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Rethinking Energy Security for Net Zero: Introducing a Supply Risk Budget

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Extended Abstract

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Abstract Summary

Europe's energy supply risks were historically dominated by dependence on imported fossil fuels. While the expansion of clean energy technologies reduces parts of this exposure, it simultaneously introduces new supply dependencies, particularly in the extraction and processing of critical raw materials. At present, energy security in decarbonizing energy systems is shaped by a broad set of energy-relevant commodities spanning both conventional fuels (e.g., coal, LNG, uranium) and energy-transition materials (e.g., copper, cobalt). Consequently, Europe's dependence on a few exporting countries for key commodities potentially affects the availability and affordability of required energy transition inputs. As the European Union pursues climate neutrality alongside stronger energy security, understanding how supply risks evolve across commodities and interact with technology transformation pathways becomes critical. The core objective of this paper is to design a supply risk budget allocation framework that captures how supply risk has evolved across commodities in the past and how it may be allocated in future energy systems. The study develops a two-stage framework: first, a supply risk quantification approach is developed and applied to historical reference years (2010 and 2024); second, a European energy system optimization model is extended to endogenously link technology deployment choices to supply chain vulnerabilities and project supply risk trajectories for 2030, 2040, and 2050. Overall, we find that aggregate supply risk exposure declines as European energy systems shift from continuous fossil fuel imports toward capital-intensive clean technologies that, once installed, require no ongoing fuel inputs. While the transition introduces new dependencies on critical materials, these are largely concentrated in upfront deployment phases rather than persistent operational flows. As a result,

geopolitical exposure becomes less recurrent and more strategically manageable over time.

Presenting Author Biography

Helen is a 3rd year PhD student from the Energy Economics Group (EEG), TU Wien. Her research focuses on cross-border dependencies and how geopolitical risks reshape energy security in a net-zero energy system. Specifically, she investigates strategies to reduce supply dependencies on critical commodities and strengthen clean energy technology industries in Europe.