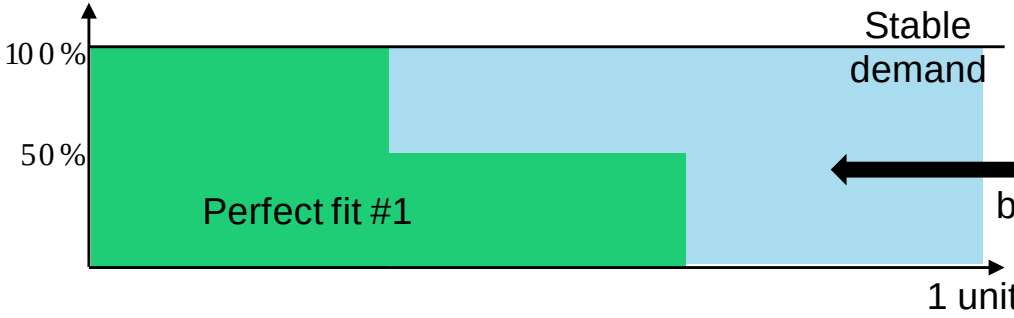
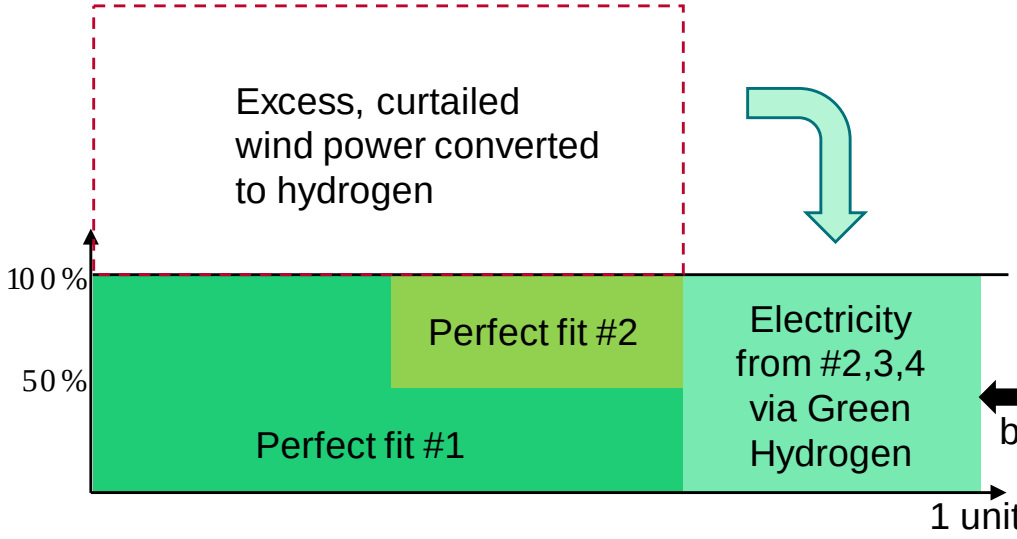


One project enough to back-up 200 wind turbines (6MW)

1.200 MW Flexible Clean Power

1,2+3

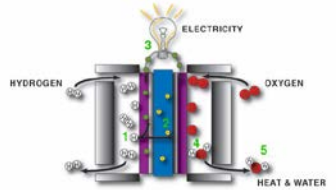


Large portfolio required to back-up 200 wind turbines (6MW)

x 400 wind turbines (6MW)

Major Substations(s)

2.400 MW Electrolysis



1.200 MW Fuel Cells

H21 North of England

- System approach to decarbonise residential heating and distributed gas use

  Fuel switch from natural gas to hydrogen

- Large-Scale: 12.5% of UK population , ~85 TWh
- 12,5 Million tons CO2 reduction per year
- 12 GW hydrogen production
- 8 TWh storage of hydrogen
- CO2 footprint 14,5 g/KWh
- Offshore CO2 storage in either UK or Norway
- Facilitating unlimited system coupling between gas and electricity
- CAPEX: £23 billion

H21 NoE Supply Concept

Greenfield Hydrogen Facility

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

Hydrogen Storage

- Location: Aldbrough
- Capacity: 8 TWh
- Confiiguration. 56 caverns at 300,000 m3

CO2 Storage

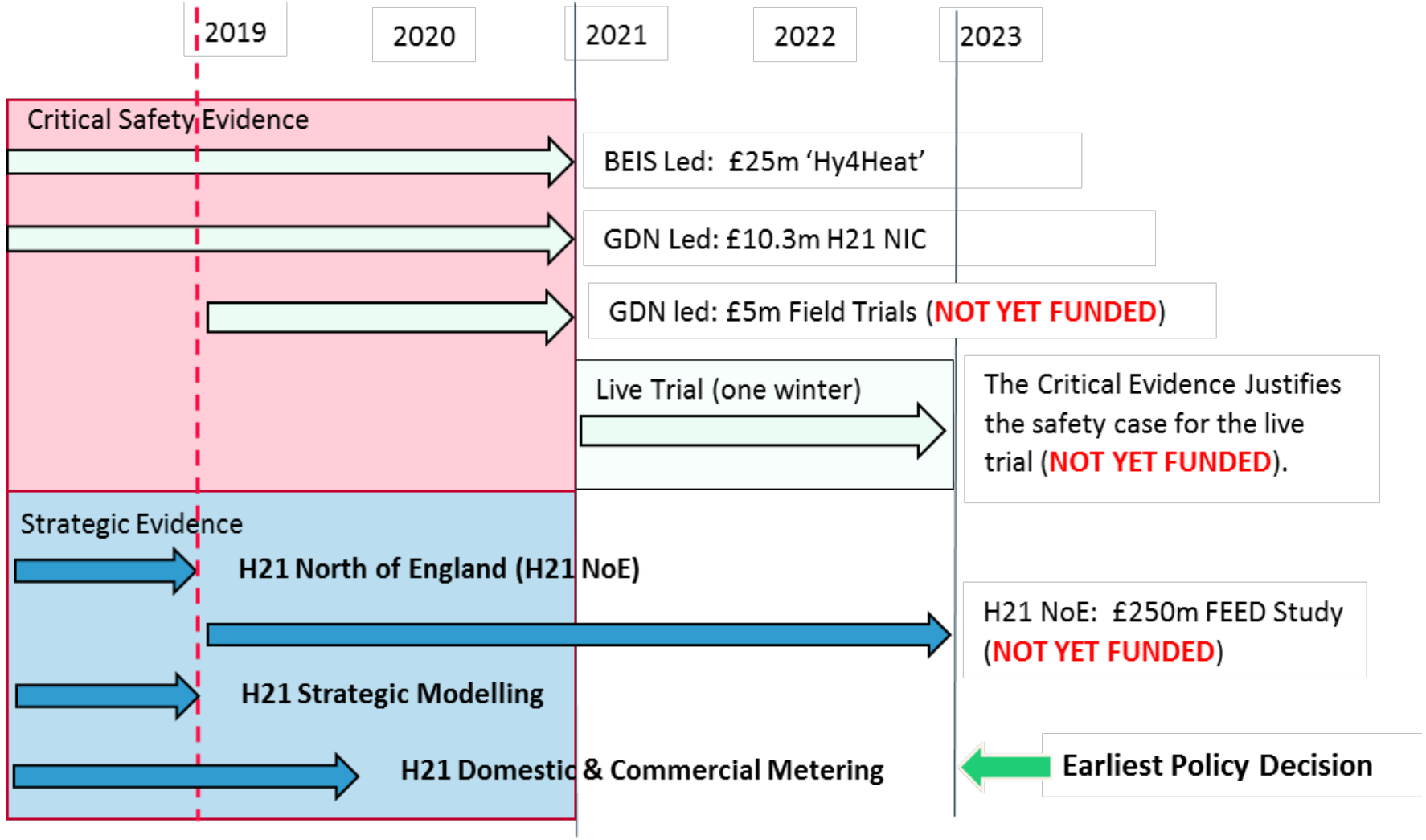
- Location: Bundter
- Capacity: +600 Million @ 17 mtpa
- Confiiguration. Saline aquifers

H21 - What will it cost?

2035 Residential Prices

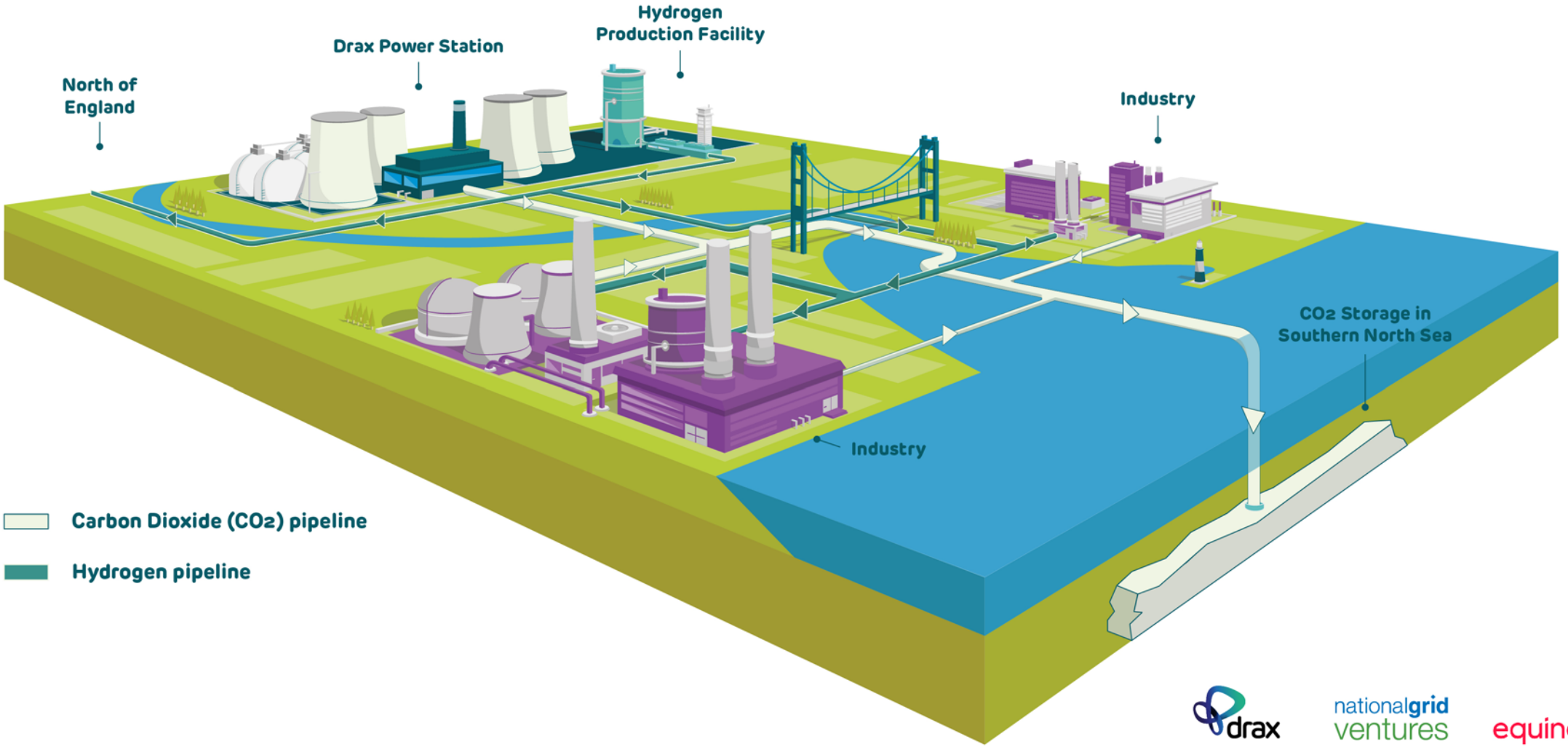
	2035 Residential Prices	CO2 Footprint
Electricity	£200/MWh (BEIS Projection)	50 g/KWh
Natural Gas	£50/MWh (BEIS Projection)	200 g/KWh
Hydrogen	£75/MWh (H21)	15 g/KWh (H21)

The Next Steps



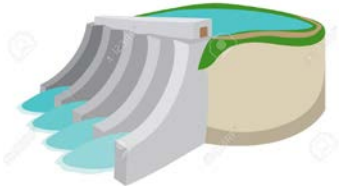
Zero Carbon Humber

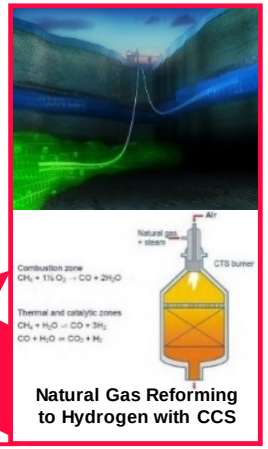
Our vision



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

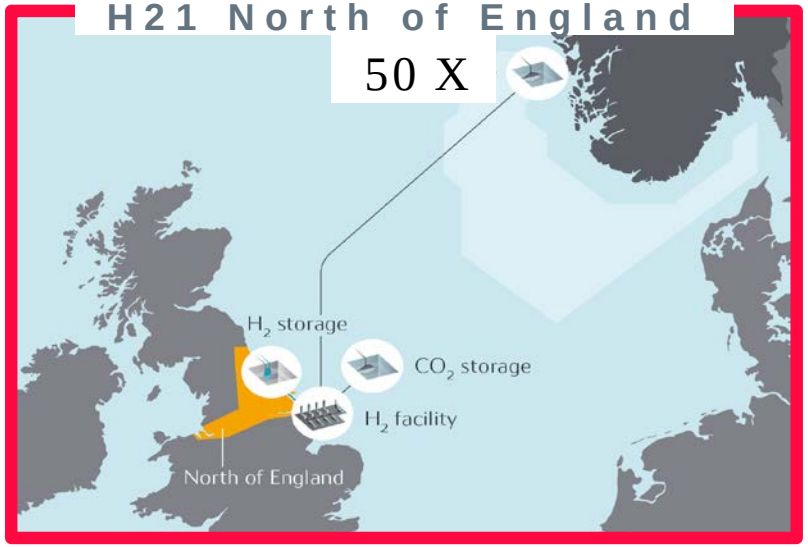


Multiple technologies to address the challenge

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

11600 000 X

Hydro

200 X

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