Hydrogen Tech World
Expo & Conference | Essen | 4–5 April 2023

Floating Wind, Hydrogen and Green Steel: Entwined Technologies Propelling a Low-Carbon Future.

Dr Jamie Frew

Traditional steel is under pressure

The Mirror has been campaigning to Save Our Steel since 2015

NEWS | POLITICS | FOOTBALL | CELEBS | TV | MONEY | ROYALS

EXCLUSIVE: Steel firm cutting 440 jobs warns 'revolution' needed to save industry on 'life support'

Jeremy Hunt considers taxpayer rescue of British Steel blast furnaces

Cabinet members lobby chancellor to offer £300mn to save the group's Scunthorpe site

Britain's steelmakers have faced soaring energy prices and rising inflation as well as softening demand because of the economic downturn © Lindsey Parnaby/AFP/Getty Images

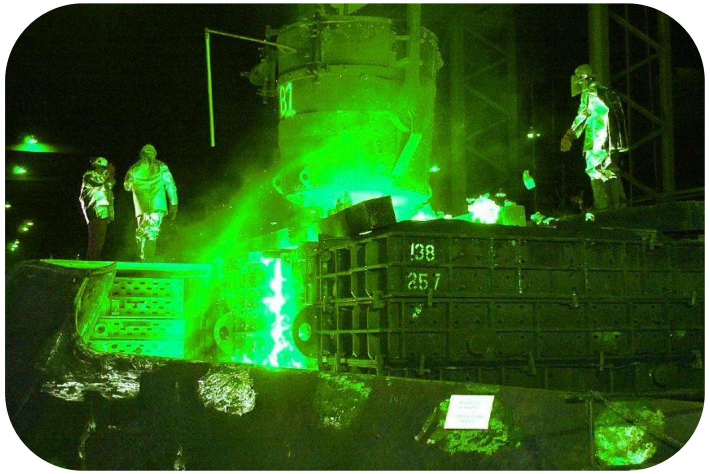
Steel makers fear deepening crisis from energy crunch as output halted

By Philip Blenkinsop

Green steel to the rescue?

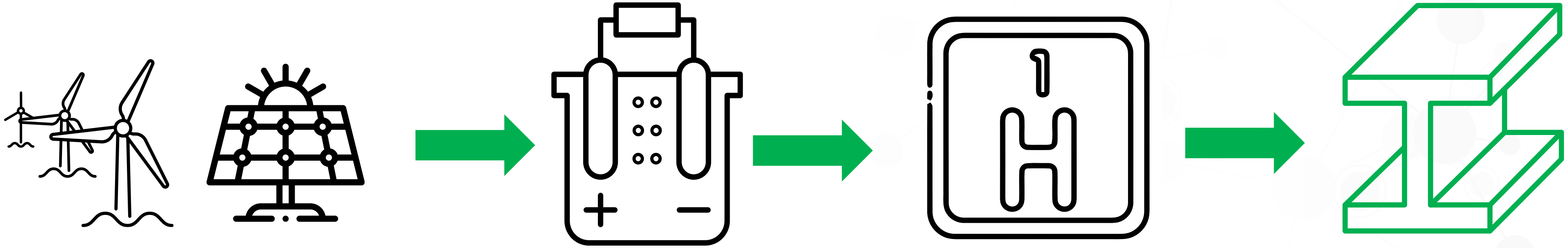
Benefits

- Low emissions
- Value added product
- Future viability of EU steel industry



Challenges

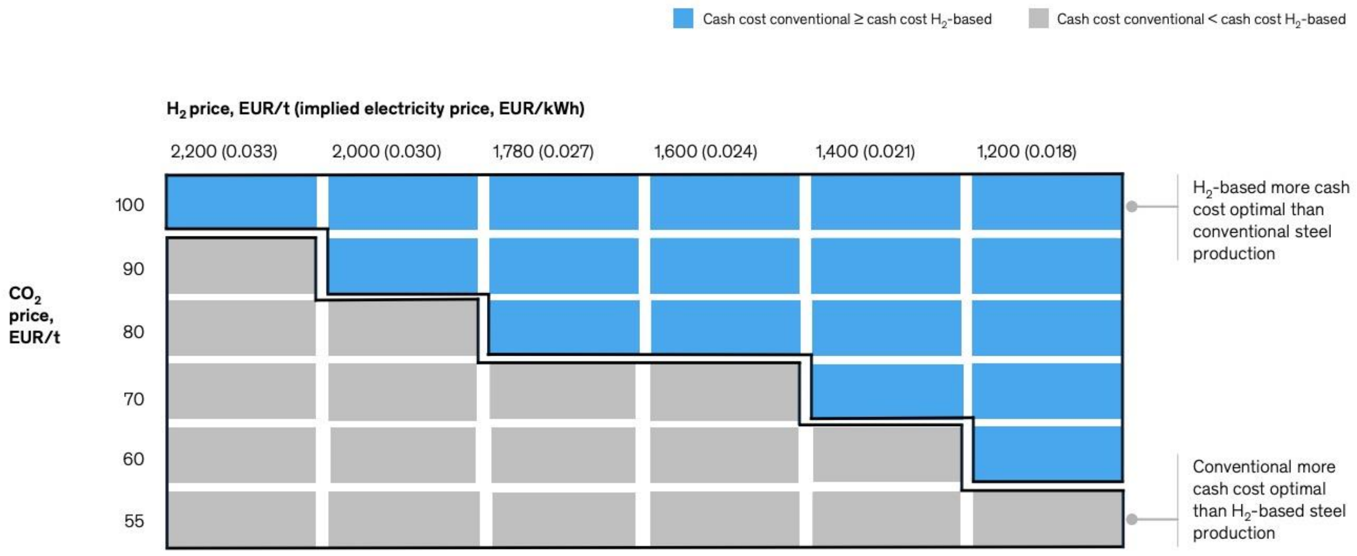
- Unproven economics
- New technology across value chain
- Huge energy demand



Variable power

Continuous process

CO2 prices are now at the level where green steel starts to make economic sense in low power price environments



SOURCE: McKinsey hydrogen-based steel model

Electrolyser CAPEX (required GW) is highly dependent on capacity factor of renewable energy supply.
~180 GW of electrolyser capacity required for EU alone @ 60%!

	Unit	Base Load (not realistic)	Solar-only	Offshore wind	Combined Solar-Wind	EU – ALL BOF
Steel output	Mtn Fe	4	4	4	4	86
Hydrogen demand	Mtn H2	0.24	0.24	0.24	0.24	5.16
H2 Capacity factor	%	**100%**	**25%**	**60%**	**70%**	60%
Electrolyser CAPEX	€Bn	**1.2**	**4.8**	**2**	**1.71**	**172**

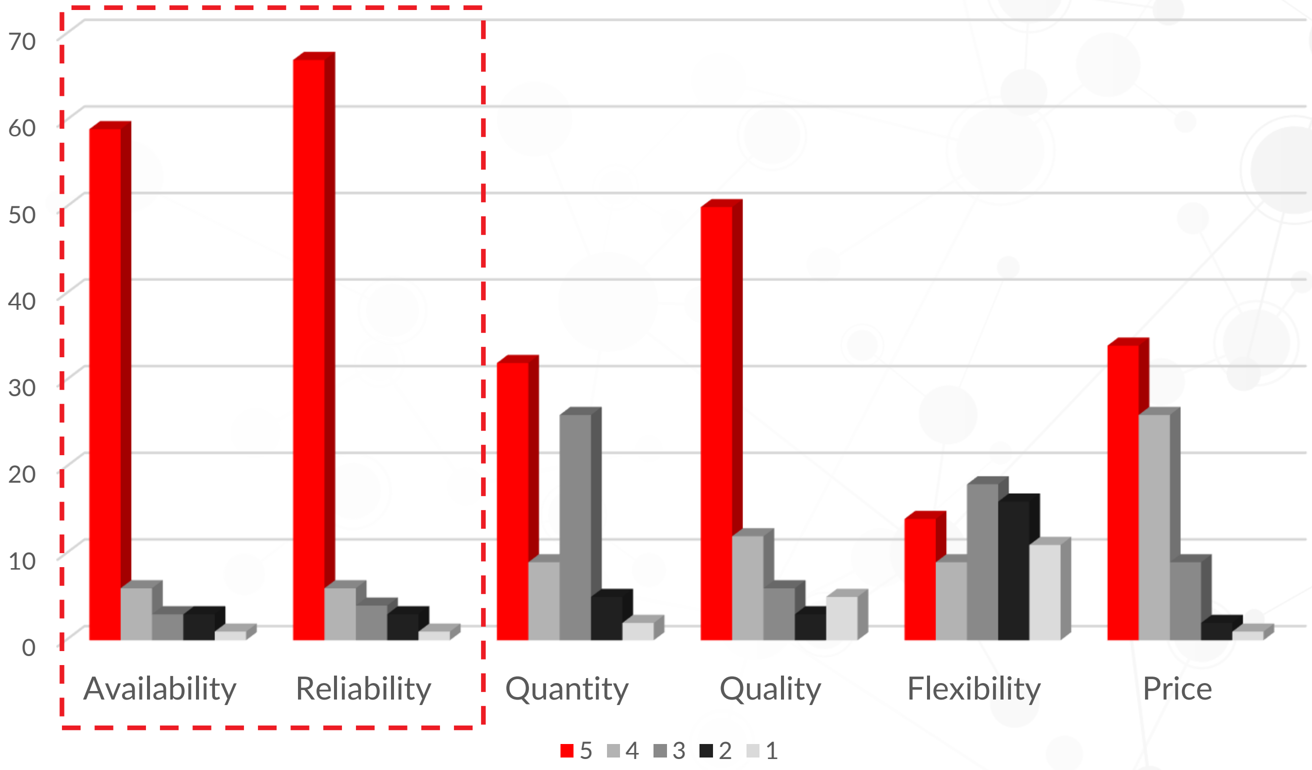
- Solar-only production faces challenges to be economic
- High-Capacity Factor offshore wind is competitive
- ~180 GW of electrolysers to convert all EU ore reduction

Industry needs dependable supplies of hydrogen

Renewable hydrogen supply intermittency is a **huge** problem for green steel

- **Availability and reliability are more important than price alone**

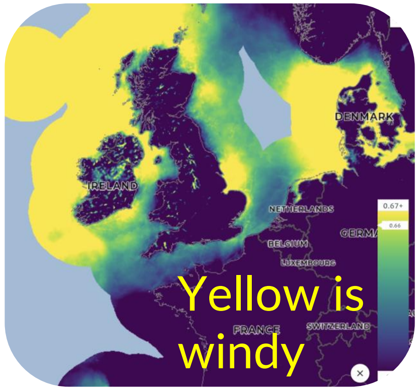
Survey of industrial hydrogen consumers: Decision criteria for purchase (rank 1-5)



Source: Esprit Associates: Global Hydrogen survey 2014

Strategies to ensure supply reliability in a RE system

1. Locate in areas with high capacity factors $

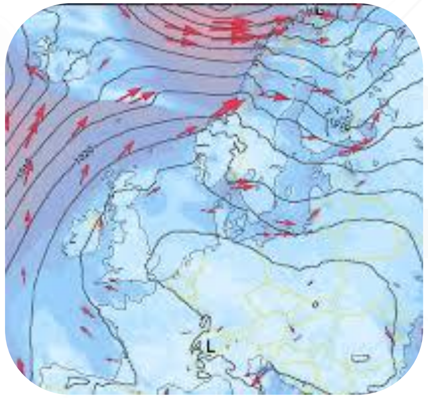


2. Diversify renewable energy sources $



3. Over-build renewable resources $$

4. Diversify geographical sourcing $$

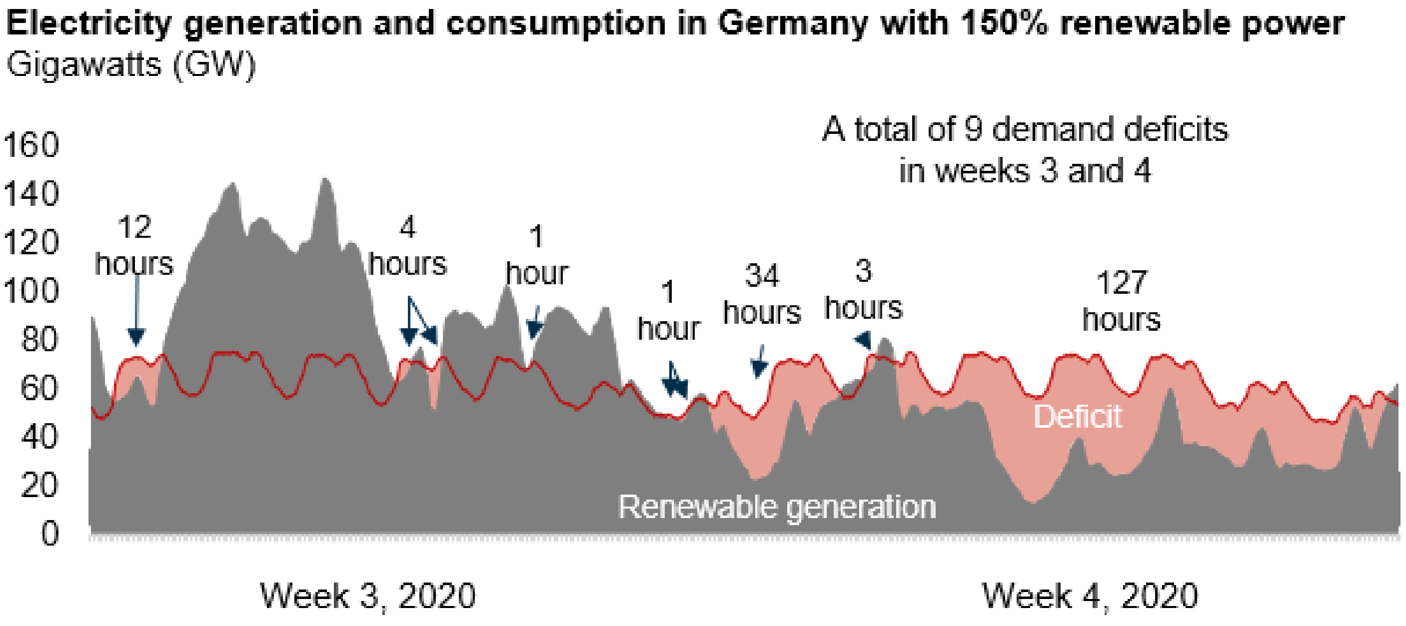


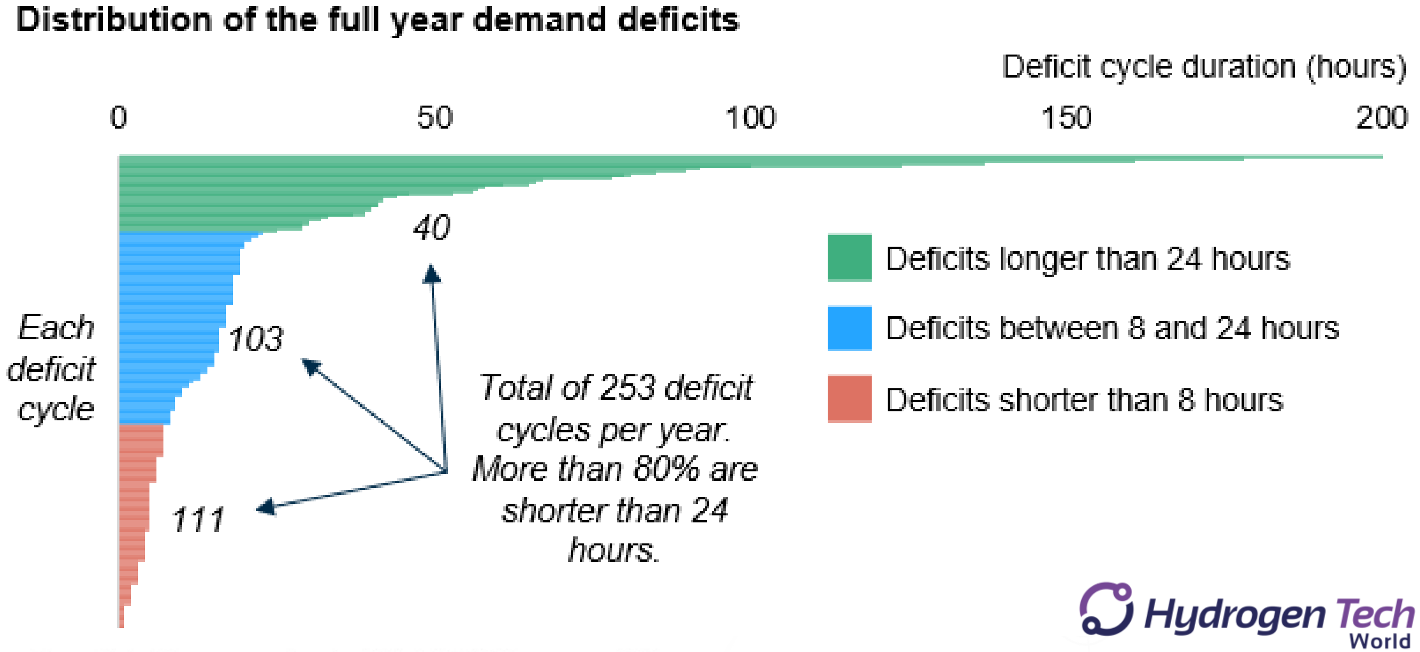
5. Storage $$$

- Upstream storage of electricity
- Downstream storage of hydrogen

Dunkelflaute
(No wind-no sun)
the nightmare of renewable energy system designers!

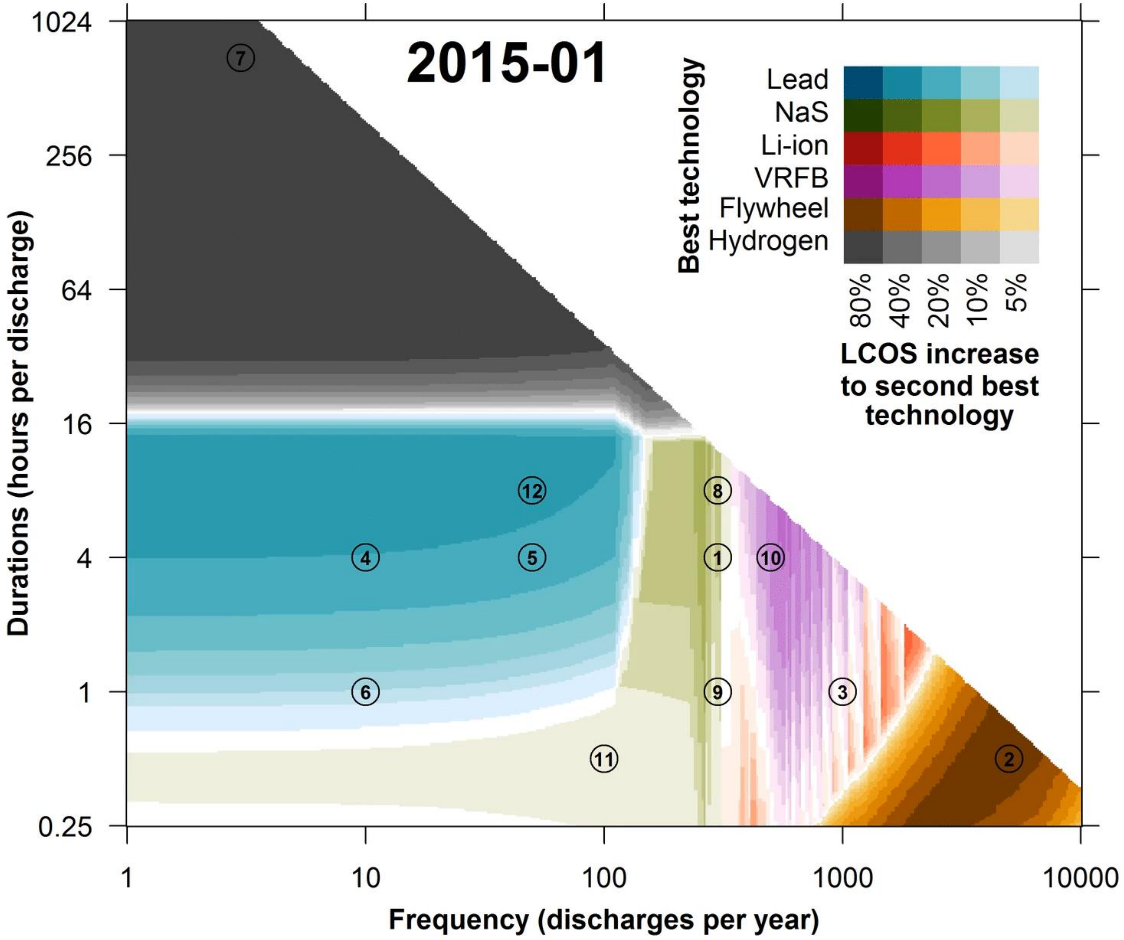
Modelling of a 150% wind-solar energy system over a wide geography





Source: Rystad Energy research and analysis, ENTSO-E Transparency Platform

IPower-2-Power: by 2030
Li-batteries beat most storage storage technologies for hours
Hydrogen excels in longer duration storage (>24hrs)



Source: O. Schmidt, S. Melchior, A. Hawkes, I. Staffell.
Projecting the future levelized cost of electricity storage technologies. Joule (2018).

Where can we put enough GWhrs for a few days?

Before the electrolyser

Batteries

- ✓ Best for short term
- ✓ Excellent efficiency
- ✗ Very high costs
- ✗ Material intensive

Hydro

- ✓ Low costs
- ✓ Good Efficiency
- ✗ Geographically limited
- ✗ In high demand for other purposes

After the electrolyser

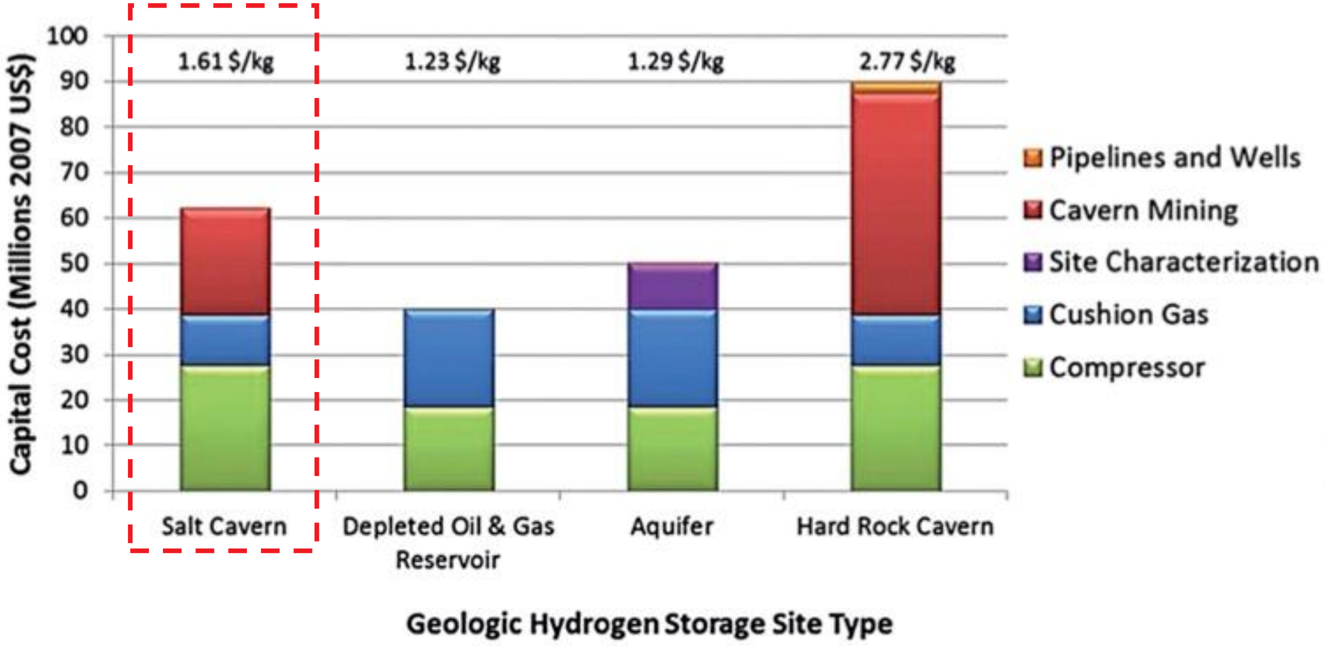
Hydrogen tanks

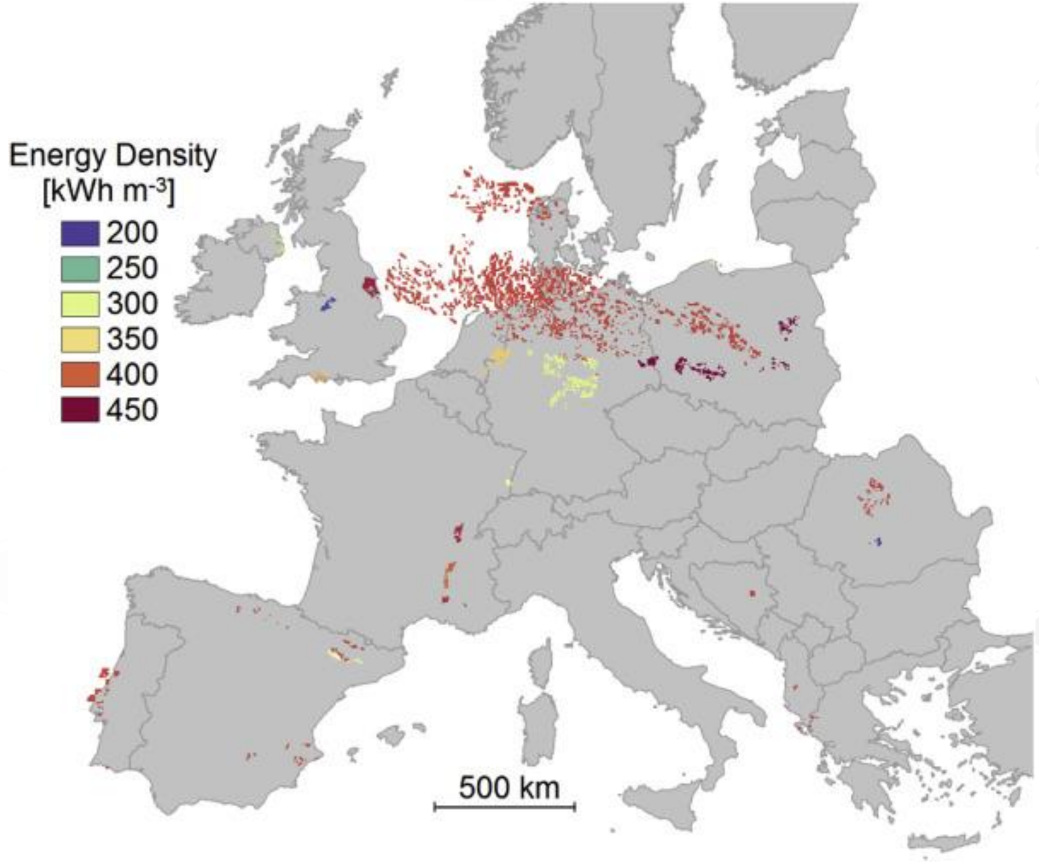
- ✓ Pure product
- ✓ Abundant material
- ✗ Permitting issues
- ✗ Cost for GW scale

Salt Caverns

- ✓ Lower costs
- ✓ Large volume
- ✗ Geographically limited
- ✗ Operational and purity issues

Issue: subsurface storage is still not really a cheap option (best ~€1/kg) and not available everywhere





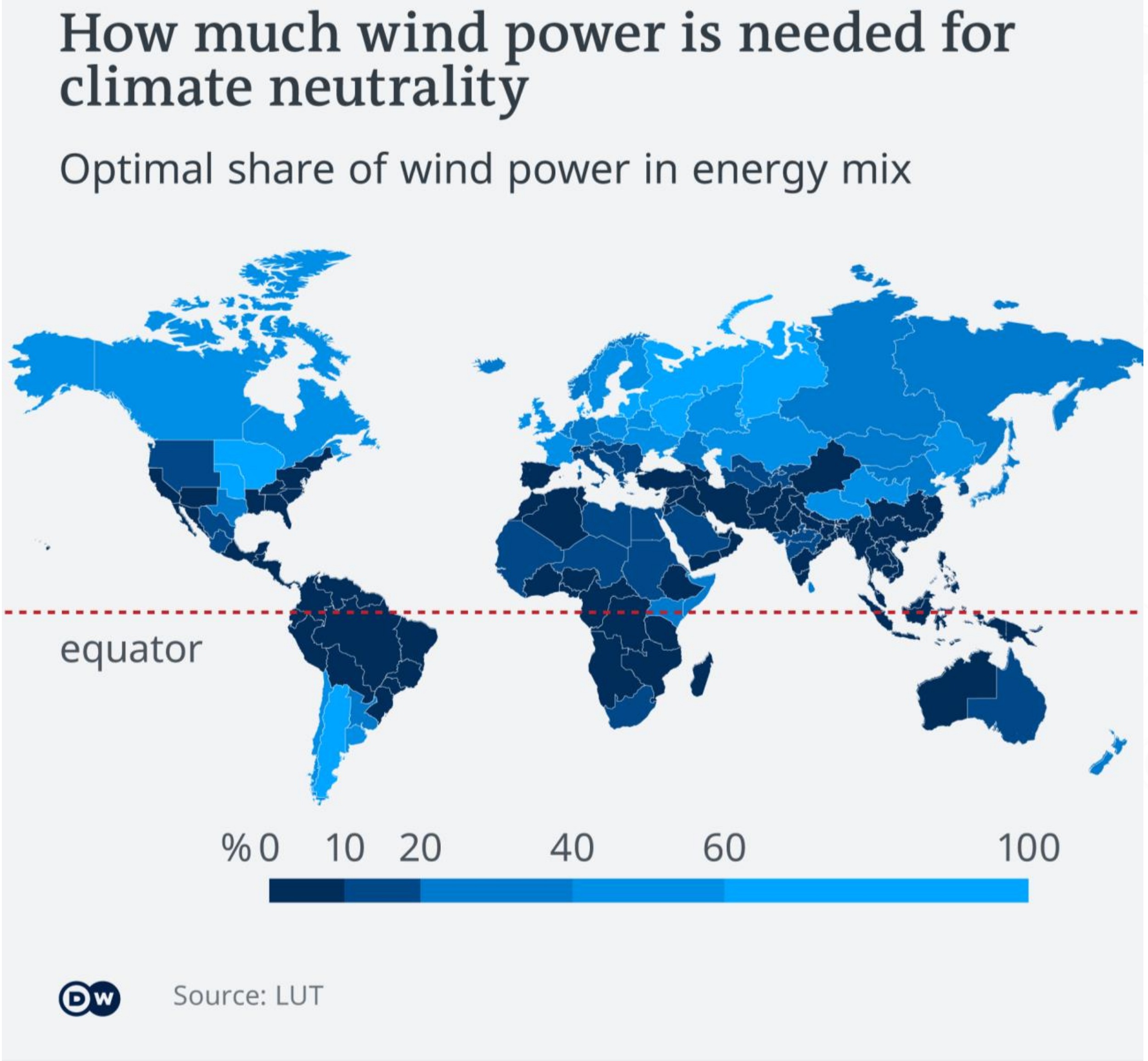
Source: Sustainable Energy Fuels, 2022,6,332

Green steel is starting to be cost effective IF:

- We have sources of energy which are abundant, cheap, with a high availability factor, and geographically diverse
- We can store hydrogen at GWh scale cost effectively and without geographic limits

Location will decide how green hydrogen is produced

Equatorial areas are solar dominated



Temperate areas are wind dominated

80% of the worlds technically exploitable wind resource is in deep water locations

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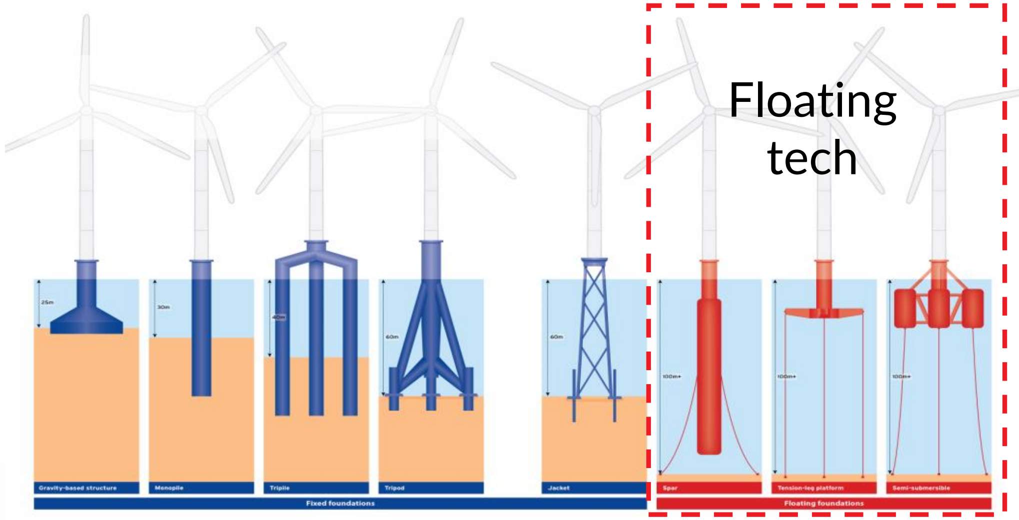
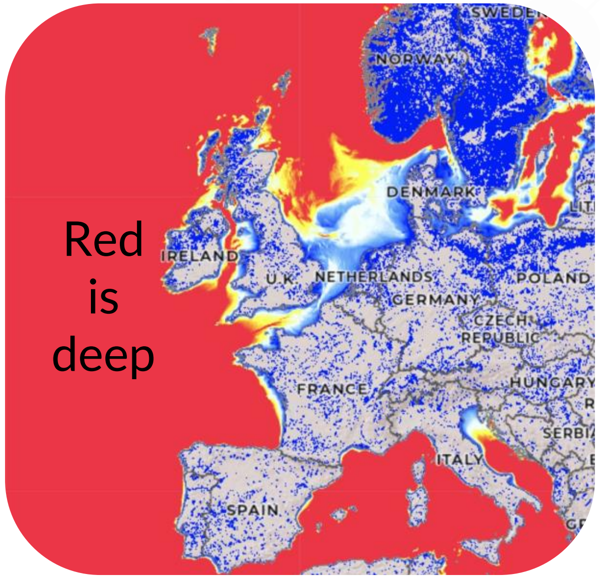
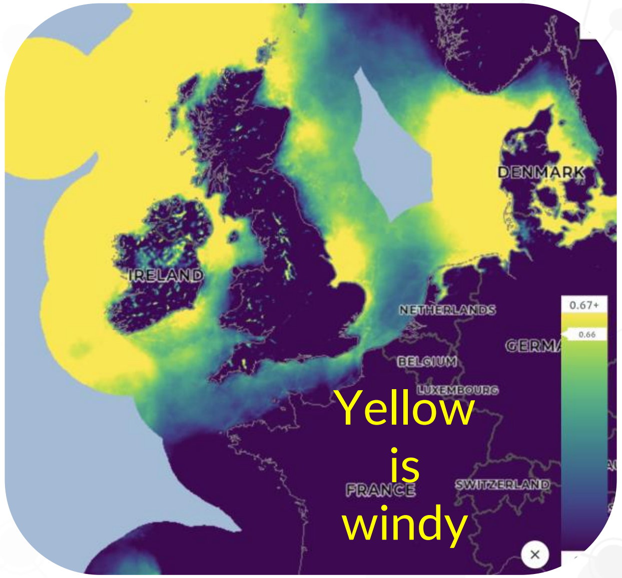
Deep-water wind resources will need to go floating

Excellent: **60%** (vs 30% availability factor onshore)





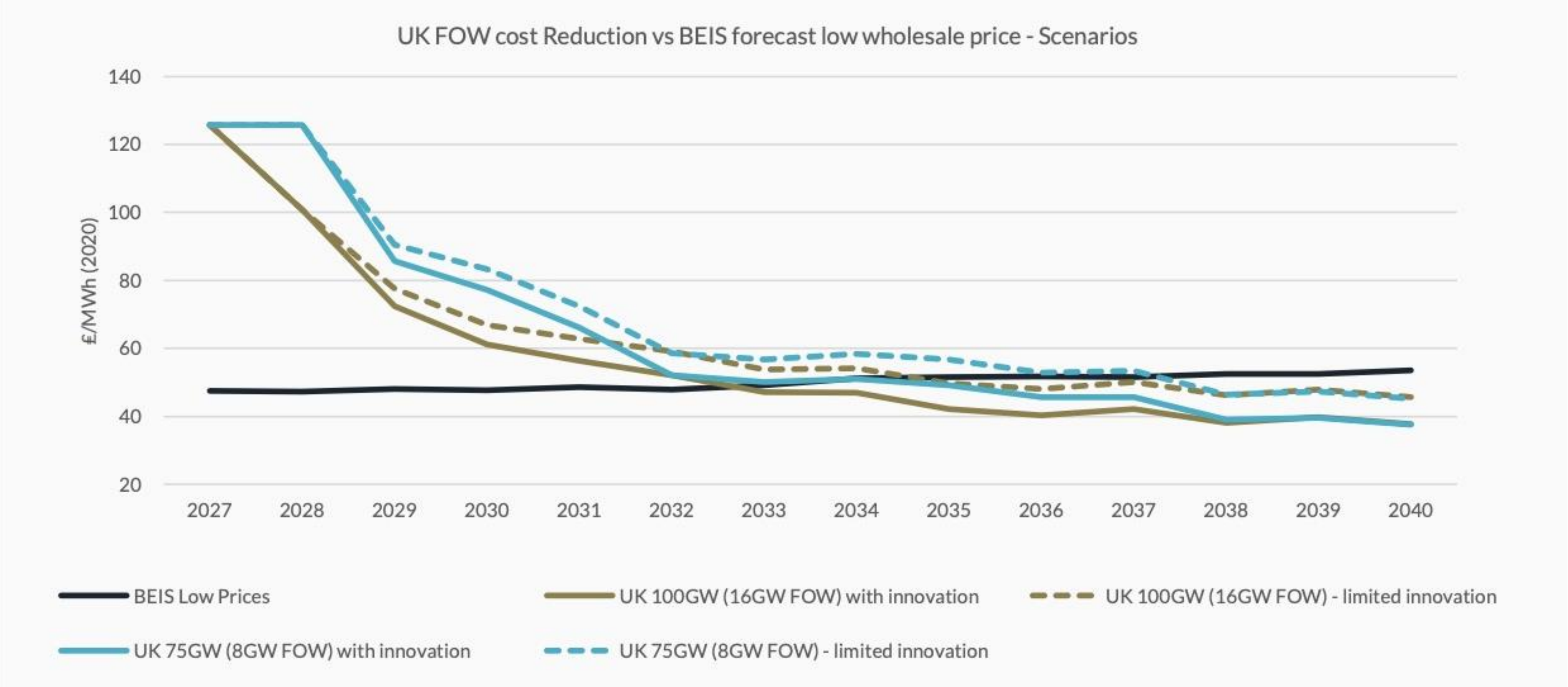


✓ Geographic diversity

✓ High availability factors

Source: Global Wind Atlas

Floating Offshore Wind (FOW) expected to be competitive before 2035



Offshore wind now at parity with onshore wind, floating vs fixed parity is within sight!

Source: ORE Catapult

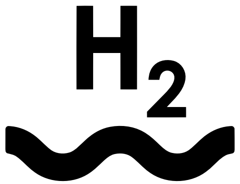
ScotWind 1 has awarded 25 GW of offshore wind projects

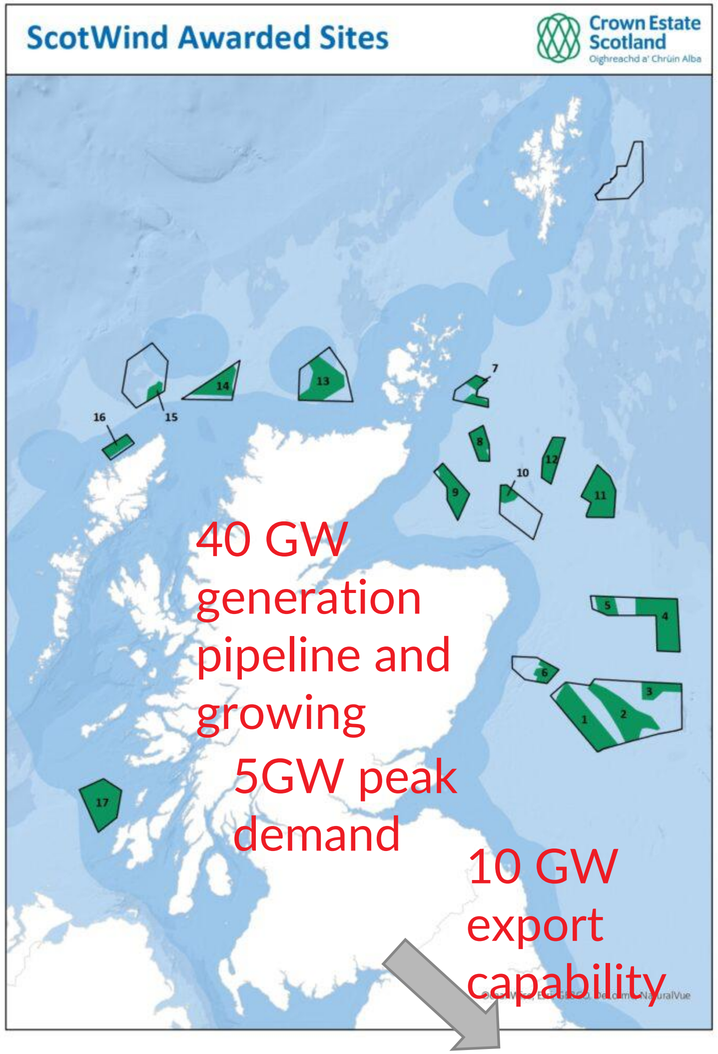
This lighthouse wind round shows floating offshore hydrogen is essential for harvesting remote offshore wind

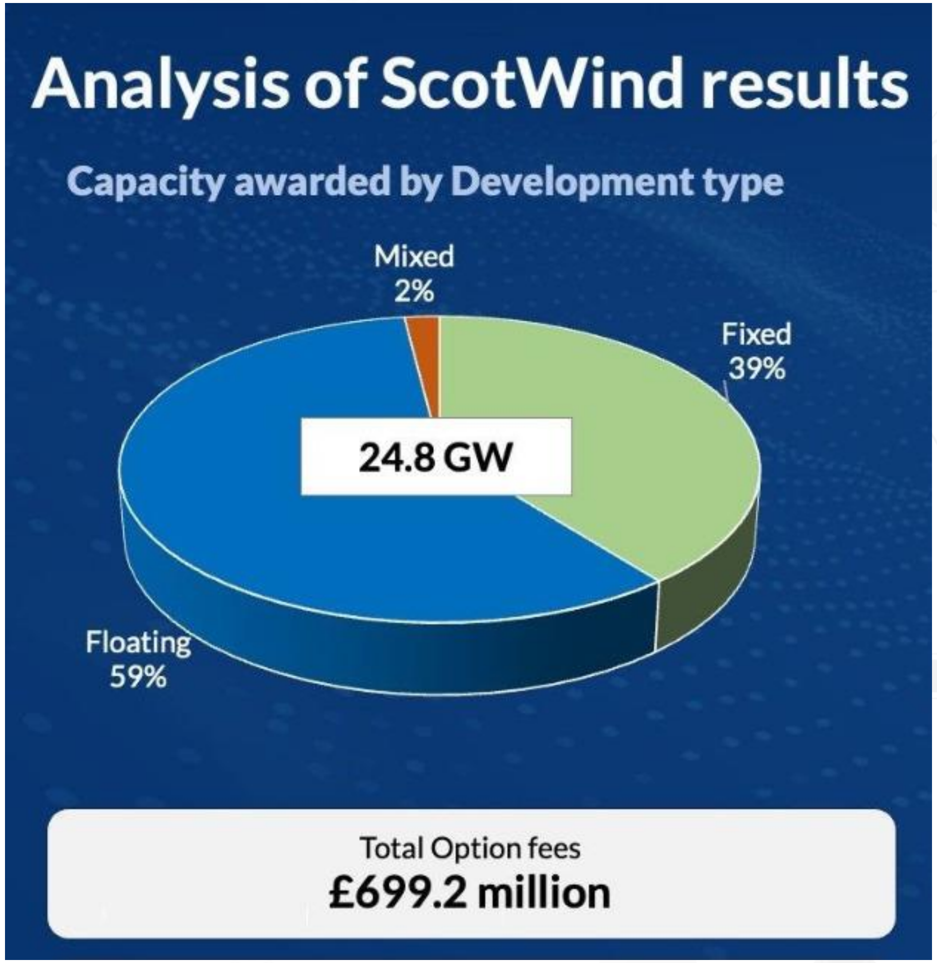
- 17 projects were awarded
- 59% floating projects
- not enough grid capacity

Harvesting energy from remote deep-water sites with HVDC is often prohibitively expensive

- **=>Hydrogen will be an essential technology to get wind energy to market**



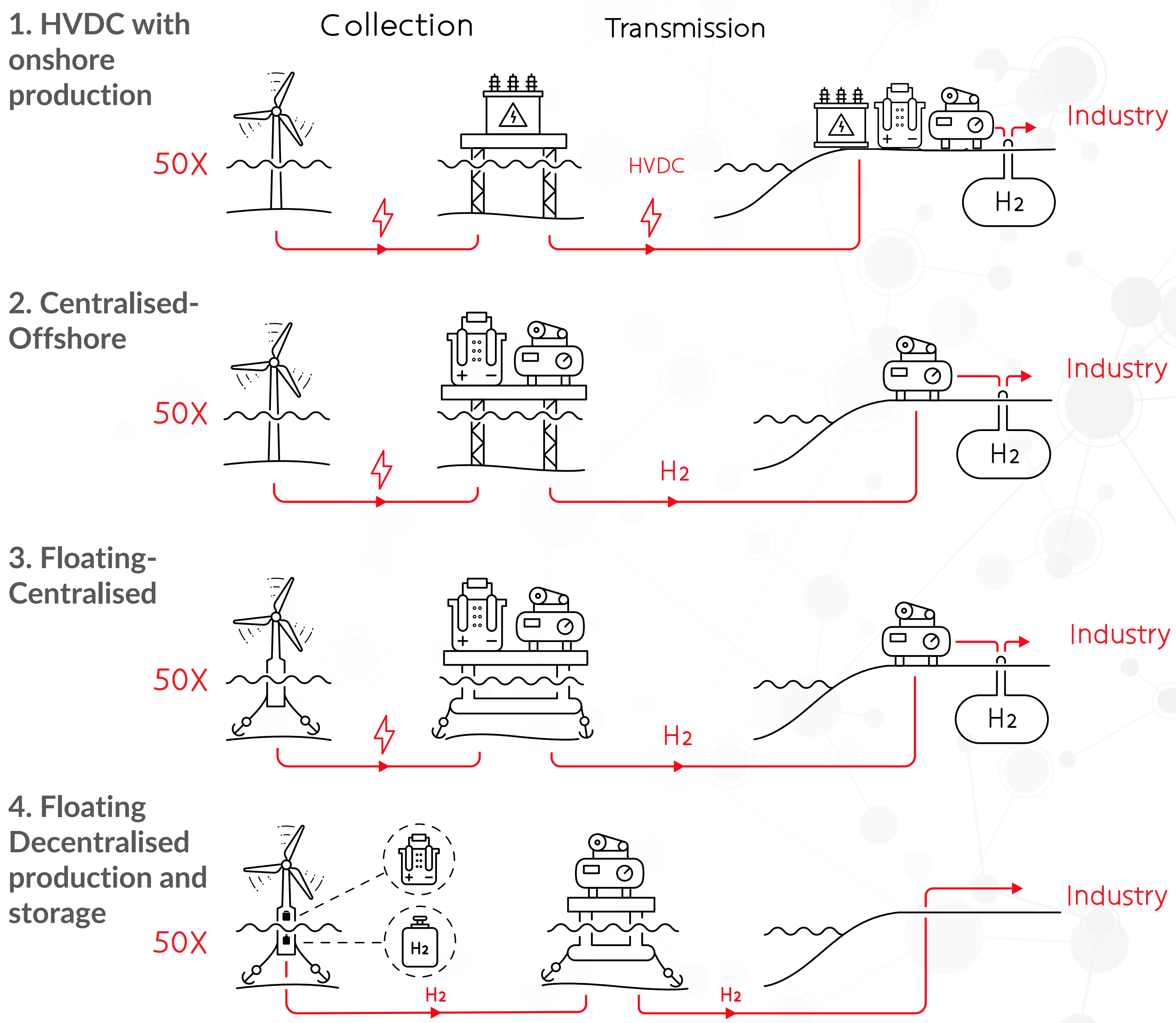




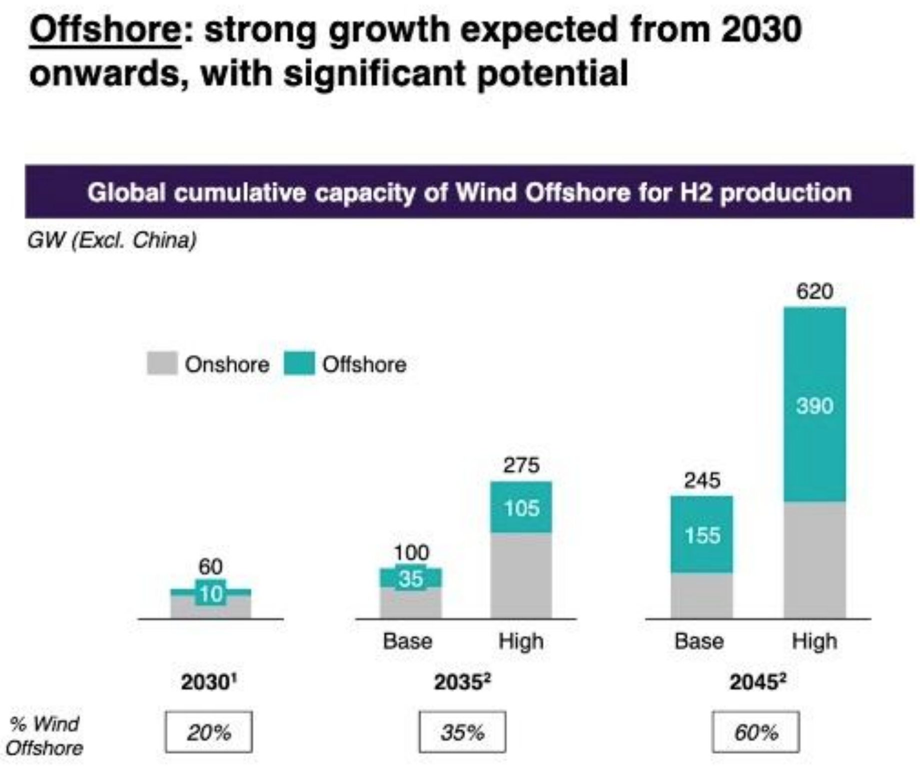
Source: Crown Estate

Many different schemes proposed for generating hydrogen from offshore wind

No clear winner yet – may be location specific



Offshore hydrogen set to generate >390 GW per year by 2045



H2- Long distance energy transport for geographic diversity

Name	Britned Cable (EL)	Nemo Cable (EL)	IUK pipeline (Natural gas)	BBL pipeline (Natural gas)
Max Capacity (GW)	1	1	33	20
CAPEX €M	600	690	713	500
Distance KM	260	140	235	230
€M per GW per KM	2.308	4.929	0.091	0.110

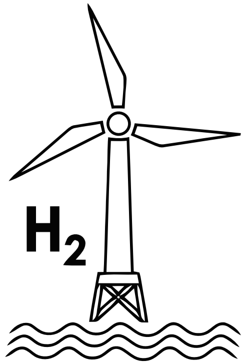
HVDC is 20x - 40x more expensive than pipeline for equivalent energy capacity

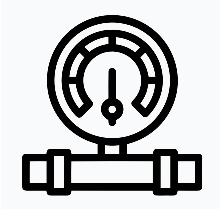
HVDC = High-Voltage Does Cost!

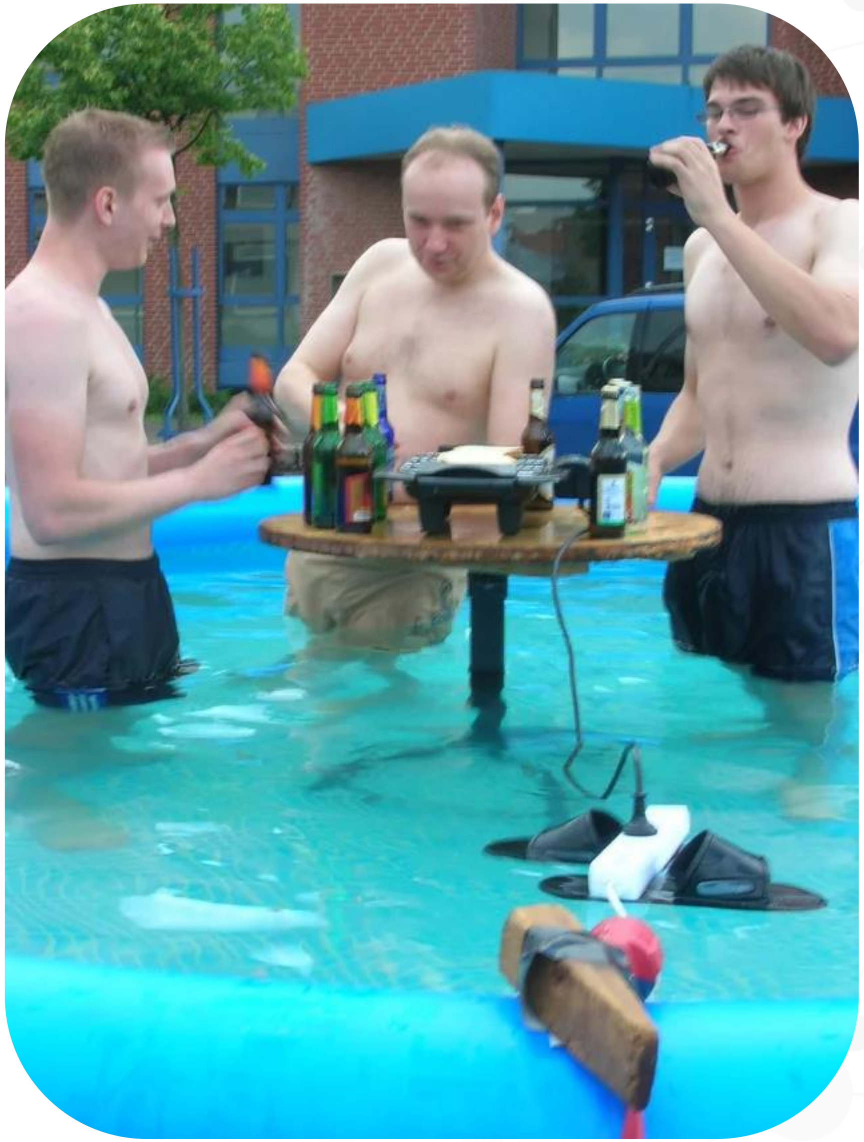
Source: Siemens Gamesa

Most people realise that mixing electricity and water is risky

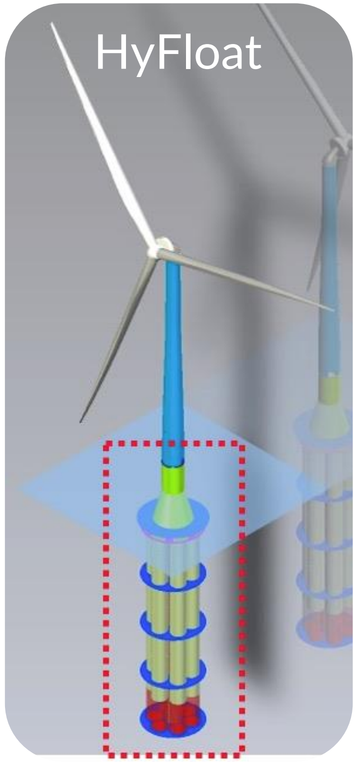
- Subsea electrical infrastructure is responsible for 80% of fixed windfarm faults
- The dynamic cables required for floating wind increase vulnerability
- Distributed production avoids risk by transferring only gas by cheap and ultra-reliable pipeline.



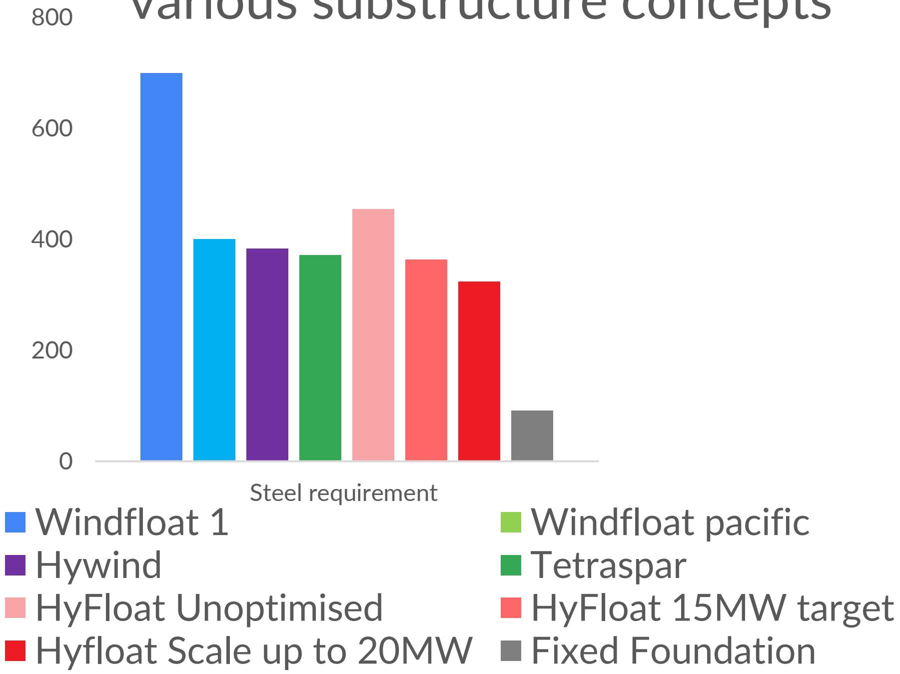




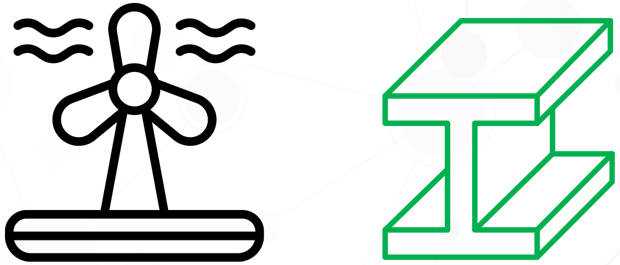
Floating foundations will be a huge early market for green steel



Mass of steel (tonnes per MW) for various substructure concepts



3x as much steel demand as fixed foundations!



Strong ESG drive in industry

Early adopter for green steel

Average floating field demand:

~0.7Mtonne of green steel per GW

If 50% of offshore wind is floating ~

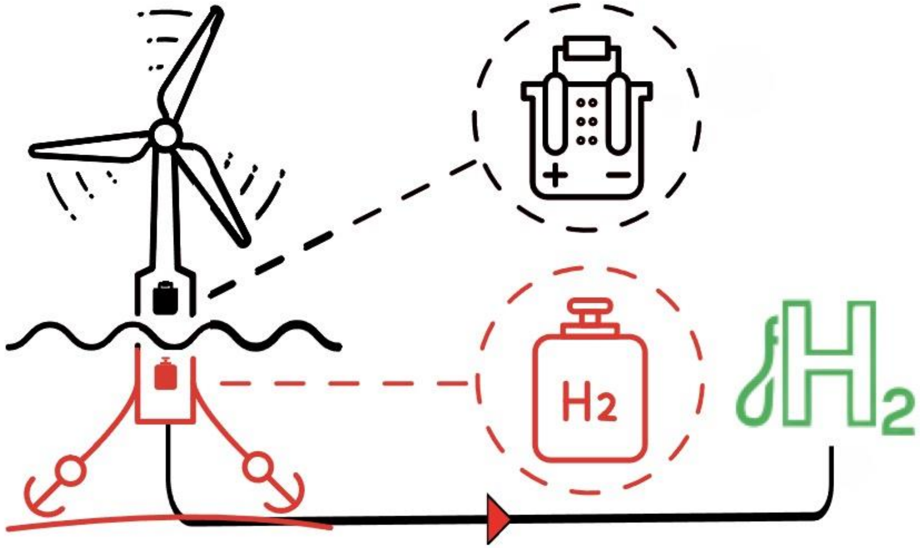
~70 Mtonne of green steel over 20 years in EU alone

HyFloat: Floating hydrogen production and storage in a single unit.

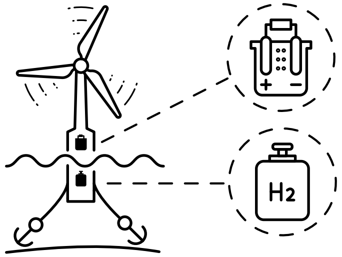
Deep sea hydrogen production offers virtually unlimited potential for renewable energy harvesting

Hydrogen consumers need stable supply but wind-based production is intermittent

HyFloat makes renewable hydrogen **reliable & available** at the low cost via dual-use of foundation for buoyancy AND hydrogen storage



Using buoyancy chambers enables vast storage of energy-dense H_2 gas. No high-pressure complexity & low costs

1x 15MW 

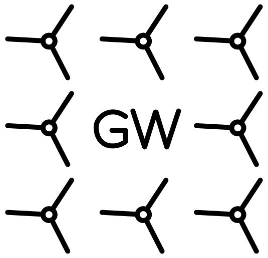
= 370 MWh (LHV)

=37x

=120

=500

=220 tonnes



= >25 $GWh_{(LHV)}$ of usable energy storage
(15,000 tonne green steel production during Dunkelflaute)

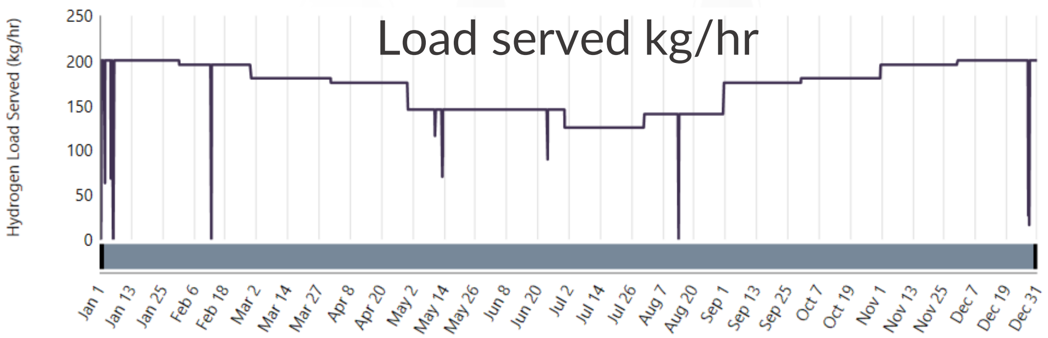
HyFloat concept achieves supply reliability **up to 99%** (Industrially excellent).

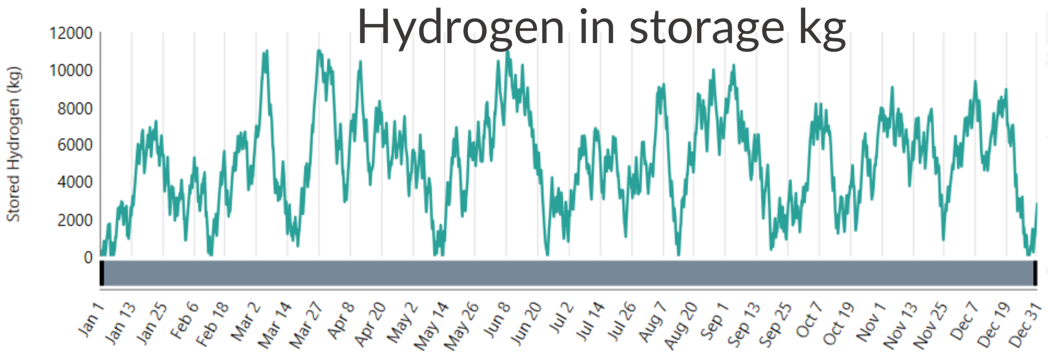
Modelled output of HyFloat system with seasonal demand scheme in a Northern North Sea, Scotland site.

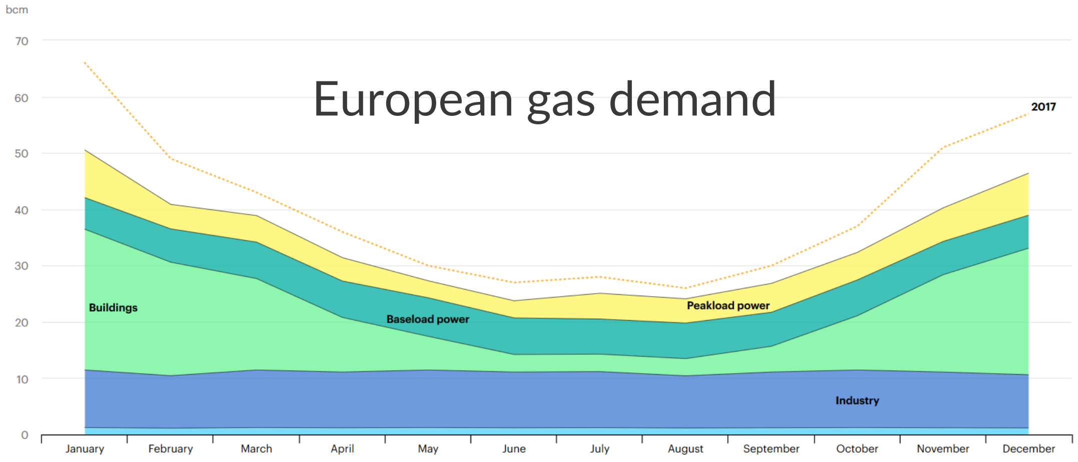
Seasonal supply profile is an excellent fit with seasonal gas demand in Europe

Modelled in

HOMER Energy by UL







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Simple PoC is the next step in our technology road map, then feasibility study to an operational pilot

✓ Phase completed ☐ Current Focus

Phases for potential collaboration of wind farm developers to deliver HyFloat

Q4/21
Pre-feasibility study ✓
Results indicate excellent economics and no major show stoppers

Q3/22-Q1/23
MVP 1
MARIN
TRL 3
basic hydrodynamic testing. Complete

MVP 2 TRL5
demonstrating storage function and assembly Q1/23
HOGESCHOOL ROTTERDAM
RDM ROTTERDAM
Ongoing

Q2/23-Q3/23
Feasibility study for target location
TRL 5
Detailed technical and economic studies

Partners
University of Strathclyde Glasgow
IBERDROLA
wood.
Pending funding decision
Scottish Government gov.scot

Q4/23-Q1/24
FEED study for pilot at target location
TRL 6
Prepare an advanced digital twin

2024-2025
Pilot engineering
Detailed engineering of pilot system.

2025 - 2026
15 MW Pilot construction
TRL 7-8
Construction of system begins

12 TO ZERO

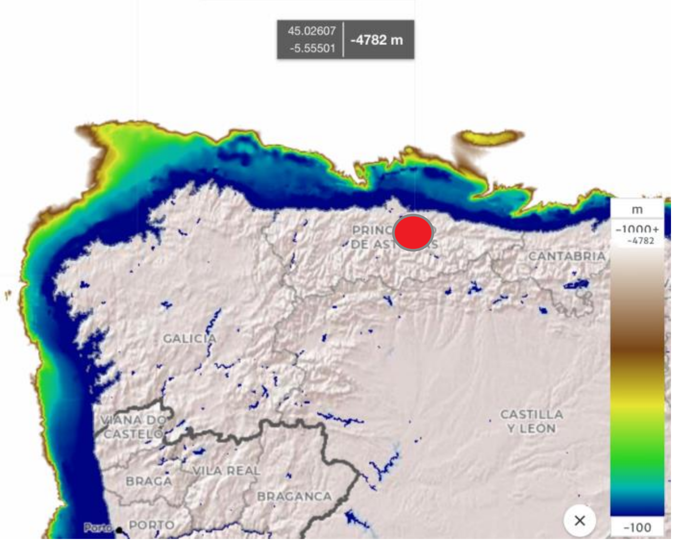
Result: HyFloat floats!

- 1st physical test of a cell spar structure
- No major issues
- Excellent hydrodynamics

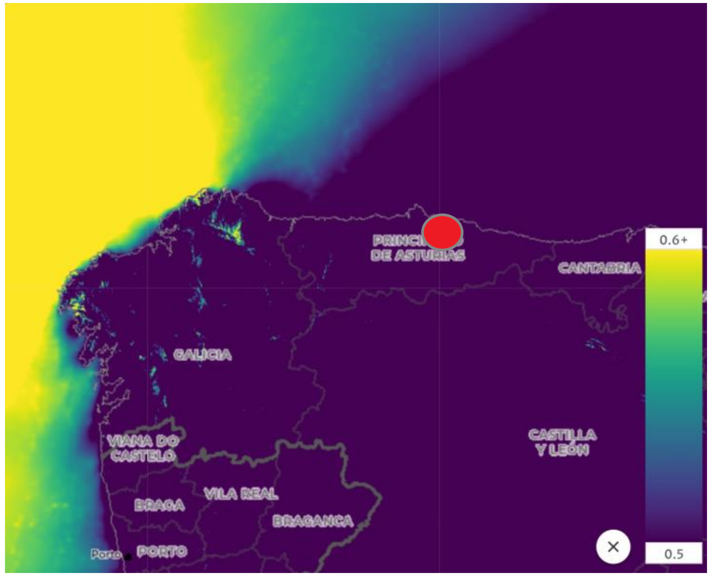
Northern Western Iberia has excellent wind potential but requires floating technology to exploit this for H2 production

HyDeal España links a number of industrial sites in this region that have high emissions and will demand vast quantities of hydrogen e.g. **ArcelorMittal** and **Grupo Fertiberia will purchase** 300 ktn/year of hydrogen by 2030

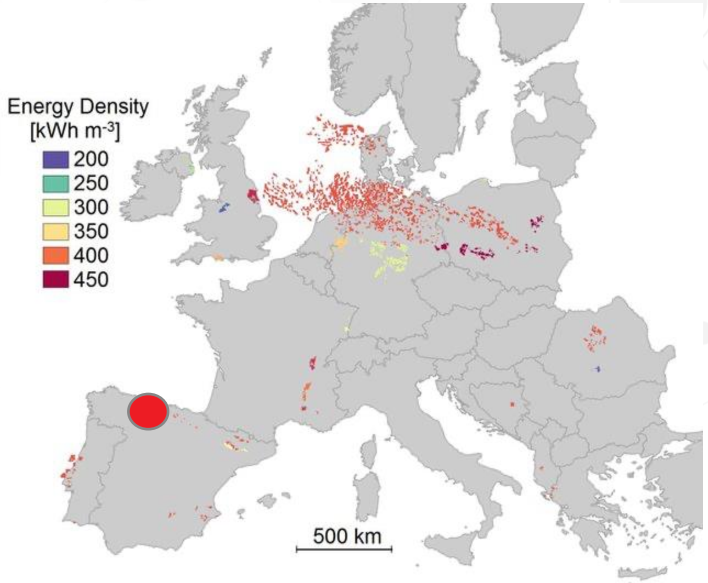
This supply planned is mainly solar, however stored hydrogen produced from wind can help to achieve the supply reliability industrial consumers demand.



Deep-water (coloured) areas: suitable for floating wind



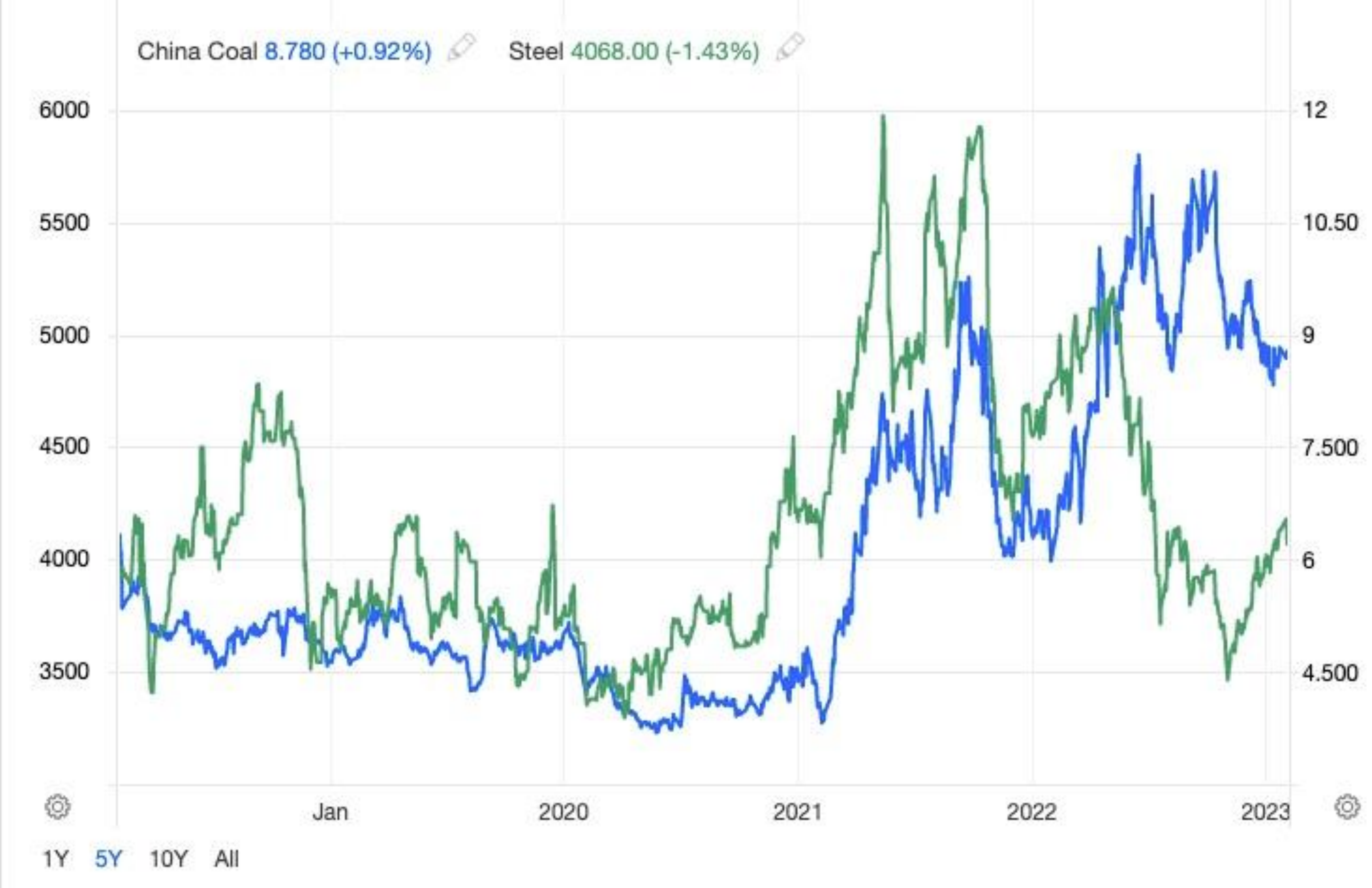
High wind availability factors: high H2 production potential

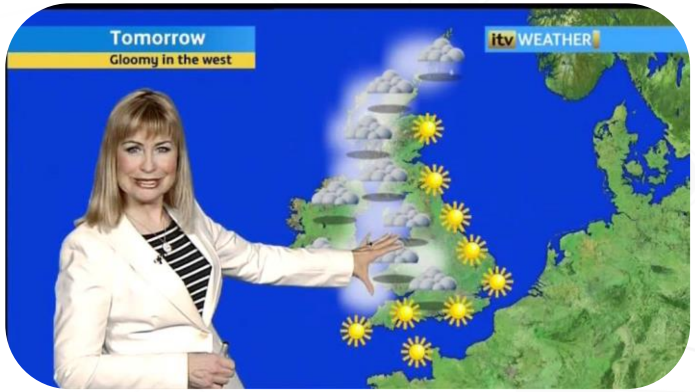


Few subsurface salt deposits: Need for alternative H2 storage

Closing question for a new commercial world

When coal is replaced by renewable hydrogen, will the price of steel be indexed on the weather forecast, or are other solutions required?





Thank you
Dr Jamie Frew