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Old magnets, new tricks: Europe's push to cut reliance on rare earths

From recycling old magnets to developing alternatives that avoid rare earths entirely, EU-funded researchers are exploring ways to make Europe's clean energy transition less dependent on overseas suppliers.

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Permanent magnets are a key component of most electric car traction motors, which turn the wheels, and of many wind turbine generators. Clean energy and clean technology increasingly depend on them. Yet Europe is vulnerable to disruptions in their supply chain.

"They are kind of indispensable for the energy transition," said Alexandre Damiens, a magnets and rare earths expert at French energy company Orano. Rare earth magnets are exceptionally strong, allowing motors to be smaller, lighter and more efficient.

Their production depends on rare earth elements, especially neodymium. China mines 60% of the world's rare earths used in magnets, refines 91% and manufactures 94% of permanent magnets, according to the International Energy Agency. This concentration exposes manufacturers to supply disruptions and trade restrictions.

Researchers in Europe are pursuing two ways to reduce that vulnerability: recover valuable materials from magnets already in circulation and develop alternatives that can do the job without rare earths.

This search for alternative solutions is also part of Europe's wider push on advanced materials – engineered materials designed to deliver improved performance in strategic technologies.

Giving old magnets a new life

Damiens is leading the EU-funded MAGELLAN, a 14-partner research initiative spanning eight European countries that is rethinking the magnet life cycle, from design and manufacture to dismantling and recycling. The team is focusing on electric car traction motors, while also exploring recovery from other forms of transport.

The researchers dismantled rotors – the spinning part of an electric motor that holds the magnets – from electric bikes, electric scooters and end-of-life electric cars to test how magnets could be extracted.

But recovering the components is only the first step. They must be made into new magnets that meet the performance demands of applications such as electric car traction motors.

The team has already produced high-performance magnets containing 25% recycled material by weight, Damiens said. The work is also helping build the specialised expertise European manufacturers need to compete internationally.

In this sense, MAGELLAN is not only about recycling, but also about developing advanced magnetic materials and manufacturing know-how that will allow secondary materials to be used in high-performance applications.

“This is building the skills capacity, enabling a new generation of magnet manufacturers in Europe that are able to incorporate secondary material and produce high-performance state-of-the-art products,” he said.

The researchers are also looking at how products can be designed so magnets are easier to remove at end of life, helping to prevent valuable materials from being lost or diluted in the waste stream or during recycling.

A coming wave of old magnets

The supply of discarded magnets is still limited, but it is expected to grow as electric vehicles reach the end of their lives and the first generations of offshore wind turbines are retired. Electric cars typically last 15 to 20 years, while offshore turbines can operate for around 30 years.

“Within the decade, the waste flow will be much higher,” said Damiens. “Recovering and recycling these rare earths will be more economically viable. You will still have some premium compared to business as usual, but there will be a strategic pay-off.”

Recycling may initially cost more than using newly mined materials, but it could strengthen Europe’s supply chain while reducing waste.

For illustration, a magnet manufacturing facility with an annual capacity of 2 000 tonnes could supply around 10% of the projected European electric vehicle traction motor market by 2040, or about 4% of the broader European permanent magnet market, the researchers estimate.

The team has demonstrated its manufacturing process on a pilot line in Grenoble, operated by Orano and the research organisation French Alternative Energies and Atomic Energy Commission. The next step is to incorporate recycled material into the process and demonstrate the resulting magnets in an electric motor.

The pilot line could also serve as a training centre, helping European manufacturers learn to work with recycled materials.

Going rare earth free

Recycling is only part of the answer. The EU-funded MagNEO project, coordinated by Norwegian research organisation SINTEF expert Spyros Diplas, is exploring magnets that avoid rare earth elements altogether.

Its 16 partners from 10 countries are developing AlNiCo magnets, an iron-based alloy containing aluminium, nickel and cobalt. Known for its use in guitar pickups, the material is also used in motors and sensors.

“AlNiCo magnets are not new,” said Diplas. “They have been developed since the Second World War. But not much has happened with their development in the last few decades.”

The MagNEO team is now revisiting the material using modern techniques, including 3D printing and experiments with different alloy compositions. Printing builds components layer by layer, making it possible to create complex shapes and internal structures that could help compensate for AlNiCo’s limitations.

MagNEO is a good example of advanced materials research at work, exploring how tailoring a material's properties could offer alternatives to rare earth magnets in some applications

Designing for circularity

Building in circularity is also part of the equation. In early experiments, researchers crushed old AlNiCo magnets and mixed them with plastic to create material for 3D printing. They also plan to recover valuable metals such as cobalt.

But AlNiCo cannot match the magnetic energy density of rare earth magnets – the amount of magnetic energy delivered in a given volume.

"It's not sensible to believe that we're going to get rare earth magnet performance with AlNiCo, or with any other magnets," he said. "It's physics – there are physical limitations."

Instead, the researchers are investigating whether improved magnets, combined with motor design alterations, can meet the needs of specific applications, including electric vehicles, wind turbines, heat pumps and ship propulsion.

"Our concept is that developing and hopefully improving the magnets will go hand-in-hand with alternative design of the motors," Diplas said.

By the project's end in 2028, the team aims to demonstrate that at least two magnet designs can be 3D-printed at industrial scale. Prototypes will be tested in selected systems alongside detailed computer simulations of complete motors.

Diplas believes that Europe should not dismiss alternative materials simply because they are less powerful on paper. With the right design, they could still provide a viable option for some applications, reducing the need for rare earths and the supply chain risks that come with them.

More than a materials challenge

Both approaches support Europe's efforts to secure materials for clean technologies. The Critical Raw Materials Act sets a target for recycling to meet 25% of the EU's annual consumption of strategic raw materials by 2030, while the Net-Zero Industry Act recognises permanent magnets as important to clean tech manufacturing.

These efforts also fit with the EU's wider focus on advanced materials as a key to competitiveness, resilience and the clean transition, including its planned Advanced Materials Act.

Turning new materials and recycling methods into viable supply options will require reliable performance, industrial-scale production and a convincing business case. MAGELLAN aims to keep rare earths in circulation for longer. MagNEO is exploring how to eliminate them from some applications completely.

Neither approach will remove Europe's dependence on overseas suppliers on its own. Together, however, they could give manufacturers more choice – and Europe greater control over the critical materials that will help power its clean energy future.

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More info

- MAGELLAN (CORDIS)
- MAGELLAN project website
- MagNEO (CORDIS)
- MagNEO project website
- Critical Raw Materials Act

- Net-Zero Industry Act