A Circular Economy for Niobium

The Challenge of Recycling

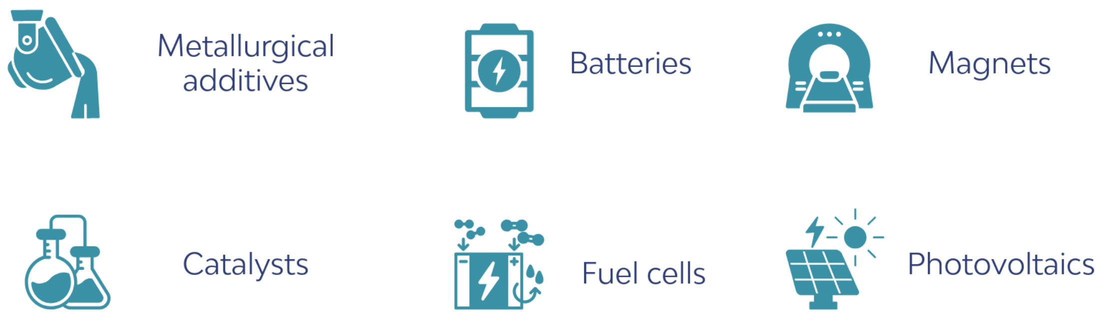
CRITICAL MINERALS

Critical minerals are metallic and non-metallic elements on which developed economies are increasingly dependent to provide clean energy and digital communications. However, their growing importance brings significant risks to the security of their supply. These risks arise from factors such as rapid growth in demand, high concentration of supply chains in particular countries, primary sources being located in conflict zones or high levels of price volatility. In response, governments in the UK, EU, US and elsewhere are developing strategies to ensure security of supply to enable the continued support of their technological and environmental goals. The UK government has identified 18 such critical minerals [1], one of which is niobium. This white paper will examine the implications, for products containing niobium, of an increased focus on resource efficiency and adoption of circular economy principles. The important and as yet little explored area of recycling is highlighted.

Niobium is a versatile element. It acts in numerous and diverse ways to provide a range of physical and chemical properties increasingly valued in modern industrial applications. The single largest use of niobium is as an alloy addition in high strength low alloy (HSLA) steels where levels of around 0.03% - 0.04% (by weight) are conventionally used to increase strength and toughness.

Recently there has been increased research interest in the wider commercial potential of niobium in addressing major societal challenges such as the digital transition (known as 'Industry 4.0') and the net-zero economy.   Dominant in the field of new application is energy storage and foremost among the researchers exploring the role of niobium has been Nobel laureate Prof. Stanley Whittingham. Some examples of niobium's versatility are shown below.

Main applications of niobium

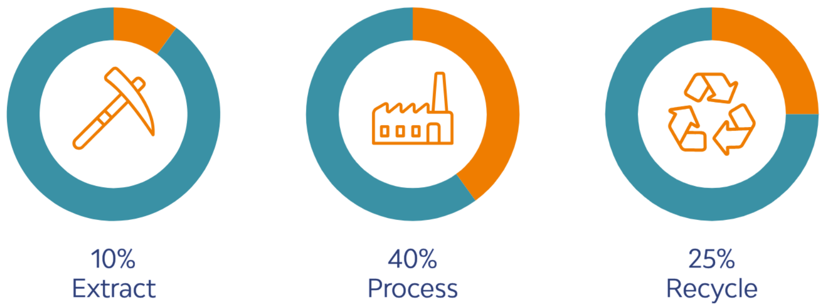


Primary niobium is predominantly sourced from abundant but non-renewable geological sources which are geographically highly concentrated, Brazil being the largest producer accounting for around 88% of world production [2]. As a consequence niobium is identified as a critical mineral (UK) or critical raw material (EU, US). Criticality assessment is the process of understanding and determining those materials that have a fundamental role in supporting modern economic prosperity and technological success. For example, zero emission vehicles, low carbon energy production and digital systems are all enabled by the use of critical minerals and access to those materials is, therefore, a concern for the security and sustainability of the UK economy.

EUROPEAN POLICY DRIVERS

The European Union's (EU) Critical Raw Material (CRM) Act came into force on 23rd May 2024 [3]. The primary objective of the EU CRM Act is to "ensure access to a secure and sustainable supply of critical raw materials, enabling Europe to meet its 2030 climate and digital objectives". The CRM Act proposes benchmarks, with the provisional agreement specifying that the EU should have the capacity to extract 10%, process 40%, and recycle 25% of its annual consumption of strategic raw materials (SRMs) by 2030. In addition, no more than 65% of the EU's annual consumption should be from a single third country. Whilst niobium is not designated as a strategic raw material, the EU CRM Act is indicative of a wider desire to reduce dependency on supply from outside countries and increase the availability of resources from within the EU. Recycling is one approach to achieving this aspiration.

2030 targets for strategic raw materials



The lifetime of products using niobium varies considerably: gas turbine blades may be replaced several times during the life span of a jet engine, MRI scanners with niobium containing superconductors are often reconditioned with the superconducting coils being re-used in refurbished machines and an electric vehicle battery may reasonably be expected to last for the lifetime of the vehicle (ca. 14 years in the UK). However, product lifetimes are not indefinite and as these important applications continue to grow there will inevitably be a reliable waste stream of niobium-rich products requiring recycling.

The current end-of-life recycling input rate (EOL-RIR) for niobium is estimated at <1% [4]. (et al. EOL-RIR is the input of secondary material arising from scrap to the total quantity of primary and secondary material consumed. This definition refers to functional recycling where materials retain the same functionality as in their primary application. Although steel is the most recycled material in the world, niobium is generally dissipative as a result of being diluted by the presence of low alloy steels in the scrap recovery process. Where scrap containing niobium is collected and reused in the steelmaking process, its functional role can be restored with further additions of primary material.

In other important applications concentrations of niobium can be significantly higher than in HSLA steels. For example, nickel-based superalloys, used in jet engines, may contain around 5% niobium by weight, superconducting wires used in the magnets of MRI scanners, high energy physics and fusion research contain typically 30-50% niobium depending on the specific composition. Next generation lithium-ion battery materials that enable fast charging and stable delivery of high energy densities may contain 15-20% niobium and with an increasing focus around the world on electrification of transport this application could become a major consumer in the next 10 years.

RECYCLING NIOBIUM

The convergence of the circular model of resource management and the recognition of the importance of critical minerals within that process will see an increased focus on recycling as a valuable secondary source of niobium. One of the most likely candidates for recovering niobium from end-of-life applications is hydrometallurgy . This is a multi-step process that starts with the initial dismantling, segregation, shredding and grinding of scrap materials to provide a feedstock for the recycling process. The hydrometallurgical process itself uses acid leaching to break down the alloy followed by separation, purification and calcination leading ultimately to a compound such as niobium pentoxide. This process ensures the efficient recovery of niobium while addressing the specific challenges posed by the alloy composition and the presence of other materials.

Hydrometallurgy involves the use of aqueous solutions for the recovery of metals from ores, concentrates, and recycled or residual materials.

Important to the success and sustainability of niobium recycling are the economics of the process and these are likely to be a function of individual value chains and variables such as niobium content, specific recycling process, yield and quality of output product as well as the requirements of the target consuming market for the recyclate.

The development of a circular economy for niobium is strategically important to diversify the supply chain, reduce environmental burden and increase market acceptance of secondary products. Recycling is technically feasible using hydrometallurgy but further work is needed to validate the economics of specific value chains. It is no longer acceptable to consign valuable materials to landfill without considering the environmental impact and economic loss that arises. Circular Niobium is a platform seeking to bring together people and businesses to develop opportunities in the circular economy for niobium. We would welcome approaches from product manufacturers, recyclers, material suppliers and processors with a focus on future oriented and sustainable business models.

References

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