# The Cost of Shifting Supply Strategy: Balancing Cost, Risk, and Diversification in the EU's Solar PV Supply

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Solar energy is the fastest-growing renewable sector in the EU. Global solar PV demand is expected to reach 700 GW by 2030 to meet decarbonization targets. Despite market stability due to overcapacity, 95% of EU solar PV module imports come from China, raising concerns about supply dependence and energy security. Global dependence on China's solar module production represents an economic, political, and environmental vulnerability. The EU's strategic options to mitigate these risks include trade diversification, accelerated deployment, and stockpiling of solar PV modules. However, quantitative analyses on solar PV module diversification remain scarce, and energy system models still focus solely on cost optimization without accounting for geopolitical risks and supply concentration.

The core objective of this work is to model a cost- and risk-minimizing strategy to diversify the EU's solar PV module imports across multiple exporting countries.

Accordingly, the following research question is answered in this paper:

- How will the EU meet its solar module demand in 2030 while enhancing import diversification, reducing geopolitical risk, and ensuring cost efficiency?

This study employs a global trade model for solar PV modules and applies a Multi-Objective Linear Programming (MOLP) optimization to address the conflicting objectives of minimizing solar PV module supply costs, mitigating geopolitical risk, and enhancing diversification. The model determines the optimal trade flows between exporting and importing regions in order to meet regional demand in 2030 while simultaneously evaluating associated import characteristics such as supply costs, geopolitical risk exposure, and supply concentration. The analysis considers three scenarios: Business as Usual (BAU), Globalization (GLOB), and Deglobalization (DEGLOB). To address uncertainty in input parameters, the study also performs a Monte Carlo simulation.

The results show that the EU can meet its solar PV module demand while substantially reducing geopolitical risk and supply concentration by 2030, though only at the expense of higher supply costs. The BAU scenario already delivers a significant improvement over 2024, lowering geopolitical risk and concentration while keeping costs moderate. Achieving very low geopolitical risk levels (40.6% below 2024 values) or a highly diversified supply structure (HHI $\leq 0.15$) is feasible, but requires additional expenditures of approximately USD 50–200/kW relative to 2024 supply costs (USD 201.2/kW), depending on the specific configuration. These results illustrate the trade-off between conflicting objectives: enhancing diversification and reducing geopolitical risk increases resilience but comes at higher supply costs.