Summary Report

Building a robust magnet supply chain for the UK

ADVANCED PROPULSION CENTRE UK

Accelerating Progress

Most electric motors used in low-emission vehicles rely on magnets made from rare earth elements

ADVANCED PROPULSION CENTRE UK

The Advanced Propulsion Centre (APC) accelerates the industrialisation of technologies that will help to realise net-zero emission vehicles. It is at the heart of the UK government's commitment to end the country's contribution to global warming by 2050.

Since its foundation in 2013, APC has funded over 113 low-carbon projects, involving more than 290 partners. The technologies developed in these projects are projected to save over 225 million tonnes of CO_2, the equivalent of removing the lifetime emissions from around 8.8 million cars.

With its deep sector expertise and cutting-edge knowledge of new propulsion technologies, APC's role in building and advising project consortia helps projects start more quickly and deliver more value. In the longer term, its work to drive innovation and encourage collaboration is building the foundations for a successful UK industry.

In 2019 the UK Government created the Automotive Transformation Fund (ATF) to accelerate the development of a net-zero vehicle supply chain, enabling UK-based manufacturers to serve global markets. ATF investments are awarded through APC to support strategically important capital and R&D investments in the UK that will help companies involved in batteries, motors and drives, power electronics, fuel cells and recycling to anchor their future in the UK.

Magnets are critical to many sectors including automotive. The APC led the workshop and the writing of this report, but received excellent support from the Industrial Strategy Challenge Fund, Driving the Electric Revolution and the Department for International Trade and Industry. This joined-up approach is continuing to help build a magnet supply chain in the UK.

Section 1

Why are rare earth elements so crucial to net-zero?

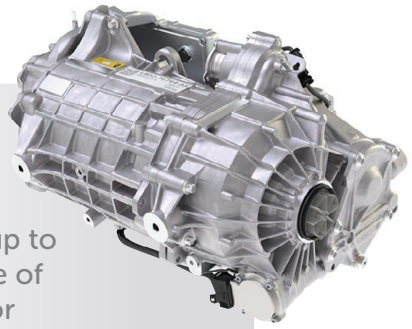
Magnets will be needed in ever increasing quantities

As we transition to greener technology there will be an increased reliance on modern products that include turbines, generators and electric motors. To get the most out of these products their efficiency needs to be high as possible, this requires them to be fitted with high-performance permanent magnets. These high-performance permanent magnets are typically made using Rare Earth Elements (REEs).

REEs, specifically neodymium, dysprosium and terbium, are used to make strong Neodymium Iron Boron (NeFeB) permanent magnets,[1] which have significantly higher magnetic field strengths than most alternatives.

Key facts

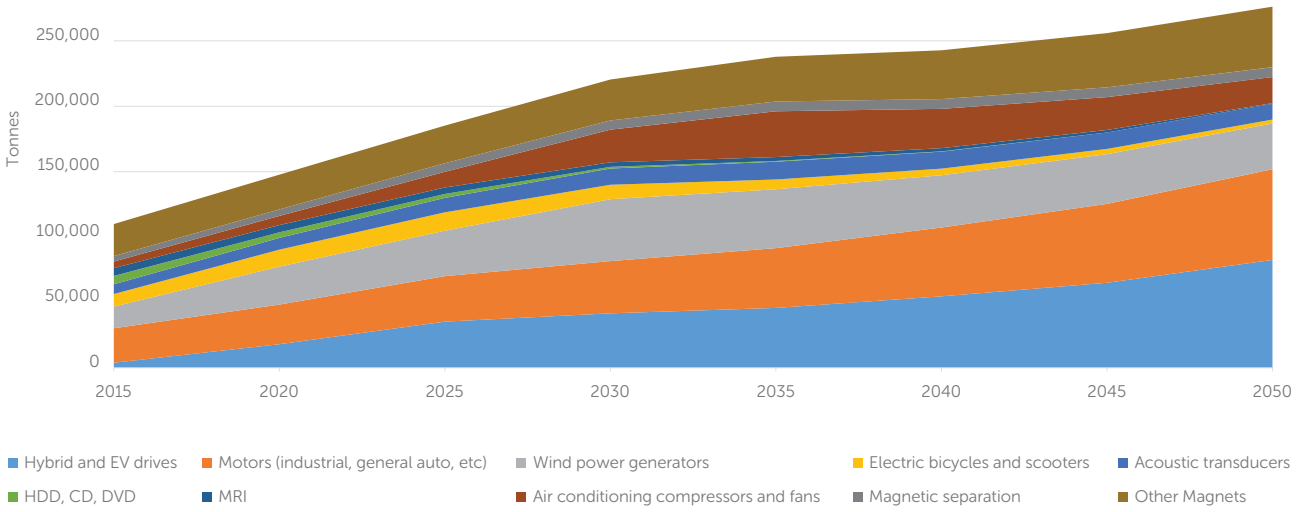
- UBS, multi-national investment bank, estimated from the breakdown of the GM Bolt electric vehicle that it uses 655% more REEs through the use of magnets than the VW Golf.
- Magnets are estimated to make up to 60% of the value of the electric machine.[2]
- Electric vehicles, industrial motors and wind power generators will use over 60% of projected magnet production by 2050, equating to nearly 250,000 tonnes per annum.
- Industry value is forecasted to rise five-fold from $2.98bn today to $15.65billion by 2030.[3]
- Shortages of key REE are expected from 2022 onwards driving the price upwards.



60%

Magnets make up to 60% of the value of an electric motor

Projected Magnet Production by Sector (tonnes)
Source: Magnetics and Materials LLC



1. To a lesser extend Samarium Cobalt (SmCo) magnets for very high-performance e-machines typically used in aerospace
2. https://neo.ubs.com/shared/d1wkuDlEbYPjF/
3. Source: Adamas Intelligence's report https://www.adamasintel.com/report/rare-earth-magnet-market-outlook-to-2030/

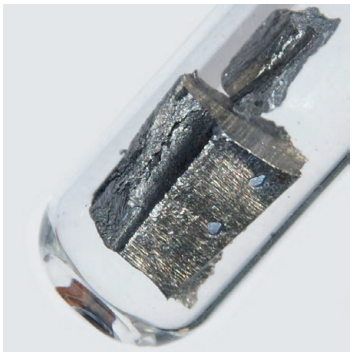
Rare Earth Elements are vital for a net-zero future

Rare Earth Elements (REE) are the fundamental chemical building blocks for all products and those specific to magnets are highlighted in the periodic table below. **Certain REEs are critical for the global transition to a net-zero economy** with the ambition that electrified transport is manufactured and powered by renewable energy.

Contradictory to their name some REEs are abundant but often not in concentrations to be able to extract on a commercial basis. This is due to the extensive processing required to remove the REEs from the very small quantities found in ore deposits.

Virtually all global rare earth deposits contain significant quantities of the key magnet rare earth element, neodymium. However, two of the other main REEs currently used in permanent magnets, dysprosium and terbium, are much less abundant and economic reserves outside China containing these two elements are limited.

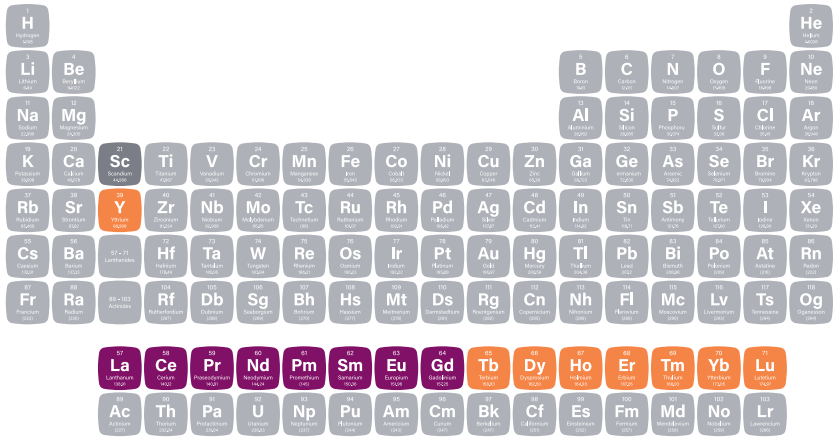
This report focuses on a subsection of REEs specifically used to create powerful permanent magnets needed in electric machines. Currently China has a dominance of supply of the REE market that has enabled Chinese companies to develop their supply chains and lead in the development of the technologies which use them.



Neodymium

Terbium

Dysprosium



Heavy Rare Earth Elements Light Rare Earth Elements

Sc (Scandium – an REE not designated as Light or Heavy)

Certain REEs are critical for the global transition to a net-zero economy with the ambition that electrified transport is manufactured and powered by renewable energy.

Bayan Obo mine, China

Section 2

Supply chain overview

The global market for rare earth elements

As part of the 'Made in China in 2025' strategic plan, the Chinese government has taken a lead in key aspects of the value chain. This has resulted in a near global monopoly in mining, refining and magnet manufacturing, effectively controlling over 90% of the market.

90%

China controls 90% of the REE magnet market

China dominates this supply chain

Mining	Refining			Magnet manufacture	Motor manufacture
Ore	Rare Earth Oxide	Nd Metal	NdFeB Alloy	NdFeB Magnet	






Improving global access

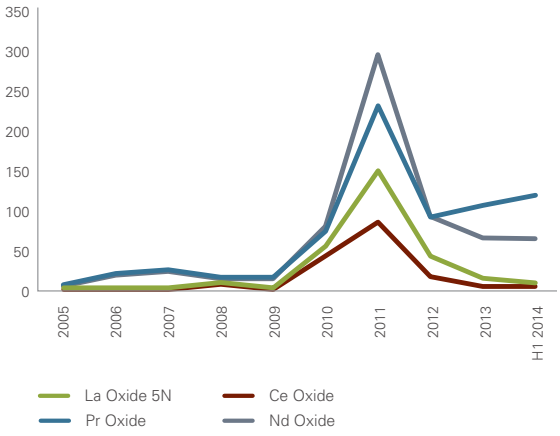
In recent years, China has influenced the market in terms of pricing and supply through export and production quotas. For example, in 2010 REE export quotas were lowered which caused an increase in price, which left some industries in a vulnerable position.

Since then efforts have been made to develop additional resources and reserves in countries including Australia, Brazil, Canada and the US. However, due to lower market prices many of these new enterprises were either put on hold or could no longer trade with the notable exception of Lynas Corporation in Australia and MP Materials in the US.

The inherent threat of instability to the global economy has been widely reported and studied by EU working groups[4] and the UK Parliament's Office for Science and Technology.[5] Escalating trade tensions between the US and China have brought this threat into sharper focus recently. China's strong position in REEs and large domestic market demand has enabled Chinese companies to build leading capability in wind turbines, electric motors as well as many other applications that require heavy and light REEs.

This challenge has been well described and extensively studied, and it is widely recognised that international collaboration is required to ensure fair, global access to rare earth elements.

The 2010-2011 REE price spike
LREE FOB prices evolution (USD/kgREO)



4. https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/erecon_en
5. https://post.parliament.uk/research-briefings/post-pn-0609/

Section 3

What should the UK do?

Turn a risk into an opportunity

If action is not taken, many UK-based sectors are at severe risk of becoming uncompetitive – including automotive, energy and defence and the organisations working with them.

The Green recovery and the transition to net zero are likely to be fundamentally undermined without strong industrial competitors with access to key ingredients.

Given China's dominance across the magnet supply chain, isolated interventions in the supply chain are unlikely to be effective. A comprehensive, co-ordinated and coherent strategy across the value chain is required. The APC and industrial partners recognise that the UK has the key building blocks to lead this strategy and as pointed out in the *Strategic UK Opportunities in Passenger Car Electrification* report,[6] magnet manufacturing is a key prospect with global reach.

Key opportunities to create a coherent supply chain

Access	UK access to cost-effective neodymium, dysprosium and terbium from Australia and other regions, supported by supply agreements for other REEs that are produced at the same time.
Processing	Upstream processing such as REE separation.
Manufacturing	Cost-effective, magnet manufacturing to reduce waste and labour intensity, ideally using less dysprosium and terbium
Recycling	Supportive measures to ramp-up magnet recycling and refining to improve competitiveness.

What can industry do?

Back in 2019, the APC ran a workshop with key UK and non-UK players from mining, electric motor manufacturing, disassembly and recycling organisations to develop a coherent way forward.

Insight obtained from the workshop highlighted key areas of expertise within the UK across the supply chain offering great capability (also reported in an article by the BBC[7]). Since this time the APC has continued to collaborate with industry to gain additional insight on the UK's position.

The UK has a unique strength in metal and alloy production through Less Common Metals Ltd and possesses a number of leading electric machine manufacturers and designers using high-end magnets across industries, such as wind, automotive, aerospace, marine, defence, health and industrial applications.

The workshop had two key outcomes:

1. A coherent, competitive strategy across the value chain is required.
2. Recognition that the UK could produce 4.5kT per annum of permanent magnets (enough for 4.5 million cars) in the UK by 2025.

Immediate actions

Collaborate	Collaborate with established, international mining companies to secure a stable, long-term supply of ores to feed into the supply chain.
Attract	Attract companies to build high-value, rare earth separation facilities in the UK.
Support	Develop local magnet manufacturing capability through scale-up and attract high-volume magnet manufacturers to the UK to supply local, European and US businesses.

6. https://www.apcuk.co.uk/opportunities-for-you/strategic-uk-opportunities-in-passenger-car-electrification/
7. https://www.bbc.co.uk/news/business-52701851

Supporting the industry to grow

Our aim is to help build a complete end-to-end magnet supply chain. Focussing on the immediate actions was widely praised and has attracted interest from significant players globally, who are able to strengthen the supply chain.

The process has started with initiatives across the APC, Driving the Electric Revolution (DER), Department of International Trade (DIT) and other agencies. These include public domain projects such as the Peak Resources investment in Teeside; a feasibility study led by SG Technologies looking into alternative, cost-effective routes to manufacture magnets; and recycling projects with Birmingham University spin-out HyproMag. In January 2021 Pensana Rare Earths Plc submitted a planning application to establish a rare earth processing facility at Saltend Chemicals Park, Yorkshire, England.[8] Additionally, the APC will have invested in the development of 1.2 million electric motors by 2027, adding to the significant growth in demand generated by electric vehicles.

In addition to this there has been significant industry investment as a response from organisations such as YASA, DANA, FORD and JLR into the development of e-machines.

In the magnet supply chain we have seen investments by SG Technologies in their manufacturing facilities, supporting YASA's product evolvement and continuing growth at Less Common Metals Ltd.

The total private investment required for this was estimated to be approximately £480m to get to 4.5kT/yr magnet manufacturing capacity (~4.5 million cars).

To provide an appropriate risk level for industry to invest to enable the growth of a domestic supply chain, long-term government policy support is necessary to create:

- High-value jobs
- Enhanced GVA
- Valuable export opportunities
- An industry of significant strategic importance.

£480m investment → 4.5kT capacity → 4.5m cars

Government and industry working together

In its current form, the market for REEs is fragile due to the dominance of one nation, companies in China control around 90% of the global market share. Heavy rare earth refining is currently dominated by China, which may lead to uncertainty in the REE prices within the global market. Strong governance and policy leadership from the UK (and other nations) is required to ensure our low-carbon industries can gain access to a stable supply of REEs and magnets. This not only bolsters our domestic manufacturing sectors but can also significantly strengthen future relations with trade partners around the world.

Government and industry should be encouraged to work collaboratively to develop a strategy to mitigate risk and encourage the investments that will be required. Supporting mechanisms could include:

- Development of a legal framework that leads to magnets that are sourced in an environmentally and ethically sound way, for example through introducing specific environmental regulation.
- Enabling key industry players to be sustainable and secure viability of the supply chain.
- Funding Capital and R&D administered through the government delivery agencies to support technologies that will enable the transition to net-zero emissions.
- Strong collaboration with nations such as Japan, Australia and the US.
- Establishing transnational funds and collaboration platforms to foster stronger international relationships and encourage further inward and outward investments.

8. https://www.mining.com/pensana-shares-surge-on-application-for-new-uk-facility/

Section 4

Summary

Permanent magnets containing REEs underpin the global road to net-zero. Globally it is appreciated that China has a near-monopoly on the current supply chain. The APC's *Strategic UK Opportunities in Passenger Car Electrification* report highlighted the opening for the UK to develop its magnet manufacturing capability and capacity through its supply chain to meet 4.5kT/yr (~4.5million cars) by 2025. The required investment to reach this ambition is not insignificant and requires the alignment for supply chain investments across the eco-system. Continued long-term government support is valued to reduce the risks enabling this industry to invest and enhance its leadership in the roll-out of EV, green energy and related technology.

If your organisation is one that is involved in this space please get in touch with the Advanced Propulsion Centre. It is important that as this strategy is moved forward we are supporting the growth and resilience of the supply chain.

Additional insight

Please contact Dave OudeNijeweme at the Advanced Propulsion Centre if you would like further information on the opportunities identified in this report.

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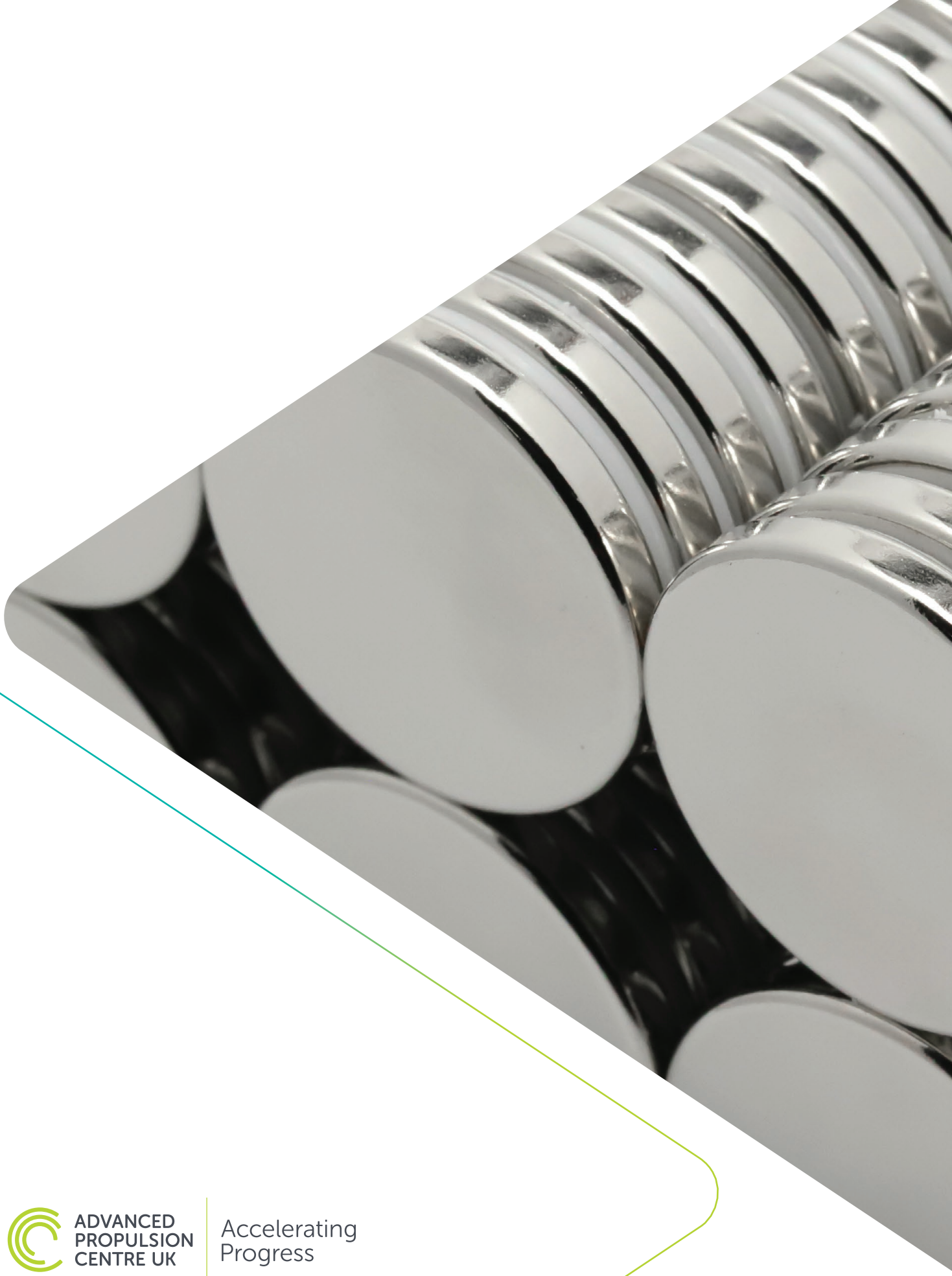
The Advanced Propulsion Centre would like to thank all the organisations listed below who contributed to this report – we appreciate your time and feedback on the document.



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