Scottish Energy Forum

"The Potential for Scotland to become a Green Hydrogen Exporter"

Gunther Newcombe, Martyn Tulloch, Alexandra Stein & Christiane Hullman

Thu 18th Jan 2024, 5.30pm doors, 6pm start
Royal Scots Club, Edinburgh

THE POTENTIAL FOR SCOTLAND TO BECOME A GREEN HYDROGEN EXPORTER

SCOTTISH GOVERNMENT POLICY AND INTERNATIONAL ENGAGEMENT TO HELP BUILD THE HYDROGEN ECONOMY

Alexandra Stein, Scottish Government,
European hydrogen envoy

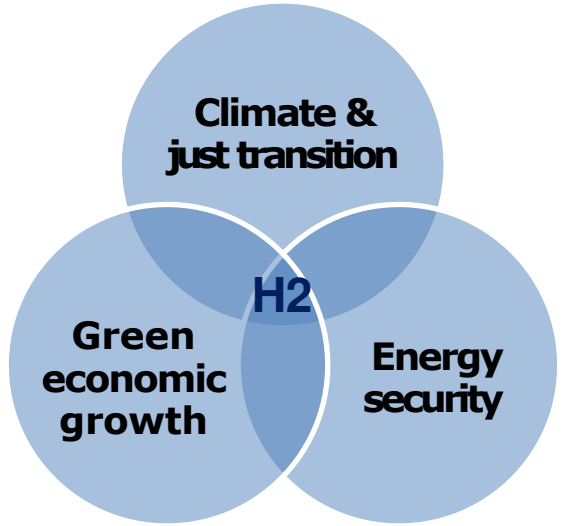
18 January 2024

Scottish Energy Forum

Annual James Watt Lecture 2024

DEVELOPING A HYDROGEN ECONOMY - SCOTTISH POLICY BACKDROP

- Climate neutral / net zero by 2045, with 75% reduction of GHG emissions by 2030
  - Maximum economic benefit and employment in a decarbonised economy, alongside a just transition
  - Energy security

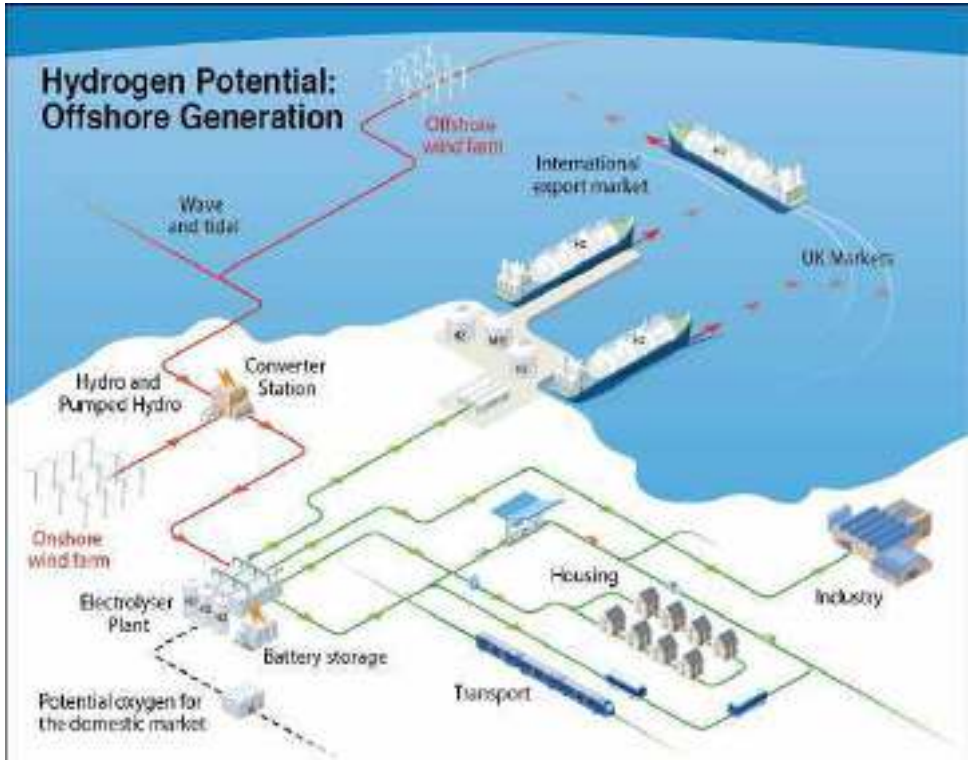


➢ Opportunity to scale up hydrogen production and deployment

➢ Domestic use and export of green H2 to rest UK and Europe

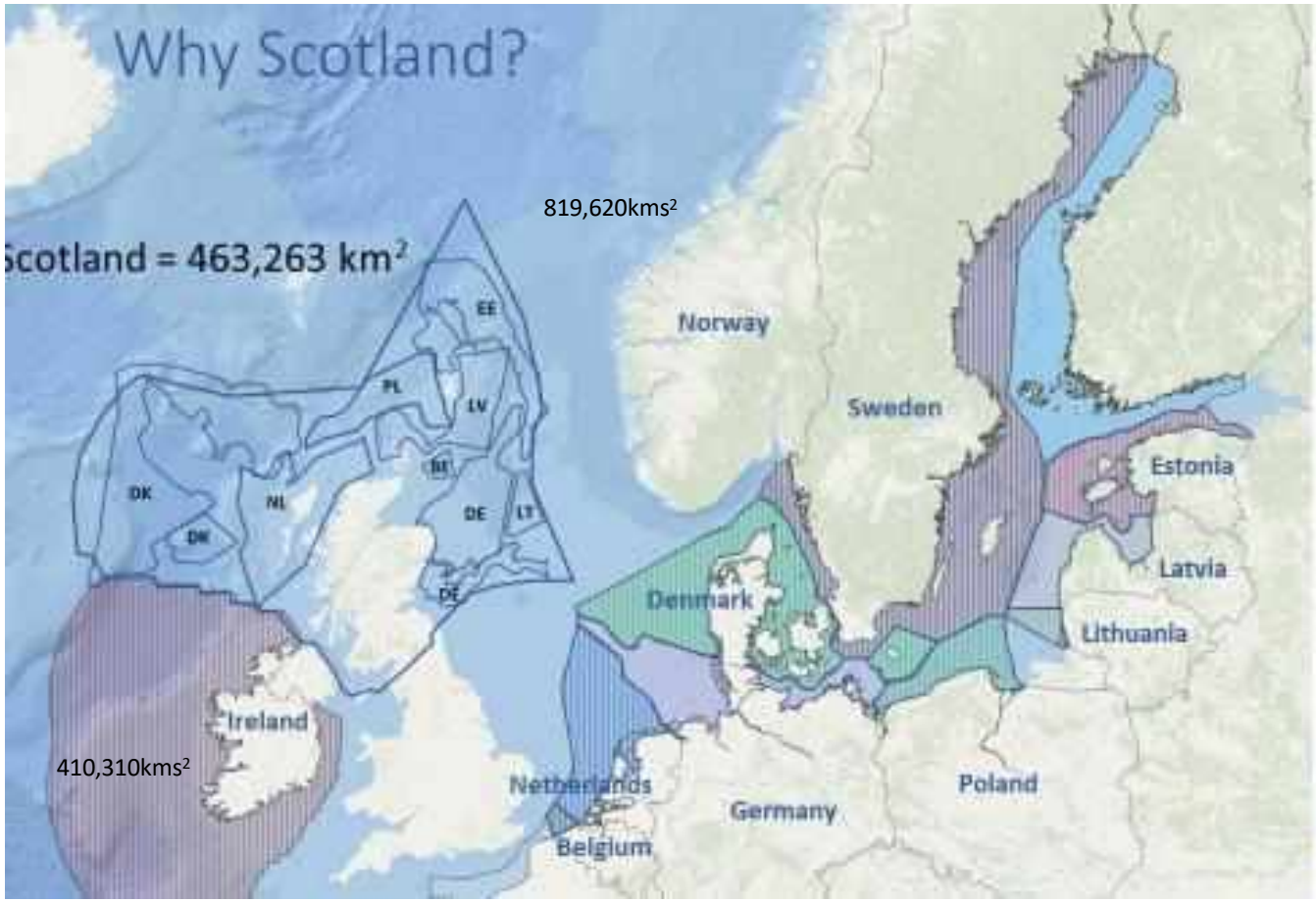
SCOTLAND'S STRENGTHS & RESOURCES

- ✓ Favourable climate & abundant natural resources
- ✓ Expertise in energy / oil & gas
  - ✓ Skilled energy workforce; 40+ years of offshore experience; large concentrations of offshore engineering expertise
  - ✓ skilled and innovative energy and sub-sea supply chains
  - ✓ experienced large-scale energy exporter
- ✓ Infrastructure
  - Oil and gas pipelines, terminals, deep water ports
- ✓ Strong onshore and offshore wind sectors
- ✓ 15-20 years developing green hydrogen
- ✓ Research and innovation expertise in renewables and H2



SCOTLAND'S LOW-COST OFFSHORE WIND RESOURCE

- Scotland's Renewable Energy Zone second largest in Europe after Norway
- Offers a huge opportunity market for offshore wind to hydrogen
- Scotland currently ahead of Norway and Ireland in development of offshore wind and in floating wind in particular
- Floating wind technology required to reap the enormous wind resource available in deeper waters further from shore



Country	EEZ in km²
Belgium	3,482
Netherlands	64,058
Denmark	104,521
Germany	56,512
Poland	29,847
Lithuania	6,800
Latvia	28,212
Estonia	36,257
Grand Total	328,689

DeepWind
North of Scotland Offshore Wind Cluster

Scottish Government
Riaghaltas na h-Alba
gov.scot

LOW CARBON ELECTRICITY –

ONSHORE & OFFSHORE WIND CAPACITY BY 2035

- Scotland already a net exporter of electricity
- Amount of **renewable electricity generated** in **Scotland** in **2021** -equivalent of **powering all households** in **Scotland** for almost **three years**
- **40GW pipeline of renewable energy projects** with a supportive investment package to drive the energy transition

➢ Role for hydrogen in transporting and storing excess energy

Wind Generation	GW	Timing
Existing onshore	9	2023
Existing offshore	2	2023
Additional onshore	8 - 12	2030
Additional offshore	9	2030
ScotWind offshore	~30	2028-35
INTOG offshore	5.5	2025-30
Total Wind Potential	**55 - 60**	**2035 onwards**

SCOTTISH HYDROGEN AMBITION AND POLICY PATHWAY

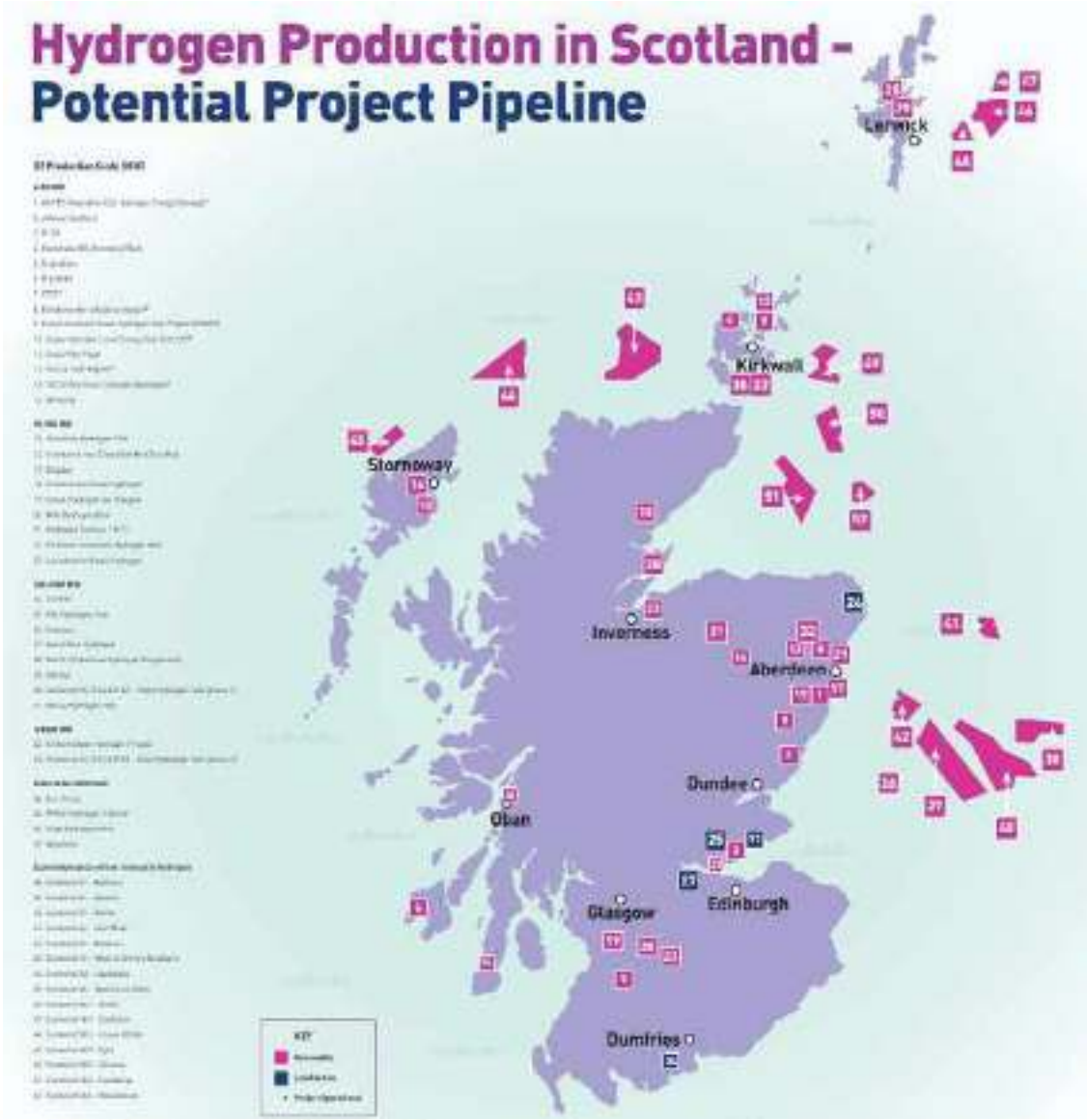
- **Vision**
  Scotland to be a leading European Hydrogen Nation

- **Ambition**

  5GW by 2030 of renewable and low-carbon hydrogen and at least **25GW by 2045**, giving potential to provide
  - up to 32 TWh per annum for domestic use by 2045 and
  - up to 94 TWh green hydrogen per annum for export by 2045

- **Focus**: renewable H2, while supporting low-carbon hydrogen production at scale linked to CCUS in 2020s

- **Impact**: 2020 analysis estimates **up to 300,000 jobs** could be protected or created, with potential **GVA impact of up to £25 billion a year by 2045**



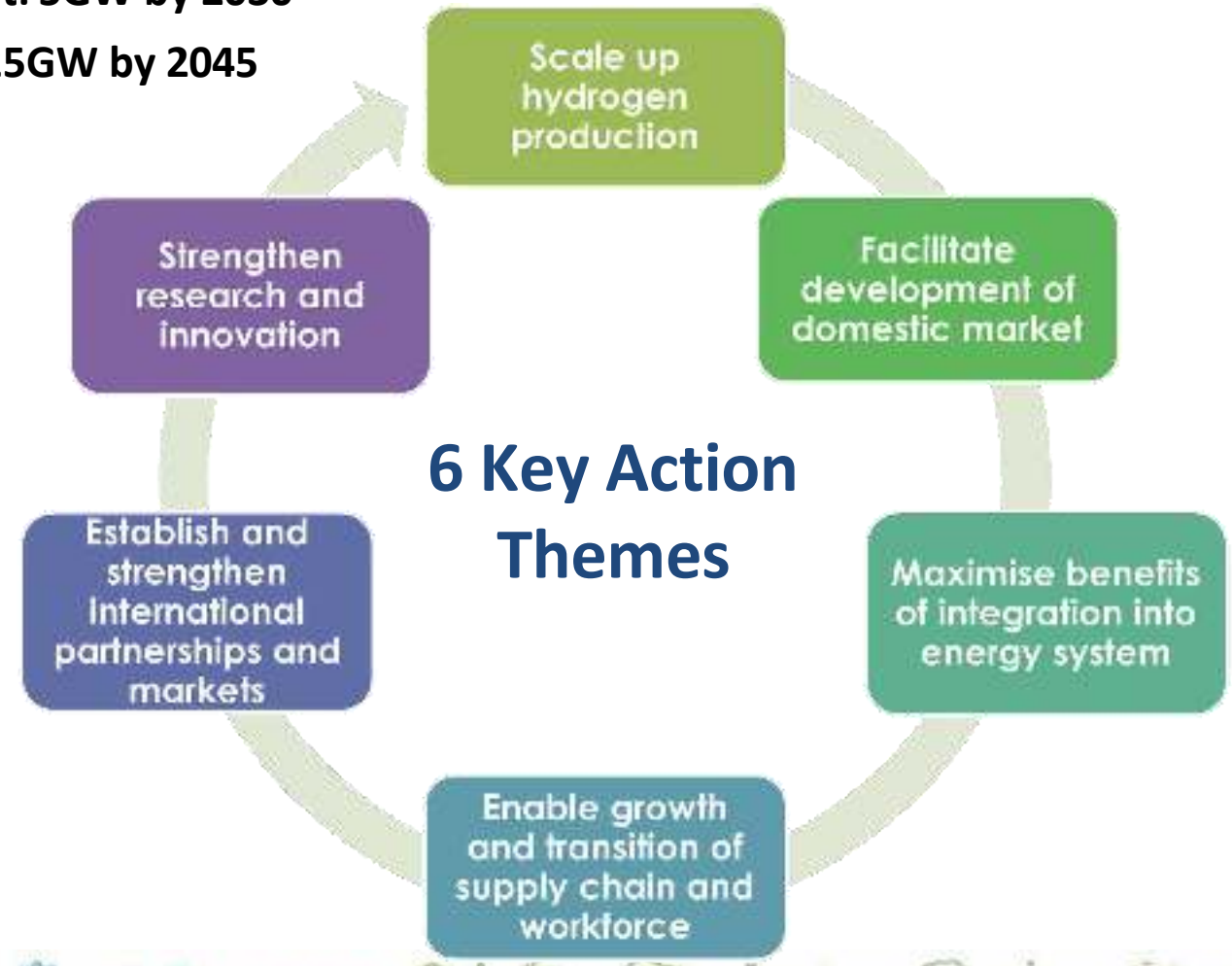
By way of general comparison: 5GW electricity can produce ~.45Mta tonnes of green H2 annually, which can generate ~17.5TWh of hydrogen. For scale reference, Scotland's total energy demand per annum is 161 TWh. i.e. 5GW of hydrogen could produce energy equivalent to 15% of Scotland's total energy demand

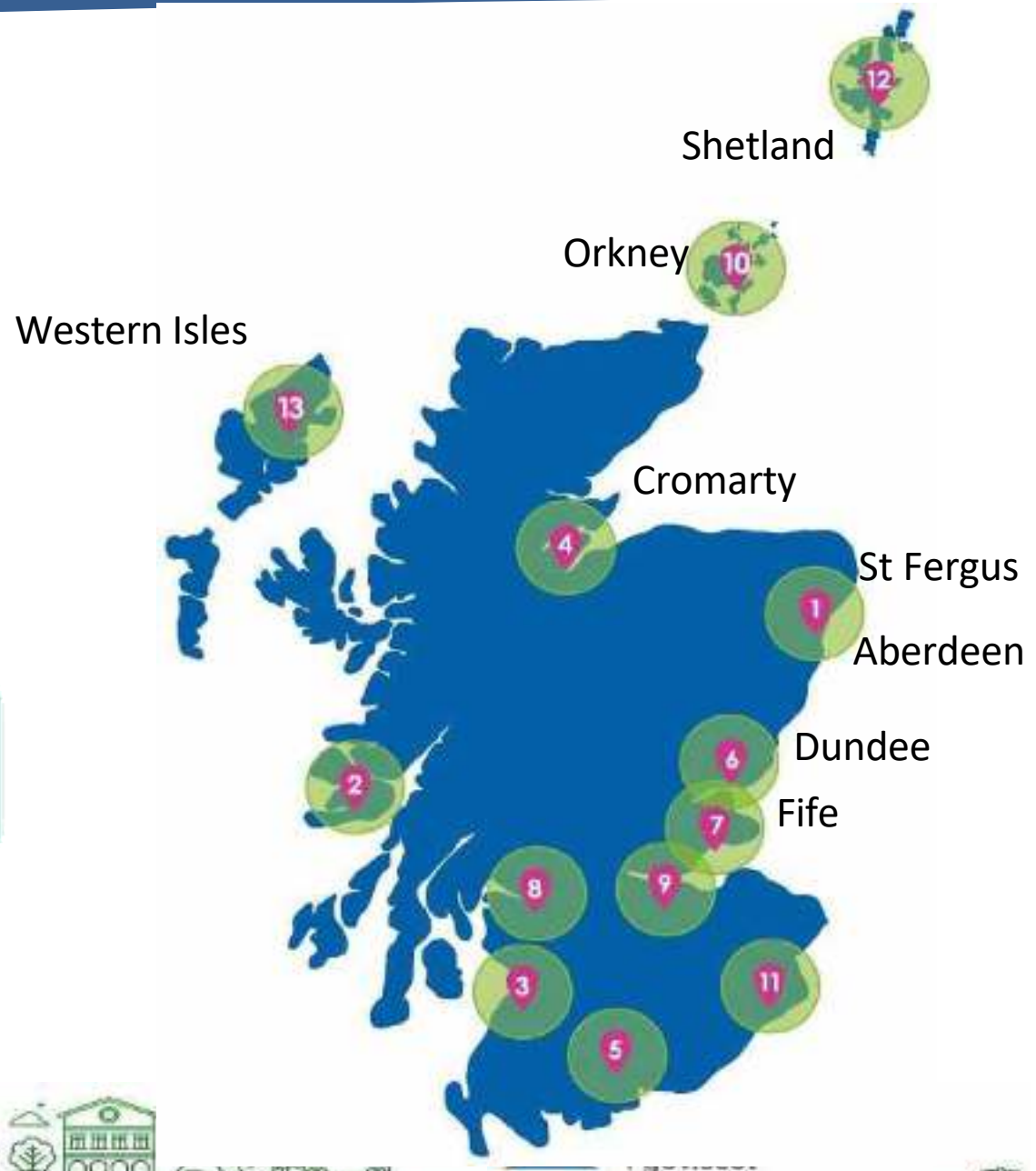
SCOTTISH GOVERNMENT HYDROGEN ACTION PLAN

6 Action Themes & 14 Regional Hydrogen Hubs

Target: 5GW by 2030

and 25GW by 2045





INTERNATIONAL ENGAGEMENT AND EXPORT OPPORTUNITIES

- Collaborative working and mutual learning to develop the global hydrogen economy more quickly

- Production of H2 in Scotland to play a significant role in supplying growing local and overseas markets

➢ Ambition for **Scotland to be a leading producer and exporter of hydrogen and hydrogen derivatives for use in UK and in Europe**

  - Goal of 5GW renewable and low-carbon hydrogen by 2030 can be translated as approx. 0.45 Mt of hydrogen produced annually for domestic and international use.
  - Goal of 25GW by 2045 ≈ approx. 3.3 Mt (126 TWh) of renewable hydrogen produced in Scotland annually

    with approx. 2.5 Mt (94 TWh) exported to UK and other European markets.
  - Potential for first hydrogen delivered from Scotland to mainland Europe in mid-to-late 2020s.

European Union has set a target to **import 10m tonnes (Mt) of hydrogen by 2030**, with recent reports indicating that global hydrogen demand could reach 115 Mt by 2030.

EXPORT OPPORTUNITIES – GERMAN EXAMPLE

Development and updating of the National Hydrogen Strategy (NHS)

Phase 1: Start of market ramp-up

Phase 2: Accelerated market ramp-up

June 2020 | September 2021 | May 2022 | July 2023

https://www.nationale-wasserstoffstrategie.de

GERMANY'S HYDROGEN STRATEGY PRIORITIES

Phase 2: Accelerated market ramp-up

Fields of action of the NHS update

1. Ensuring availability of sufficient hydrogen
2. Developing a hydrogen infrastructure
3. Implementing hydrogen applications (industry, transport, electricity, heat)
4. Creating good framework conditions

2023 | 2024 | 2026 | 2030

Short-term | Medium-term | Long-term

Cross-cutting field of action

Germany to become a **leading provider** of hydrogen technologies **by 2030**

GERMANY'S HYDROGEN DEMAND

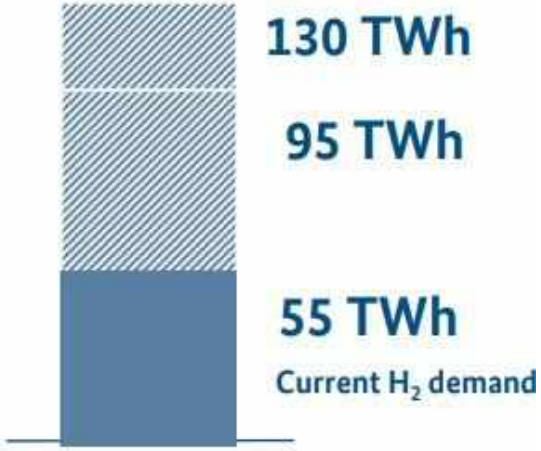
The projected total hydrogen demand is 95-130 TWh by 2030

At least 10 GW

Domestic H_2 generation up to 2030

45-90 TWh

Projected H_2 and derivatives imports up to 2030



95-130 TWh

Projected total H_2 and derivatives demand by 2030

GERMAN INDUSTRIAL REQUIREMENTS

German industry will be a major off-taker of green hydrogen by 2030

Important **heavy industry** stakeholders in Germany:

thyssenkrupp ArcelorMittal SALZGITTER AG Stahl und Technologie Aurubis

Important **chemical** industry stakeholders in Germany:

BASF We create chemistry BAYER covestro

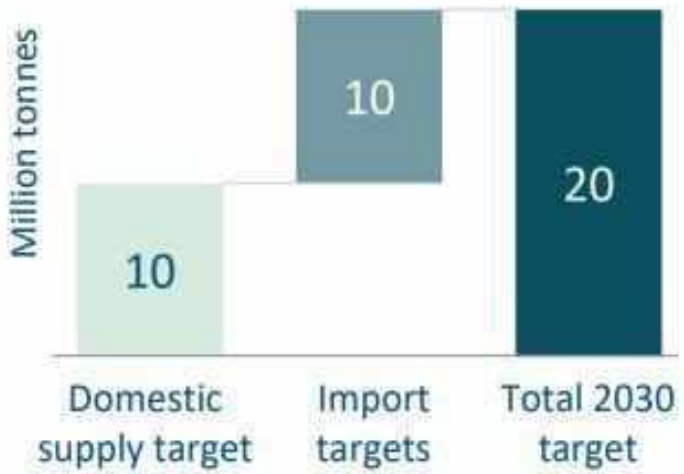
German H_2 **demand by 2030**:

The steel industry expects a demand of 24 TWh hydrogen by 2030. This alone corresponds to ~20 % of Germany's national hydrogen demand in 2030.

ALIGNMENT WITH EU HYDROGEN STRATEGY AND CORRIDORS

Around 60% of EU's hydrogen import demand is expected in Belgium, Germany and the Netherlands

EU's renewable hydrogen target for 2030:



The five possible future hydrogen supply corridors are:

Corridor A: **North Africa & Southern Europe**
Corridor B: **Southwest Europe & North Africa**
Corridor C: **North Sea**
Corridor D: **Nordic and Baltic regions**
Corridor E: **East and South-East Europe**

Image: EHB 2022

INTERNATIONAL ENGAGEMENT ON HYDROGEN

In line with Scottish Government HAP commitment to

working collaboratively with international partners to develop the global hydrogen economy more quickly

Objectives

1: To cement Scotland's profile in key target regions as a potential major green hydrogen producer for international markets and build relationships that will support future trade opportunities.

2: To realise opportunities for Scottish supply chain in international markets.

3: To attract inward investment to support the development of the supply chain in Scotland's growing hydrogen sector.

4: To attract international capital to investable projects in Scotland.

5: To ensure that domestic policy development is informed by international best practice and keeps pace with global developments.

6: To support Scottish industry and academia to drive critical research and technological advancements through international collaboration and knowledge sharing.

Activity

- **Building in-country relationships** to advance objectives in key regions (e.g., policy workshops, B2B engagement, policy monitoring and reporting)
- Co-operation under **MoUs** with partners, including priority German states (e.g. Baden-Württemberg, Bavaria, Hamburg, Lower Saxony, North Rhine-Westphalia), Occitania, Denmark.
- Ministerial and official participation in **key overseas events** (e.g. World Hydrogen Summit; European Hydrogen Week; COP; state-level events).
- **Inward political and trade delegations** to foster collaboration and showcase Scotland's hydrogen offer.
- Supporting **key projects** to help unlock international trade opportunity (Hydrogen Backbone Link Project; LOHC Transport from Scotland (LHyTS) Project; Scot2Ger).
- **Activity under recent UK agreements** with e.g. Germany, Denmark and Ireland; engagement with UKG to ensure Scottish interests are represented internationally.
- Co-leadership (with South Australia) of the **Green Hydrogen Taskforce**, as part of the Net Zero Futures Policy Forum.

REALISING SCOTLAND'S TRADE POTENTIAL –

SCOTTISH HYDROGEN SECTOR EXPORT PLAN DUE 2024

Provide confidence to those wishing to buy Hydrogen as a commodity from Scotland, that Scotland has an executable plan to deliver that commodity and good and services to them.

Provide confidence to those wishing to invest in the production and trading of Hydrogen from Scotland, that the required eco-system is in place to achieve that.

Identify clear opportunities for Scottish businesses to trade internationally in support of the export of Hydrogen as a commodity and its related goods and services (ie supply chain).

Work with companies to ensure that they are "trade ready" to ensure that they can secure international opportunities within the H2 sector.

Scottish Government Hydrogen Journey

Policy Documents

Hydrogen Policy Statement (2020)

Hydrogen Action Plan (2022)

Other links

Hydrogen Assessment Report (2020)

Deep decarbonisation pathways for Scottish industries: research report (2020)

Offshore wind to green hydrogen: opportunity assessment (2020)

Scot2Ger: Development of a Green Hydrogen Supply Chain from Scotland to Germany (2022)

Scotland Hydrogen Investment Proposition (2022)

Introduction to Electrolysers - Assessment of electrolysers (2022)

Cost reduction pathways of green hydrogen production in Scotland (2022)

Hydrogen as a storage medium in Scotland (2023)

Net Zero Technology Centre

Technology Driving Transition

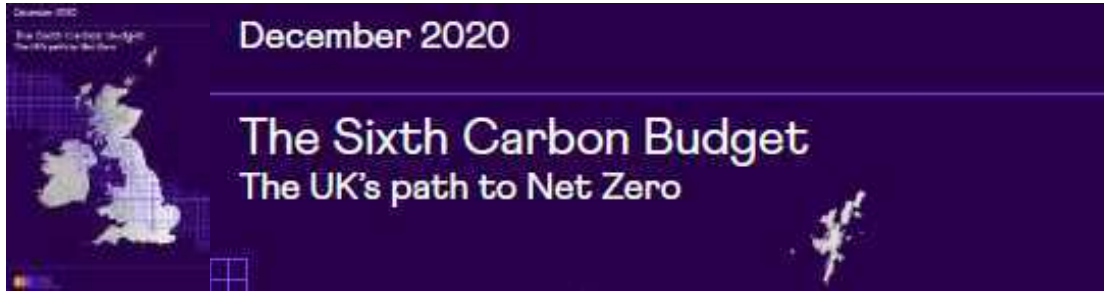
Scottish Energy Forum

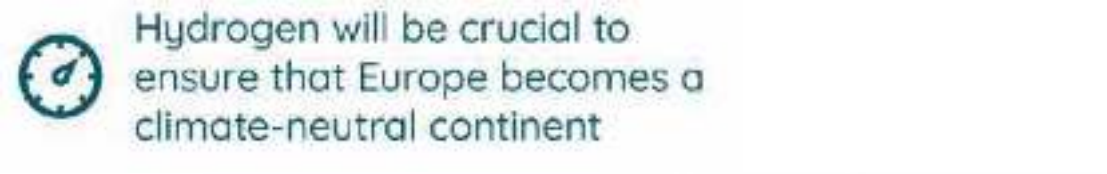
Annual James Watt Lecture 2024

The potential for Scotland to become an exporter of hydrogen

Martyn Tulloch, Director of Energy Transition

18th January 2024





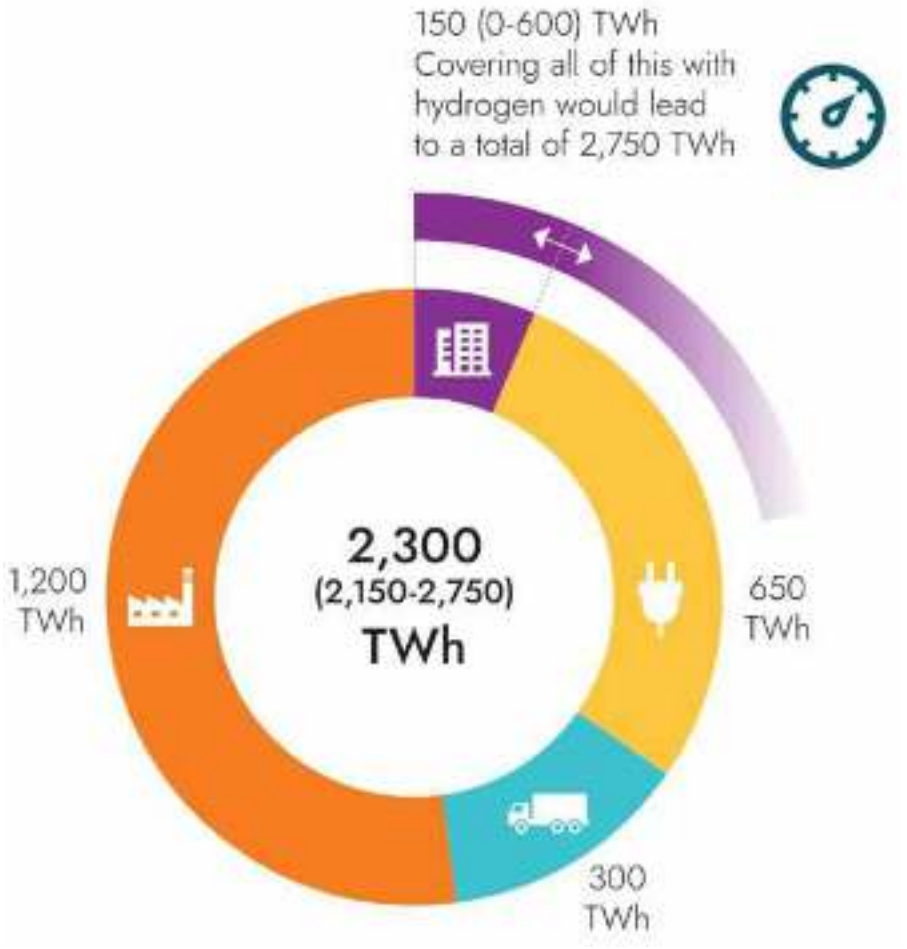


Figure 2.7 Energy demand (TWh) by sector in The Balanced Net Zero Pathway

The Energy Transition Opportunity

Scottish Government
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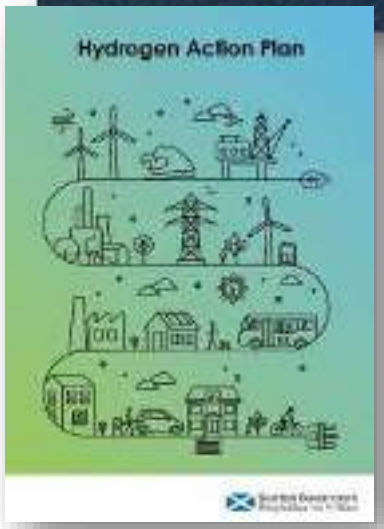
Net Zero Technology Centre

Wood Mackenzie



	Oil & Gas	Off. Wind	Hydrogen	CCS	Annual Revenue	Scotland
	£13.5Bn	£0.4Bn	-	-		£13.9Bn
2020	£15Bn	2			£17Bn	
	£1.5Bn	£1.6Bn	-	-		£3.1Bn
	£9Bn	£5.2Bn 1	£5.2Bn 5	£0.6Bn 3		£29Bn
	-	£5.8Bn	£8.8Bn	£3.4Bn		£18.1Bn

Scotland's Low Cost Green Hydrogen Potential

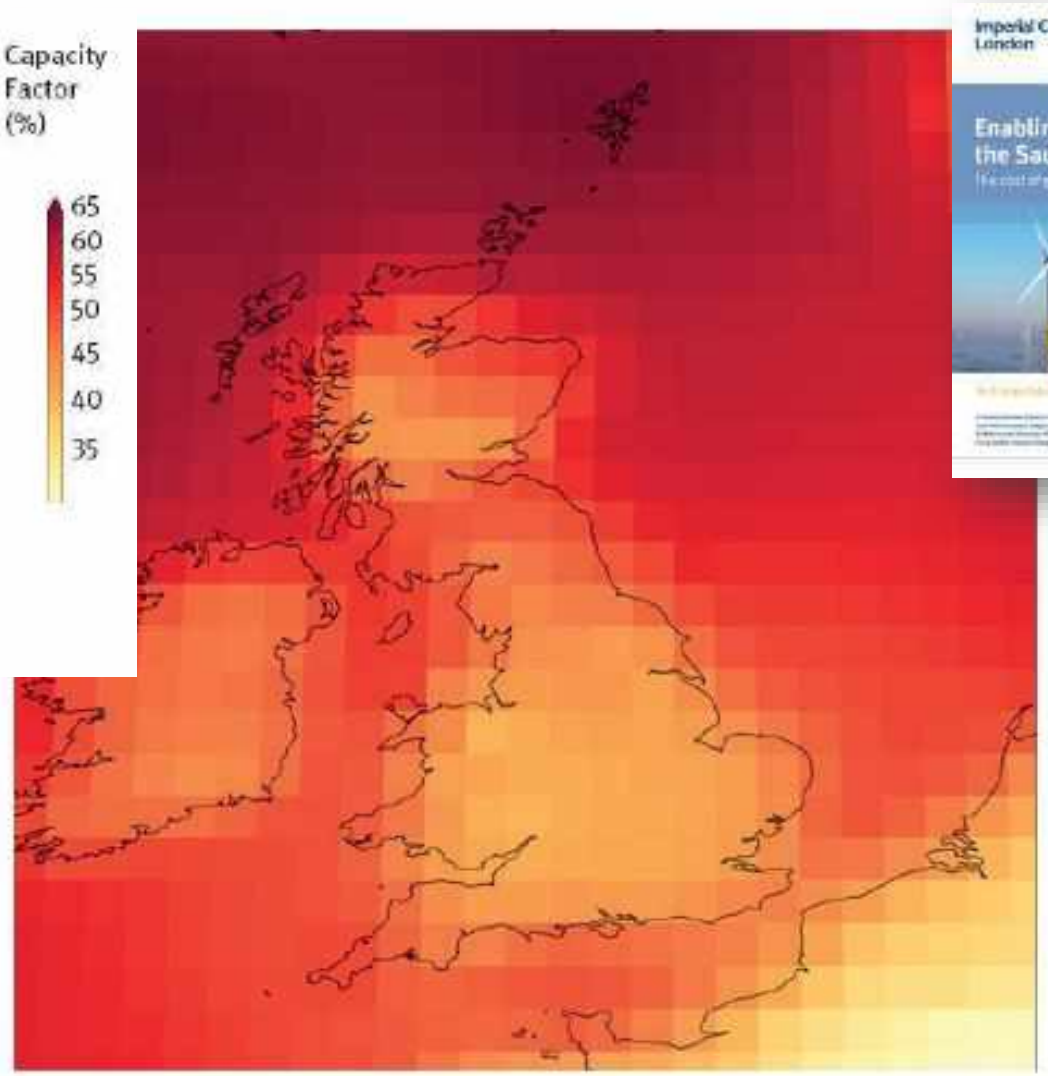


Figure 2 A heatmap presenting the average wind capacity factor across the UK in 2022, with data taken from NASA's MERRA-2 Dataset. Capacity factor measures the annual electricity output relative to the output that would be produced if the wind turbine ran at its full capacity all through the year.

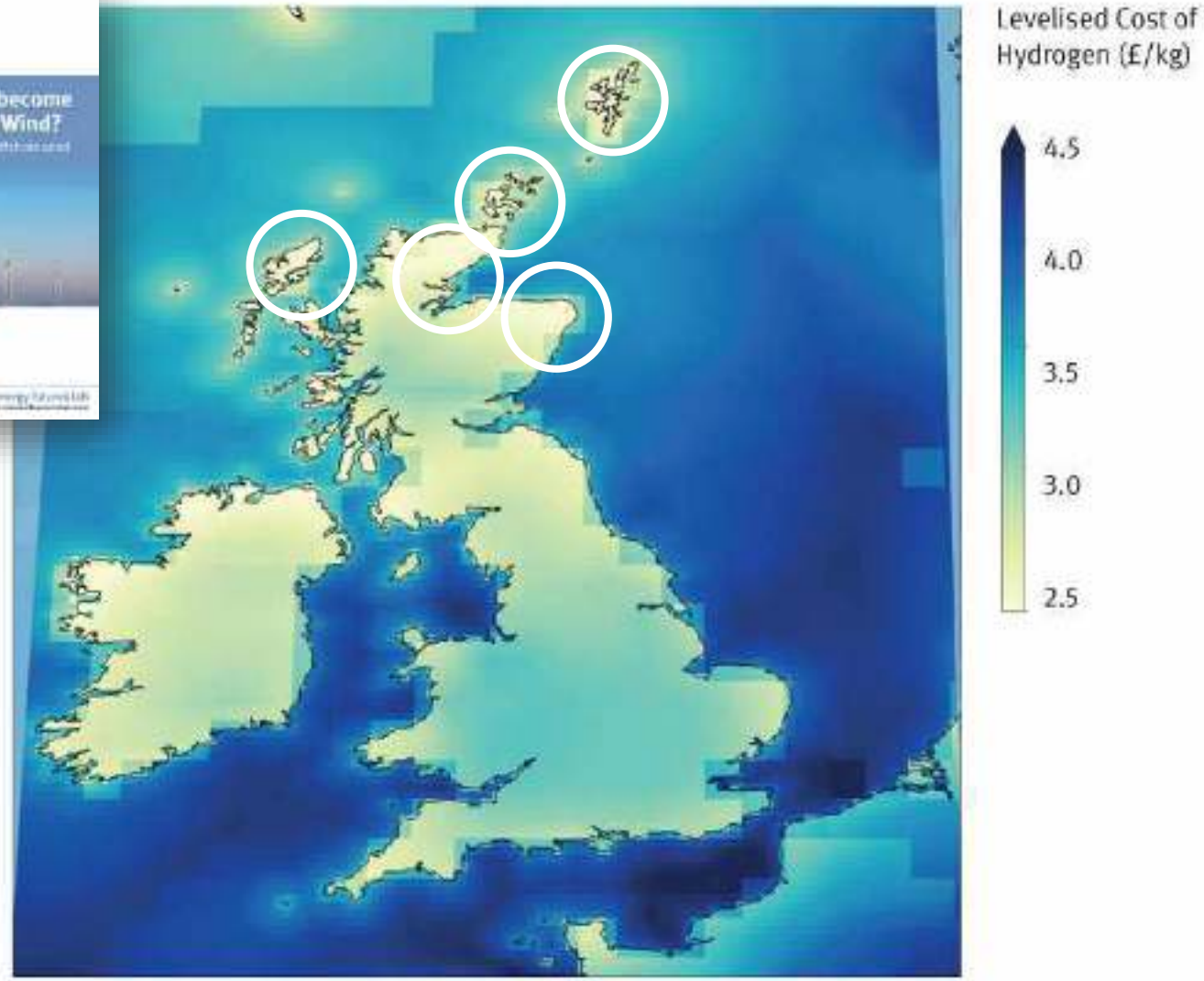
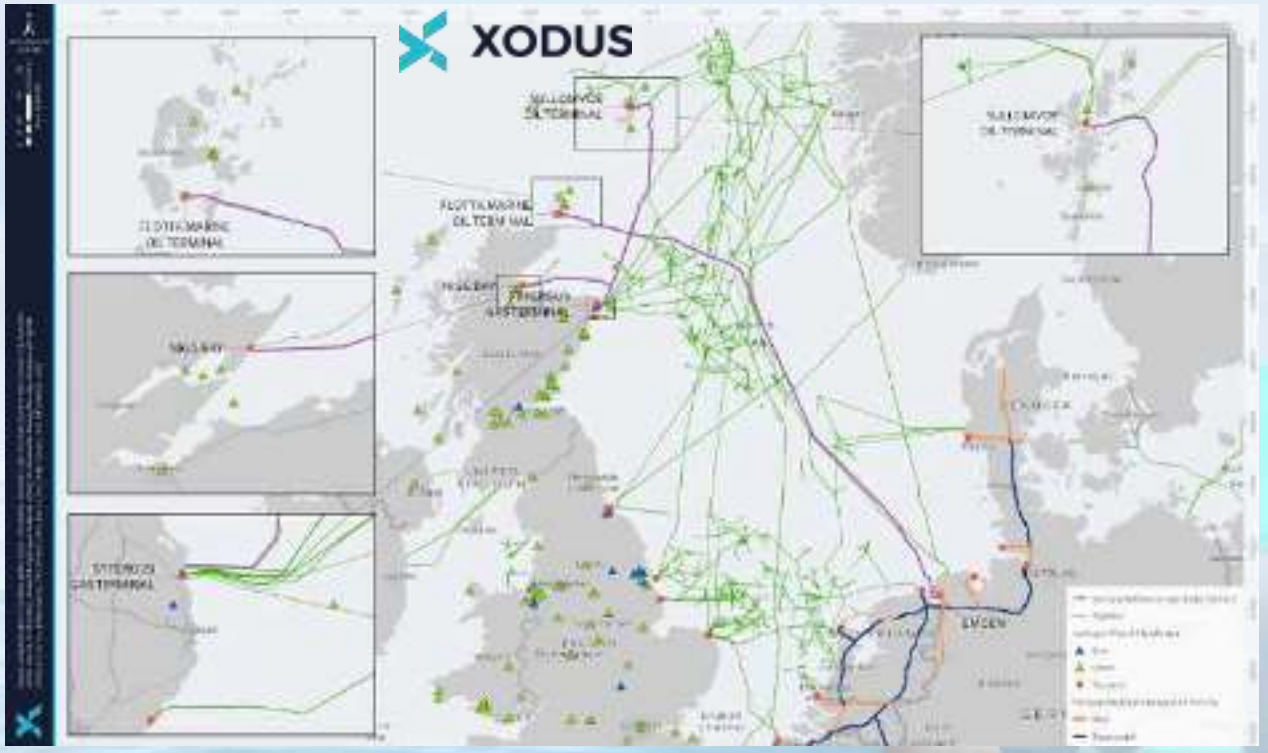
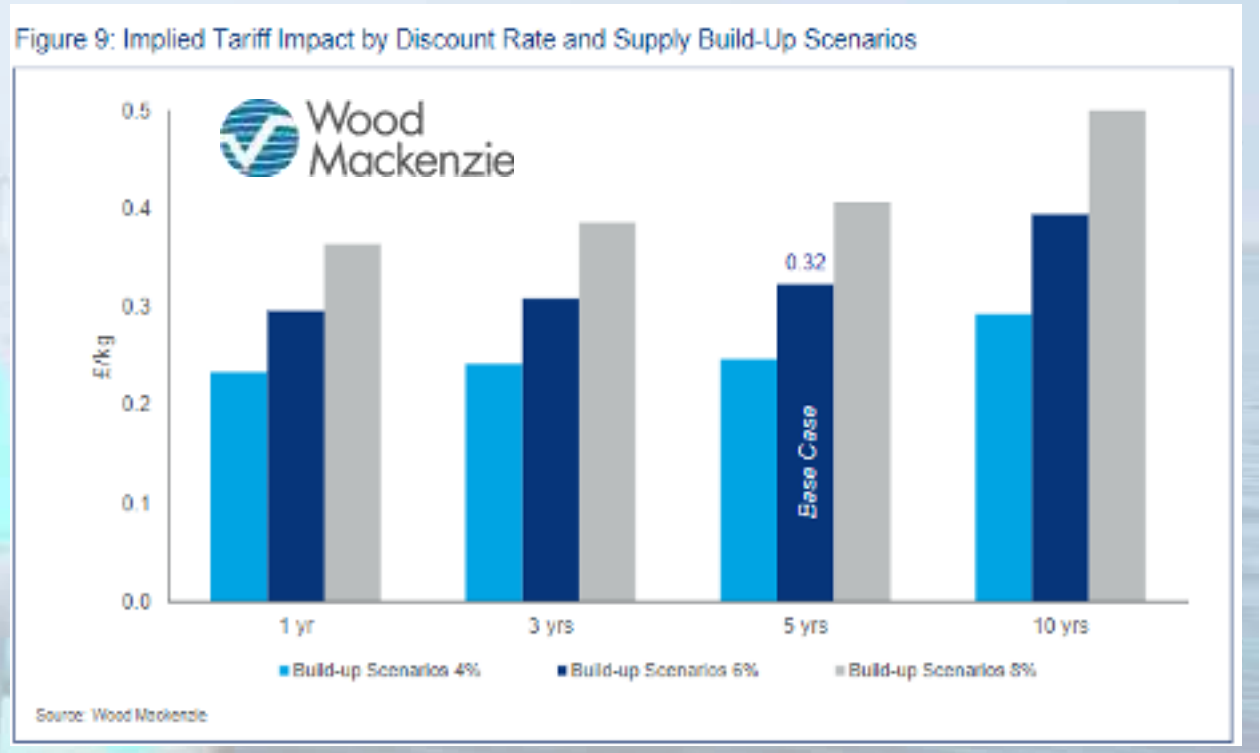


Figure 9 Heatmap showing how the levelised cost of hydrogen produced from co-located wind energy varies across the country.

The Offshore Hydrogen Backbone Link Project – Ph 1



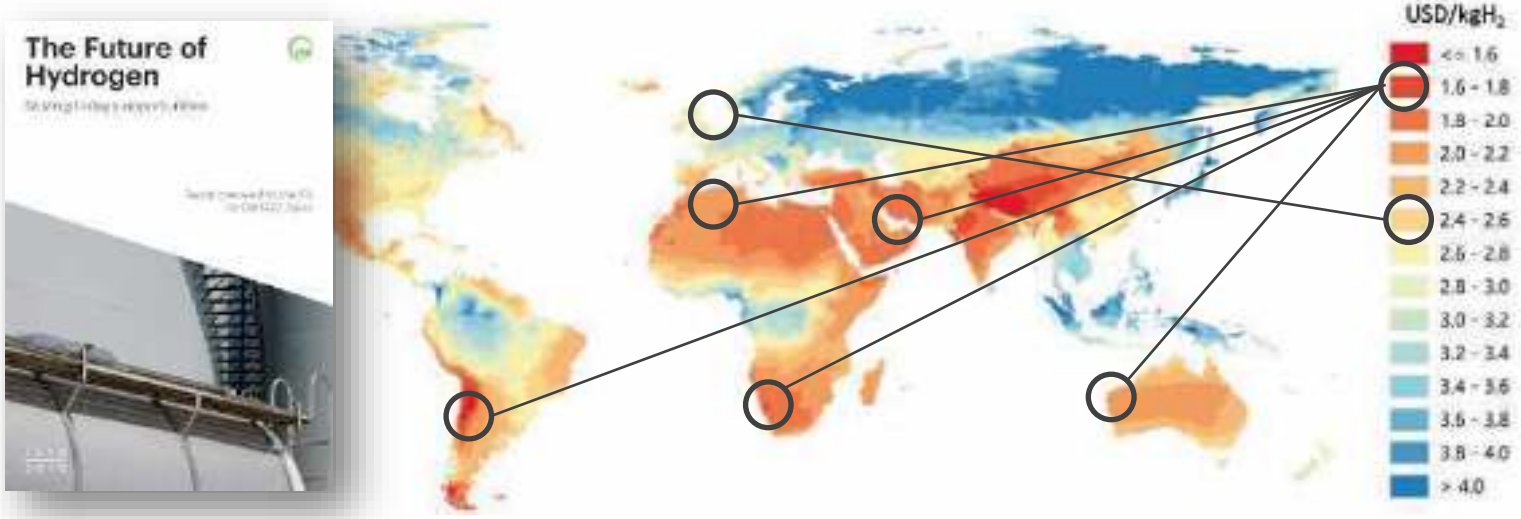


- 2, 5 & 10 GW Design Cases for 100% Hydrogen
- Range from: 1,400 – 1,500 km
- Circa £2.7 bn for 10 GW case
- 90% utilisation
- 6% IRR
- Implied Tariff €0.36/kg
- Sensitivities with pipeline size & build up scenarios

Scottish Government Riaghaltas na h-Alba gov.scot | kellas MIDSTREAM | Shell | eQ enQuest | Shetland Islands Council | Crown Estate Scotland | Wood Mackenzie | XODUS | wood. | Worley | DNV·GL | SGN | nationalgrid

Business Case

Figure 14. Hydrogen costs from hybrid solar PV and onshore wind systems in the long term



	Scotland	M. East, N, Africa, Chile…
H2 Production	€2.6/kg	€1.7/kg
H2 Transport	€0.4/kg	€1.4/kg
H2 to EU Customer	€3.0/kg	€3.1/kg
Security of Supply	+	-
Shared Ownership	+	-
Supply Chain Jobs & Revenue	+	-

€1.4-2.4/kg

€0.4/kg

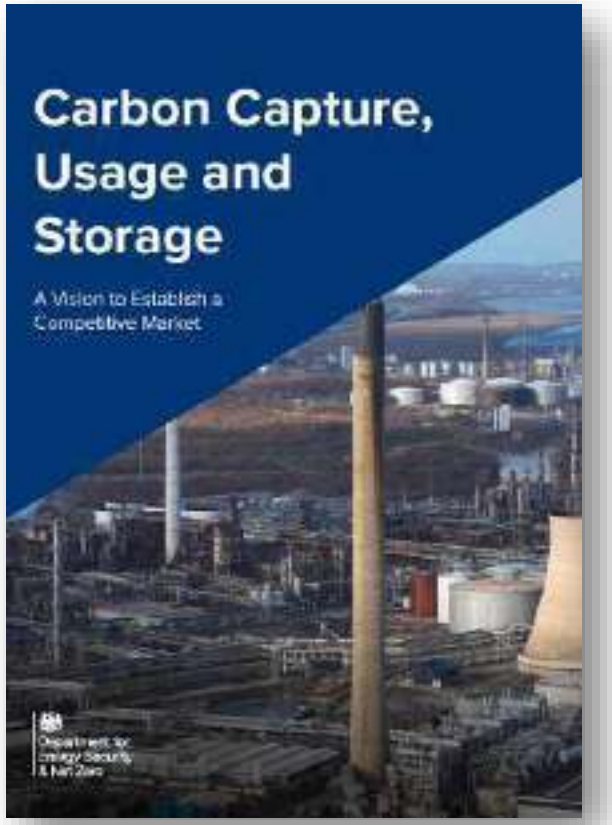


Figure 8: Distribution of Storage Capacity in the UK Continental Shelf

CO_2 Point Sources (Top 50)
Saline aquifer (confined)
Saline aquifer (open)
Depleted hydrocarbon fields

Size MT
10
100
1,000

Norther orth Sea
14

Central N Sea
40Gt

East Irish Sea
6Gt

Sou

English Channel
1Gt

0 50 100 200 300km

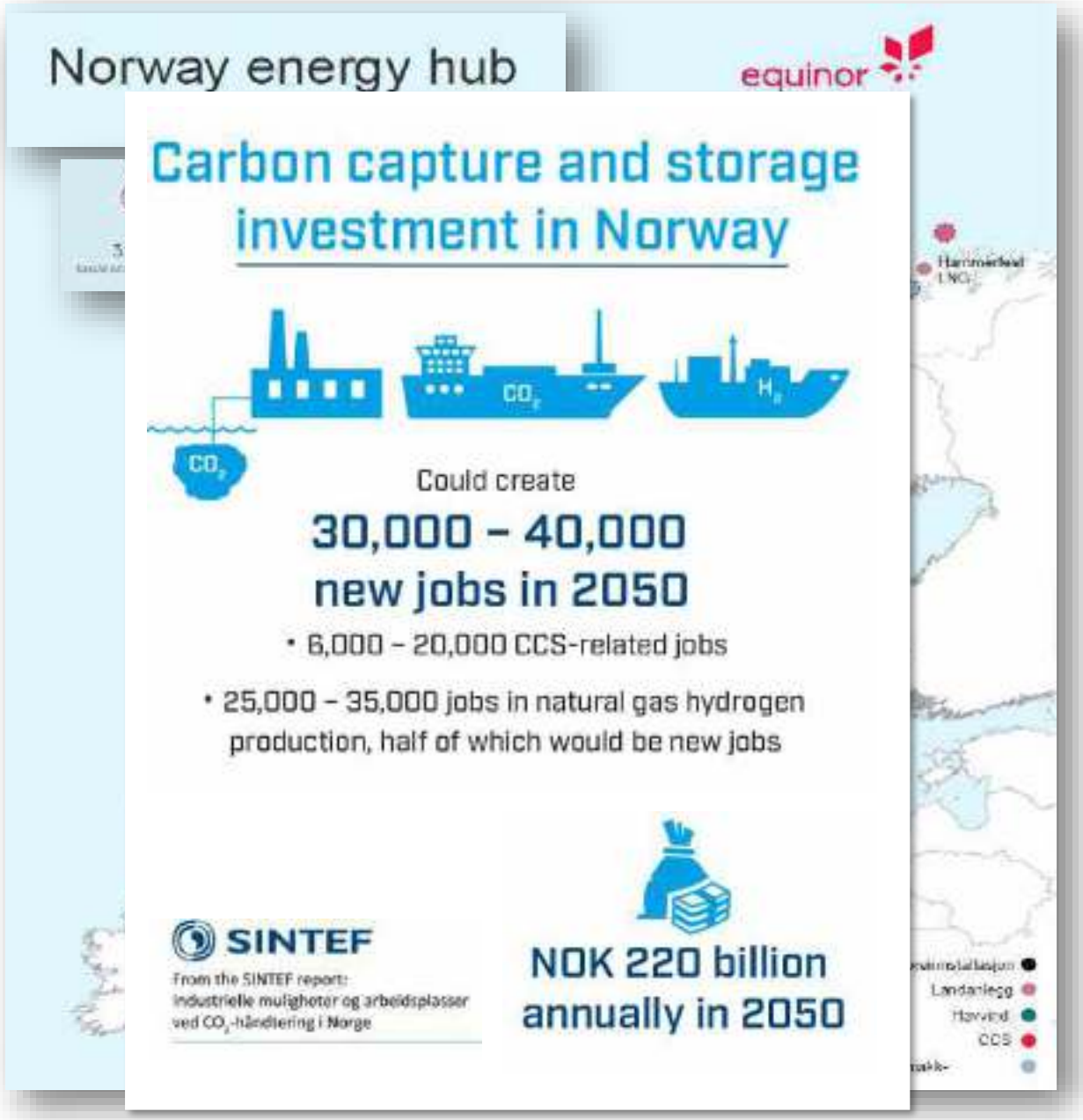
A
B
C

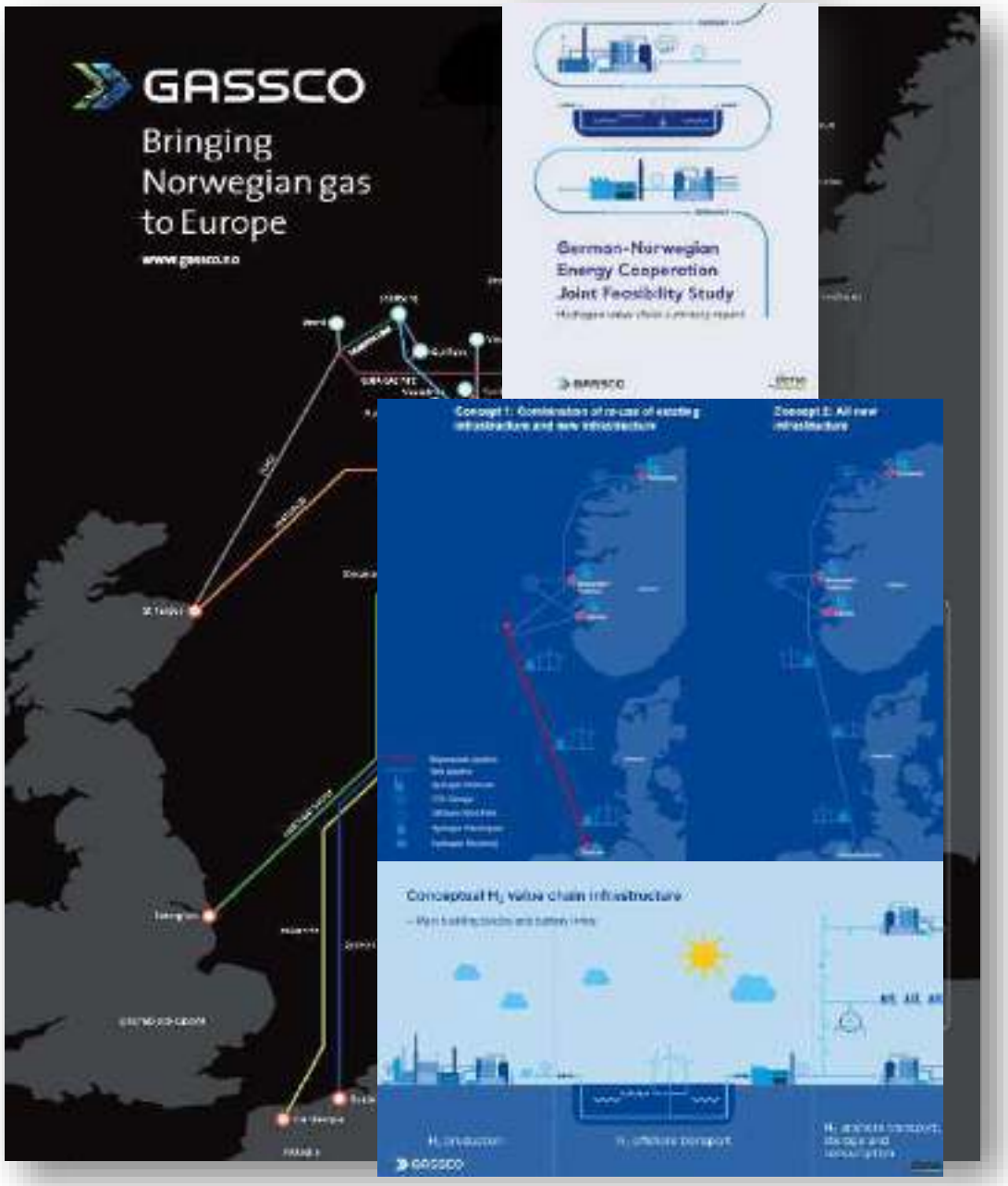
Storage units with less than 20 Mt of storage capacity are not included in this figu

54MT (71%)

76MT

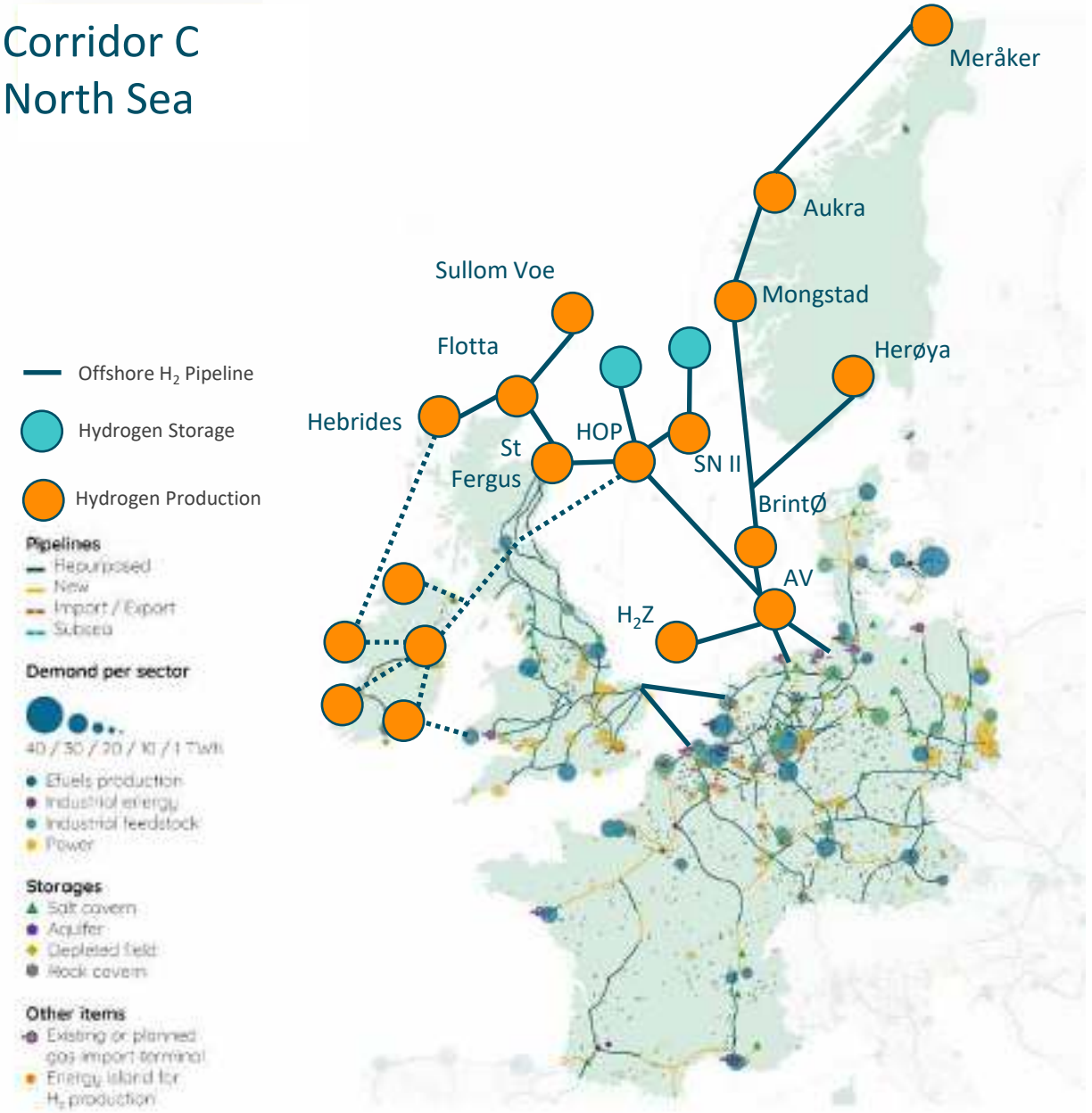
Norway


Norway energy hub
equinor
Carbon capture and storage investment in Norway
Could create
30,000 – 40,000 new jobs in 2050
• 6,000 – 20,000 CCS-related jobs
• 25,000 – 35,000 jobs in natural gas hydrogen production, half of which would be new jobs
NOK 220 billion annually in 2050
SINTEF
From the SINTEF report:
Industrielle muligheter og arbeidsplasser ved CO2-håndtering i Norge
Landanlegg
Havvind
CCS


GASSCO
Bringing Norwegian gas to Europe
www.gassco.no
German-Norwegian Energy Cooperation Joint Feasibility Study

Working together

Corridor C
North Sea



Offshore Hydrogen Backbone Link Phase 2 (2023-25)

Scottish Government
Riaghaltas na h-Alba
gov.scot

eQ EnQuest

kellas

Port of Rotterdam

FORTESCUE FUTURE INDUSTRIES

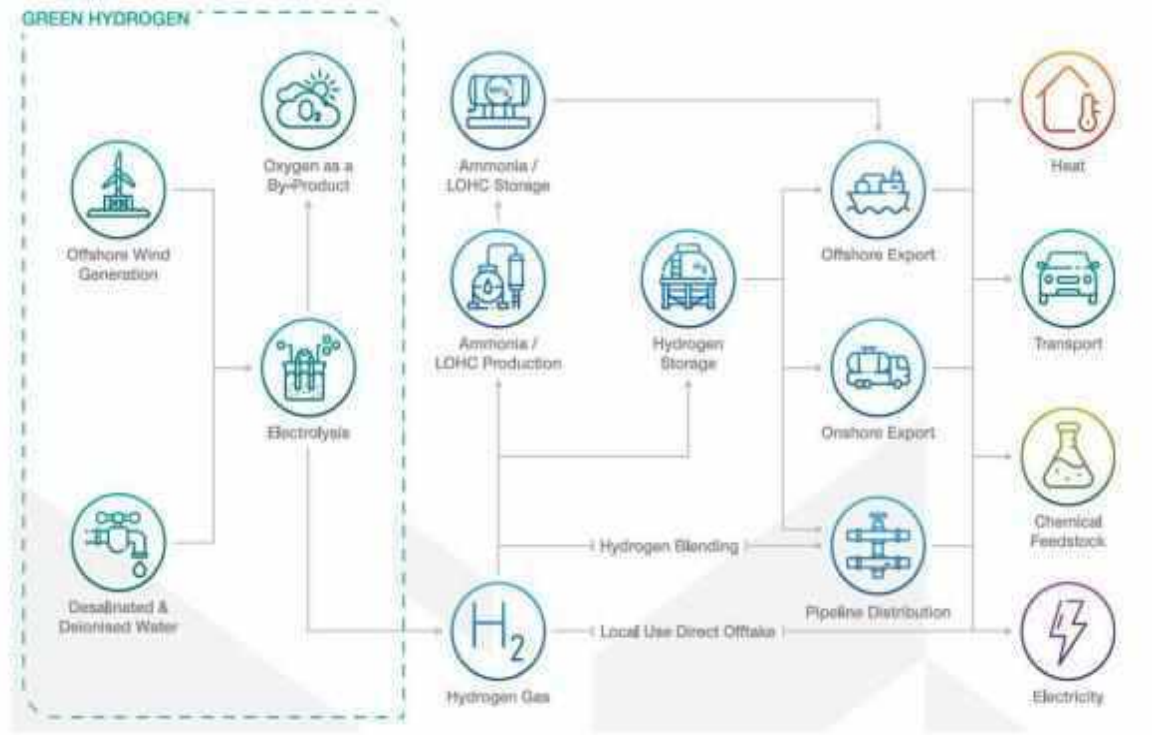
STOREGGA

ESB Energy for generations

Net Zero Technology Centre
Technology Driving Transition

Scotland Hydrogen Action Plan

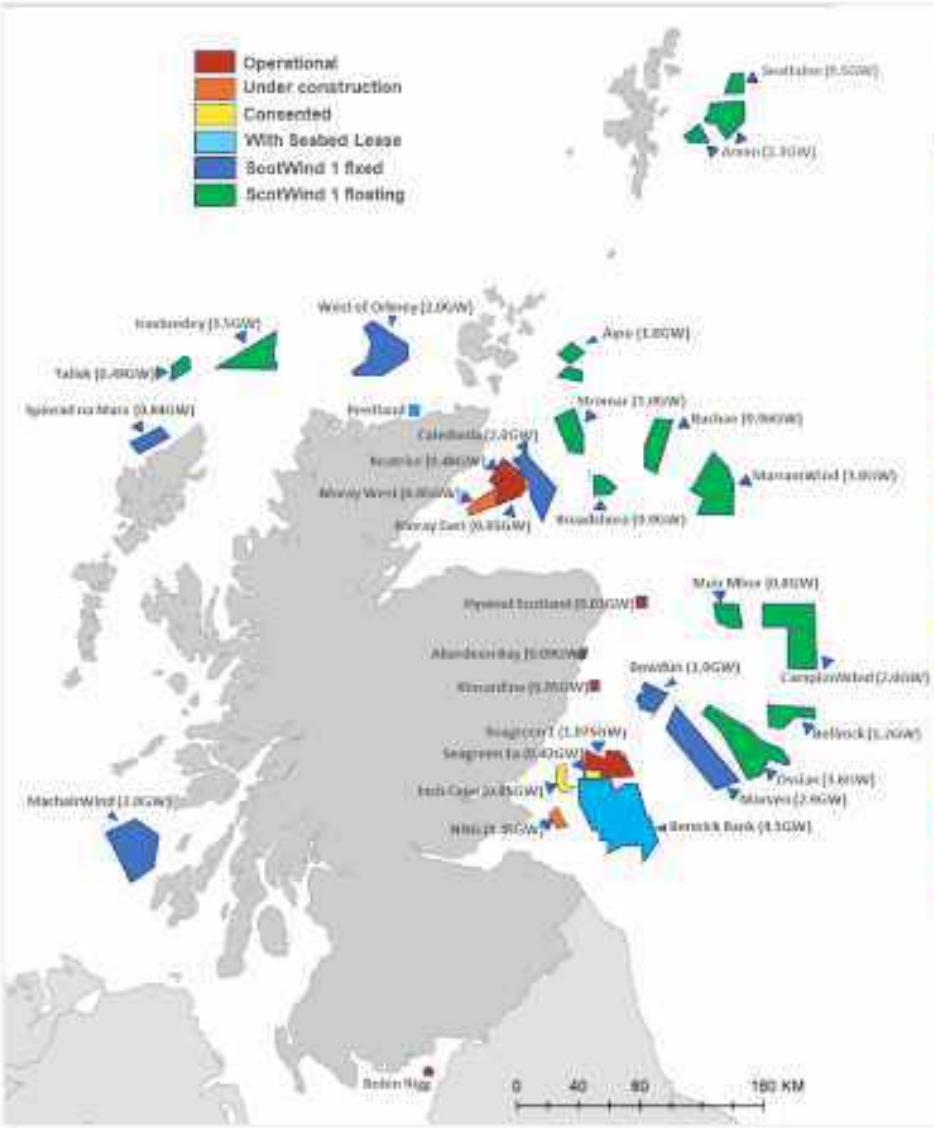
"Ambition is for Scotland to become a leading producer and exporter of hydrogen and hydrogen derivatives for use in the UK and in Europe, with the first hydrogen delivered from Scotland to mainland Europe in the mid-2020s"



"Ambition for at least 5GW of renewable and low carbon hydrogen production capacity by 2030 and 25GWby 2045"

Data source: Scottish Government

ScotWind Energy Source



ScotWind Round

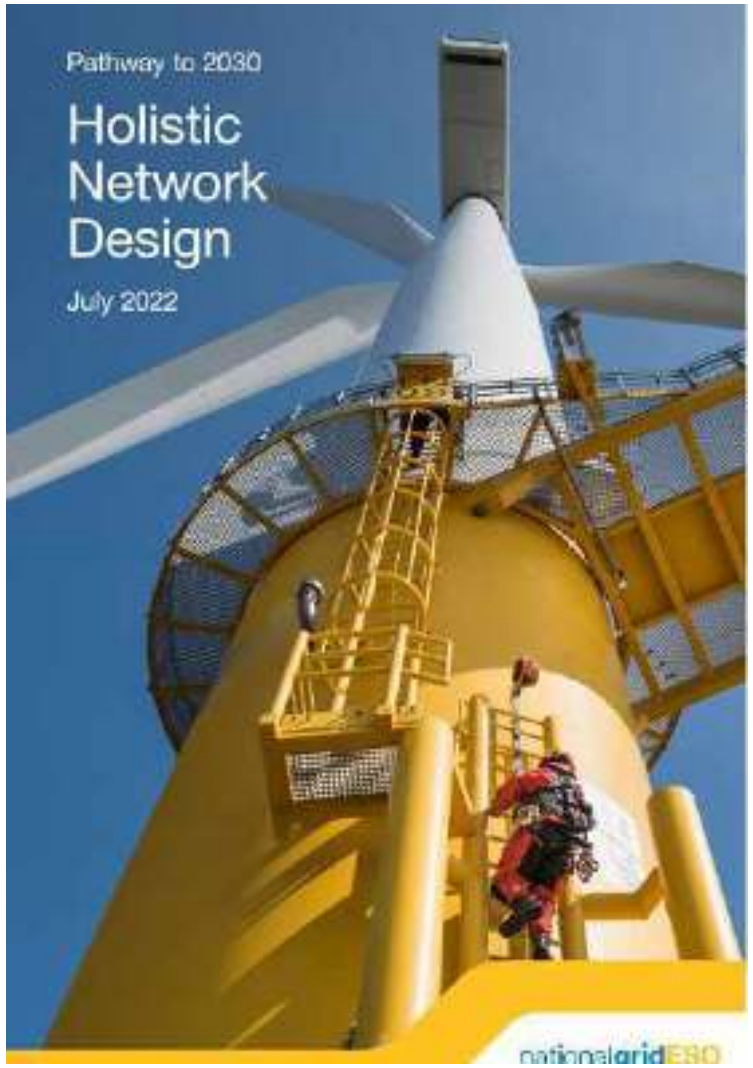
SITE	DEVELOPERS	CAPACITY
Morven	BP and EnBW	2,907MW
Ossian	SSE Renewables, CIP and Marubeni	3,610MW
Bellrock	BlueFloat Energy¦ Renantis Partnership	1,200MW
CampionWind	ScottishPower Renewables and Shell	2,000MW
Muir Mhor	Vattenfall and Fred Olsen Renewables	798MW
Bowdun	Thistle Wind Partners	1,008MW
Ayre	Thistle Wind Partners	1,008MW
Stromar	Orsted and BlueFloat Energy¦ Renantis Partnership	1,000MW
Caledonia	Ocean Winds	2,000MW
Broadshore	BlueFloat Energy¦ Renantis Partnership	900MW
MarramWind	ScottishPower Renewables and Shell	3,000MW
Buchan	Floating Energy Allyance	960MW
West of Orkney	RIDG, Corio Generation and TotalEnergies	2,000MW
Havbredey	Northland Power	1,500MW
Talisk	Magnora Offshore Wind	495MW
Spiorad an Mara	Northland Power	840MW
MachairWind	ScottishPower Renewables	2,000MW
Arwen 1a	Mainstream RP and Ocean Winds	500MW
Arwen	Mainstream RP and Ocean Winds	1,800MW
Sealtainn	ESB Asset Management	500MW

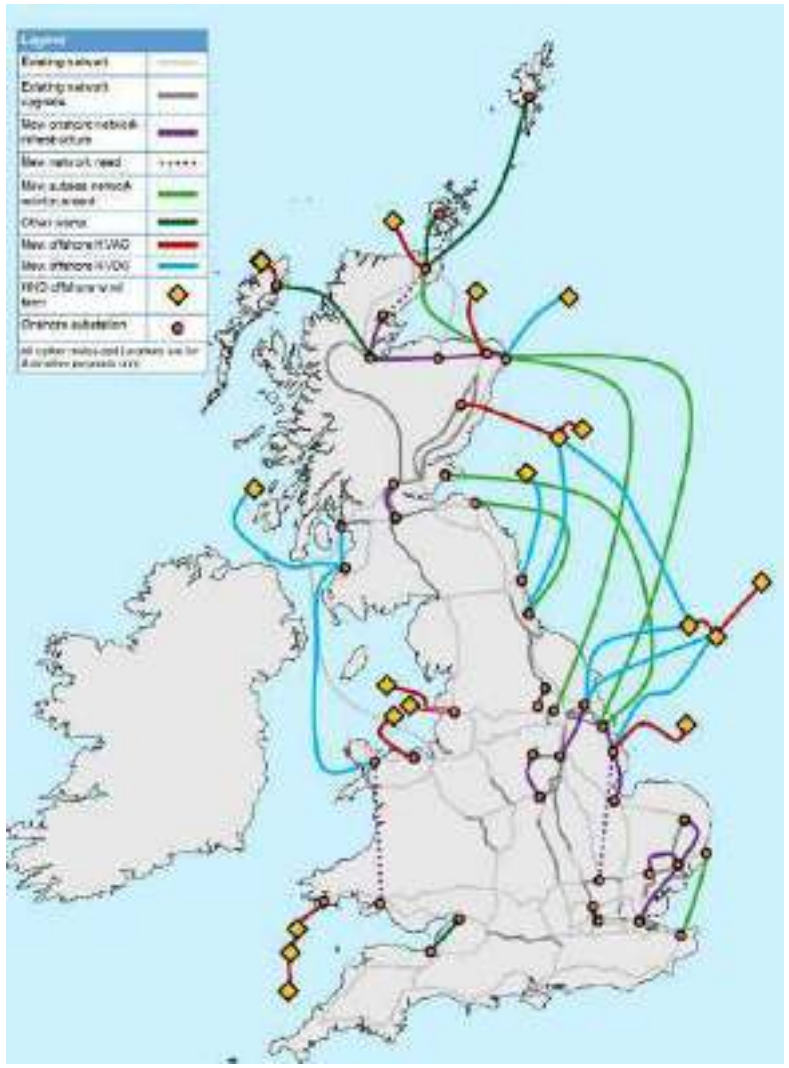
Stoura

Total = 30,026MW
Floating Wind = 19,271MW (64%)

Data source: Crown Estate Scotland

Holistic Network Design (HND)





- HND looks to connect 50GW of offshore wind, including 23GW of new projects, in UK by 2030 which includes 11 GW currently 'in scope' ScotWind licences
- Significant additional wind potential exists for Scottish green hydrogen production

Data source: National Grid ESO

Regional Hydrogen Energy Hubs

1. Aberdeen
2. Argyll & Islands
3. Ayrshire
4. Cromarty
5. Dumfries & Galloway
6. Dundee
7. Fife
8. Glasgow
9. Grangemouth
10. Orkney
11. Scottish Borders
12. Shetland
13. Western Isles

A **Regional Hydrogen Energy Hub** is a geographic location (region, city, island, industrial cluster) that is host to the entire hydrogen value chain, from production, storage and distribution to end-use. Regional Hydrogen Hubs will include multiple end-users with applications ideally covering more than one sector.

Hydrogen Energy Super Hub

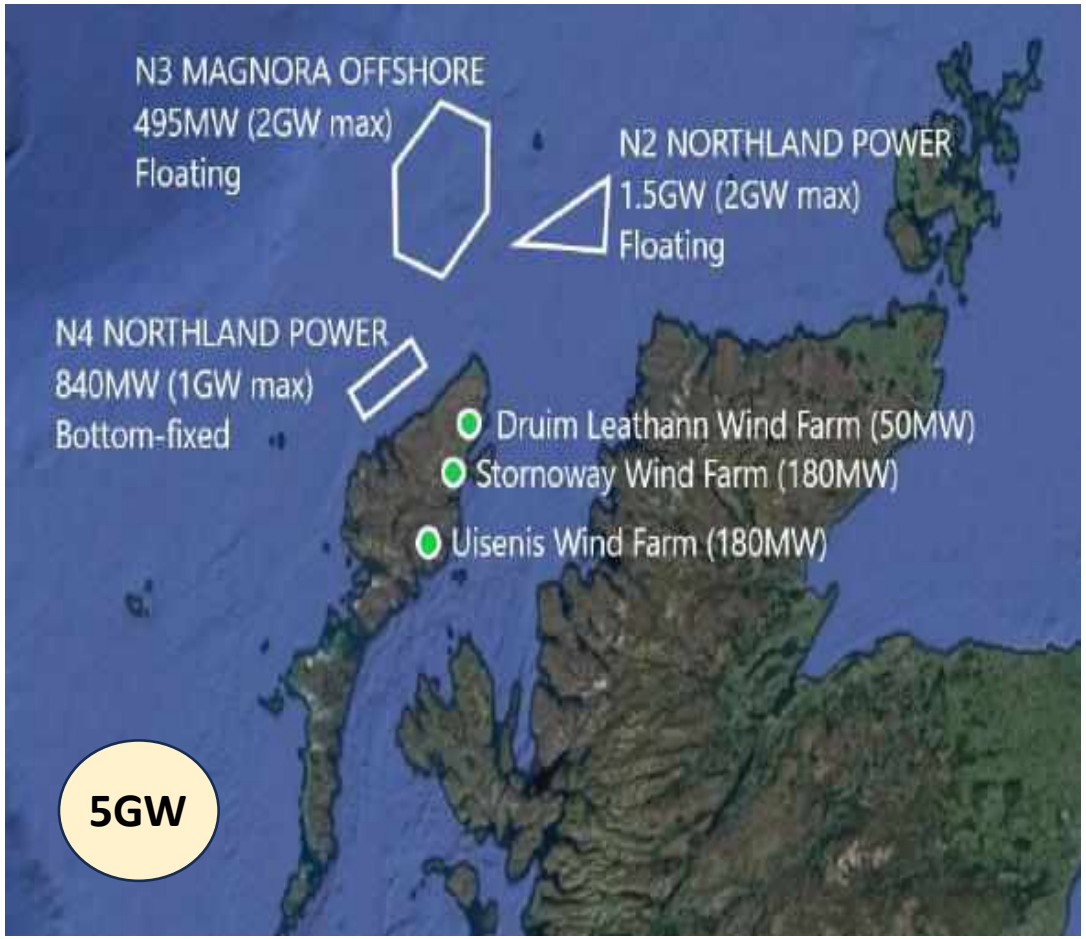
Orkney

Shetland

Outer Hebrides

Data source: Scottish Government

Outer Hebrides Ambitions



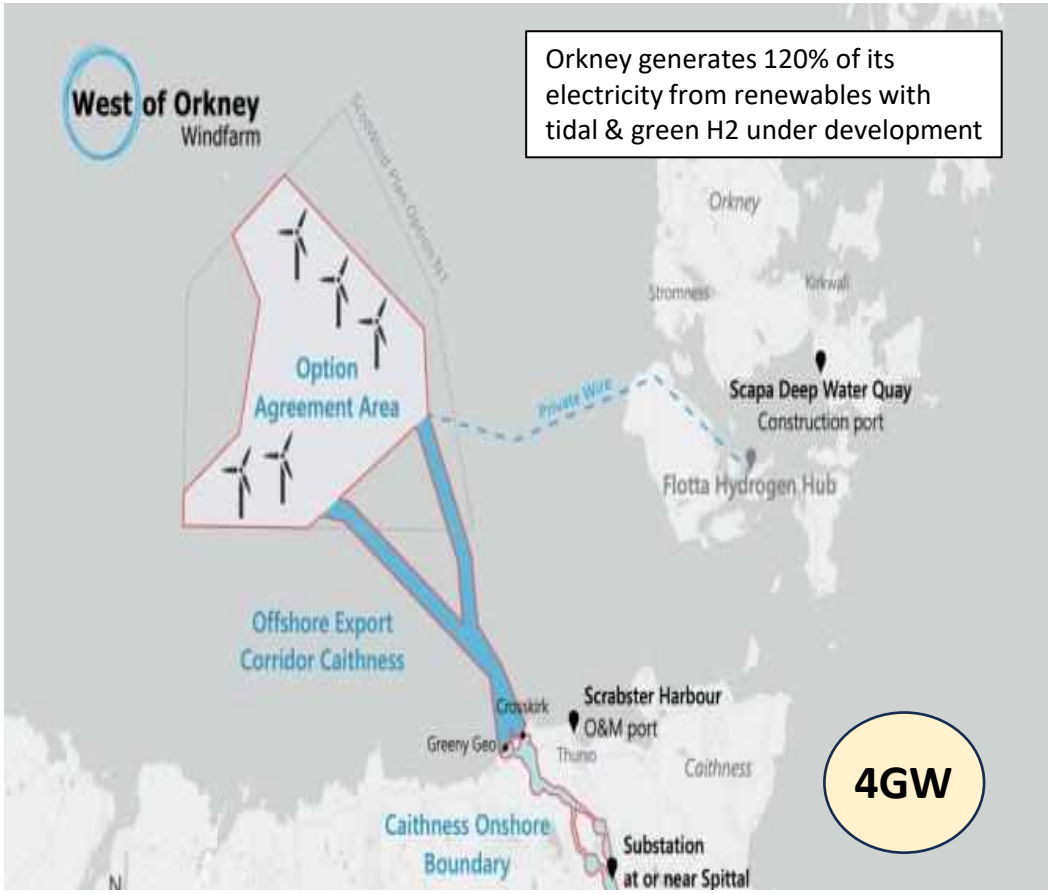
Wind Potential

Data Source: Pan-Island workshop

Arnish Port Development

Data Source: Stornoway Port Website

Orkney Ambitions



Renewable Energy Potential

Data Source: West of Orkney windfarm & OREF websites

Flotta Hydrogen Hub

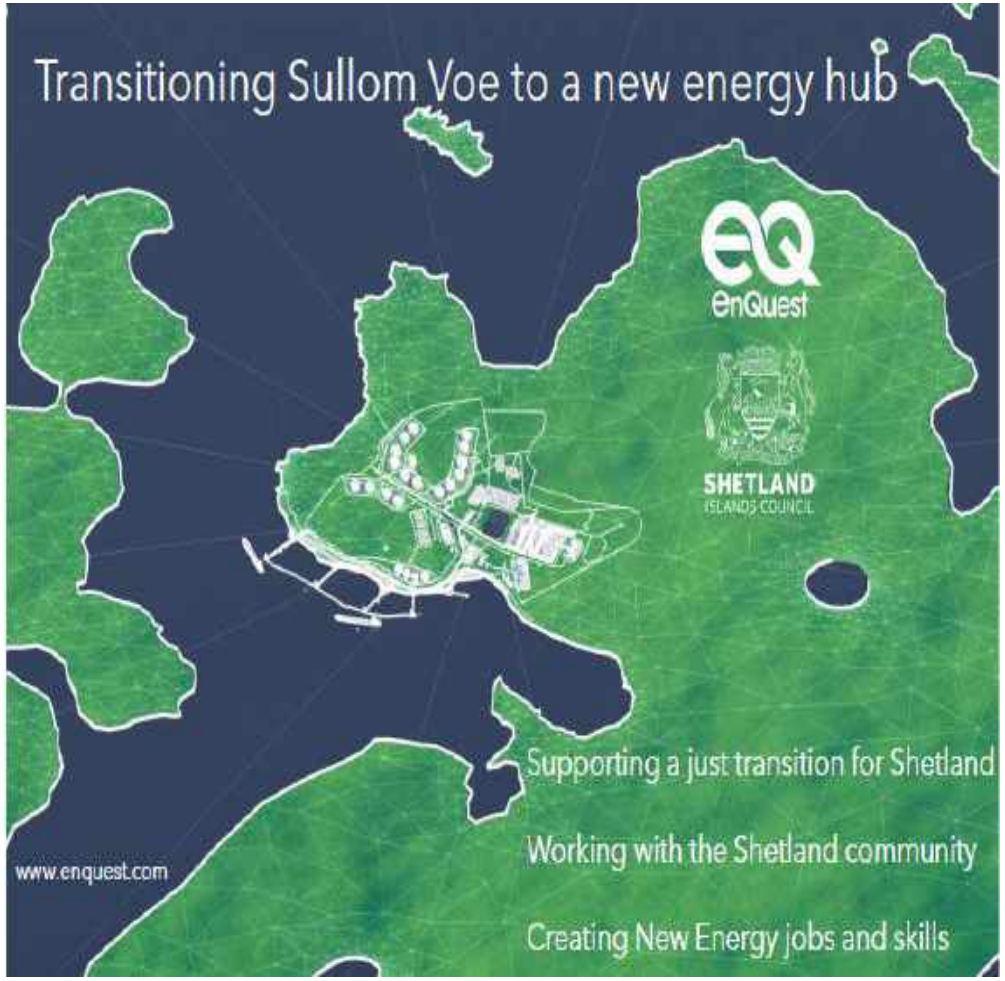
Data Source: Flotta H2 Hub website

Shetland Ambitions

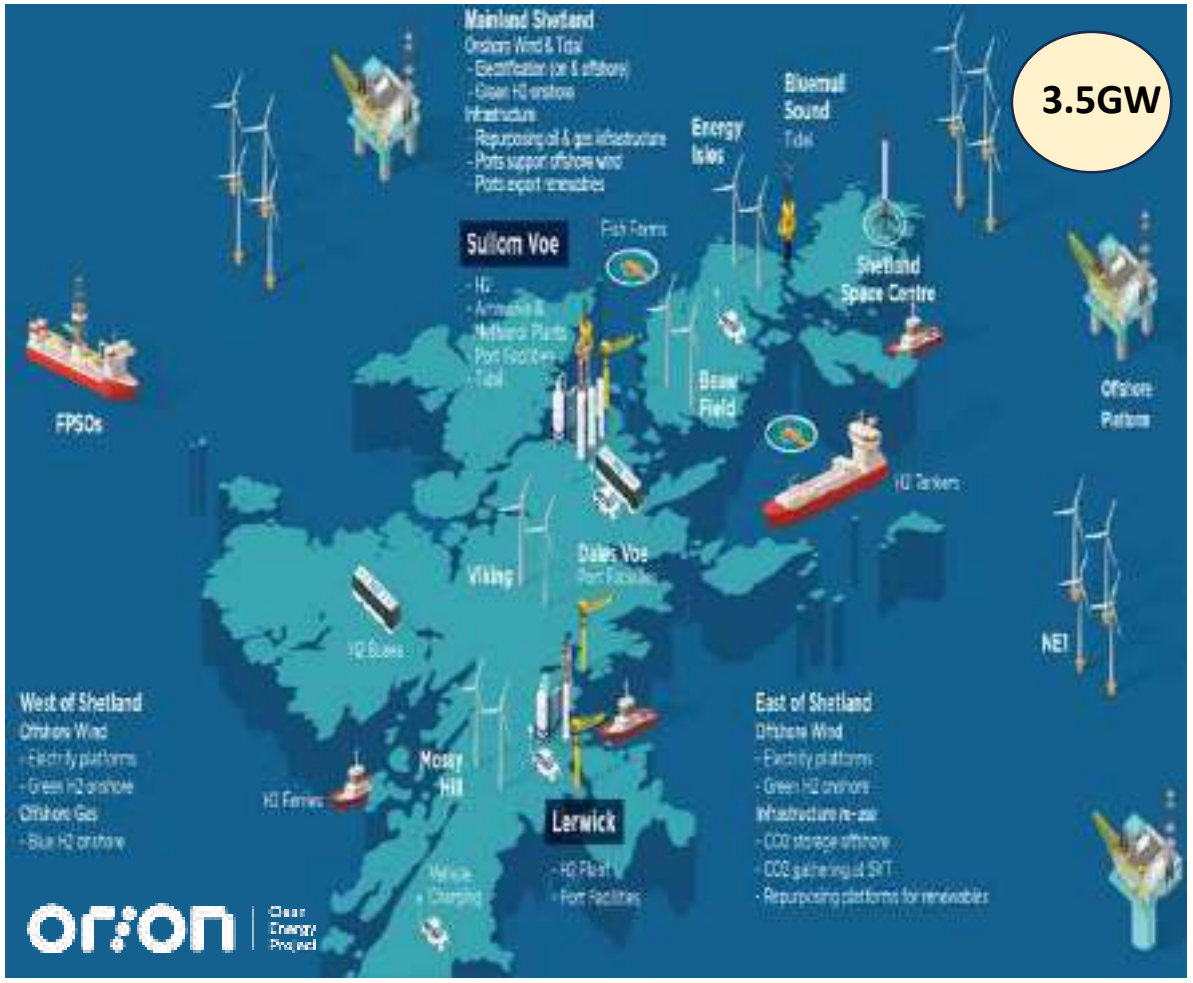
Four carbon storage licences in the northern North Sea

Green hydrogen production

Sustainable power to support offshore electrification



Sullom Voe Transformation

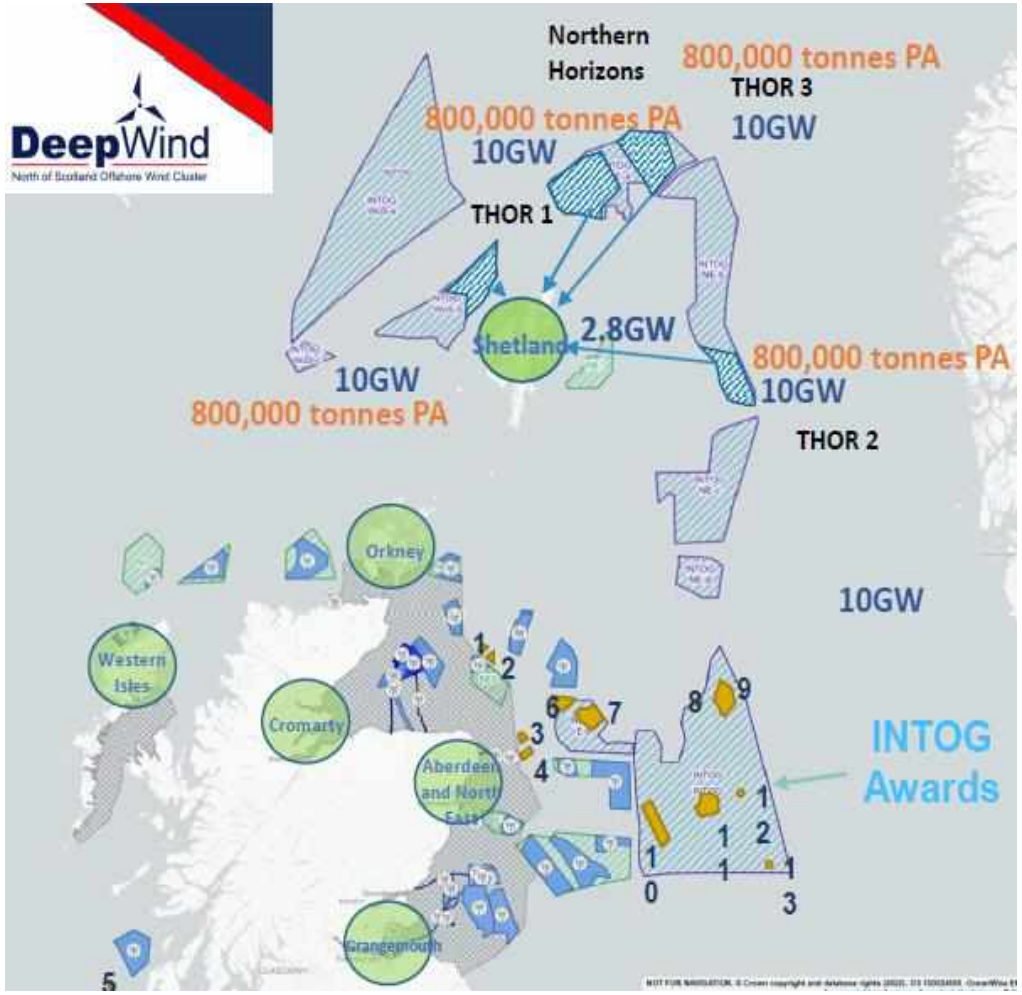


ORION Project

Data source: SHFCA Conference October 2023

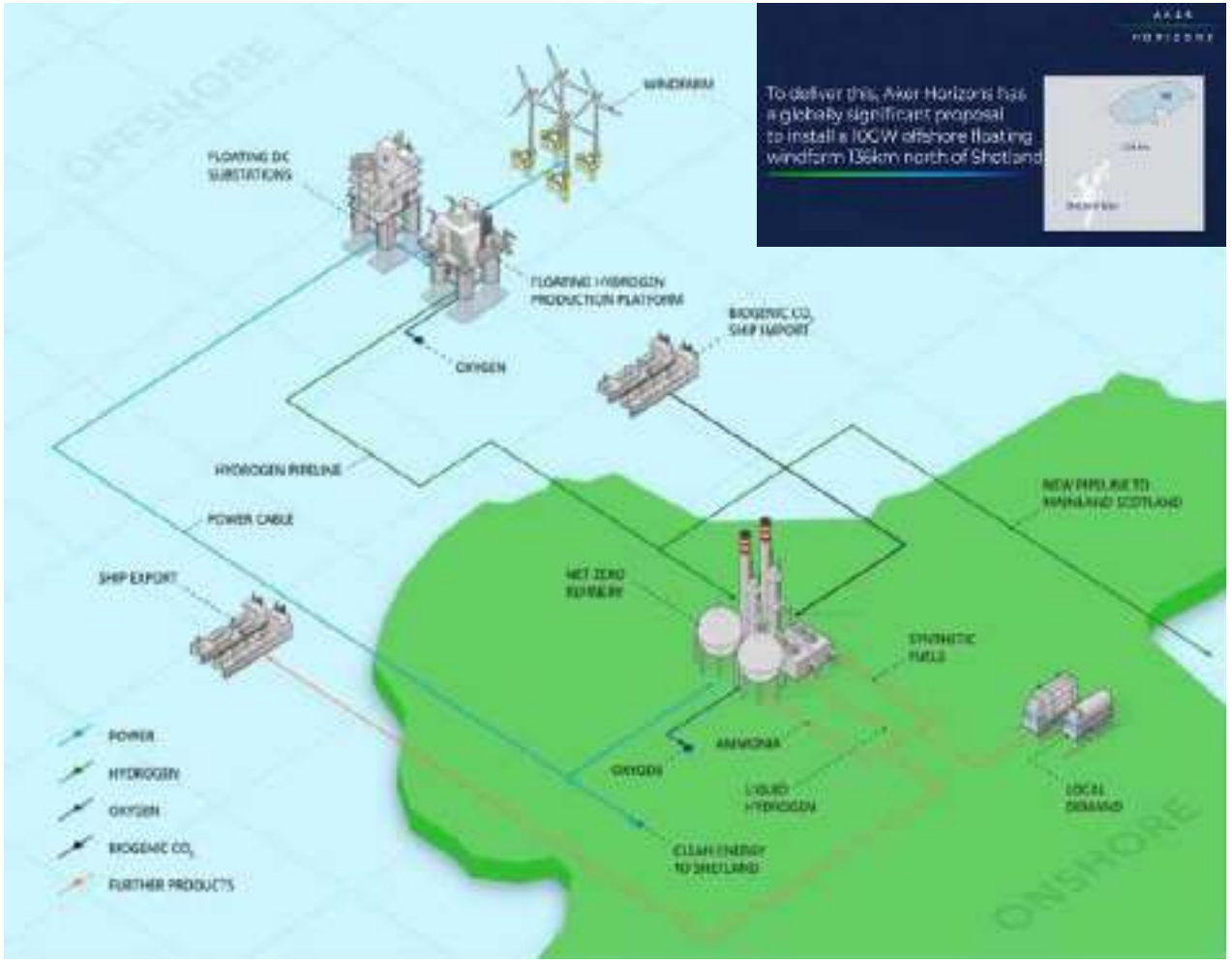
Data source: ORION Project

Additional Wind Resource



40GW + additional wind potential

Data source: Deepwind



Upside potential recognized by industry

Data source: Aker Horizon presentation COP 26

Pan Island Cooperation

- Outer Hebrides, Orkney & Shetland working together on Low Carbon Future through ICNZ
- Pan Island potential to become a hydrogen energy super hub being discussed
- Potential next step undertake study to outline resource potential, community benefit & technical and economic synergies

Data source: ICNZ website

Data source: Pan-Island Workshop October 2023