Hydrogen: A Business Opportunity for the North East Region

Chair: Kirsty Lynch, Pale Blue Dot
Session 3: Hydrogen Projects

> H21 North of England – Anna Korolko, Equinor
> Acorn Hydrogen & CCS – Dave Mackinnon, Total
> Offshore Power to Hydrogen – Molly Iliffe, ERM
> Aberdeen Vision Project – Charlotte Hartley, Pale Blue Dot
H21 North of England

**Speaker:** Anna Korolko, Equinor
Climate change act 2008

The net UK carbon account for all six Kyoto greenhouse gases for the year 2050 is at least 80% lower than the 2000 baseline.

(june 2019)

- 32% of CO2 in UK comes from heating
- 70% of heating in UK comes from natural gas
H21 North of England

- A deep decarbonization of 14% of UK's heat demand by 2034
- Up to 20 Mt CO2 emission reductions per year
Energising the lives of 170 million people every day
Among the world’s largest offshore operators
Over 20,000 employees
Hydrogen production

\[ \text{CH}_4 + \text{H}_2\text{O} + \frac{1}{2} \text{O}_2 = 3 \text{H}_2 + \text{CO}_2 \]
Equinor has >20 years experience of carbon capture and storage

- Sleipner CCS since 1996
- Snøhvit CCS since 2008
- Norwegian CCS value chain project (2023/2024-)
- CO₂ capture test centre (TCM) since 2012
Sleipner

- Gas field with 5-9% CO2 content
- 0.9 MT CO2/year
- Worlds first capture and storage offshore
- Injection started in 1996
- 23 years assurance monitoring
- Since 2017 also includes processing of CO2 from Gudrun field
Snøhvit

First onshore capture - offshore storage project (combined with LNG)
Engineering concept study for a 17 - 20 Mtpa storage scheme for H21 (UK storage option):

- Assessed 3 Triassic Bunter sandstone structures in UK Southern North Sea
- Solutions involve 12 sub-sea wells drilled from 4 templates
- Baseload and seasonal fluctuations assessed
Inter-seasonal hydrogen storage

8 TWh = 62,000 Australian megabatteries

Safe design area ensuring security of supply
<table>
<thead>
<tr>
<th></th>
<th>2035 residential prices</th>
<th>CO2 footprint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>£200/MWh (BEIS projection)</td>
<td>50 g/KWh</td>
</tr>
<tr>
<td>Natural gas</td>
<td>£50/MWh (BEIS projection)</td>
<td>100 g/KWh</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>£75/MWh (H21)</td>
<td>15 g/KWh</td>
</tr>
</tbody>
</table>
UK Hydrogen Conversion Position in 2050

Phase 1
H21 NoE
Conversion 2028 - 2034
14% UK heat
30% Power (H21 XL) for North of England

Phase 2
H21 South Yorkshire & East/
West Midlands
2033-2039

Phase 3
H21 Scotland
2030-2032

Phase 4
H21 South Wales & South West
2036-2037

Phase 5
H21 East Anglia & Home Counties
2040-2045

Phase 6
H21 London
2045-2050
Zero Carbon Humber
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: Vattenfall and Gasunie

**New Projects**
- Maritime transport – Norway
- Clean Hydrogen Pilot - Norway
- Heat and power – Germany with OGE
- Power and Industry – NL (12-20 TWh)
- Power and Industry – France
Thank you!
Acorn Hydrogen and CCS

Speaker: Dave MacKinnon, Total
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Total’s ambition is to reduce carbon intensity by 15% between 2015 — the date of the Paris Agreement — and 2030.

**Carbon intensity**
Base 100 in 2015 (75 gCO₂/kbtu)

Possible Sales Mix 2040
- Natural gas: 45-55%
- Oil (incl. biofuels): 30-40%
- Low carbon electricity: 15-20%

**Improve energy intensity**
energy efficiency, optimization, etc.

Develop greener energies

Emerging CO₂, H₂ solutions
capture, valorize, offset and store
WHO IS TOTAL

98,277 Employees

8 Million Customers worldwide each day

No.4 Oil and gas company worldwide
2.6 Mboe/d produced in 2017
of which approximately 48% gas

Refining and Chemicals
A globally ranked integrated manufacturer

European Leader
In fuel retailing
2.4 Mt of biofuels blended into gasoline and diesel in 2017

No.2 LNG managed:
15.6 Mt

30% Decrease
In direct greenhouse gas emissions

Midstream and Downstream Gas
Growing presence further downstream in the gas value chain

R&D spending of
912 million USD
in 2017

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World's second-largest LNG operator

~5 million sites and customers, of which ~80% are B2C sites

A major player in renewable energies with ~2 GW of capacity developed

5 combined-cycle gas-fired power plants in Europe, including one in development

Strategic Partnerships to access emerging technologies e.g. ChargePoint

Present in more than 30 countries

SAFT: 4,300 employees 14 production facilities

~10 million people reached by our Access to Energy program
ONGOING INTEGRATION ACROSS THE NATURAL GAS AND ELECTRICITY VALUE CHAINS

2011

SUNPOWER

2016

SAFT

2017

Global LNG

2018

KKR

Acquisition of two CCGT plants

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Achieving the energy transition **will require hydrogen at large scale**…

Europe’s transition to decarbonised systems is underway
Hydrogen could provide up to 24% of total energy demand, or up to ~2,250 TWh of energy in the EU by 2050.
UK B2B ONLY SALES VOLUMES

GAS (MN TH)

ELECTRICITY (TWH)

Investing in Growing & Transforming Energy Markets
UK NATURAL GAS DEPENDENCY

UK depends on gas for heat and ~40% of electricity generation
The Scottish government will legislate to reduce greenhouse gas emissions to net-zero by 2045, five years ahead of UK legislation (2050).

Gas is a crucial energy vector in UK. Decarbonising heat is arguably the greatest challenge in meeting ‘net-zero’ targets.
UK "INDUSTRIAL" CLUSTERS → WHY SCOTLAND?

- Earlier Scottish target - 2045 target
- Enabled by Low Geological Risk & Brownfield Facilities
- ‘Early’ Acorn proposed as an Enabler to other UK Clusters
- Hydrogen could act as the Cornerstone of Acorn
- Gas & Renewables drive a potential Hydrogen Economy
"ACORN" – HYDROGEN (& CCS) PROJECT

DECARBONISING NATURAL GAS IN NORTH-EAST SCOTLAND

**St Fergus Area: New H₂ Reforming & CCS**

- **CO₂ Capture** (Pre-combustion)
- **CO₂ Transport** ~ 0.45 Mt/yr
- **CO₂ Storage** (New Subsea Wells)

- **Phase 1**: Goldeneye
  - Storage build-out:
    - Atlantic / Cromarty
    - East Mey

- **Phase 1**: Blend up to 2% (vol) Hydrogen into nat. grid
- **Hydrogen Sales**: ~ 0.05 Mt/yr
- **Nat. Gas**: ~ 0.17 Mt/yr

- **Pipeline Reuse**
  - Supply build-out: Modular expansion of H₂ plant
    - CO₂ import - Peterhead Port (Shipping)
    - CO₂ import - Grangemouth (FEEDER10 pipe)

- **Hydrogen Sales Build-out**:
  - National Grid: > 2% H₂ blend
  - Aberdeen: up to 100% H₂ local blend + transport

- **BEIS Hydrogen Supply Competition Phase 1 - Delivery September 2019**

- **Dev. Studies**
- **Project**
- **Phase 1 Build-out**

- **FID 2022**
- **First H₂ 2025 / 2026**

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- Pale Blue Dot Energy & Total study under HSC-1 funding. Shell & Chrysaor joining under HSC-2
- Advanced reforming technology to generate Hydrogen from natural gas (Nat. Grid / St Fergus Terminals)
- Pre-combustion (higher efficiency) capture of by-product CO₂
- Transport using existing pipelines + offshore storage
KEY OBJECTIVES

1. Evaluate the potential of different flow schemes for the production of low-carbon $H_2$
2. Reduce energy requirements and cost of low-carbon $H_2$
3. Maximize $H_2$ and $CO_2$ purity/recovery
4. Launch strategic research partnerships to drive forward the development of technologies
5. Identify the most promising technologies for scaling-up
6. Establish a low-carbon Hydrogen Business Model
H2 GENERATION CONCEPT

Identify the most promising technologies for scaling-up
ACORN = 200MW (LHV): 67 KNM³ H₂/hr ≈ 144 TH₂/day

✓ Enough to power ~470k FCEVs - Toyota Mirai (15k km/year @ 0.76 kgH₂/100 km*)

✓ 365 days of production adds up to a total of 1.7 TWh (LHV), or ~3.7% of total electricity production in Portugal in 2017 (Total = 47.66 TWh**)

✓ Equivalent to ~13k “Mega Batteries”

✓ < 0.1% of the total Hydrogen demand projected for Europe in 2050 (Total = 2252TWh, 2-degree scenario in Hydrogen Roadmap for Europe 2019)

** https://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do
ACORN H₂ ➔ BUILD OUT

Hydrogen Blend Requirements for St Fergus NTS Blending

>30% of the UK Gas Consumption passes through St Fergus

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SUMMARY

• Committed to Energy Transition

• Already Integrating climate into strategy – taking into account anticipated market trends

• Evaluate the potential for the production of low-carbon H₂

• North Sea Region already offers significant potential

• Must Understand and Establish Energy Price Points, before Scale Up

• Unlikely to be a single solution
Offshore Power To Hydrogen

Speaker: Molly Iliffe, ERM
Offshore Power to Hydrogen

Molly Iliffe, ERM

October 2019
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ERM’s Hydrogen Expertise

- **Techno-economic feasibility** including detailed cost estimates, financial modelling, and technical concept select for new projects.

- Future **scenario development** for the energy transition, including development of hydrogen demand and supply scenarios.

- Development and analysis of **strategic responses** to climate change and the energy transition.

- Hydrogen **hazard assessment and risk assessment** (hydrogen production facilities and pipelines).

- **Stakeholder engagement** (technical and non-technical).

- **Safety & environmental consent** delivery for projects.

- **Lifecycle assessment**
Feasibility Study of Large Scale Hydrogen Production from Offshore Wind in the UK

- Commissioned by **Offshore Wind Innovation Hub**, with **ORE Catapult** as key delivery party.
- Review of likely scenarios for implementation of hydrogen production.
- Estimation of macroeconomic benefit including:
  - Job creation and GVA
  - Supply chain readiness
  - Policy requirements
- Provides a case for government investment.
- Work completed July 2019. Will be published in combined OWIH study later this year.
Business case underpinned by robust analysis

Estimate hydrogen demand

Installed capacity of floating wind required

Capex, Opex and Decex

Complementary role for green and blue hydrogen.

Development of floating wind at deep water sites to meet demand.

Learning rates applied based on historic comparable industry trends.
Business case underpinned by robust analysis

UK supply of Capex, Opex and Decex.
Size of export market.

Apply GVA and employment multipliers

Return on government investment

% of worldwide hydrogen market that the UK could realistically capture.

Economic benefit in terms of:
- Gross value added (GVA)
- Job creation

- New employment of over 8.4 million FTE years cumulatively to 2100.
- Delivery of cumulative GVA of £270bn to 2100.

Table 5. Return on Government Investment

<table>
<thead>
<tr>
<th>20% hydrogen blended into gas network</th>
<th>100% hydrogen in gas network by 2100</th>
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<tbody>
<tr>
<td>Government investment required</td>
<td>ROI</td>
</tr>
<tr>
<td>£bn</td>
<td>£ GVA for each £1 gov investment</td>
</tr>
<tr>
<td></td>
<td>Government investment required</td>
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</tr>
<tr>
<td>£bn</td>
<td>£ GVA for each £1 gov investment</td>
</tr>
<tr>
<td>1.4</td>
<td>3.6 in Year 2050</td>
</tr>
<tr>
<td></td>
<td>22.4 in Year 2050</td>
</tr>
<tr>
<td>20.5 in Year 2100</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>186.9 in Year 2100</td>
</tr>
</tbody>
</table>

Figure 15. UK Content (%)

Figure 17. GVA generated in year (Kbn)
The results demonstrate a clear business case for large scale deployment of hydrogen from floating wind

- Transition **opportunity** for the UKNS oil and gas industry.
- Production of hydrogen at scale, comparable to current wholesale **price** of natural gas.
- **Investment in UK ports** and traditional areas of manufacturing (particularly UK East Coast).
- Delivery of UK’s **carbon emissions reduction** target by 2050.
- **Energy security**: no future reliance on gas imports.
- Potential to **export** UK hydrogen technology and services to the rest of the world.
- Delivery of cumulative **GVA of £270bn** to 2100.
- New employment of over **8.4 million FTE years** cumulatively to 2100.

Potential UK Ports benefitting from offshore floating wind for hydrogen
Key enablers to capture this opportunity

- Creating the **market conditions** for hydrogen to be blended into the UK gas network to kick-start the hydrogen market at scale.

- A **Government long term commitment** to transition from natural gas to 100% hydrogen in the UK gas network.

- Making available **seabed rights** for development of floating wind sites. These could include areas that have already been evaluated as not suitable for electricity generation, but may still be viable for floating offshore hydrogen using new or existing pipeline infrastructure.

- Long term sustained investment and regeneration of **port assets, infrastructure, fabrication yards and UK manufacturing** value chain.

- Removal of regulatory restrictions in a number of related **regulations** (e.g. Gas Safety (Management) Regulations; and Gas (Calculation of Thermal Energy) Regulations)

- **Short and medium term investment in floating hydrogen production through pilot and pre-commercial projects through to the first commercial hydrogen wind farm.**
DOLPHYN: Example green hydrogen concept to capture the opportunity

- ERM original design for production of ‘green’ hydrogen at scale from offshore wind.
- Floating semi-submersible (floating platform) design with integrated wind turbine, PEM electrolysis and desalination facilities.
- Enable the best UK offshore wind resources to be accessed in deep water at distances from land up to several hundred kilometres.
- Single 10MW unit will produce in excess of 800 Te of hydrogen per year, exported back to shore via a pipeline.
- Design has been taken through inception, definition, early technoeconomic feasibility, concept selection, and FEED.
Development of optimal design, to ensure cost parity with “brown” options

- Design has been developed through a detailed technical and financial evaluation process to achieve the lowest predicted cost for producing hydrogen from renewables at scale in the UK.
- Concept selection included modelling of Capex, Opex, Decex, hydrogen production, losses and construction schedule in order to compare potential project designs.

Design has been developed through a detailed technical and financial evaluation process to achieve the lowest predicted cost for producing hydrogen from renewables at scale in the UK.

Concept selection included modelling of Capex, Opex, Decex, hydrogen production, losses and construction schedule in order to compare potential project designs.
The Front End Engineering work is now complete and the project will move forward to detailed design stage, with a view to making a final investment decision on a 2MW prototype facility by March 2021.

Target date for the operational start-up of the 2MW prototype facility of Summer 2023.

A 10MW full scale pre-commercial facility is planned to follow by 2026.

Continue to work with partners developing complementary projects in the emerging hydrogen economy including blue hydrogen/CCUS, transportation of hydrogen, end users (transportation, industry, heating). Collaboration is key to success!
Thank you

Molly Iliffe
Senior Consultant
Energy and Climate Change
Molly.iliffe@erm.com
Edinburgh, UK
Aberdeen Vision Project

Speaker: Charlotte Hartley, Pale Blue Dot
This year marks the fifty-year anniversary of the first person to land on the moon so I would like to open my presentation with a quote from John F Kennedy’s 1962 speech ‘We Choose to go to the Moon’.

We meet at a college noted for knowledge, in a city noted for progress, in a State noted for strength, and we stand in need of all three, for we meet in an hour of change and challenge, in a decade of hope and fear, in an age of both knowledge and ignorance. The greater our knowledge increases, the greater our ignorance unfolds.

Today, we meet in a city noted for oil and gas production, in a State (country) noted for ambitious climate change mitigation targets. Like in 1962, we meet in an hour of change and challenge, in a decade of hope and fear. It may seem strange to apply this statement to climate change when it was originally describing the Cold War, but it describes the challenge of decarbonisation quite aptly.

The Aberdeen Vision Project, which we have heard about briefly a few times earlier in the day, is designed to build upon the phased transition to enable a managed implementation of the energy system towards hydrogen. It builds upon other hydrogen transformation projects (H21, HyNet, H100) and links with other decarbonisation projects (Cavendish, Methiltoune). The focus is the transport and use of hydrogen produced from reformed natural gas from St Fergus in North East Scotland. Much of the material is regionally specific and linked to other facilities and projects in the region, particularly the Acorn Project.
The project is based upon hydrogen production from advanced steam methane reforming (SMR) technology located at the St Fergus Gas Terminal, with associated CO2 capture and CO2 transport and storage through the Acorn CCS project.

It is a collaborative project between SGN, National Grid and ourselves, Pale Blue Dot Energy.