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Metal supply constraints for a low-carbon economy?

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ABSTRACT

Low-carbon energy systems are more metal-intensive than traditional energy systems. Concerns have been expressed that this may hamper the transition to a low-carbon economy. We estimate the required extraction of Fe, Al, Cu, Ni, Cr, In, Nd, Dy, Li, Zn, and Pb until 2050 under several technology-specific low-carbon scenarios. Annual metal demand for the electricity and road transportation systems may rise dramatically for indium, neodymium, dysprosium, and lithium, by factors of more than three orders of magnitude. However, in the base year 2000 the dominant uses were often in other sectors. Since growth in these other, previously dominant sectors has been less pronounced, the overall growth in society's metal needs is much less dramatic than in the electricity and transportation sectors. Total annual demand for the researched metals would rise by a factor of 3–4.5, corresponding to compound growth rates of between 2% and 3%. Such growth rates are similar or lower compared with historical growth rate levels over the last few decades. Prolonged higher levels have existed for copper, for example, with production rising by 8% per year from 1992 to 2006. Yet this state of affairs does not give cause for complacency. The richest resources may have been used, production is showing a tendency towards becoming very large-scale, and development times have increased, all leading to greater risks of disruption. It is therefore crucial, when developing specific technologies, that the resource-specific constraints are analyzed and options for substitution are developed where risks are high.

1. Introduction

Low-carbon energy systems are considerably more metal-intensive than traditional energy systems, and authors have warned that this may hamper the transition to a low-carbon economy (Alonso et al., 2012). Especially assessments focusing on the implementation of low-carbon technologies in the energy and transportation sectors show a dramatic increase in the metal demands of those sectors (Kleijn et al., 2011; Roelich et al., 2014). For some metals it has been reported that the rapid increase in demand is not problematic. Availability of Lithium, currently an essential element for electric vehicle batteries, is not expected to be a bottleneck for the rapid and widespread adoption of electric vehicles (Gruber et al., 2011). On the basis of a dynamic material flow model for the base metals aluminum, copper, chromium, nickel, lead, and iron, Elshkaki and Graedel (2013) found that supply is not limiting the introduction of renewable electricity generation technologies. On the other hand, they found that constraints in the supply of silver, tellurium, indium, and germanium could limit the introduction of some PV technologies (Elshkaki and Graedel, 2013). Most of these studies, however, did not take into account that the additional demand for low-carbon technologies should be considered in the context of a general increase in primary production of these metals for the entire economic system, also in relation to the build-up of infrastructure in newly developing countries.

This paper investigates potential bottlenecks in the supply of a wide range of metals, assuming the gradual introduction of far-reaching climate policies leading to full global implementation by 2050. We use a novel combination of methodologies, covering both the power generation and automotive sectors in detail and the broader economy more generally.

The novel aspect of our method is that specific data on the metal requirements for low-carbon energy and energy technologies are analyzed in combination with long-term socio-economic scenarios implemented in a global multi-regional Input-Output model, which captures the global metal requirements and global greenhouse gas emissions of the global economy. This allows us to create a consistent scenario of metal demand and greenhouse gas (GHG) emissions. For instance, if mining of a particular metal increases, there will be an

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