

Benefits of spatial integration and deployment coordination

Optimal allocation of wind capacity in Europe

Javier López Prol, Fernando de Llano Paz, Anxo Calvo Silvosa, Sungmin O

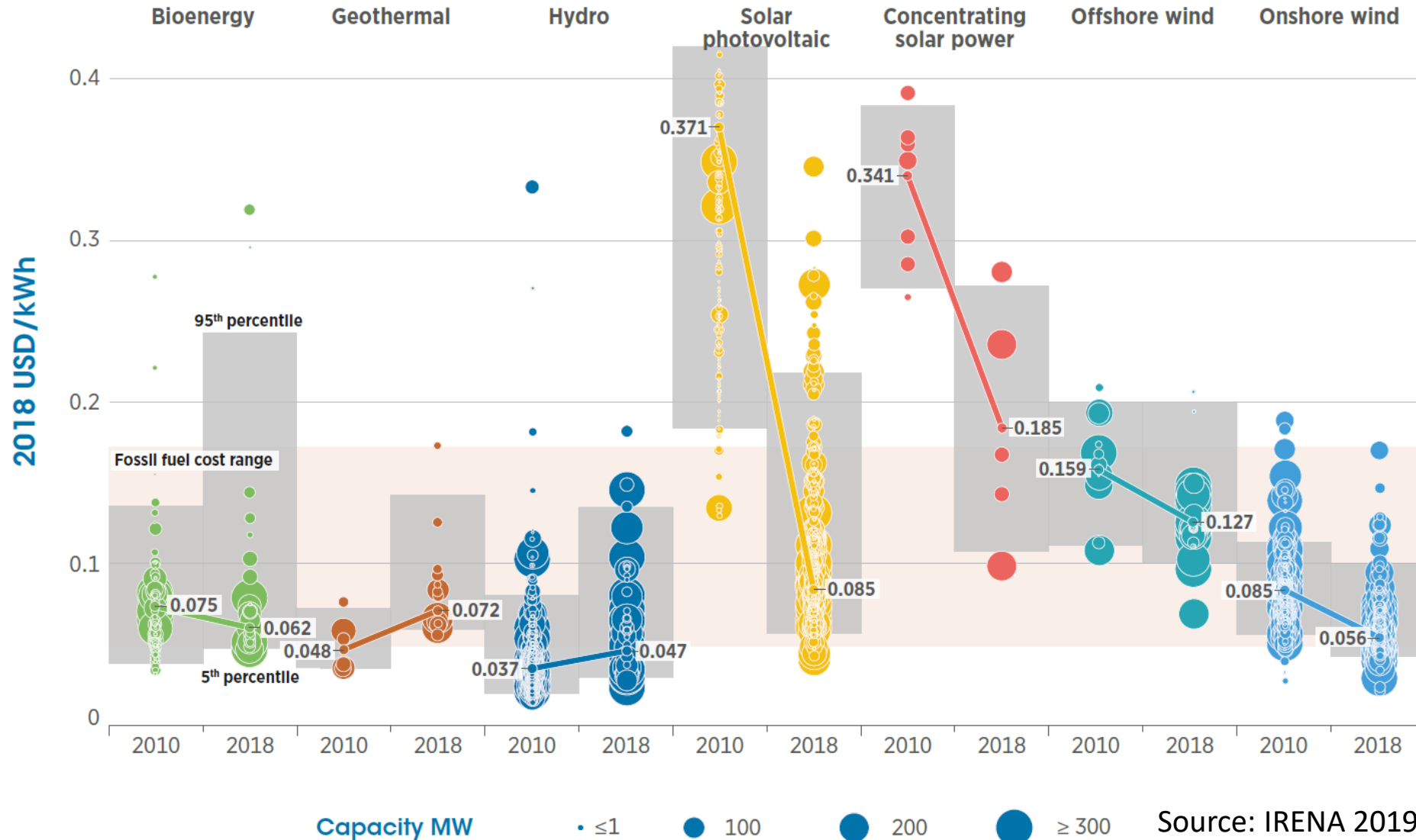
IAEE, Ljubljana, August 2019



Max Planck Institute
for Biogeochemistry



Problem

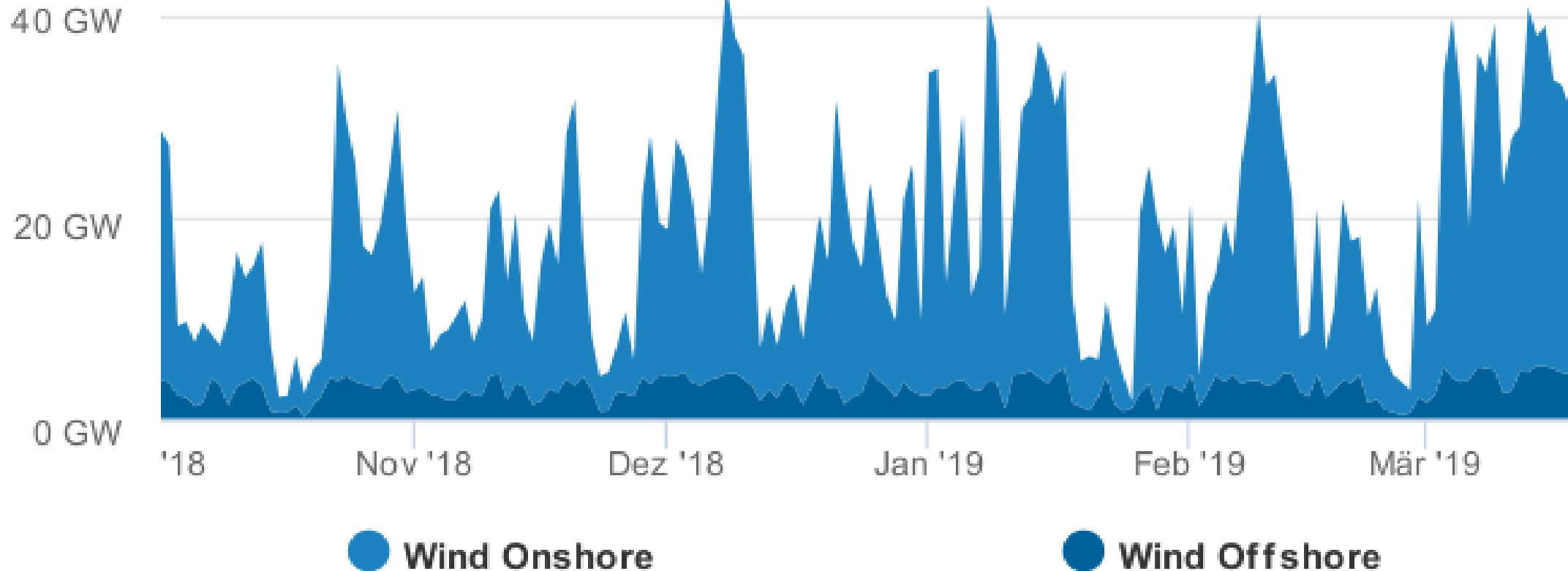


Wind power is one of the cheapest electricity generation technologies...

Problem

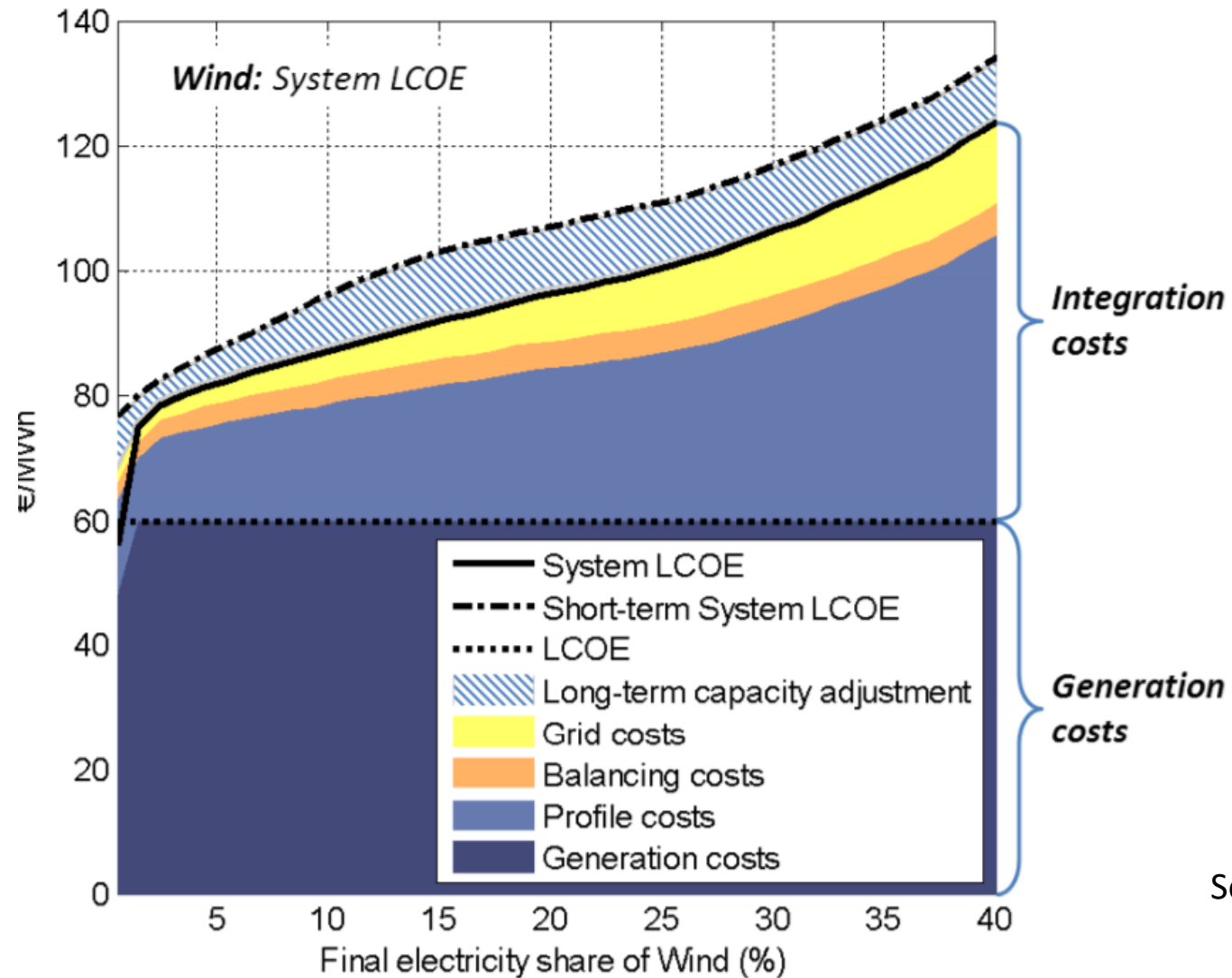
... but it is variable

Wind generation in Germany (October 2018 – March 2019)



Source: Agora Energiewende

Problem



Source: Ueckerdt et al. 2013

Problem

nature
energy

ARTICLES

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Start-up costs of thermal power plants in markets with increasing shares of variable renewable generation

Wolf-Peter Schill^{1*}, Michael Pahle² and Christian Gambardella²

The emerging literature on power markets with high shares of variable renewable energy sources suggests that the costs of more frequent start-ups of thermal power plants may become an increasing concern. Here we investigate how this develops in Germany, where the share of variable renewables is expected to grow from 14% in 2013 to 34% in 2030. We show that the overall number of start-ups grows by 81%, while respective costs increase by 119% in this period. Related to variable renewables' production, start-up costs increase by a mere €0.70 per additional megawatt hour. While the expansion of variable renewables alone would increase start-up costs, more flexible biomass power plants and additional power storage have counteracting effects. Yet changes in reserve provision and fuel prices increase start-up costs again. The relevance of start-up costs may grow further under continued renewable expansion, but could be mitigated by increasing system flexibility.

Solution

Spatial integration and deployment coordination

to optimize the capacity factor (CF) – variability (SD) trade-off

Optimal wind capacity *portfolio*

(shares of installed capacity per country)

to achieve max. CF per unit of SD

Method

Modern portfolio theory (Markovitz portfolio optimization)

$$\min(\sigma_p) = \min \left(\sqrt{\sum_{i=1}^n x_i^2 \sigma_i^2 + \sum_{i=1}^n \sum_{j=1}^n x_i x_j \rho_{ij} \sigma_i \sigma_j} \right)$$

s. t.

$$x_i \in \mathbb{R} \geq 0$$

$$\sum x_i = 1$$

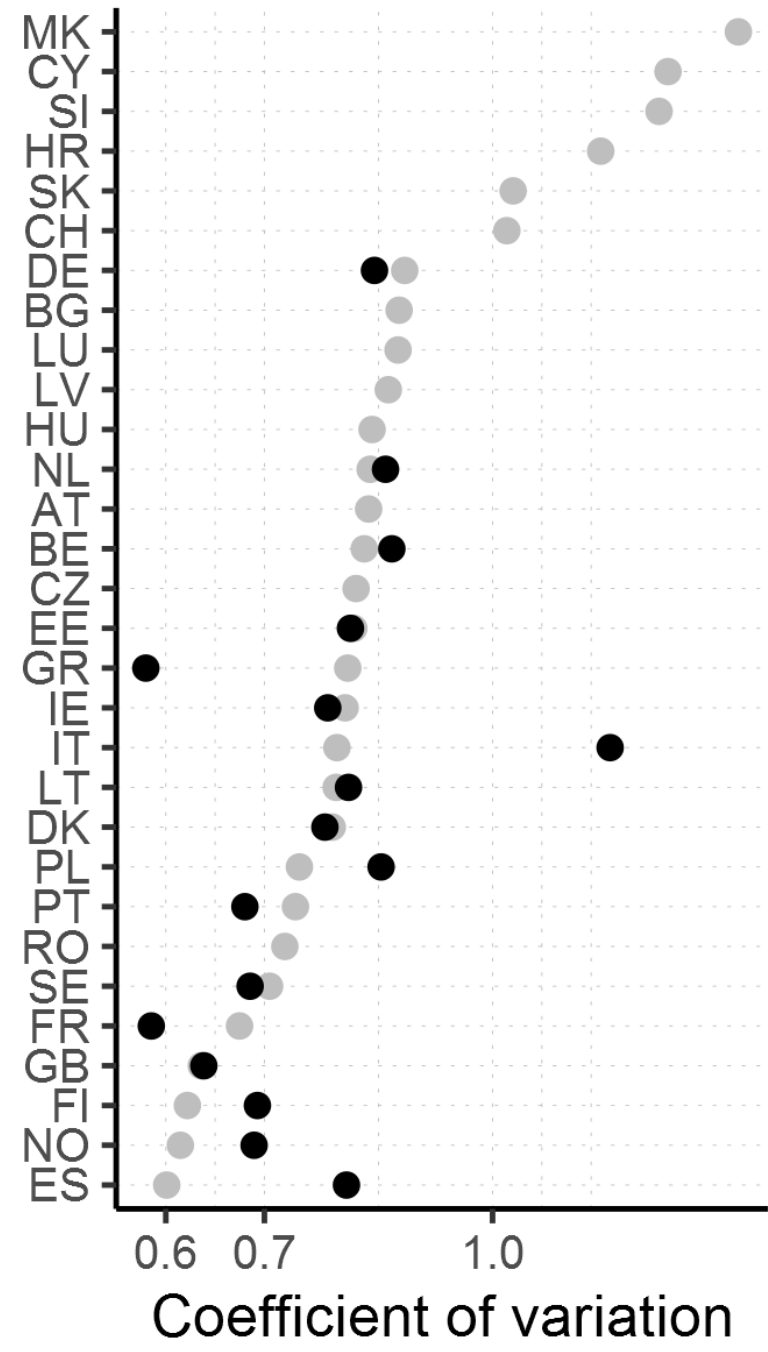
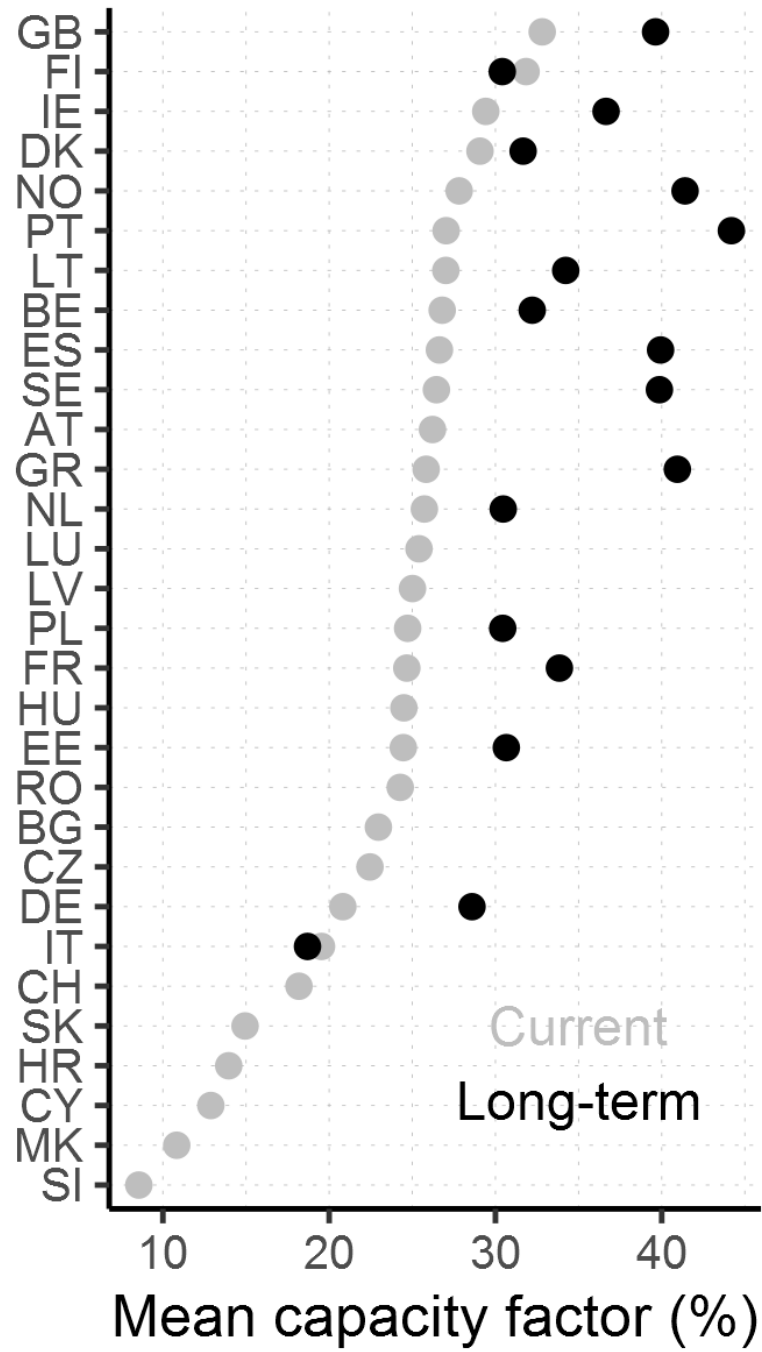
Data

Hourly CF

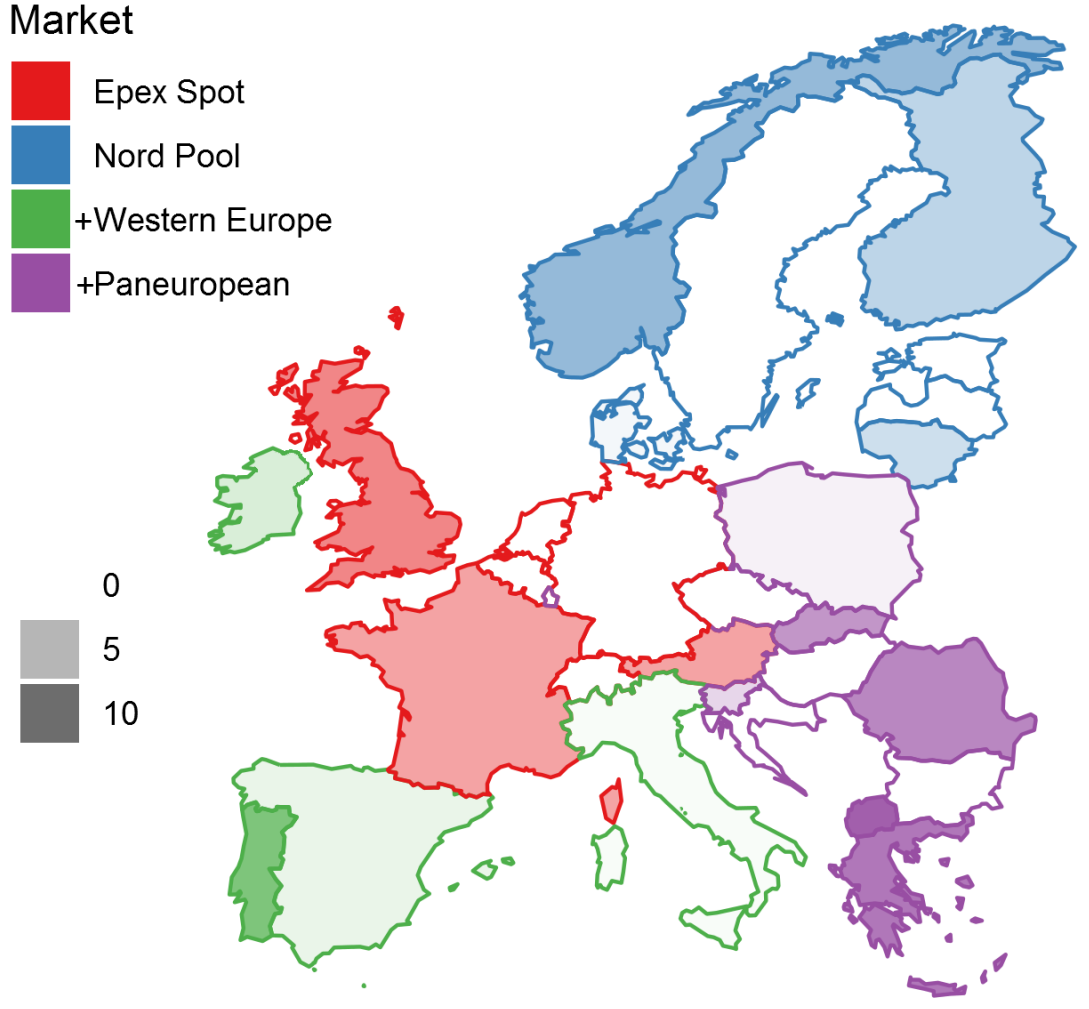
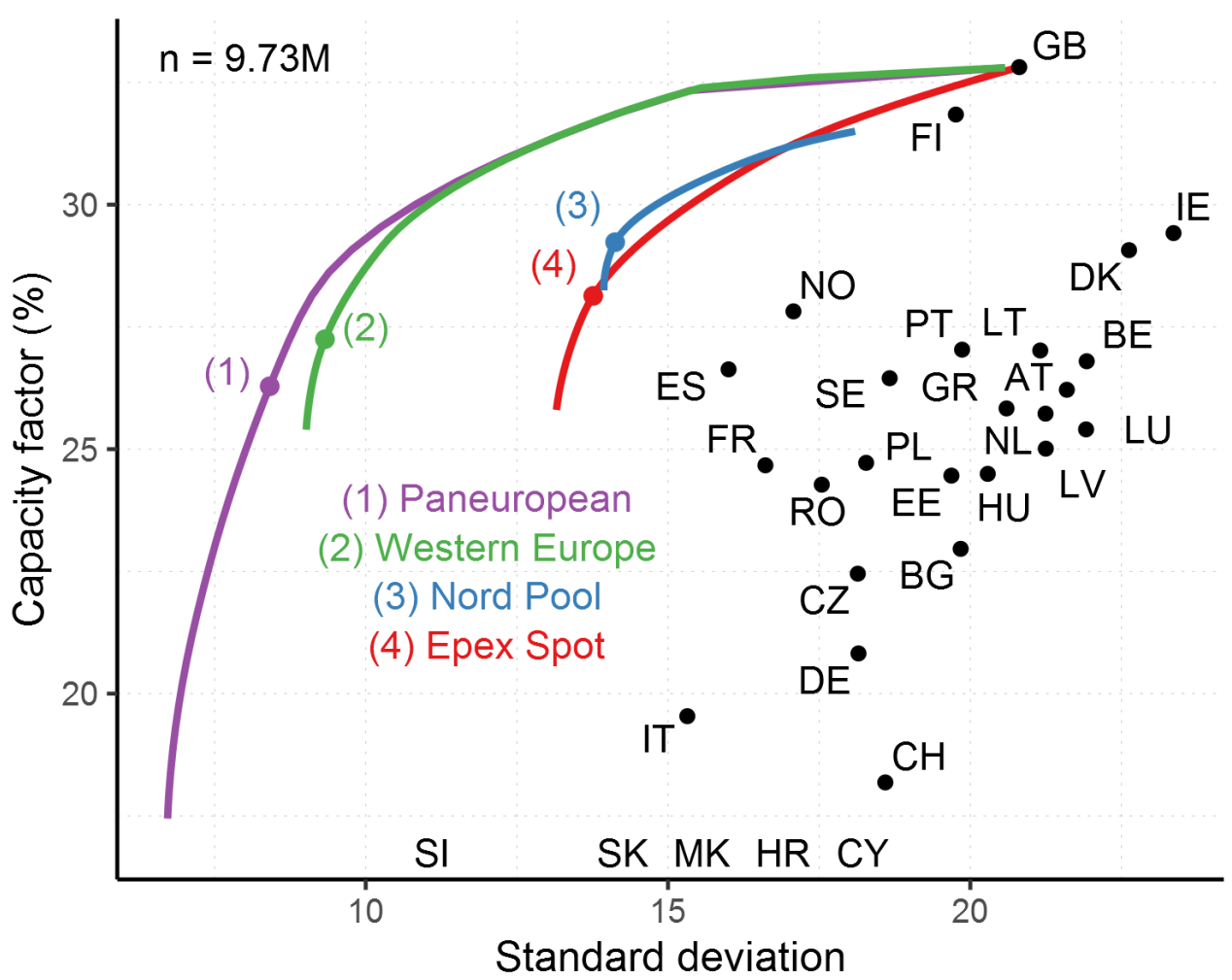
30 countries

30 years

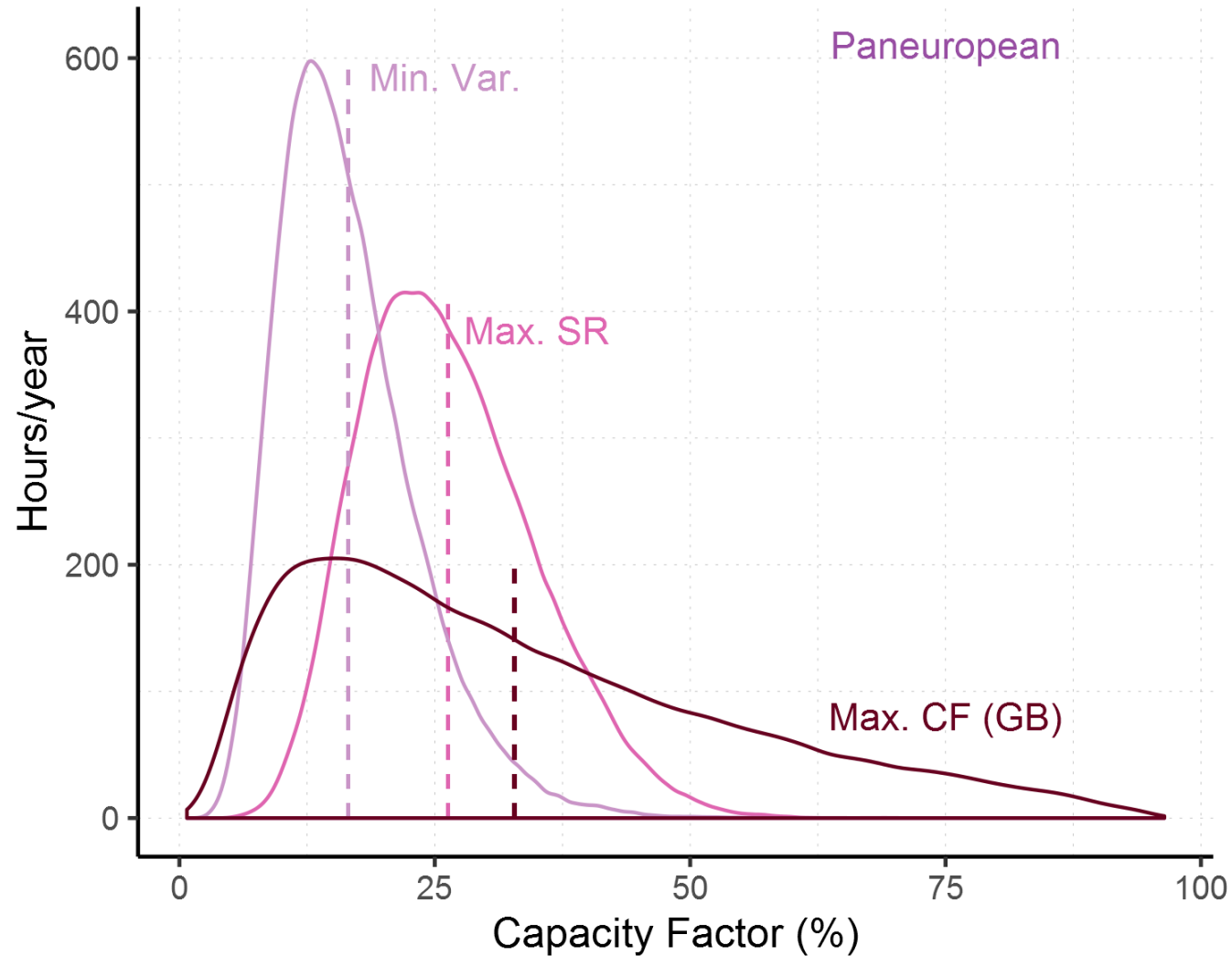
n = 9.7M



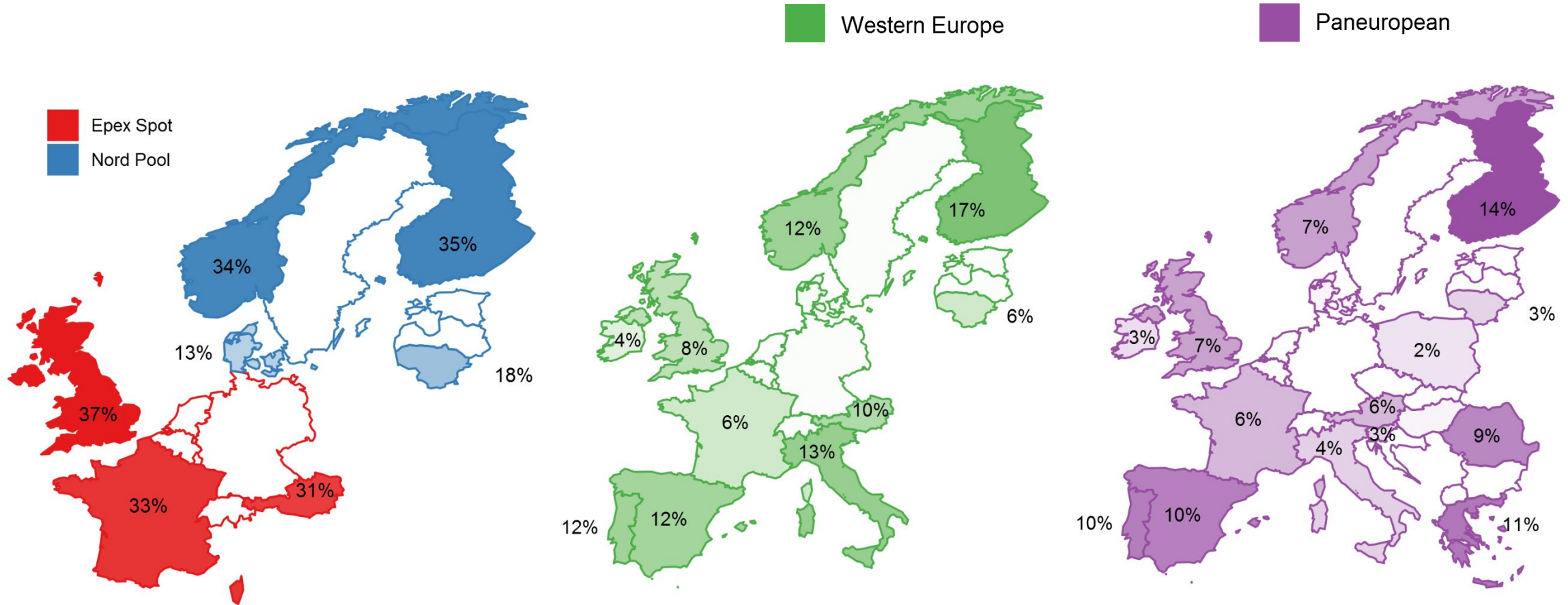
Efficient frontiers and optimal portfolios



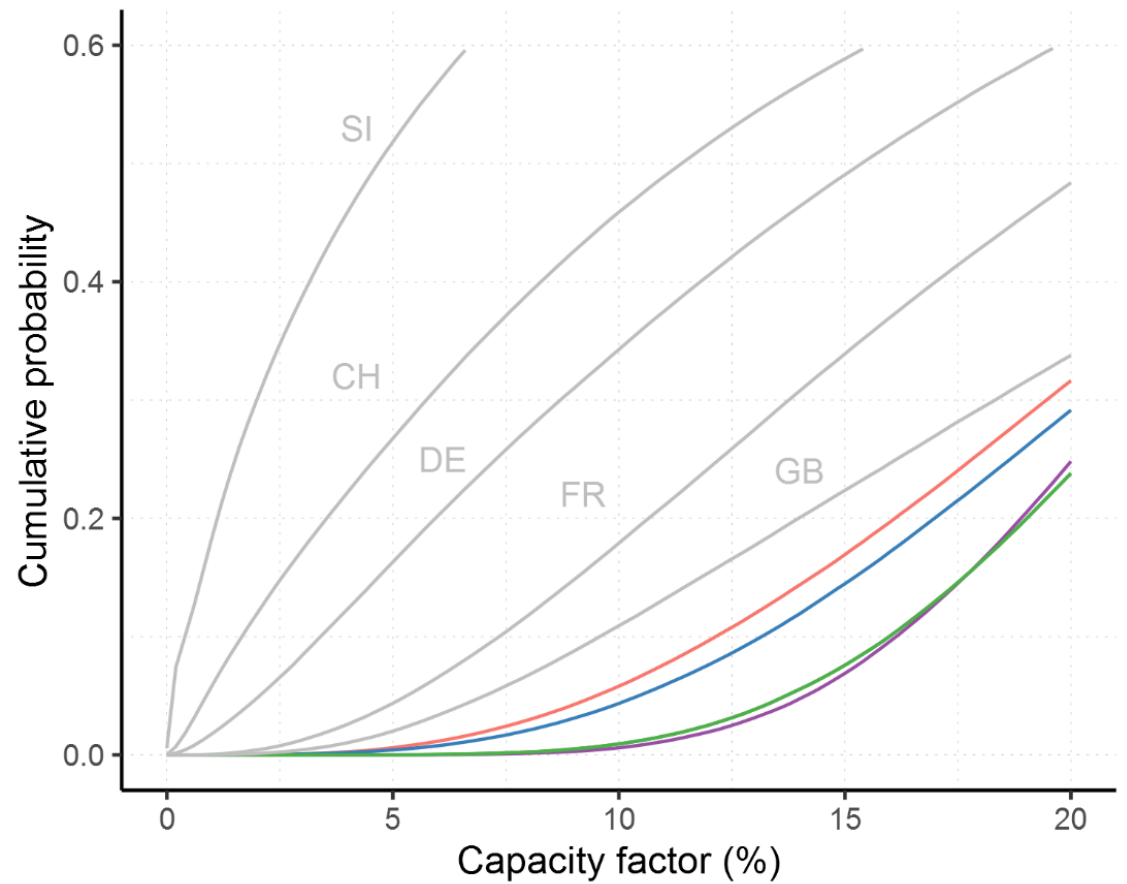
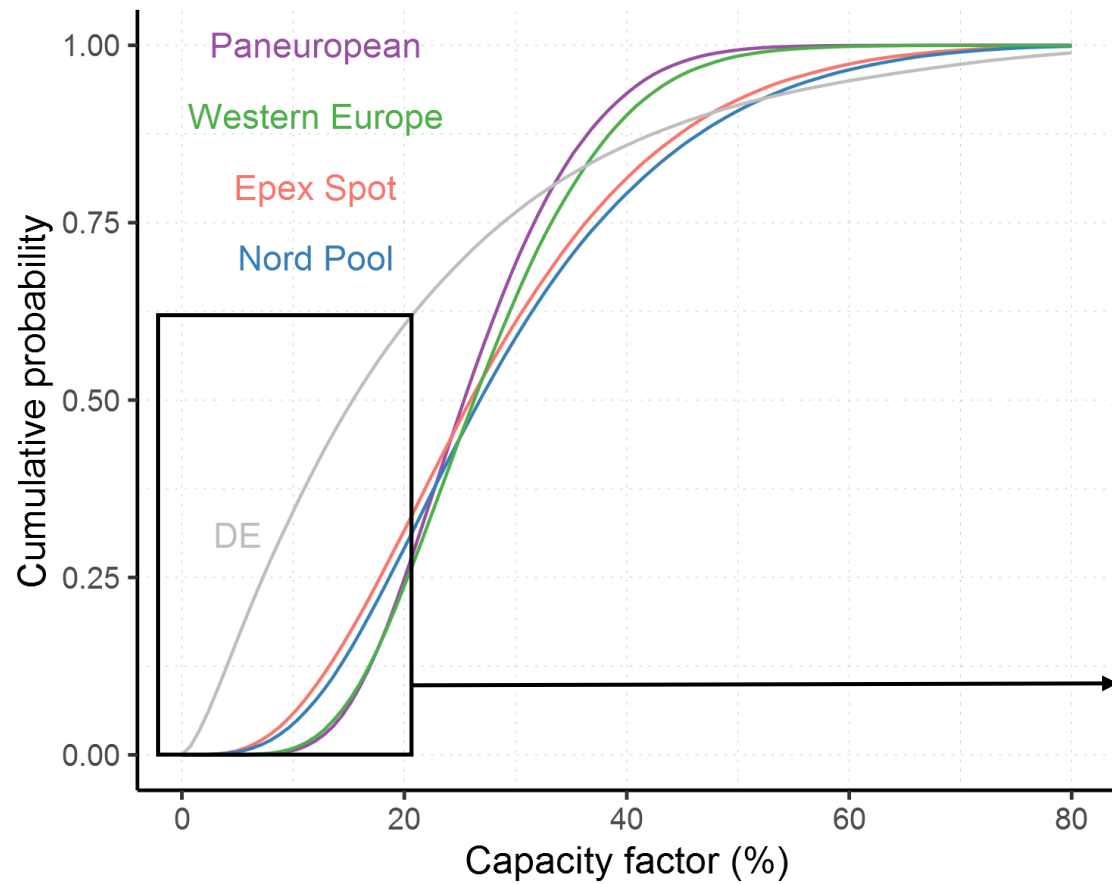
CF pdf of different portfolios



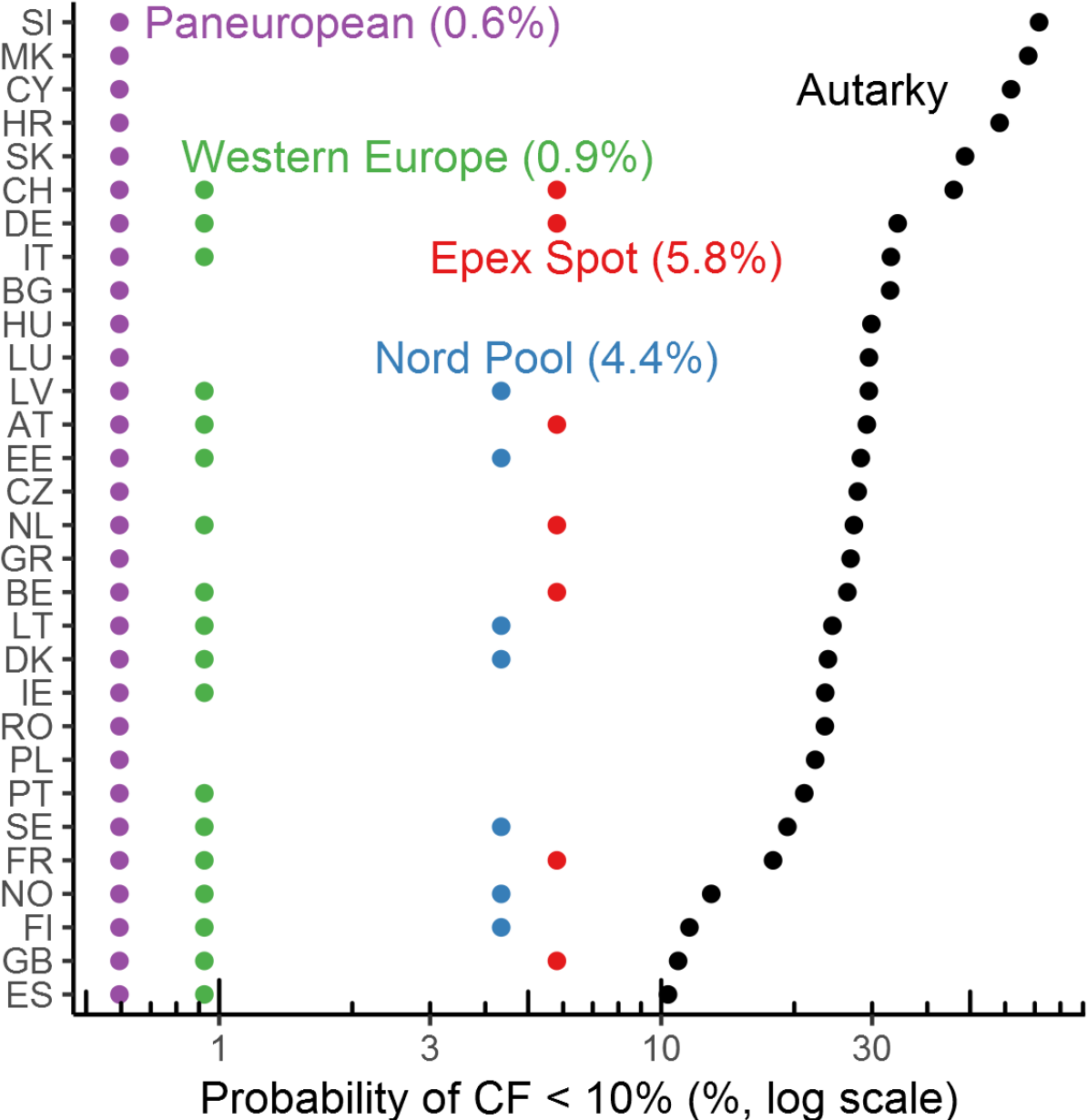
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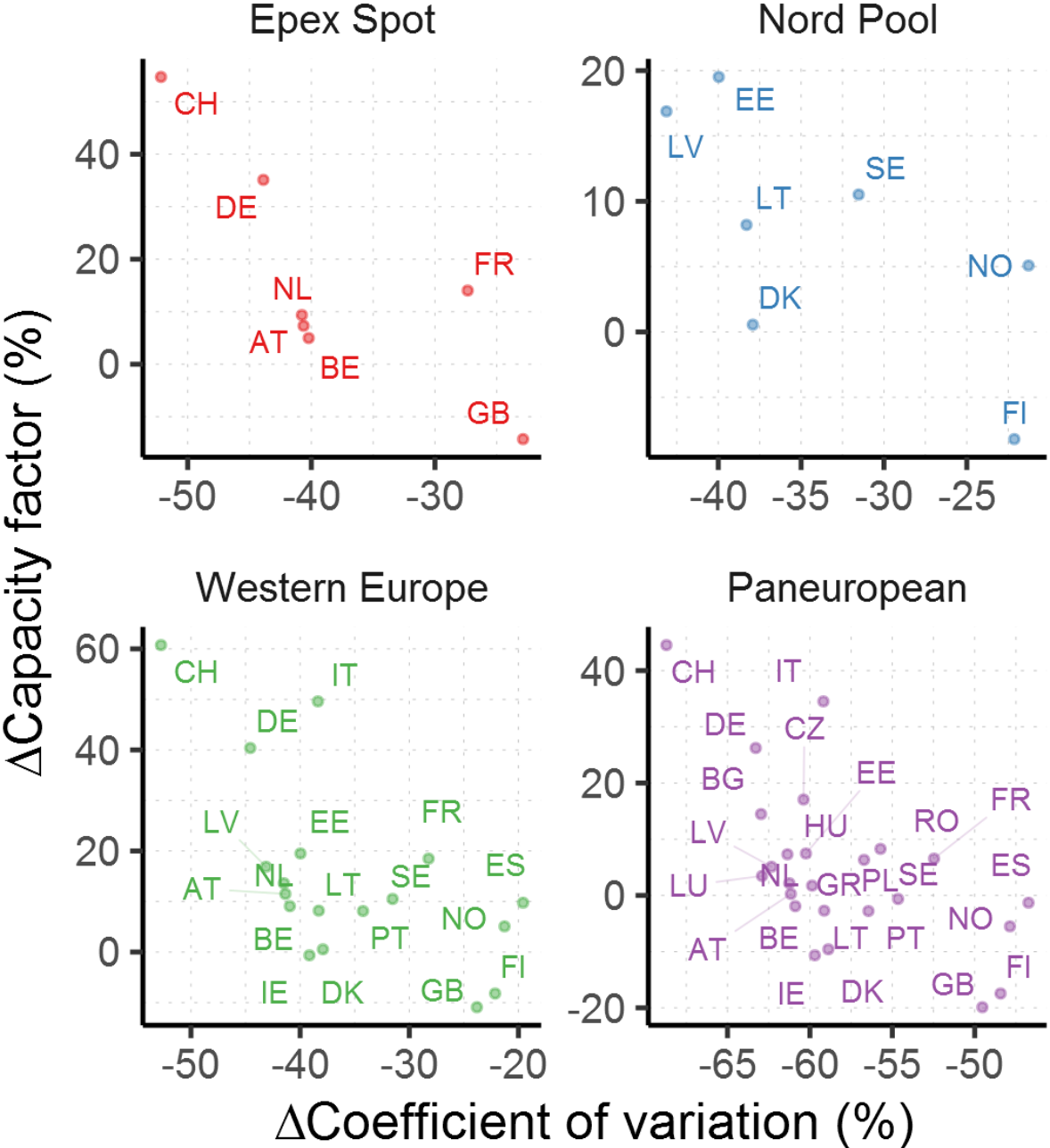
Benefits of SI&DC



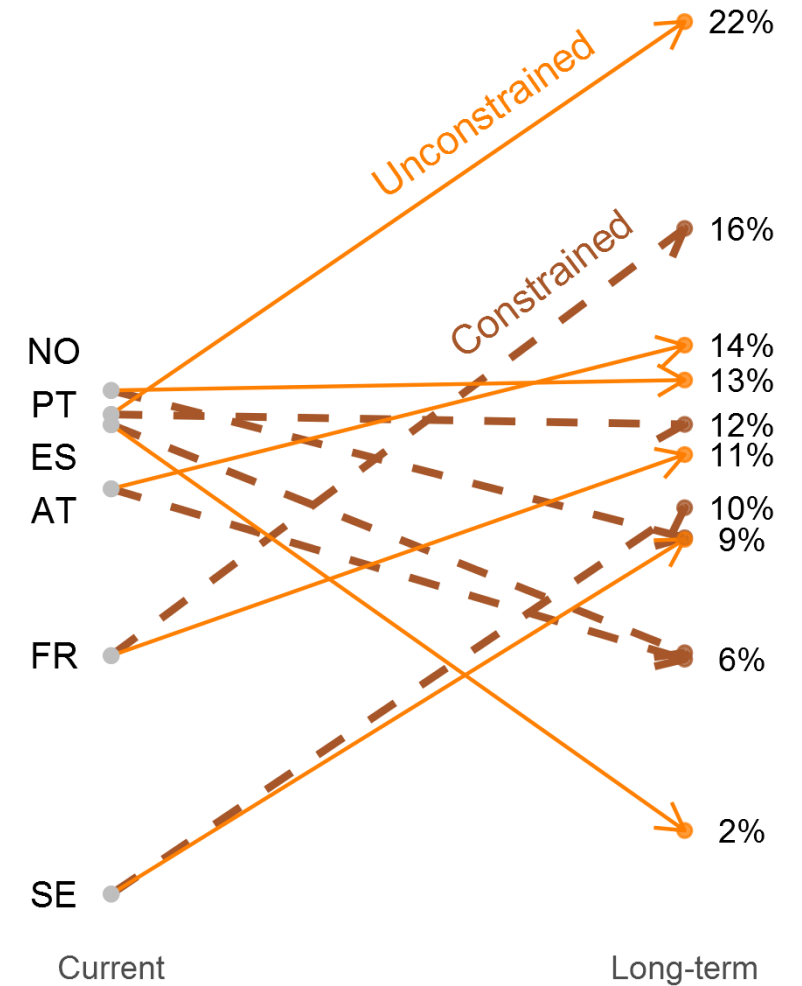
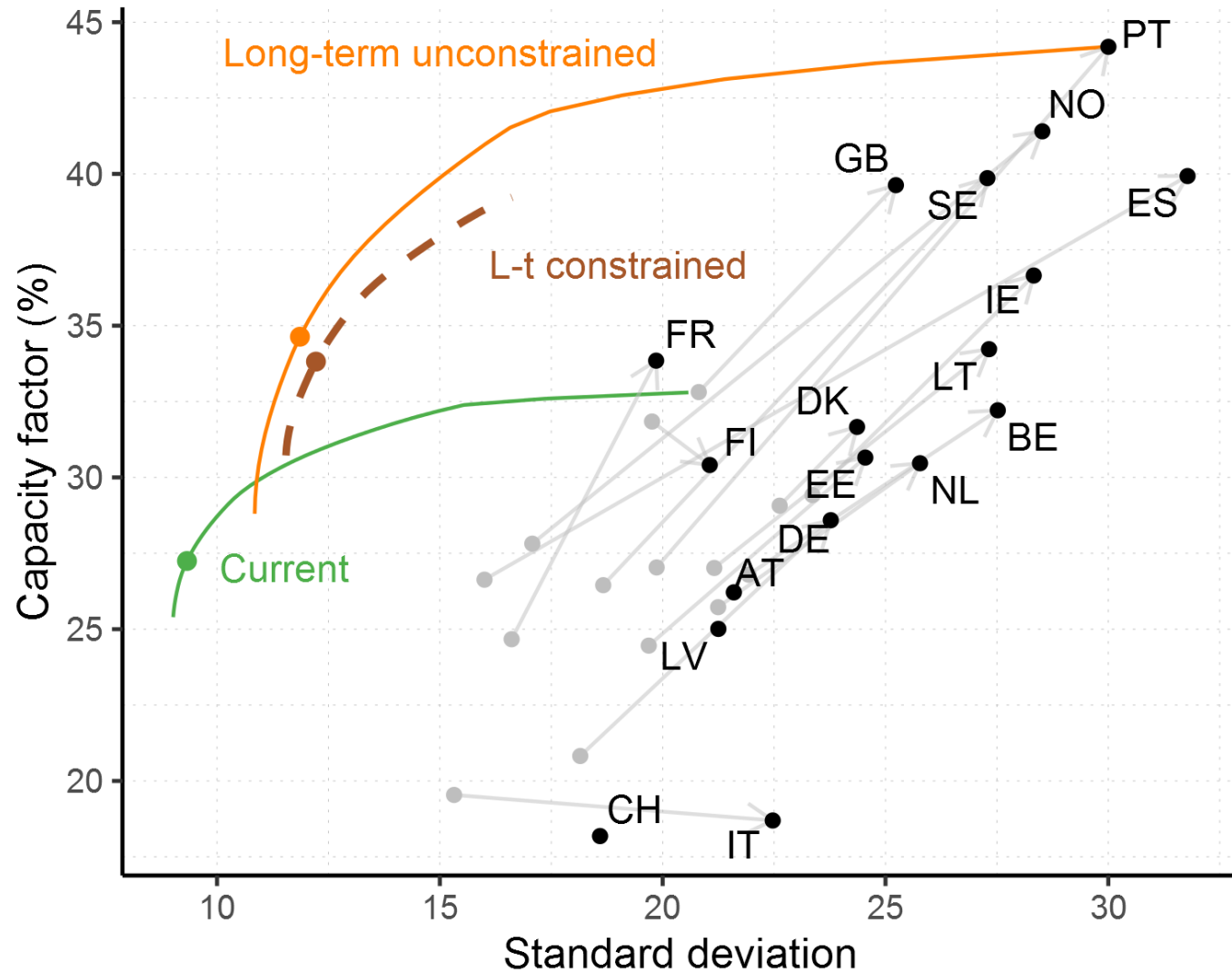
Benefits



Benefits

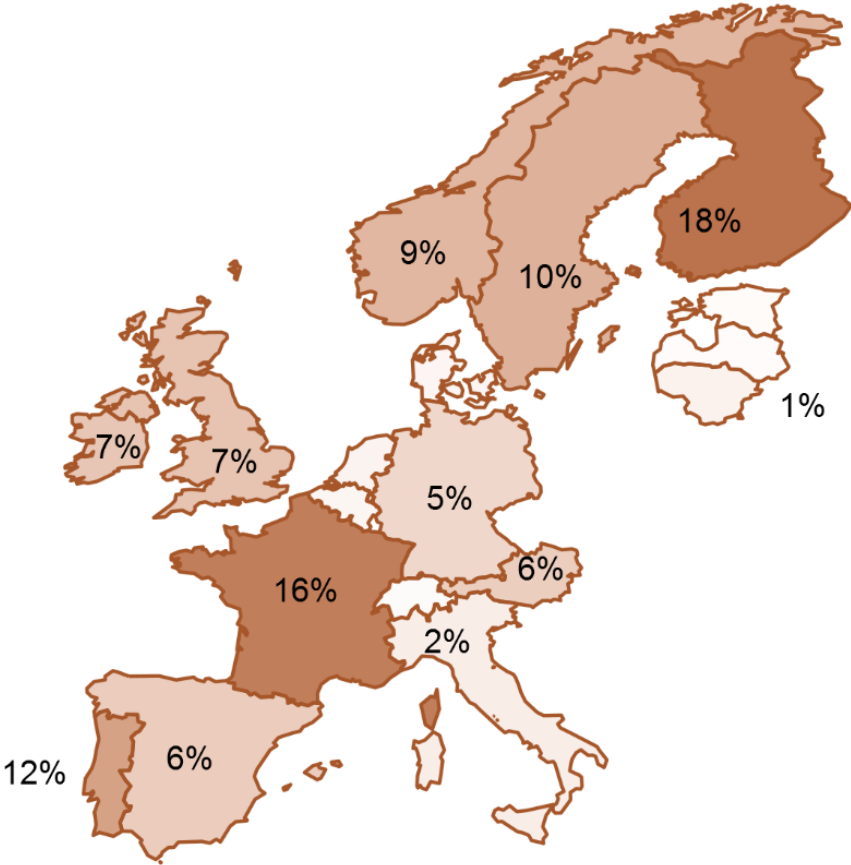


Current v. (un)constrained long-term

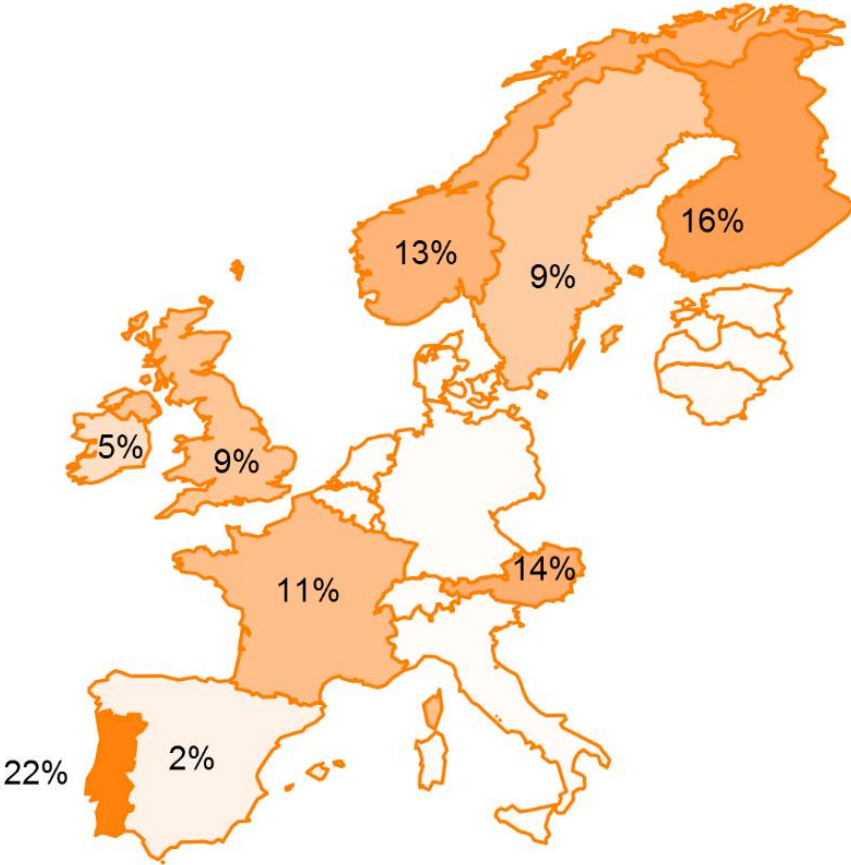


Long-term

Constrained



Unconstrained

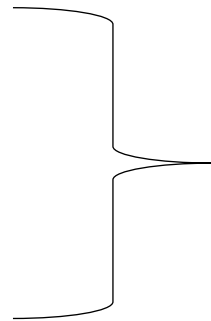


Conclusions

Spatial integration and deployment coordination provide significant benefits in terms of

- higher CFs

- lower variability



lower probability of low-generation events

Thank you

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Appendix

Constrained optimal portfolio

