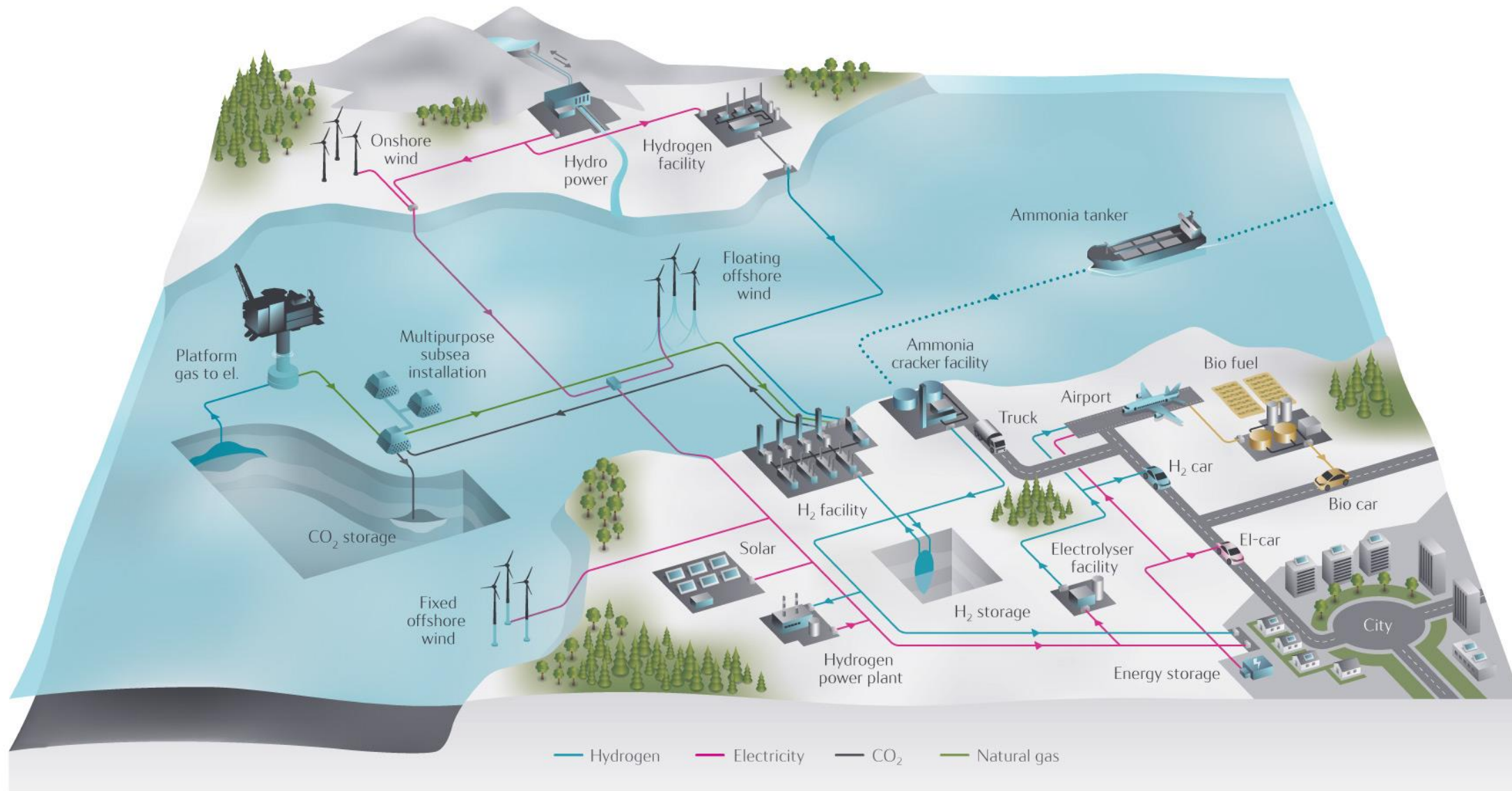


Low Carbon Solutions

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

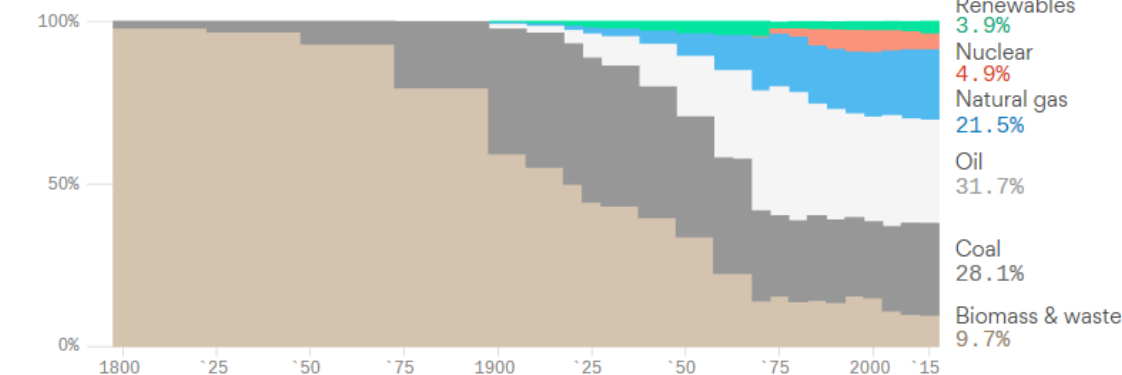
Gas combination with renewables
(gas and electricity)

Hydrogen and renewable electricity
smartly integrated

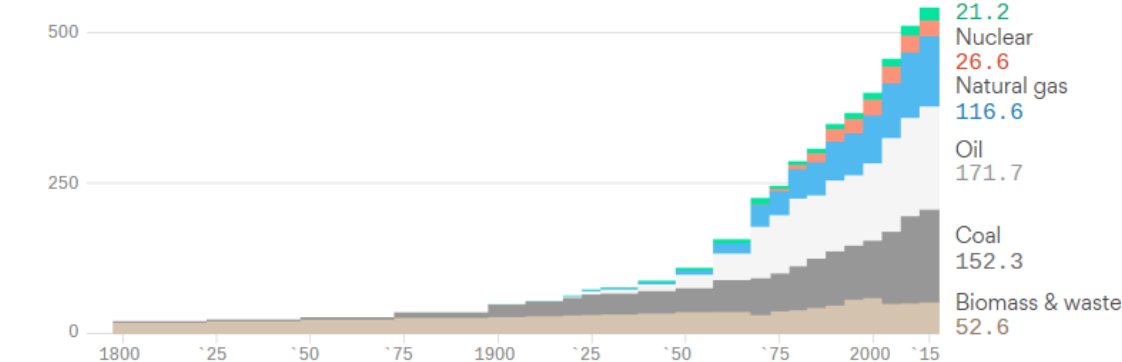
Despite new technology, there has never been an energy transition in the past...

Global energy sources, 1800–2015

BY SHARE



BY TOTAL QBTu



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, all energy use has to be carbon neutral by 2050!
- 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

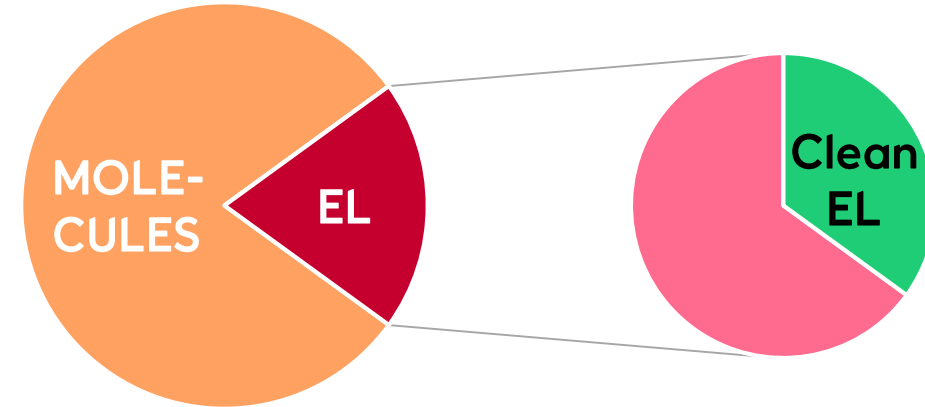
The Challenge and the Tool-Box



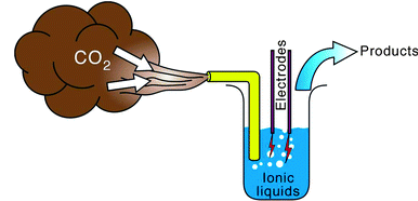
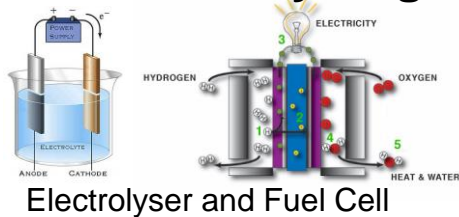
Cost Efficiency EL : MOL

Energy Transport 1 : 10
Long Term Storage 1 : 100

European Energy-Mix 2018



Green Hydrogen and Power to X

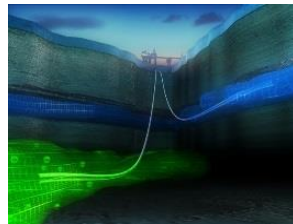


CCS



Hard-to-Decarbonize Industry

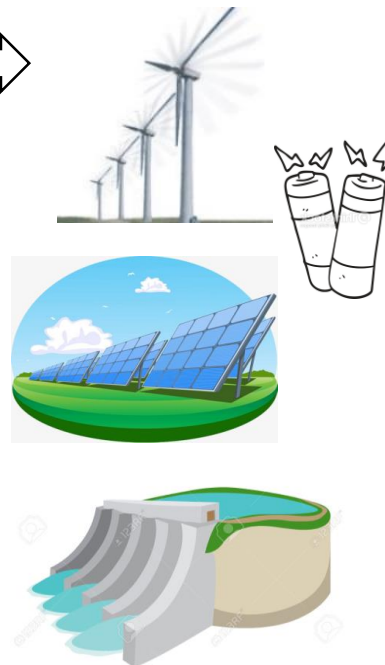
Blue Hydrogen



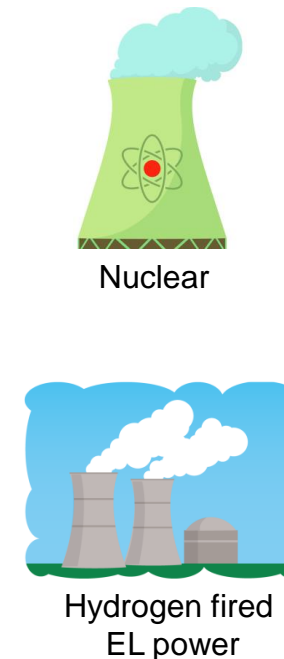
Permanent CO2 Storage (CCS)



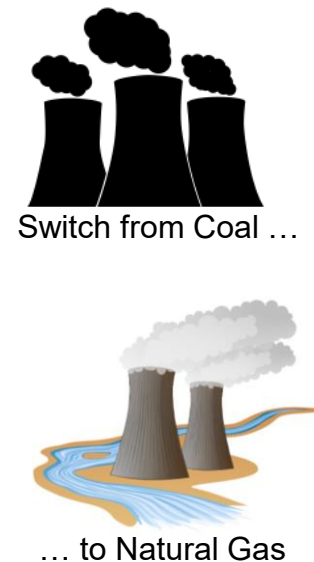
Renewable EL



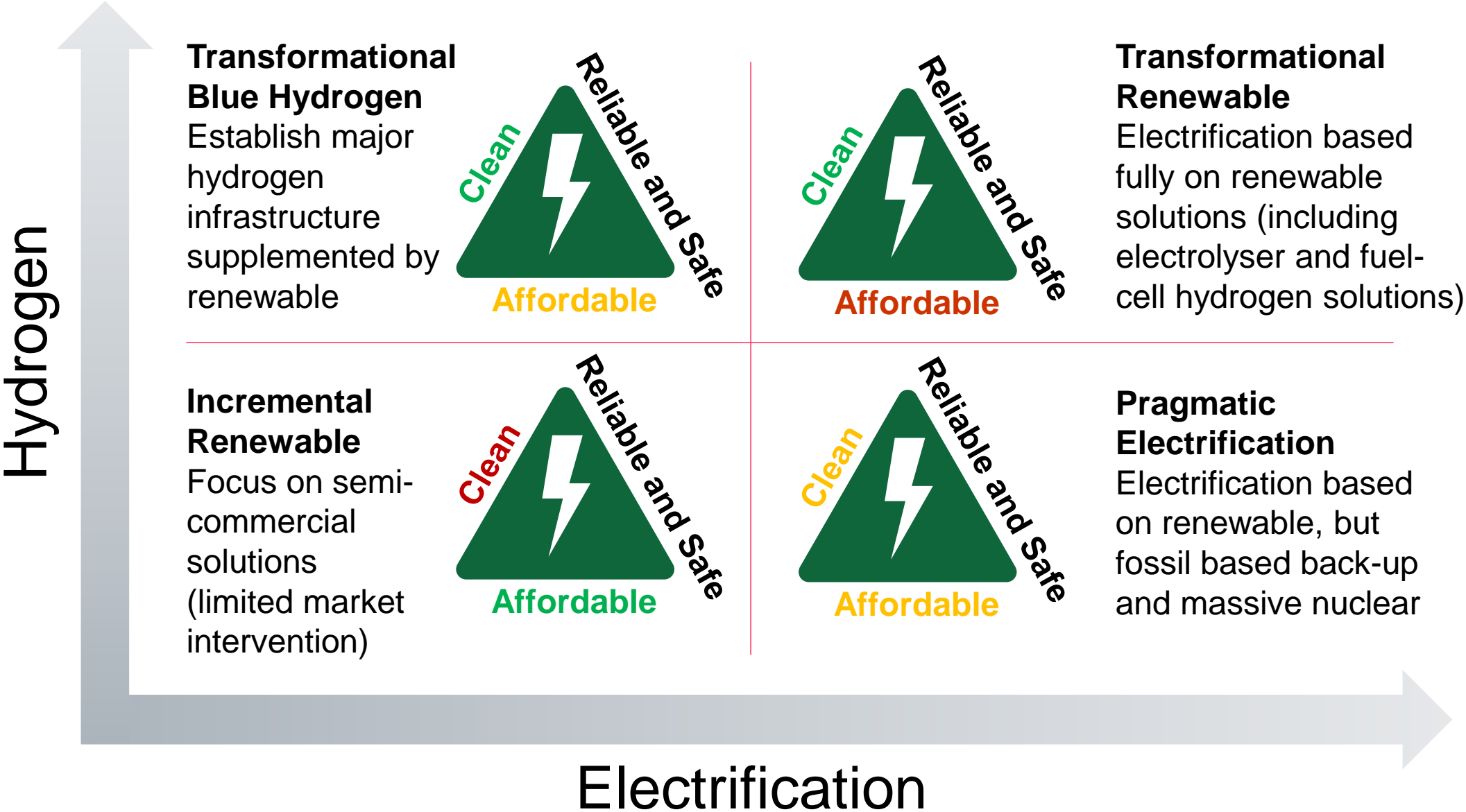
Zero Carbon EL



Improve Carbon Efficiency



Decarbonization of the “molecule sector”



Northern Lights - Visualisation of CO2 storage hub



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**

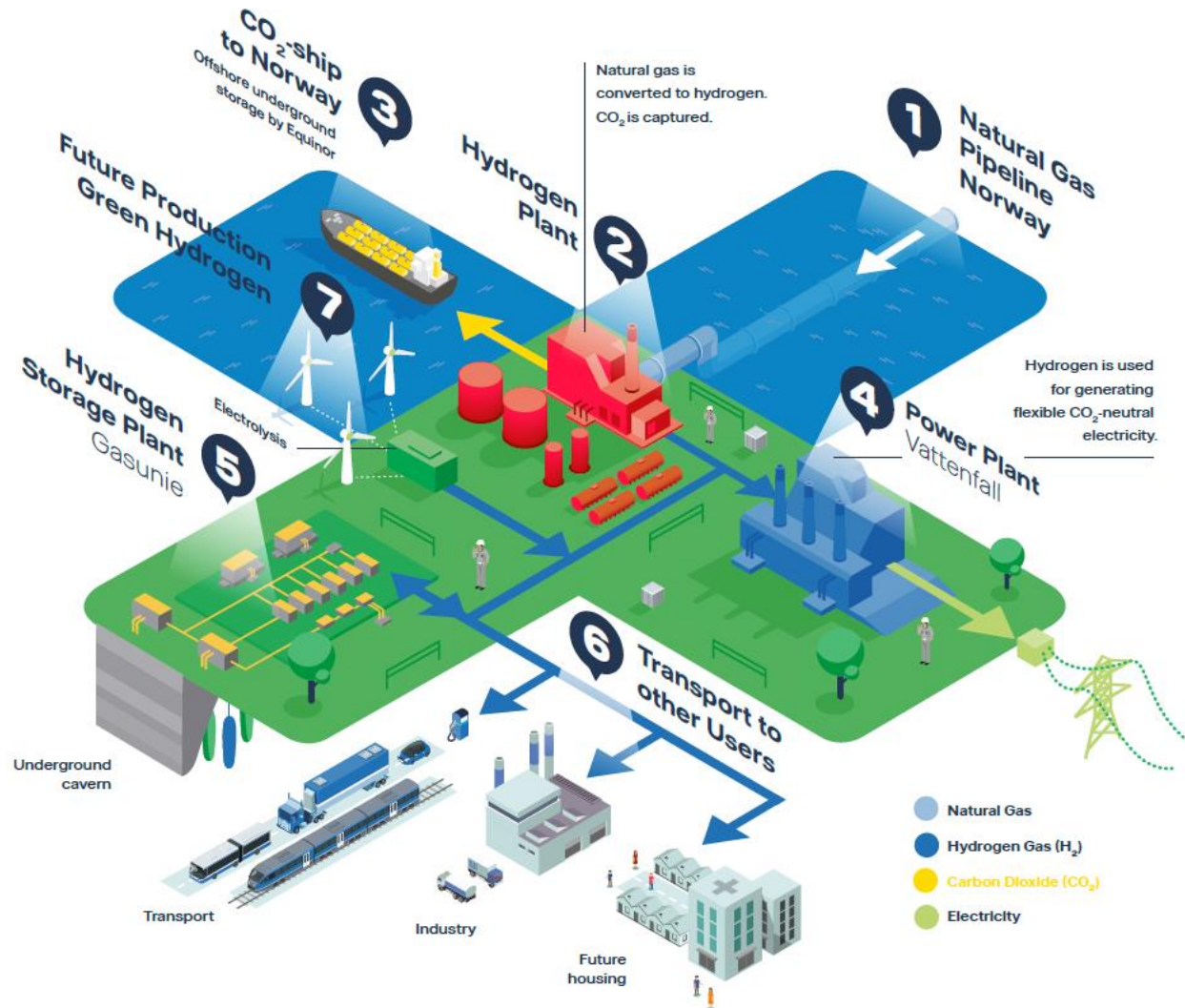


New Projects

- 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



- 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:



&

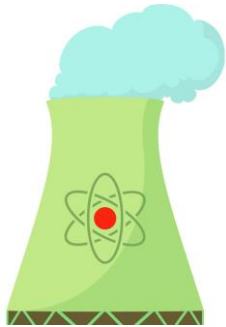
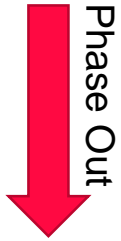


Demand for Clean and Flexible Power Expected to go up

Baseload



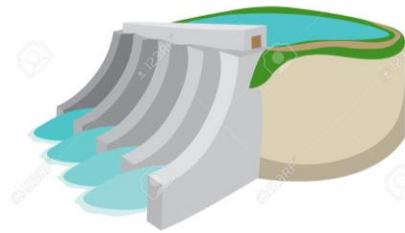
Coal



Nuclear

?

Flexible



Hydro



Gas → Clean Hydrogen



Intermittent



Wind



Solar



**Balance
Supply
&
Demand**

Perfect fit of Offshore Wind and Hydrogen



360 MW



20.000 x 20ft (2,5 days backup)



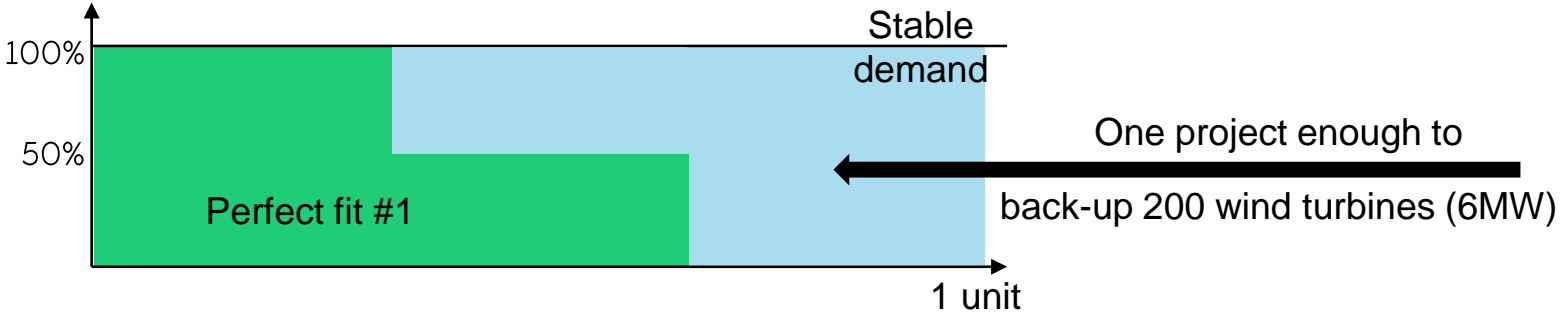
440 Mw Unlimited, Clean Backup

Wind Intermittency Managed via Blue or Green Hydrogen

Simplified concepts



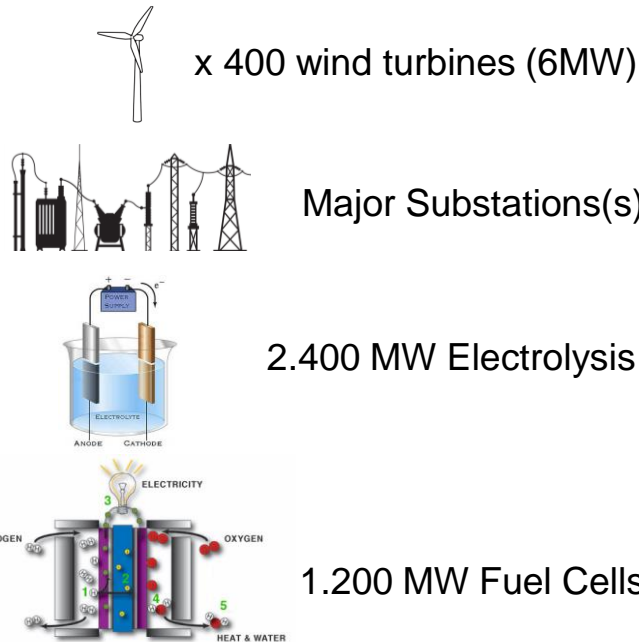
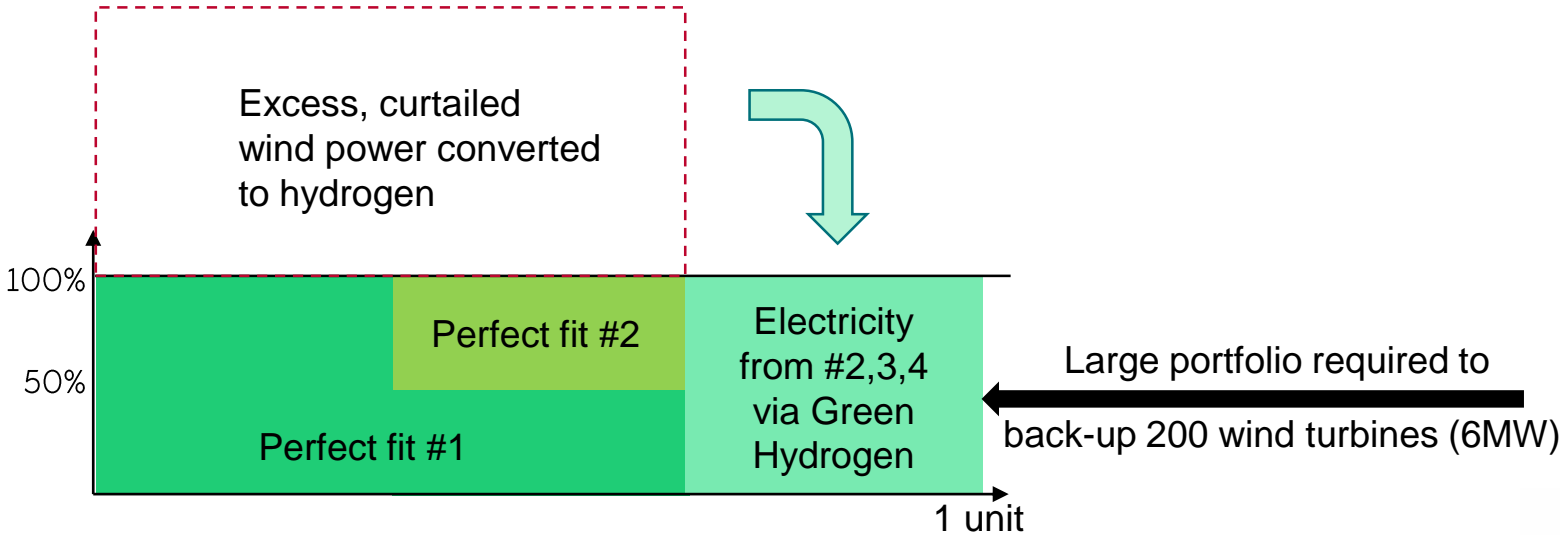
#1



1.200 MW Flexible Clean Power



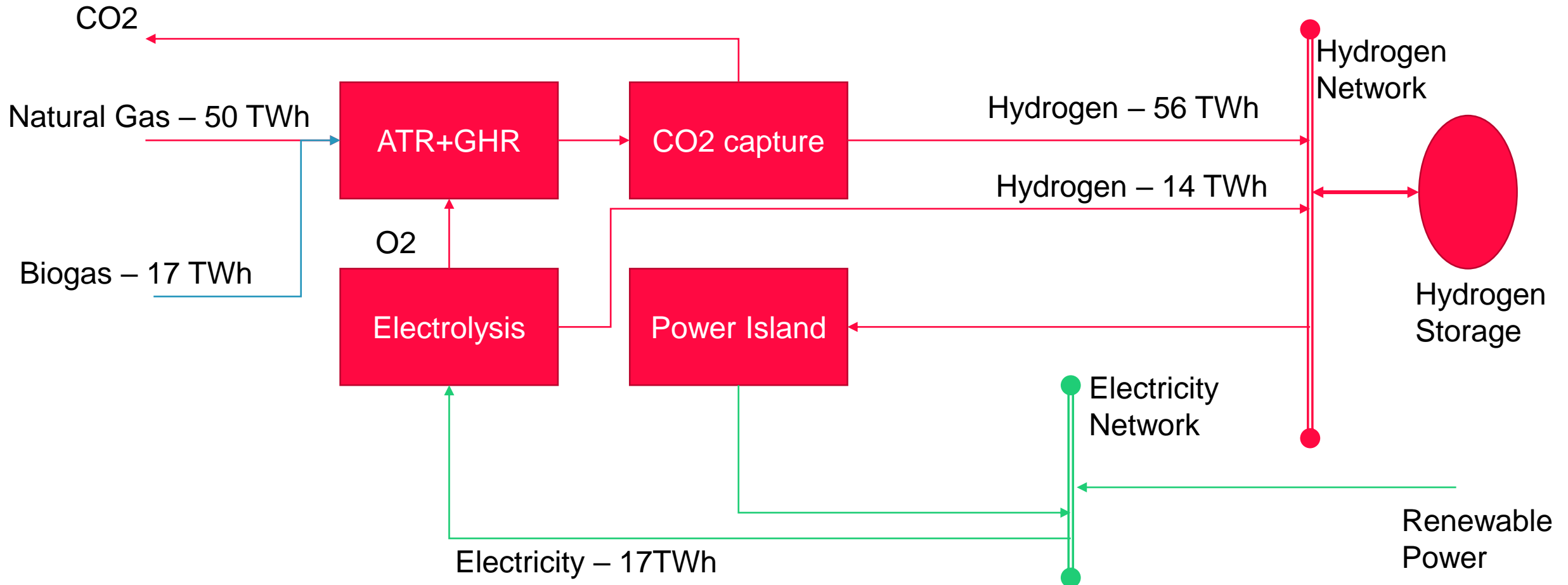
#1,2+3



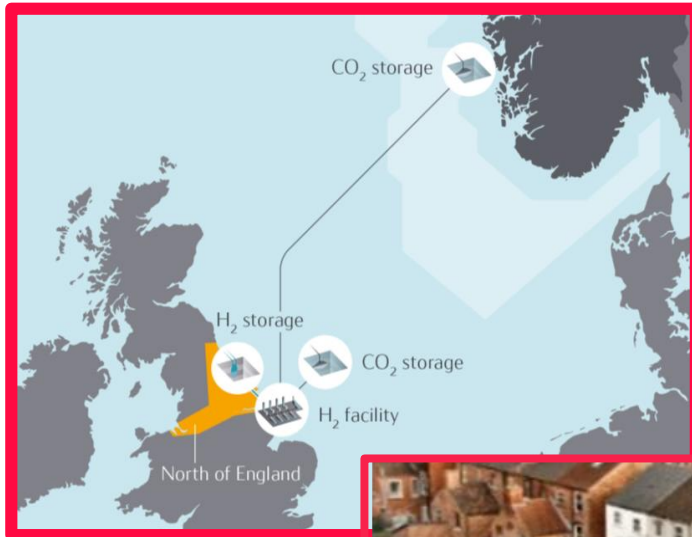
ATR Potential Development

– *reducing Natural Gas consumption 50% by introducing renewable power and Biogas*

CO2 footprint: - 46 g/KWh



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



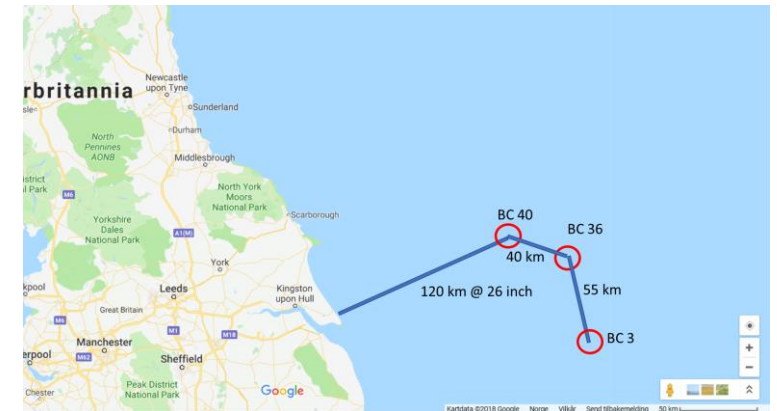
Greenfield Hydrogen Facility

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



Hydrogen Storage

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



CO2 Storage

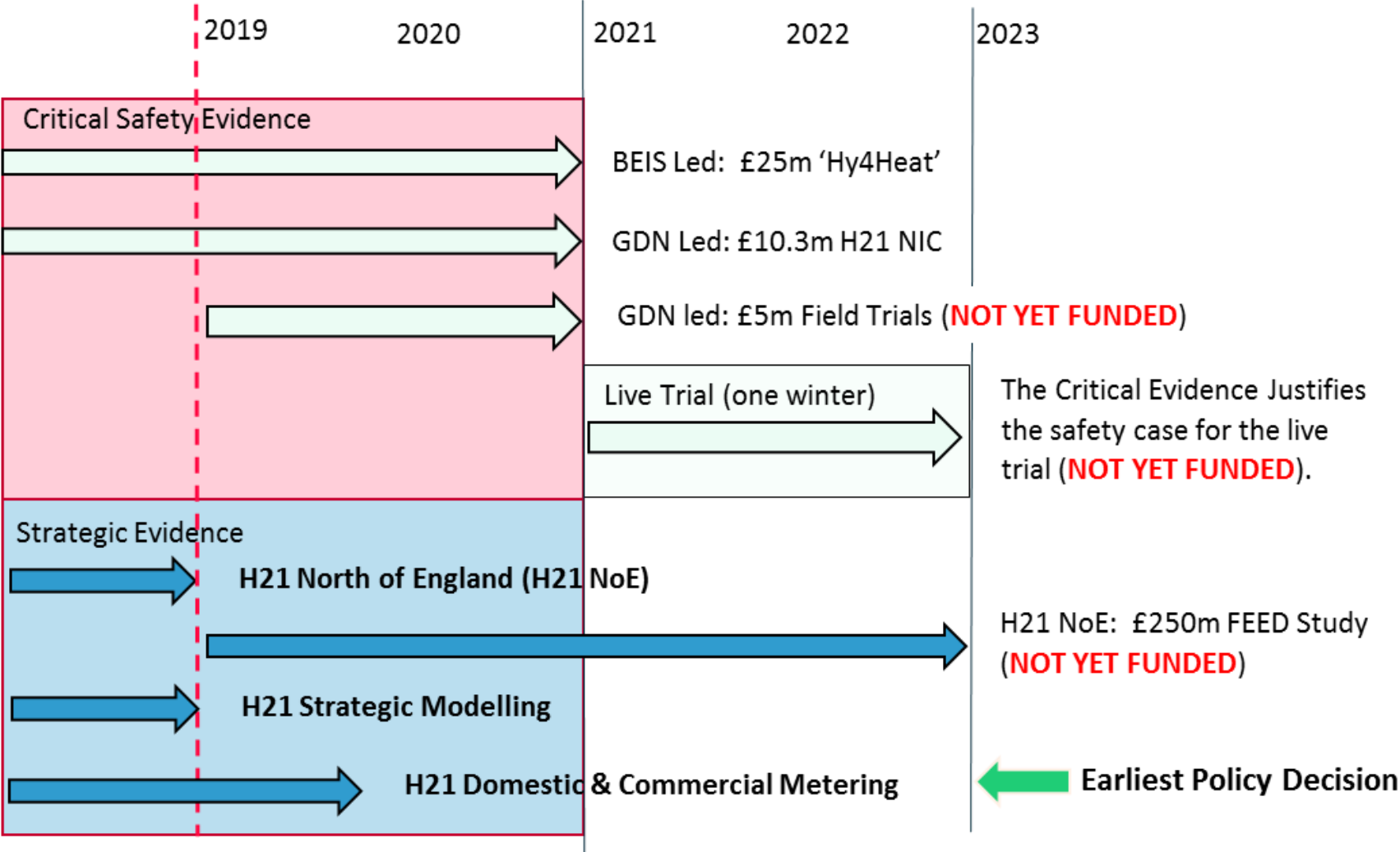
- Location: Bundter
- Capacity: +600 Million @ 17 mtpa
- Configuration. Saline aquifers

H21 - What will it cost?

2035 Residential Prices

	<u>2035 Residential Prices</u>	<u>CO2 Footprint</u>
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)

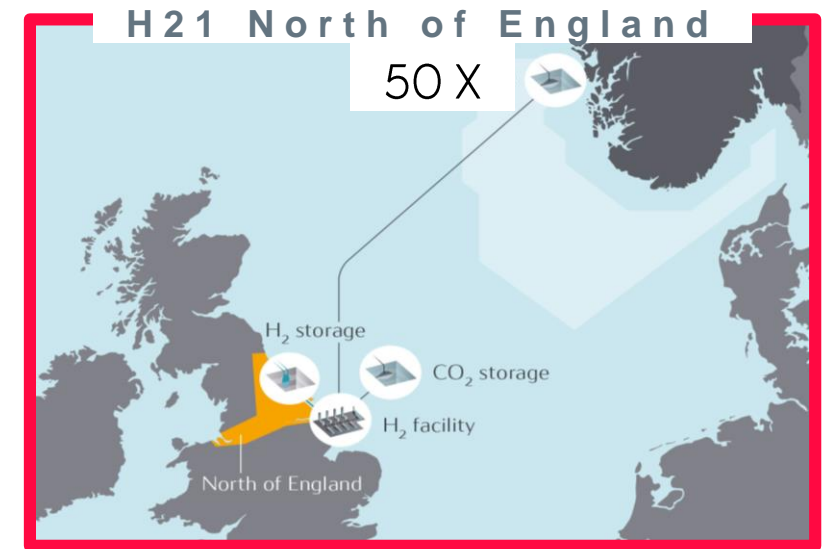
The Next Steps



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



TESLA 75D Li-Batteries

Battery park

11 600 000 X



World largest battery park in Australia (129 MWh)

Hydro

200 X



Norways biggest hydro electrical storage -Blåsjø

Decarbonising Energy Systems

Easy ← complexity to decarbonise → Hard

Transport



Battery (mostly) plus Hydrogen for Heavy Duty



Hydrogen Fuel-Cell Trains

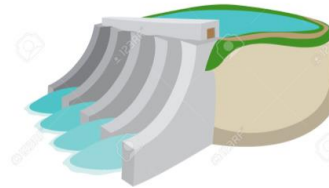


Liquid Hydrogen and Fuel-Cells for long haul Big Ships

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

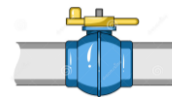


CCS for Industry without other Alternatives

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

Key Messages



- Decarbonizing 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 solutions on which we need to start working today
- Hydrogen from natural gas with permanent offshore storage of CO2 offers:
 - **Low cost** – *Gas reforming is the most cost effective hydrogen pathway*
 - **Low technical risk** - *Proven technology in H2 production and CO2 storage*
 - **A clean value chain** – *The CO2 is returned to permanent offshore storage*
 - **Large scale** – *The industry has demonstrated a track-record of mega projects*
- Hydrogen from natural gas with CCS will establish a robust hydrogen infrastructure that green hydrogen can utilize

Low Carbon Solutions

Steinar Eikaas

Head of Low Carbon Solutions - Equinor

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