A wide-angle photograph of an offshore wind farm with numerous white wind turbines stretching across the horizon over a dark blue sea under a clear sky. A semi-transparent white box with a green border is overlaid on the image, containing the title text.

GreenSpur

The solution to rare earth problem in offshore wind

8 December 2021

UK Magnetics Society

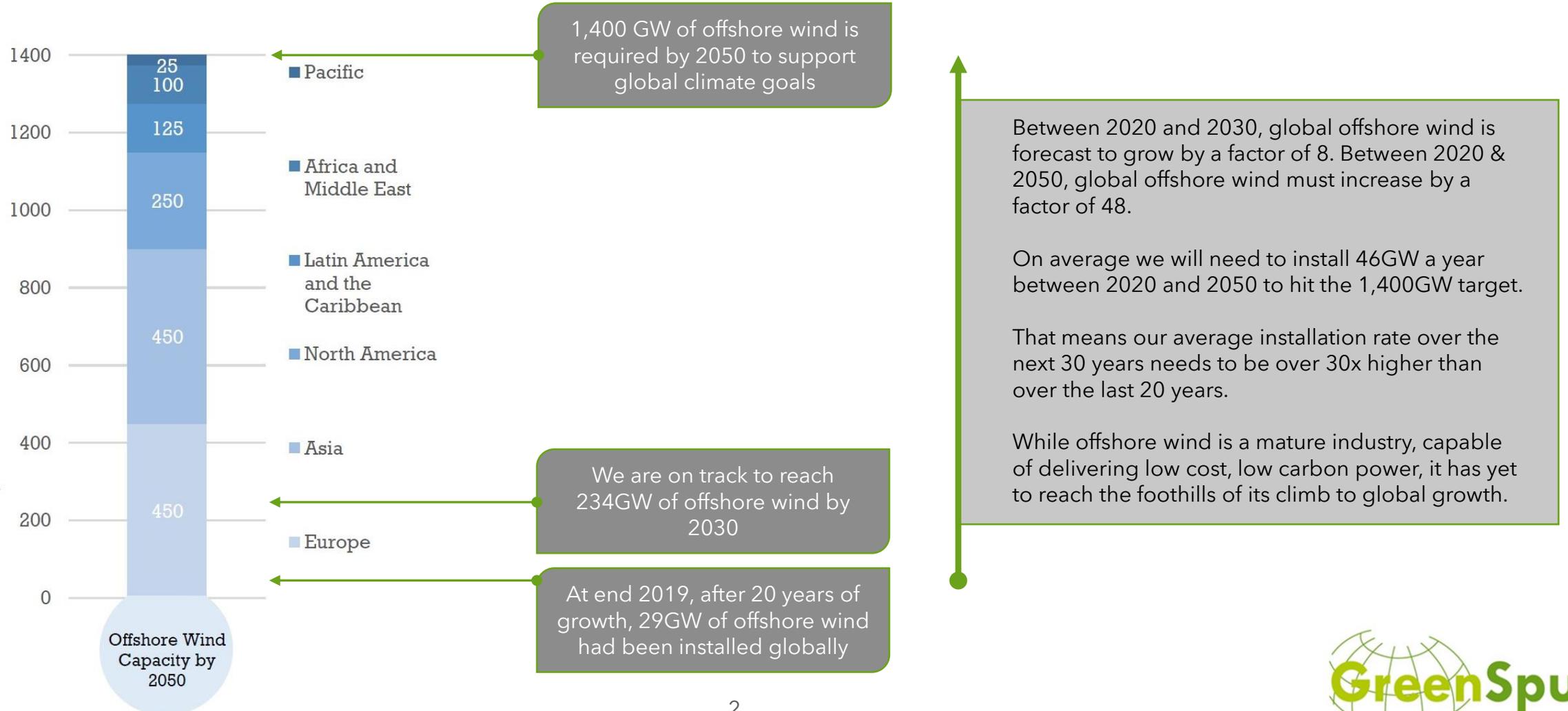
Managing Rare Earth Risk

Substitution Strategies Must be Part of the Answer



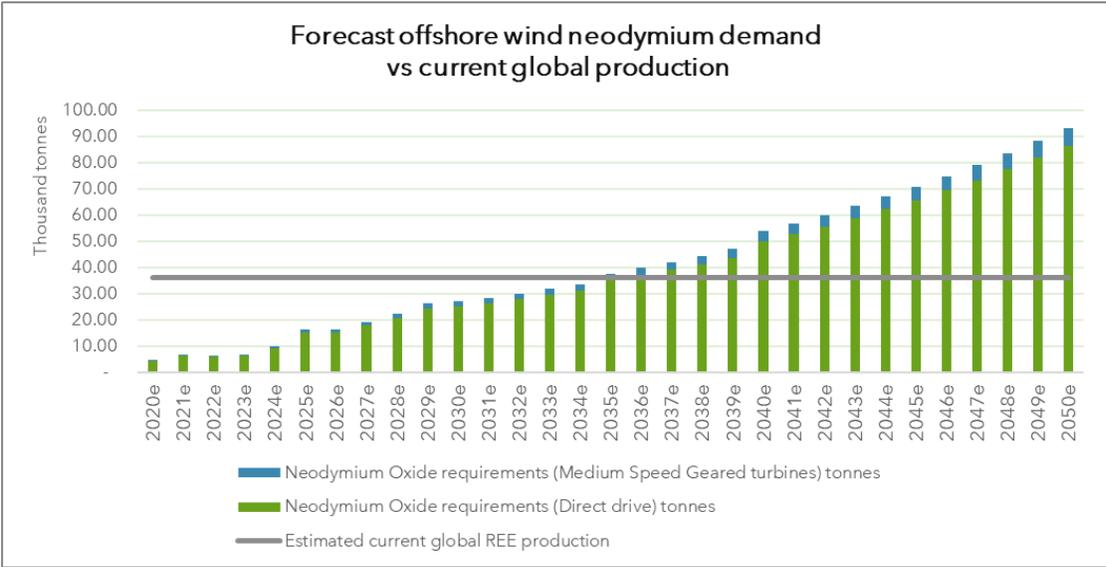
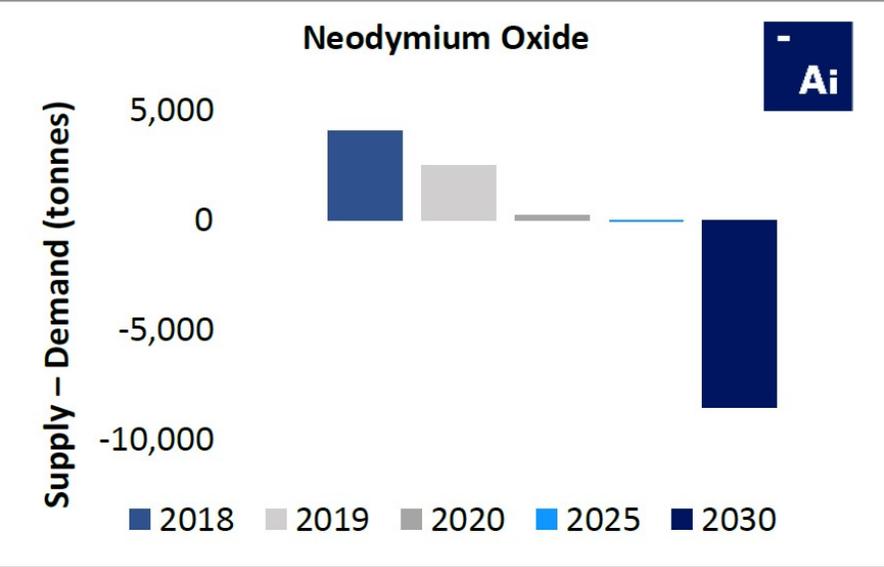
Offshore wind growth to 2050

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



Rare-Earth demand is forecast to outstrip supply by mid 2030s

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)

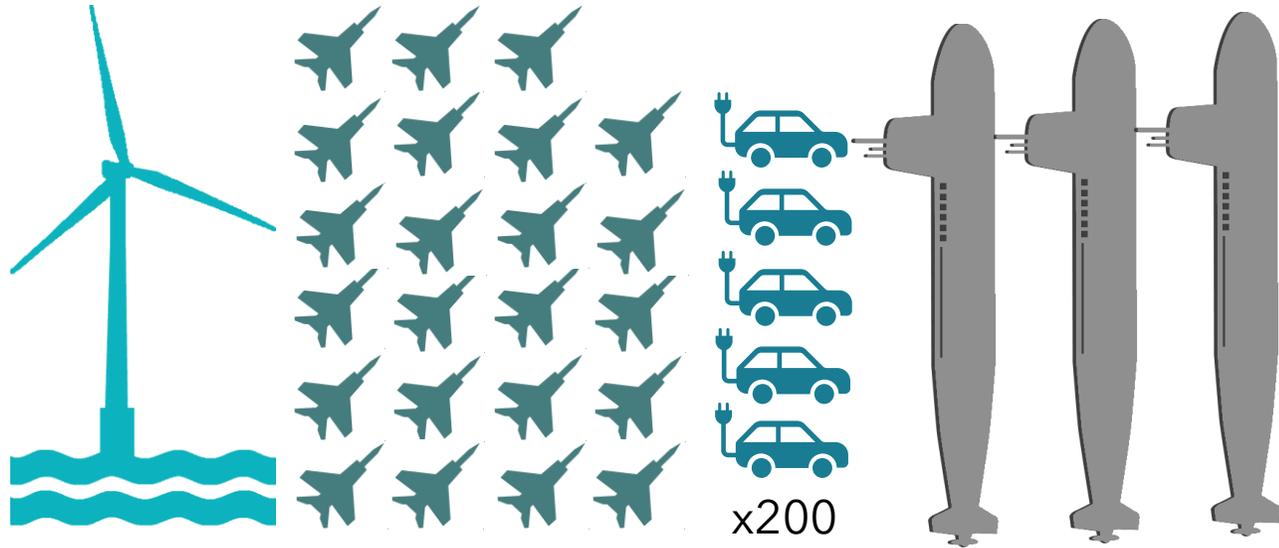
Offshore wind alone is expected to become one of the big demand users of rare earth magnets. Currently estimated to need 10% of demand, offshore wind growth projections show that rapid scale up of demand from offshore wind mean this single industry’s own demand will exceed total current world supply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



Offshore wind is uniquely exposed to rare-earth risk

It breaks the smaller, faster, lighter product rule



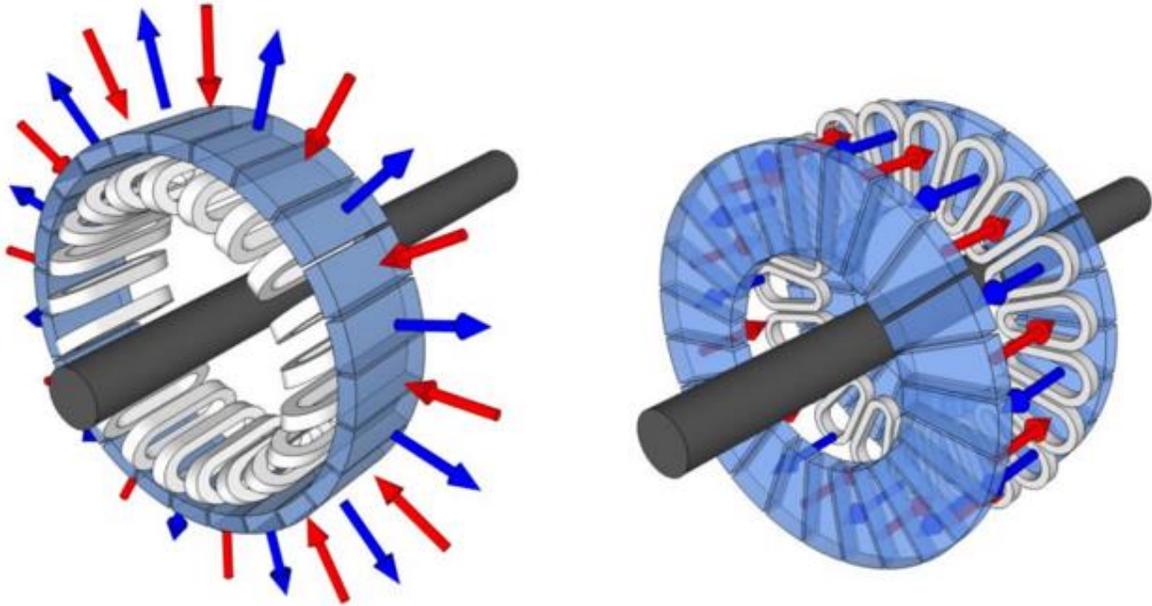
Concerns over access to rare earth elements have been identified as a strategic threat by the US and UK Governments.

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.

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



Market reaction to the GreenSpur rare-earth free generator

18 members of the UK supply chain interviewed with OREC Q4 2020

- We have presented our initial concept to the market - OEMs and developers. Their reactions were: **"it's a great idea, but you will be too heavy."** This is not surprising as our magnets are much weaker than neodymium rare earth.
- In Q4 2020, we interviewed 18 active members of the UK supply chain with the support of the ORE Catapult (UK equivalent of NREL). The impact of REE supply chain risk was acknowledged, **but again the issue of weight was brought up.**
- We were advised to conduct an evaluation of our generator technology using the NREL 15MW Reference Turbine.
- With the help of Warwick Manufacturing Group (WMG) we developed our own internal System Model using the NREL 15MW Reference Turbine. Initial analysis was completed in the summer of 2021.



The market was right at the time, but we now have a solution!

Based on a preliminary assessment using a new Iron Nitride Magnet from Niron Magnetics

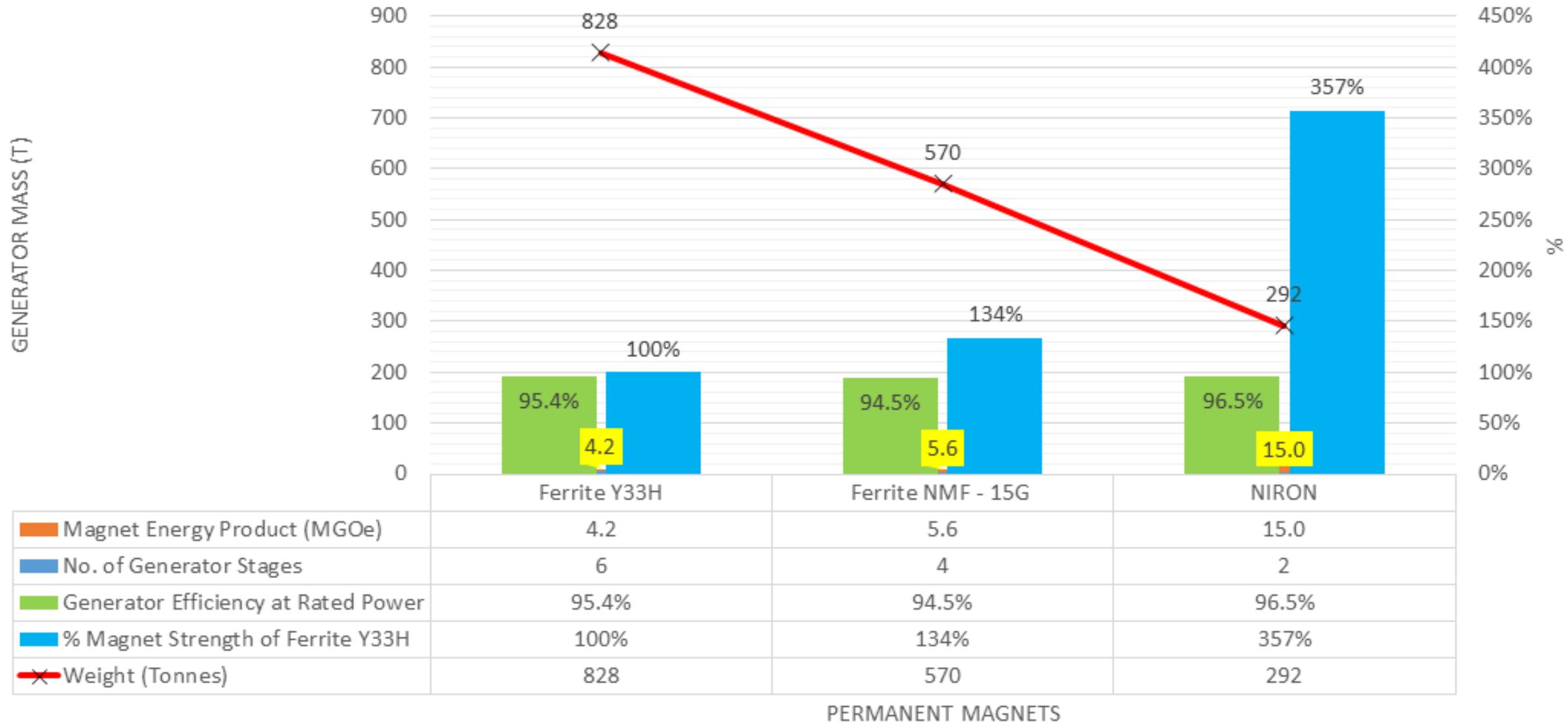
Design Case	Magnets	Generator Stages	Generator Mass (t)	$\mu_{\text{GENERATOR}}$ @15MW	Comment
GSW1370	Y33H	3	440	86.04%	Low Strength Ferrite Magnets could not get near the Target Mass Value
		4	570	92.39%	
		5	698	94.34%	
		6	828	95.44%	
GSW1371	NMF15-G	3	440	91.89%	Higher Strength magnets make an Improvement but are still too heavy
		4	570	94.49%	
		5	698	95.75%	
GSW1394	NIRON GEN 1 IRON NITRIDE	2	292	96.50%	The Gen 1 CEM from Niron delivers a game changing solution
NREL (Benchmark)	NdFeB	1	387	96.50%	NREL Set a Target Mass Value

- The Niron's Gen 1 Clean Earth Magnet (CEM) delivers a game changing solution
- The offshore wind CAPEX spend between to 2050 is estimated to be circa \$2tn
- Generator mass of 292t is an initial estimation and needs validation



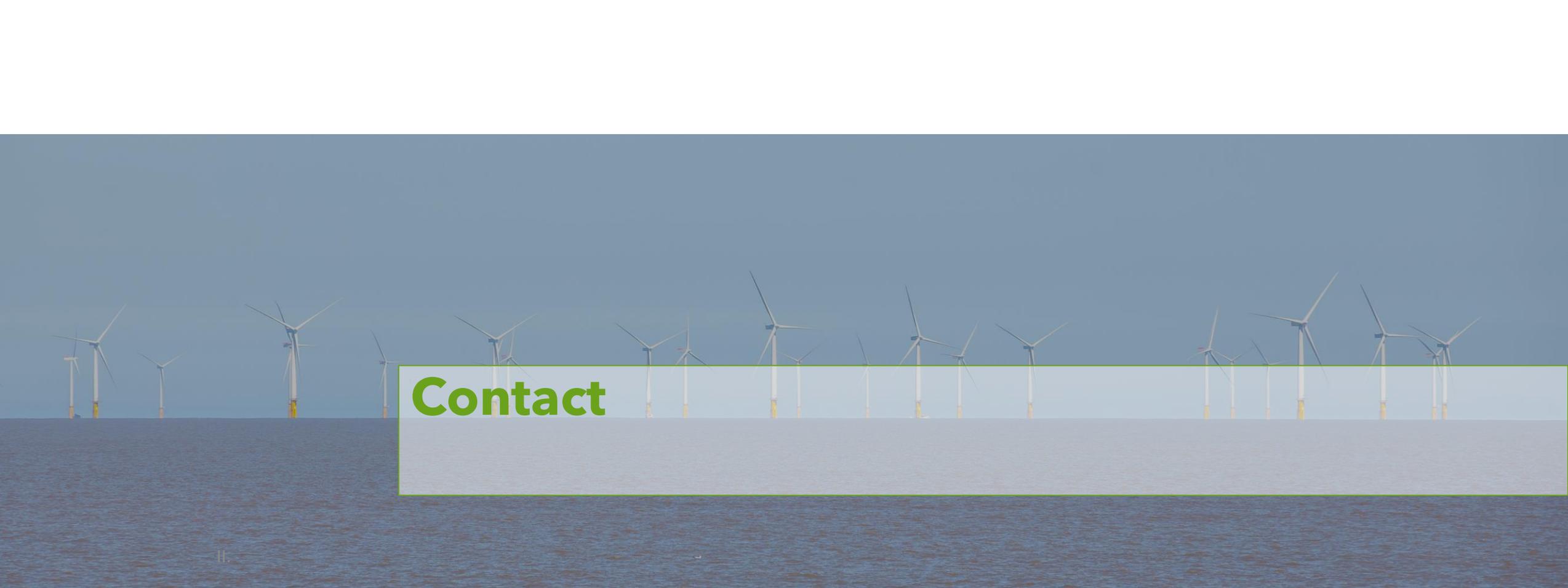
Mass Reduction Achieved via Gen 1 CEM

Sensitivity of Generator Mass with Increasing Permanent Magnet Strength



Conclusions

- We need to look at new ways to managing rare earth risk.
- New intermediate higher strength magnets, such as the Gen 1 CEM from Niron Magnetics, will make new substation technologies commercially viable. The GreenSpur generator is just one example!
- There are **BIG** prizes available in several **multi £TN global markets.**
- Collaboration will be essential.
- **The UK has an opportunity to play a leading role as a global innovator.**



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