Abstract

The transition to a sustainable and carbon-neutral economy is increasingly constrained by the availability and management of critical materials. This research delves into the complexities surrounding these materials, with a focus on their role in green technologies such as electric vehicles and wind turbines. This thesis presents an exploration into the integration of Material Flow Analysis (MFA) with Input-Output (IO) methodologies, a union pivotal to the field of Industrial Ecology and particularly crucial in the study of critical materials. This integrated approach, forming the backbone of the research, enables a comprehensive examination of the flow of materials and their economic ramifications, essential for understanding and managing the complex dynamics of critical resources in a sustainable manner. Structured around three distinct case studies, the thesis delves into various dimensions of critical materials, with a specific focus on nickel due to its significance in renewable technologies.

The first case study utilizes a Multi-Regional Input-Output (MRIO) framework for an in-depth supply risk assessment of global nickel products. By incorporating a range of socio-economic and environmental indicators, this study provides a nuanced understanding of the vulnerabilities and geopolitical interdependencies within the nickel supply chain.

The second case study extends the scope by integrating Complex Network Analysis (CNA) with MRIO, offering a detailed exploration of the global nickel supply chain. This approach illuminates the dynamic trade relationships and strategic roles of different countries, revealing the intricate network that sustains the global trade of nickel.

In the third case study, the research takes an innovative turn by combining dynamic Material Flow Analysis (dMFA) with MRIO to project future demand for critical materials like Cobalt, Lithium, Neodymium, and Dysprosium under varying low-carbon energy scenarios. The findings from this study are critical, highlighting substantial supply risks for certain materials and the potential of recycling in alleviating these concerns.

Throughout the thesis, the complexities and challenges inherent in the integration of MFA and IO methodologies are acknowledged, with emphasis on the limitations posed by data dependency and the intricacies of such analyses. The thesis concludes with strategic recommendations for future research directions, including the potential integration of other methodologies with the MFA-IO framework and improvements in MRIO modeling and data

collection methods.

Overall, this thesis makes a significant contribution to the field of Industrial Ecology by employing a multidisciplinary approach to the study of critical materials. It provides essential insights for policymakers and industry leaders, offering strategic guidance for the sustainable management of these materials, which is crucial for advancing the green transition.