Energy Systems Analysis @ DLR

European Energy Research Alliance

MULTI-OBJECTIVE OPTIMIZATION FOR EUROPEAN POWER SYSTEM PLANNING

Contact: Hans-Christian.Gils@dlr.de, Karl-Kien.Cao@dlr.de, Suzanne.LeBihan@dlr.de, Madhura.Yeligeti@dlr.de

REMix
Renewable Energy Mix

Methods for Multi-Criteria Energy Systems Optimization

- Open source energy system modelling framework REMix
- Evaluating infrastructure requirements along transformation pathways for integrated energy systems
- Considering diverse requirements: CO_2 targets, domestic supply shares, …
- Multi-criteria optimization, investigating best tradeoffs between two or more different indicators (research of Pareto-optimal solutions)
- Pareto methods: MGA, Epsilon-constraint, Sandwiching, Random weighting

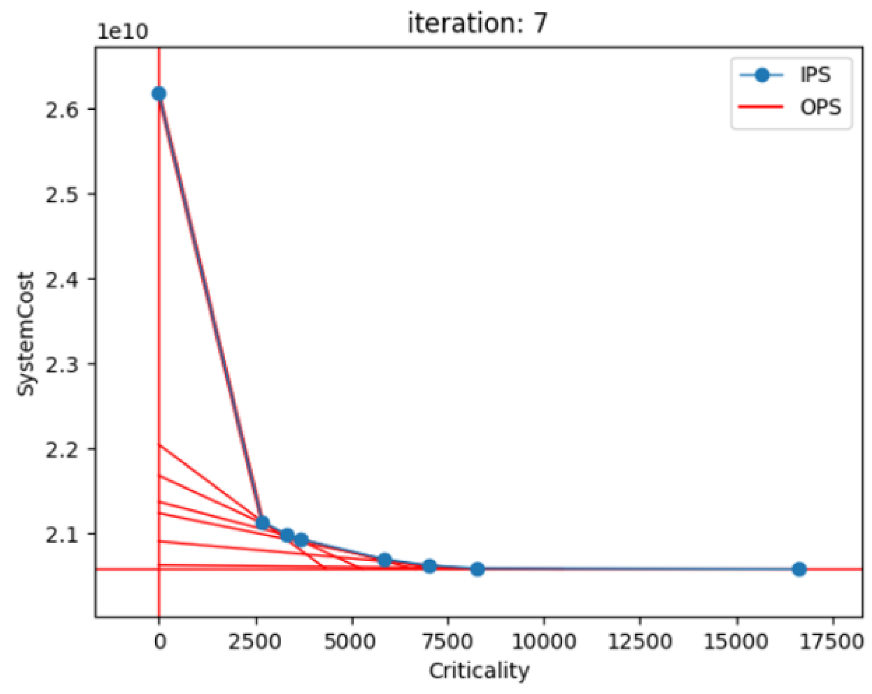

Figure 1: Exemplary pareto-points obtained with the Sandwiching method

Use case: Energy Systems Resilience

- Structural resilience of energy systems against external shocks (e.g. extreme weather events, hacker attacks) depends on the systems design
- Renewable energy supply, decentralization, digitalization and sector coupling notably change the requirements for resilient system design
- Basis for structural resilience indicators: degree of connectivity, diversity, redundancy, or self-sufficiency

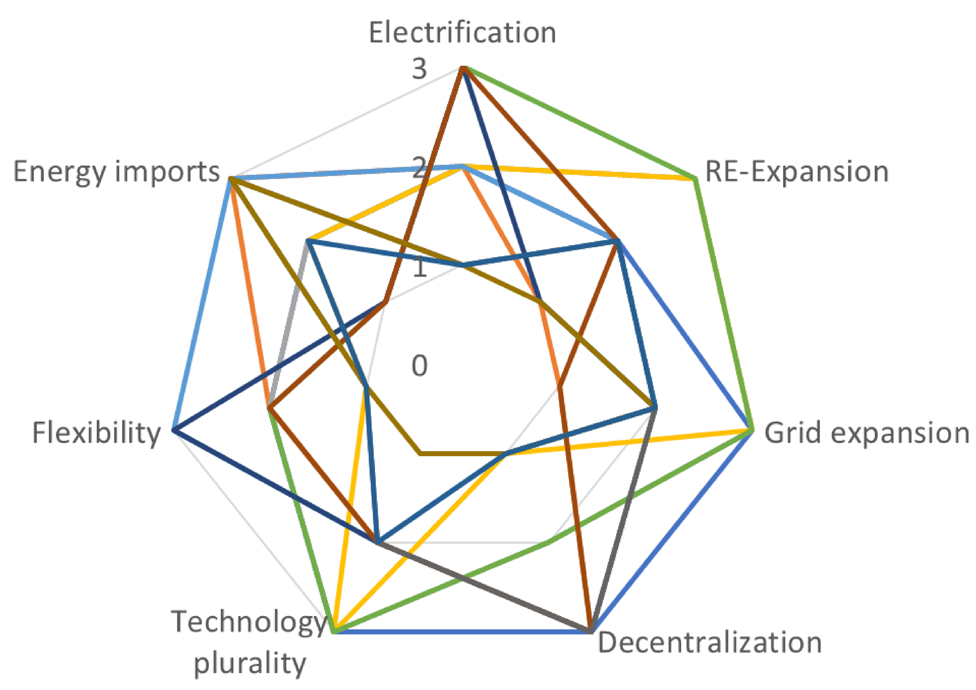

Figure 2: Evaluation of structural resilience

Use case: Critical Materials

- Basis: Raw material criticality based on state-of-the-art methods
- Defining sub-technologies whose criticality depends on their raw material composition
- Determining criticality index for wind energy converters, photovoltaic technologies, and battery storage
- Calculating criticality factors considering different kinds of risk (geopolitical risk or market risk)

Case study: Costs vs. Critical Materials

- Basis: Data set for a Power System Model of Continental Europe (infrastructure data, renewable energy potentials)
- Integration of the criticality for renewable power generation and storage technologies into an instance of the REMix energy system modelling framework
- Minimizing of system cost and system criticality using Epsilon-constraint
- Investigation of the shift in technologies for power generation and storage introduced by criticality

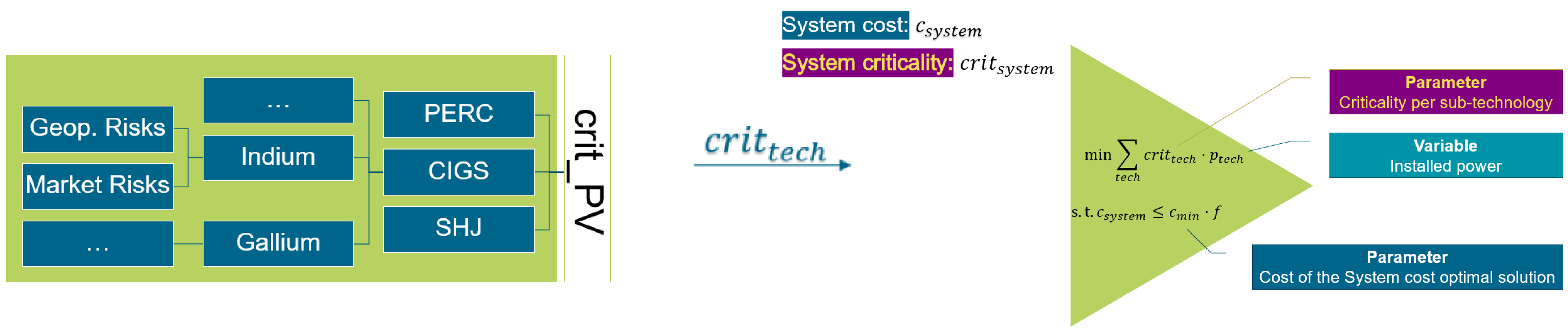

Figure 3: Exemplary data processing workflow for multi-objective optimization of system costs vs. critical materials

Exemplary results

Approach with geopolitical/market risks and Epsilon-constraint Pareto-points

- Integrating market risks into the energy system model leads to shifts from wind (cost minimum) to solar power generation (criticality minimum at 2% cost increase)
- Both geopolitical and market risks lead to shifts from power generation with silicon heterojunction solar cells to passivated emitter and rear cells
- Wind energy converters without permanent magnets and lithium iron phosphate batteries are dominantly favoured

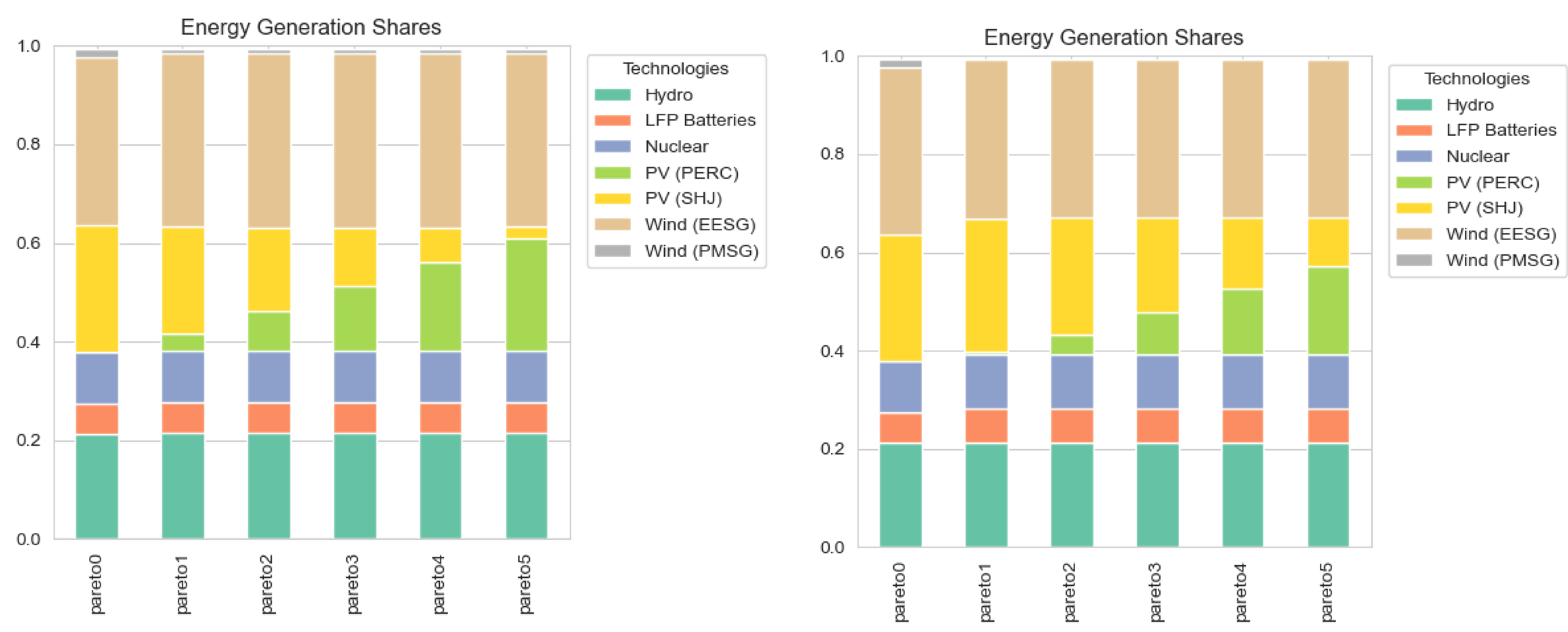

Figure 4: Power generation share for continental European power systems - Approach with geopolitical risks as criticality (left) and market risks (right)

German Aerospace Center (DLR)
Institute of Networked Energy Systems
Department for Energy Systems Analysis
www.dlr.de/ve

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