Sustainable Titanium Supply

Circular Economy Practices versus Rising Aviation Demand

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Aviation is currently undergoing an ambitious transformation towards a higher degree of sustainability. The multifaceted challenge encompasses the decarbonisation imperative, but also other key challenges as e.g. described in the "Fly the Green Deal". This includes the further integration of circular economy principles, which are already being applied in aviation to a higher degree than in other sectors, when considering lifetimes, product stewardship and maintenance, repair and overhaul activities. The extent to which circular economy principles can help address the identified key challenges and can be more than an end in themselves, however, remains unclear. Therefore, the potential of an increasing circularity in aviation remains largely overlooked, especially on a systemic scale.

This study aims to address this gap by examining to what extent circularity principles, such as remanufacturing and recycling, can ensure a sufficient supply to meet the rising demand of aviation for titanium. It is also discussed how circular economy principles are inherited in the aviation sector to date and what further steps have to be taken to get a clearer view on the potential for sustainable material supply from a circular aviation economy.

In order to do so, it is first necessary to present an aviation tailored version of the butterfly diagram. Secondly, a material flow analysis of the critical raw material titanium in the civil aviation sector is conducted by showing the historic, current and future titanium demand and supply. Furthermore, an analysis of the potential regarding stored aircraft is performed. These analyses are put into context of circularity principles defined by the butterfly diagram and the R-ladder. Titanium supply is chosen as use case, because of its high economic importance for the aviation sector in combination with its significant supply risk. The economic importance is due to its unique mechanical properties, which also enable lighter and more fuel efficient aircraft designs. The supply risk is grounded in a high import reliance of both main aircraft manufacturing companies in combination with a highly concentrated titanium production, most of it closely connected to China and Russia. Additionally, a majority of all mined titanium metal is flowing into the aviation sector already and the Russian invasion of Ukraine has resulted in increased titanium supply issues.

The results of this study show a drastic increase in the demand for titanium in the near future driven by ongoing growth in the aviation sector combined with a rising share of titanium in the bill of materials of modern aircraft. At the same time the potential amount of recyclable material from retired aircraft is not sufficient to mitigate the long-term trend of growing demand. While there is a potential to mitigate short term disruptions of supply chains by recycling retired or stored aircraft, for long term supply insurance either a drastic increase in raw material supply or other circularity principles such as reuse and remanufacturing have to be considered. They have the advantage to be applicable earlier in the aircraft lifetime, as well as ensuring a higher retained value of the product material system.

The presented study enables a deeper understanding of the circular economy potential regarding critical raw materials in aviation and therefore of circular economy in general. The presented methodology and data lay the basis for further studies regarding critical materials other than titanium, more advanced future scenarios and especially detailed studies regarding the specific effects of certain circularity principles with a focus on non-recycling activities.

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