WASTE management world.

Recycling: Rarely so Critical

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As renewable energy finally takes off, China, which controls 97% of the global supply of rare earth elements, vital to much renewable technology, has tightened supply. As industry and governments around the world scramble for solutions, the complex process of recycling rare earths has moved into the spotlight. Ben Messenger investigates.

Over recent years there has been much discussion across the world of declining fossil fuel supplies, 'peak oil' and the increasingly urgent need for sustainable energy production. And that talk has not gone unanswered. According to the Renewable Energy Policy Network for the 21st Century (REN21) in 2009 over $160 billion was invested globally in renewable energy capacity and manufacturing facilities, a figure that in the face of severe economic conditions rose to $211 billion in 2010.

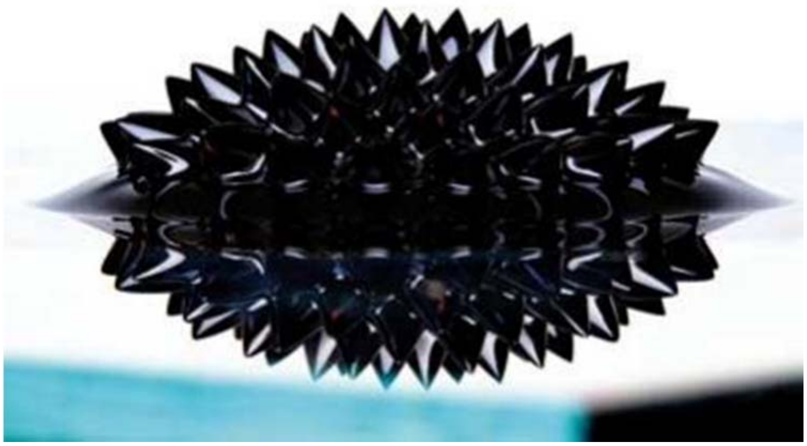
In the U.S. renewable energy accounted for an estimated 25% of newly installed generating capacity in 2010 and by the end of the year made up 11.6% of total capacity. Meanwhile China added some 29 GW of renewable capacity, which now accounts for around 26% of its total capacity. In the same year renewables accounted for some 41% of new capacity in the EU with 22.6 GW of installations. Globally 39 GW of wind capacity was installed taking the total to 198 MW, while the total existing Solar Photovoltaic (PV) capacity grew 72% in 2010 to around 40 GW.

Clearly, when it comes to renewable energy the world has put its money where its mouth is. Few could argue that's a bad thing, while some still claim that it's too little too late. Either way, for all the benefits the shift towards 'green' energy brings, it also creates problems of its own - or at least greatly exacerbates existing ones.

Critical materials

A recent report by the Stratfor Global Intelligence Service finds that a typical 1.5 MW wind turbine requires about 350 kg of Rare Earth Elements (REE) - mostly neodymium. REEs are a set of 17 elements in the periodic table, which despite their name, are almost all relatively plentiful in the Earth's crust, with Cerium being approximately as abundant as copper at 68 parts per million. However, these elements are highly dispersed and the rarity is finding them in concentrated mineral form known as a rare earth mineral.

The scarcity of concentrated deposits means that by comparison to other materials, REEs are only available in tiny quantities. The U.S. Congressional Research Service (CRS) estimates that global production of all 17 REEs combined amounts to just 124,000 tons (114,500 tonnes) annually, while world demand is 134,000 tons (121,600 tonnes) per year and projected to rise to 180,000 tons (163,300 tonnes) by 2012. According to the CRS new mining projects could take 10 years to reach production, and the shortfall is being met by previously mined stocks.



Ferrofluid demonstrates the powerful magnetic field of a neodymium magnet Credit: Gregory F. Maxwell

To exacerbate the situation, not only is demand outstripping supply, but the supply is controlled almost exclusively by just one country - China. The CRS estimates that China controls roughly 97% of the world's entire production capacity of REEs. However, the refining of REEs is potentially extremely harmful to the environment, involving boiling acid and other toxic chemicals. While many of its export customers remain sceptical of its motivations, under the guise of reducing the undoubted environmental damage being done in the country, over recent years China has imposed stringent production and export quotas on the industry.

Many governments around the world have hailed the hi-tech and 'green' industries as beacons of hope lighting the way to economic recovery. However these industries are susceptible to a faltering supply of REEs, so it is perhaps unsurprising that Japan, the EU, the U.S. and other countries have all voiced their displeasure at China's actions.

Strategies

In 2009 Japan published a document entitled 'Strategy for Ensuring Stable Supplies of Rare Metals'. As one of its four pillars for securing supplies of rare metals, including REEs, the strategy calls for the recycling of such materials from scrap. Furthermore, it urges the government to facilitate the recovery of used rare metals by establishing a new recycling system and better utilising the existing system, as well as promoting research and development of recycling technology. In addition, Japan's environmental ministry has recently set out plans to develop a system for recycling the rare and precious metals used in 45 gadgets such as mobile phones.

Strategies covering critical material supply, including many REEs have also been recently produced by both the EU and the U.S. Both of these documents call for the development of recycling technologies to help meet the rising demand for REEs.

Recycling: the easy option?

As politicians and policy advisers contemplate the questions posed by critical material supply chains, recycling is no doubt an obvious solution. But how?

The very nature of some of these materials means that often there is no component within a device that is made from an REE and easily separated. Rather that they have been an ingredient within the material of a given component. Shredding an electrical appliance into tiny pieces and separating the fragments is one thing, but separating the elements of a molecule is quite another. For example, rare earth magnets are alloyed metals consisting of roughly two thirds iron and one third rare earth metals, with neodymium added for a stronger magnetic force than in ordinary magnets, and dysprosium added to enhance heat resistance.

The process of separating and collecting rare earth magnets safely from products not only requires a great deal of time and effort but also uses acids and other chemicals for the process of extracting rare earths. This results in toxic liquid wastes, the disposal of which creates environmental and cost issues.

According to K.A. Gschneidner, Jr. of the Ames Laboratory, U.S. Department of Energy and Department of Materials Science and Engineering Iowa State University, there is little recycling of rare earth containing products, except in Japan. One of the major problems is that REEs only constitute a small fraction of the final product. As a result, the percentage is about the same as that of the poorer ore bodies which are mined today, or ~2%. For mobile phones and portable music devices it is much worse, the rare earth magnets weigh less than 0.1% of the device.

Furthermore, a recent study by European environmental research consultancy, Öko-Institut e.V., - Study on Rare Earths and Their Recycling - found that while electronic scrap is often recycled in classic pyro-metallurgical plants and metals recovered, rare earths are lost as they become a part of the slag which is not currently recovered. The reasons the Öko-Institut sites for this are dissipative applications, low prices and the tendency of REE to move into the slags of smelter plants. Nevertheless the sharp increase of the rare earth prices in 2010 and the high media coverage of possible supply shortages and export restrictions by China have put the issue of recycling rare earths on the agenda worldwide.

According to John Shegerian, chairman and CEO of Electronic Recyclers International (ERI), which is working with partners to develop the technology to recycle REEs from e-waste, the recovery of these materials will be "one of the next future trends of urban mining". However, Shegarian also points out that while some breakthroughs have been made, the technology is currently on the frontier of what is possible and not perfected yet.

Recent developments

The Japanese government has set aside some $1.2 billon for research into rare earth recycling, as well as opening new supply routes and the stockpiling of REEs. As part of this push, Japan's Ministry of Economy, Trade and Industry selected Tokyo based Hitachi for a project to find technology solutions for the recycling of rare earth metals from 'urban mines'.

Hitachi has developed a method to recycle high-performance rare earth magnets from the motors of hard disk drives (HDD), air conditioners and other compressors. Specifically, it has developed machinery to separate rare earth magnets from end-of-life products, and then to extract REEs from rare earth magnets. Experiments of neodymium and dysprosium extraction technologies were conducted using a dry process rather than using acids and other chemicals.

For HDDs, a drum type unit spins to shake and prang the HDDs continuously, which loosens screws and disassembles the HDDs into their structural components such as the casing, disk, and rare earth magnet. Because the components containing rare earth magnets emerge from the machinery separately, workers can pick out the desired components easily by visual screening. Non rare earth materials are removed, heat is applied to distil the excess extraction material, and rare earths alloy remains.

The machine has a capacity to process around 100 magnets per hour - around eight times faster than using manual labour. Hitachi aims to commence full recycling operations by 2013.

A world of opportunity

The Öko-Institut estimates that around 20% of REEs are used in the production of high performance magnets, such as those used in a range of devices from hard drives to wind turbines. However, the largest single use comes from the glass polishing and ceramics industry, which includes solar panels and display technologies. Catalysts including those used in the automotive and petroleum refining industries account for a further 20%, batteries 18% and lighting 7%. The remainder is used in a myriad of products and processes from water treatment to missile production.

While the number of solar PV panels reaching end-of-life is currently very low, the industry has enjoyed a meteoric rise of late, and in coming years the quantity of solar panels entering the waste stream will increase exponentially. According to Jan Clyncke, managing director of European solar panel recycling network, PV CYCLE, recycling operations have already started across Europe. For Cadmium-Teluride based panels the recycling process begins by crushing the module and separating the different fractions. This recycling process is designed to recover up to 90% of the glass and 95% of the semiconductor material.

Hitachi's dry recycling system can separate and process the rare earth magnets in hard drives

Meanwhile, automotive catalysts enjoy a very high recycling rate. However, the process is focused on the recovery of valuable platinum group metals. The recovery of the REE content, mainly cerium, from these catalysts has not yet become a focus. Currently these elements are moved into the slags from smelter processes due to the high affinity of the REE to oxygen. With the low cost of Cerium it's debatable as to whether recovery of REE from spent automotive catalysts will be prominent in the future.

The recovery of REE from lighting is however taking place. According to Mark Smith, president and CEO of Molycorp, which claims to be the western hemisphere's only producer of rare earth oxide, rare earth phosphors in compact fluorescent light bulbs are prime for recycling. Europium, yttrium and terbium are used in a powdery form in the light bulb itself. These powdered rare earths can be reprocessed and reconstituted for use by light bulb manufacturers.

The future

The Öko-Institut suggests taking action in the short term in order to establish a European recycling scheme for REEs and proposes the development of a recycling scheme based on the following steps prior to a large scale implementation:

- Forming a European competence network with recyclers, manufacturers and politicians
- Basic research is necessary as few companies in Europe are involved in rare earth refining
- Material flow analysis to identify the main waste streams
- Integrate REE containing waste collections into existing schemes such as the WEEE Directive
- Major R&D projects into the complex chemical processes
- Analyse whether the European Investment Bank could reduce financial risks for investments
- Adapt the legal EU framework in order to optimise post consumer rare earth recycling.

Conclusions

The concept of 'peak oil', the point at which the world reaches the maximum rate of petroleum extraction, is widely understood. Some argue that REEs are also reaching a similar point, and that if it has not happened already, the point at which the global supply of these materials is unable to grow will soon be upon us. With so many key industries dependent on REE supplies it seems that there are only three options; increase supply, reduce consumption or recycle existing supplies.

Fuelled by the rise of renewable energy it does not seem likely that demand for REEs is going to fall anytime soon, and new supplies will be slow to arrive. Up until now very little recycling has taken place, partly due to the complexity of the processes and partly due to the low price of virgin materials. However, the dramatic increase in prices precipitated by China's actions has for the first time provided the opportunity to build an economically viable recycling industry for REEs.

And with Japan's environmental ministry now developing a system to recycle rare and precious metals in 45 gadgets, including the mobile phones, other countries could soon follow.

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