



GreenSpur

building a sustainable future for offshore wind

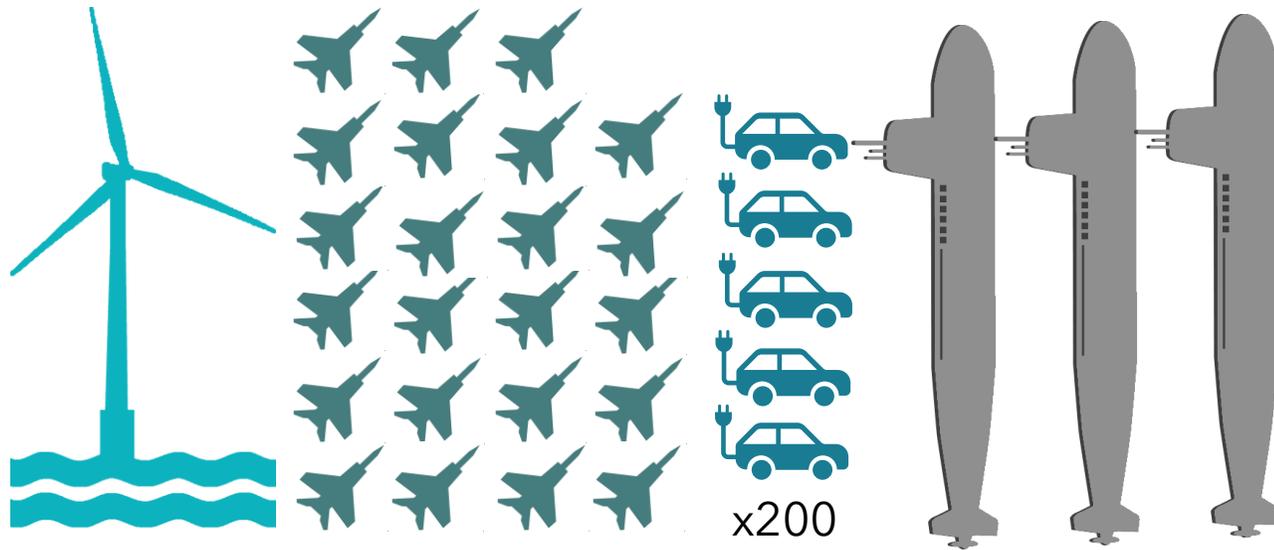
29 June 2021

The ORE Catapult and RenewableUK Conference on
Circular Economy in the Wind Sector

The GreenSpur Rare Earth Free Permanent Magnet Generator



Offshore wind is uniquely exposed to rare earth risks



Concerns over access to rare earth elements have been identified as a strategic threat by the US and UK Governments.

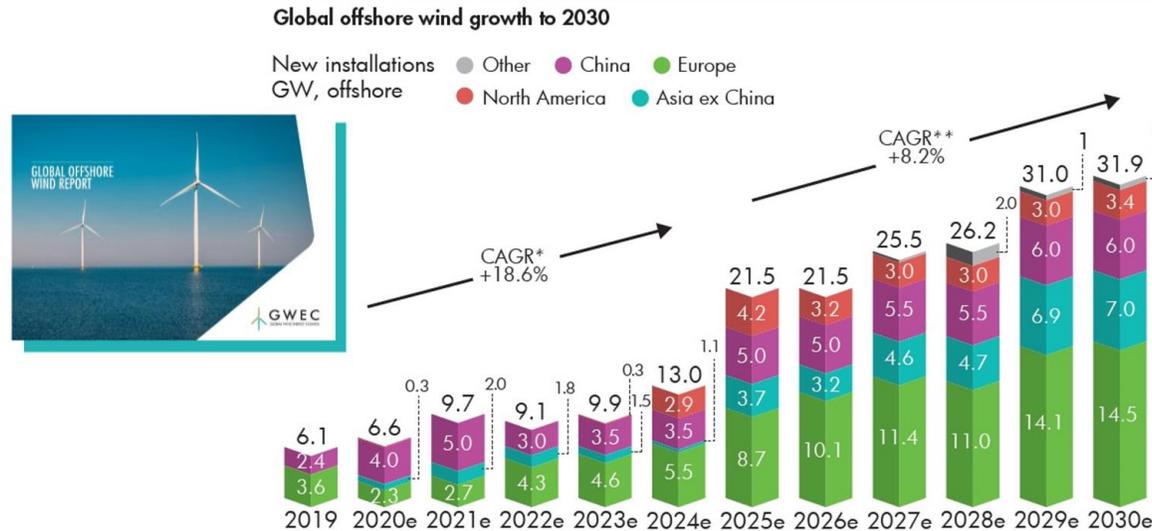
China has emphasised publicly that it would use access to rare earth elements as a means of protecting what it sees as its strategic interests.

Consequently, there is a focus on identifying alternative sources of rare earth materials, and seeking to minimise their use where possible.

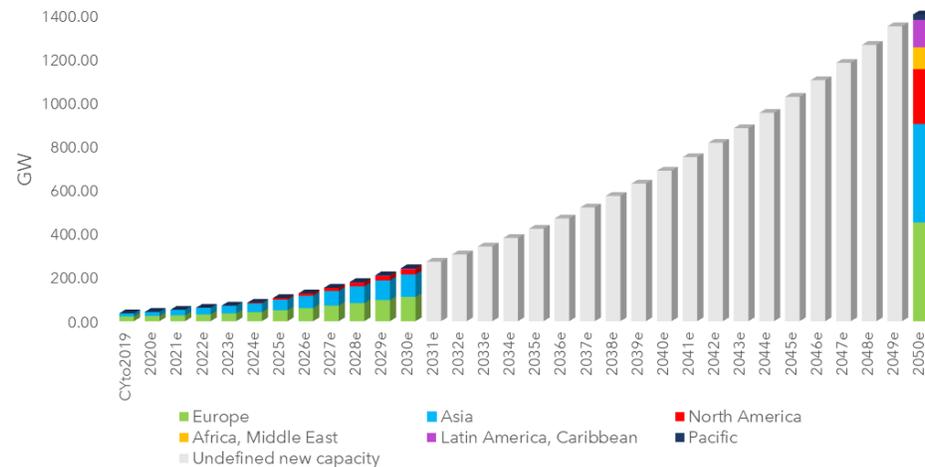
A single 14MW direct drive turbine requires the same amount of rare earths as 23 F-35 fighter jets, or 3 US navy submarines or 1,000 electric vehicles. Despite this higher dependency, the offshore wind sector viewpoint is predominantly one of underplaying rare earth risk or relying on actions from governments such as EU to implement successful policy action to tackle dependency on Critical Raw Materials.

Offshore wind growth to 2030

Global offshore growth 2030 to 2050



* CAGR = Compound Annual Growth Rate
Source: GWEC Market Intelligence, June 2020

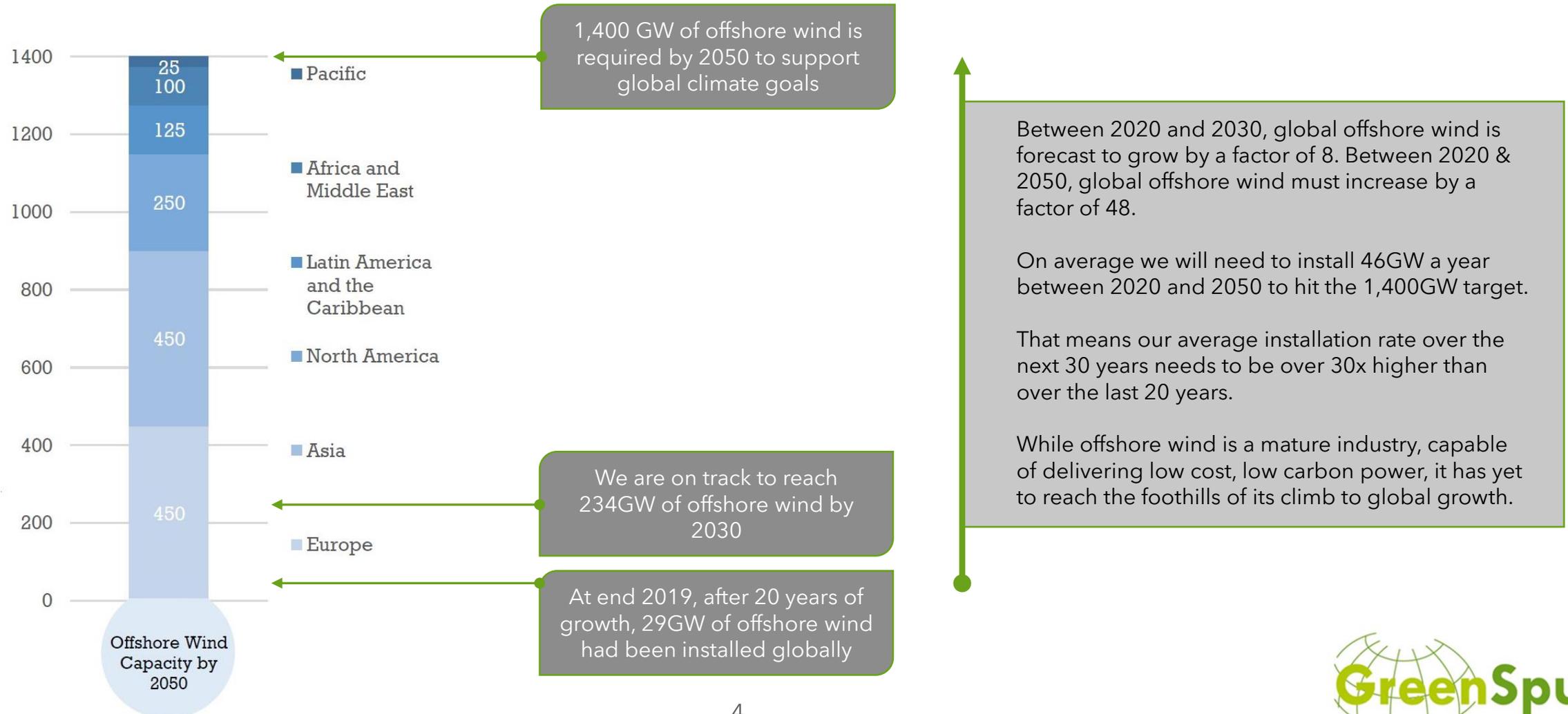


KEY OBSERVATIONS

- The Global Wind Energy Council is forecasting growth of 300GW of offshore wind by 2030 (top left), 8x total installed capacity in 2020.
- While the UK remains the largest offshore wind market, China is expected to overtake it by end 2021. Europe remains the single biggest regional market out to 2030 with a 45% share of installations.
- Significant growth in the US, Taiwan, South Korea, Japan and Vietnam is also expected, as offshore wind moves into new markets.
- The UN backed *Ocean Renewable Energy Action Coalition* is forecasting growth of 1.4TW by 2050. For comparison the International Energy Agency forecasts 1000GW by 2050, and the UN's International Renewable Energy Agency forecasts 2000GW.
- Bottom right shows GWEC's 2030 forecast in comparison to the OREAC 2050, showing levels of growth required post 2030.
- Between 2020 and 2050 offshore capacity will grow by a factor of 40+
- Sources: GWEC (June 2020) Market Intelligence, June 2020 and OREAC (2021) *The Power of Our Ocean* report

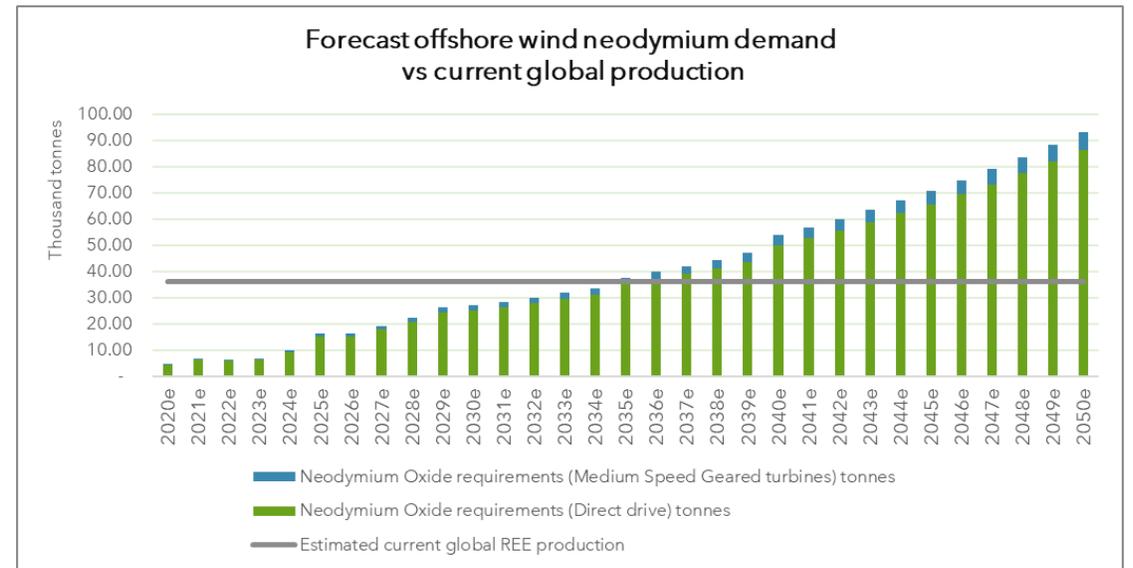
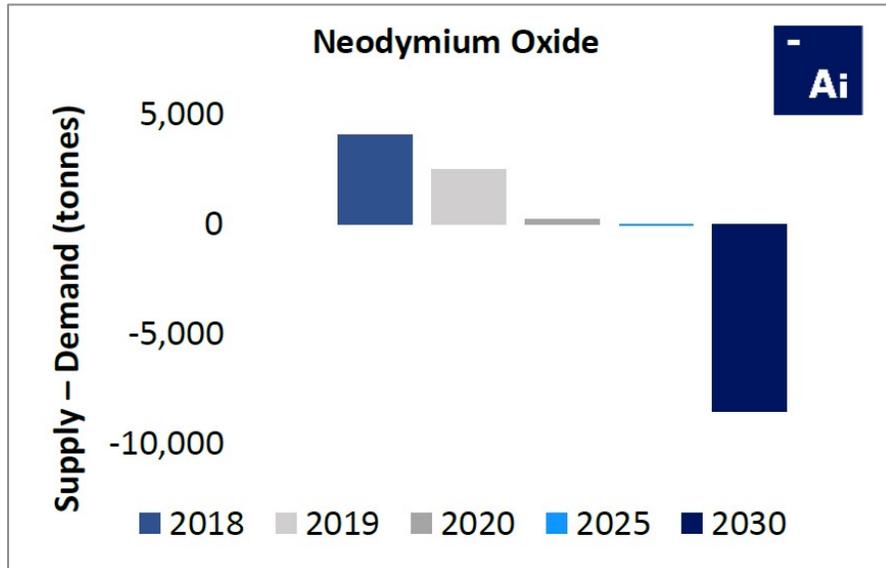
Offshore wind growth to 2050

To meet global climate goals, offshore wind must expand by a factor of almost 50 between 2020 and 2050.



Demand is forecast to outstrip supply in medium term

Growth is driven mainly by wind and EV growth



Forecasts show that global annual demand for neodymium oxide will substantially exceed demand by 2030 leading to shortages of these critical magnet materials if additional sources of supply are not developed. Forecast demand growth would require an increase in rare earth production of 15% each year, equivalent to opening a new mine the size of California's Mountain Pass each year (or the size of Batou mine every three years)

Offshore wind alone is expected to become one of the big demand users of rare earth magnets. Currently estimated to need 10% of demand, offshore wind growth projections show that rapid scale up of demand from offshore wind mean this single industry's own demand will exceed total current world supply by 2035.

Sources: Left, Adamis Intelligence 2019
Right, LumenEE analysis of rare earth demand based on GWEC Market Intelligence & OREAC offshore wind forecast
Forecast growth and mine equivalence from Physics Today, February 2021



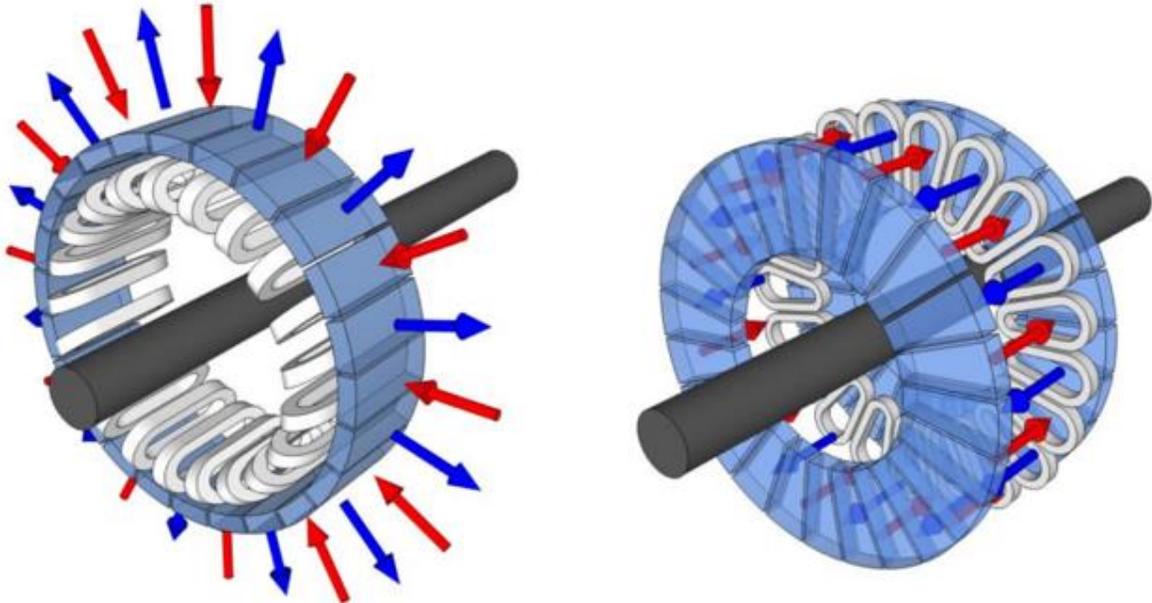
Design Objectives and Benefits

Our **primary objective** was to **eliminate the use of rare earth magnets**, but we were also aware that for the technology to be adopted it would need to be cost-effective and scalable to deliver the long-term growth targets that the industry was forecasting.

The benefits will be a **low cost, environmentally friendly solution**, which addresses long-term rare earth risk and accelerates offshore wind's global scaling potential.



GreenSpur's Axial Flux Generator



Arrangement of magnets in radial (left) vs axial (right) flux architectures

KEY OBSERVATIONS

- Existing multi-MW DD-PMGs adopt a radial-flux design.
- Ferrite is 1/3rd of the strength of rare earth magnets, so more material is needed.
- Move to an axial-flux design opens up "unused generator area", which enables the generator to operate within the same space envelope.
- Extensive research has been undertaken to optimise the design.

The Unused Generator Area Of A Radial Flux Design



Current Position

- **We have:**

- 11 international patent filings, 6 granted in various markets, scope for more.
- Extensive computer models.
- A single stage 250kW unit part of a 4-stage 1MW design.
- Developed initial manufacturing techniques.
- Systems Model.

- **Challenges include:**

- Light weighting.
- **Magnet optimisation - the impact of increasing magnet strength is transformational.**

The Impact of Increasing Magnet Strength - More Power or Less Mass!

Magnet Grade	% Magnet Strength Increase	% Generator Power Increase	% Generator Mass Reduction
Y33H magnet - used in our 250kW generator	0.0%	0%	N/A
Hitachi Metals NM-15G - strongest ferrite on the market	14.3%	31%	23.4%
Target strength / increase - within 3 years	30.0%	69%	40.8%
Target strength / increase - within 5 years	50.0%	125%	55.6%

Over the last 20 years extensive research has been undertaken to improve the strength of rare earth magnets, and neodymium iron boron magnets are now almost twice as powerful as they were 10 years ago. There has been negligible research into improving the strength of "boring" ferrite magnets, but GreenSpur is now working with partners to change this!



Solutions

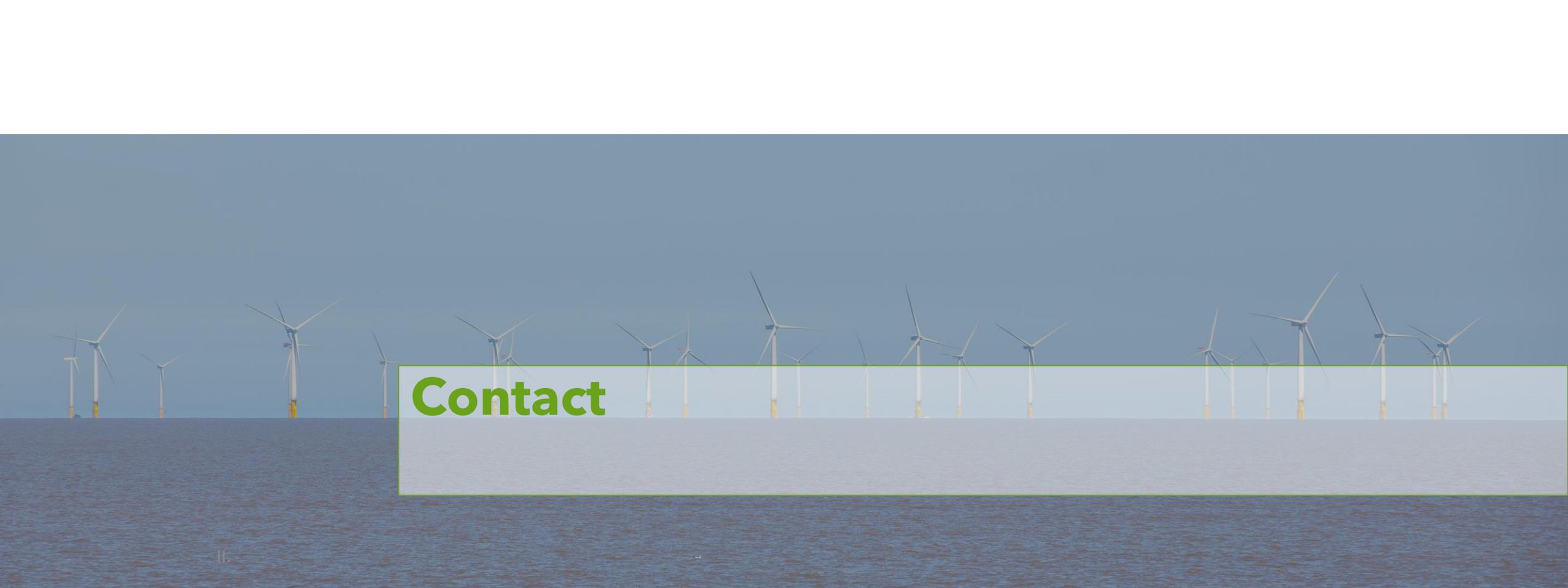
We believe that there are significant medium to long-term opportunities for our technology in the global offshore wind market.

We are looking for a strategic co-development partner.

We will require investment and /or grant funding, but have significant proprietary knowledge, Intellectual Property and a Technology Roadmap.

Our door is open, so please contact me if you would like to arrange a discussion.





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