大学院教育支援機構（DoGS）海外渡航助成金　報告書

Outcome report

計画名 **Plan**	Research Visit to Bavarian Center for Battery Technology and International Round Table on Materials Criticality, 2025
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研究科・専攻・学年 **Graduate school/Division/Year level**	Graduate School of Energy Science, Department of Social Environmental Energy Science/ Energy Economics/ D2
渡航国 **Country**	Bayreuth in Germany and Ljubljana in Slovenia
渡航日程 **Travel schedule**	07 年 02 月 05 日 ～ 07 年 02 月 25 日

Outline of the travel plan

This report outlines the impact of my recent research trip, made possible by the combined support of the Division of Graduate Studies Overseas research grant and the Graduate School of Energy Science GCOE funding. This journey encompassed a 12-day research stay at the Chair of Ecological Resources at the University of Bayreuth, Germany which is associated with the Bavarian Center for Battery Technology followed by attendance at the International Roundtable on Critical Minerals 2025 in Slovenia. My time at Bayreuth from 6th February 2025 to 17th February 2025 provided invaluable insights into incorporating the Economic Complexity Indicators in assessing the criticality of minerals. The exchange also led me to study various energy related indicators which can be used to assess the criticality of minerals and materials that will directly strengthen my research through this expert collaboration. The conference in Ljubljana, Slovenia, a seminal conference in the field of critical materials, offered a comprehensive overview of current research and future trends. The discussions and presentations significantly enhanced my understanding of the challenges and opportunities surrounding critical mineral resources, which will directly inform and improve my ongoing research. It also provided me with the opportunity to build the network and further research collaboration with academic experts and policymakers across the world.

Objectives of the Trip

My primary objective was to present my ongoing PhD research on cascading risk in mineral supply chain networks and solicit expert feedback. Secondary objectives included identifying potential research gaps and establishing professional connections.

Outcome

My research exchange at the University of Bayreuth, under the mentorship of Professor Christoph Helbig, associated with **Bavarian Center for Battery Technology,** was a period of intense intellectual growth and collaborative discovery. Professor Helbig's profound expertise in criticality illuminated the vital

connection between supply disruption likelihood and resilience, providing a powerful framework for integrated assessment. He emphasized the vast potential for research into resilience mechanisms for critical minerals, particularly those underpinning green energy technologies. . Due to the busy schedule of Prof. Helbig, I could not visit the Bavarian Center for Battery Technology lab, and the data acquisition could not be done. But his advice on theoretical framework still helped my research in strengthening the research modelling and methodology.

The laboratory's diverse environment, with researchers from Nigeria, Germany, and Iran, fostered a rich exchange of perspectives, significantly contributing to the research outcomes. This cross-cultural collaboration broadened my understanding of global resource challenges. Notably, attending a research discussion on the lifecycle of zinc and lead, conducted by one of Professor Helbig's students, proved profoundly insightful. The findings, which revealed that zinc recycling can be more energy-intensive and toxic than virgin production, challenged my initial assumptions about incorporating recycling as a universally positive indicator in criticality assessments. This thought-provoking discovery has prompted me to reconsider the complexities of recycling's role in sustainable resource management.

Professor Helbig's guidance also provided a nuanced understanding of the distinct European approach to criticality, contrasting it with US and Japanese perspectives. His collaborative work in Chile, a key lithium mining region, highlighted the Global South's crucial role in lithium supply security and underscored the ethical imperative of sustainable mining practices.

The collaborative atmosphere with Professor Helbig's PhD students further refined my methodology. Their expertise in lithium-ion batteries and criticality assessments, coupled with discussions on official government criticality indicators, significantly enhanced my research. This exchange not only expanded my research scope but also instilled a deeper appreciation for the global, interdisciplinary, and ethical dimensions of critical mineral supply chains

Figure 1: Prof. Christoph Helbig and his PhD Students at University of Bayreuth

Research Presentation and Feedback

The International Roundtable on Critical Minerals 2025, in Ljubljana, Slovenia, my first IRTC, was a transformative experience. IRTC is a premier forum for global leaders in critical materials, served as a pivotal catalyst for my research. My presentation, "Criticality Assessment: Cascading Risk in Multi-Level Materials' Supply Chain Network," illuminated the complex, interconnected nature of global supply chains and the omnipresent risk factors that permeate them. This work, which introduced a novel application of economic indicators within criticality assessment, resonated strongly with both academic and policy-focused audiences.

The invitation to participate in a high-level panel discussion further validated the significance of my research, particularly in addressing risk management within the Global North and South context. This platform allowed me to articulate the crucial role of economic theory in evaluating material criticality through the lens of supply chain networks. I was particularly encouraged by the positive reception of my work from Ton Bastein, Principal Scientist at TNO Netherlands, and Dr. Peter Buchholz, Head of DERA at BGR. They both expressed appreciation for my economic perspective on criticality assessments and eagerly anticipated the publication of my findings.

Moreover, my interaction with Dr. Luis Tercero Espinoza, Head of the Raw Materials Business Unit at the Fraunhofer Institute for Systems and Innovation (Fraunhofer Institute) facilitated a crucial dialogue on the practical application of criticality models. The discussions with policymakers, emphasizing the necessity for streamlined, real-world models, provided a critical contrast to the often-theoretical nature of academic research. This experience solidified my position within the criticality assessment domain, offering a unique opportunity to communicate my research vision and forge vital connections for future interdisciplinary collaborations. The conference, therefore, served as a vital global platform, allowing me to effectively communicate my research and positioned it for significant future impact.

Figure 2: My presentation at IRTC Conference, Ljubljana

Research Gap Identification and Future Directions

The international research visits at the University of Bayreuth and the attending this conference and engaging in discussions facilitated the identification of a significant research gap concerning the development of resilience mechanisms within criticality assessments. This observation informed me of the next phase of my research, focusing on strategies for mitigating supply chain vulnerabilities.

Figure 3: At the invited panel discussion at IRTC Conference

Networking and Knowledge Exchange

The research trip and conference provided unparalleled engagement with academic experts and policymakers from the European Union globally, gaining insights into diverse methodological approaches. Furthermore, I established valuable connections with representatives from JOGMEC and MUFG, fostering potential collaborations and knowledge exchange with the Japanese experts and researcher as well.

Research Implications

This research exchange and conference significantly contributed to the advancement of my PhD research. The constructive feedback received, the identification of a crucial research gap, and the extensive networking opportunities have provided a strong foundation for future research and professional development. The insights gained from policymakers regarding the translation of academic research into practical policy will be particularly valuable in ensuring the relevance and impact of my work.

Prospects for the future

Building on this success, I will publish a paper applying economic complexity to mineral supply chain networks. Furthermore, I will continue to keep exchanging my research with Prof. Christoph Helbig and will utilize his research expertise in research leading to my other part of the thesis. I will also develop a research exchange plan to pursue a research collaboration with TNO, Netherlands, at the invitation of Dr. Ton Bastein, ensuring my research gains global insights. This collaboration will undoubtedly open significant opportunities for myself and my lab at Kyoto University, solidifying our lab work and position as leaders in this research field.

Side Note on European culture, geographical landscape, architecture, trains and Cuisines

This research trip to Europe, beyond its academic achievements, provided a profound cultural immersion that will undoubtedly enrich my perspective. The experience underscored the importance of work-life balance in European culture, where evenings and Sundays are dedicated to personal time and family. This observation, rooted in legal regulations, highlighted a societal value that resonated deeply. The journey from Munich to Slovenia offered breathtaking views of the Austrian Alps, fostering a tangible appreciation for the region's geographical beauty.

Figure 4: Gothic Architecture (Left) at Bayreuth and Austrian Alps (Right)

Exploring Gothic architecture, palaces, and museums, particularly the historical old city of Munich, provided invaluable context for understanding European heritage. Discovering a dedicated Japanese room within the New Palace in Bayreuth created a powerful sense of connection to my own cultural background. The efficient, albeit occasionally delayed, German train system, with its dedicated bicycle spaces, showcased a commitment to sustainable transportation. The culinary experiences, particularly enjoying Franconian cuisine and beer, were a delightful highlight. **The student-centric pricing model observed in university cafeterias, where students receive significantly subsidized meals, is a practice I intend to advocate for at Kyoto University.**

Figure 5: Japanese Room in New Palace at Bayreuth

Important Point for Safety

Furthermore, my research visits coincided with the German election period and the unfortunate incident in Munich on 13 February 2025, the IRAC system proved to be an invaluable safety net. The prompt communication and support from the Japanese government and embassy reinforced my confidence in their commitment to the well-being of their citizens abroad. This experience underscored the importance of robust safety protocols and instilled a lasting appreciation for the support provided. These cultural and practical insights, alongside the academic achievements, will undoubtedly leave a lasting impact on my future work and contributions.