MULTI-CRITERIA ENERGY SYSTEM OPTIMIZATION: COSTS VS. CRITICAL MATERIALS

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Content

The implementation of a climate-neutral energy supply can be realized by numerous commercially available technologies. Optimization models that determine the technology mix bottom-up on the basis of monetary costs are often used to draft corresponding energy system designs. In this step, the demand and availability of the required raw materials, are usually not taken into account although material bottlenecks can hamper the implementation of required infrastructure measures [1]. The novelty of the work presented is therefore the model-endogenous consideration of critical raw materials in energy system optimization in order to determine future energy system designs on the basis of various optimization criteria, such as costs and resources criticality.

Methodology

We use an instance of the modeling framework REMix [2]. It is parameterized mainly using a consistent data set for a highly renewable European electricity system [3]. Additionally, we extend the technological scope of the model by introducing sub-categories of the usual technology types. In other words, we distinguish different types of photovoltaics, wind energy converters and batteries with regard to their material demands, e.g., lithium nickel cobalt manganese oxide and lithium iron phosphate batteries. For each sub-category, the typical techno-economic data, such as investment costs is extended by a mass-weighted criticality factor. This criticality factor is derived from raw material proportions used for manufacturing [1] and based on state-of-the-art methods used to assess the criticality of raw materials [4,5]. Aggregated to the energy system level it serves as additional optimization objective besides the system costs. To observe pareto-optimal technology mixes we run REMix with different approaches for multi-criteria optimization, e.g., the augmented epsilon-constraint method.

Results

Figure 1 shows exemplary results of our proof-of-concept. It depicts the technology switch between two battery technologies in terms of power generation. The basis for the result is the expansion of storage capacities that are subject to different technology specific criticalities and techno-economic parameters. At an individual country level, we observe partial substitutions of lithium iron phosphate batteries by redox-flow batteries. Further results are as expected: If only the criticality of storage technologies is considered, the total amount of installed units decreases and the missing flexibility is compensated by expensive but uncritical power imports.

Next, we scale-up the model scope to scenarios at the European level and implement a broader set of sub-technologies for power generation, whereas the system criticality is expanded to photovoltaics and wind energy converters. Therefore, we expect to observe more significant technology substitutions.

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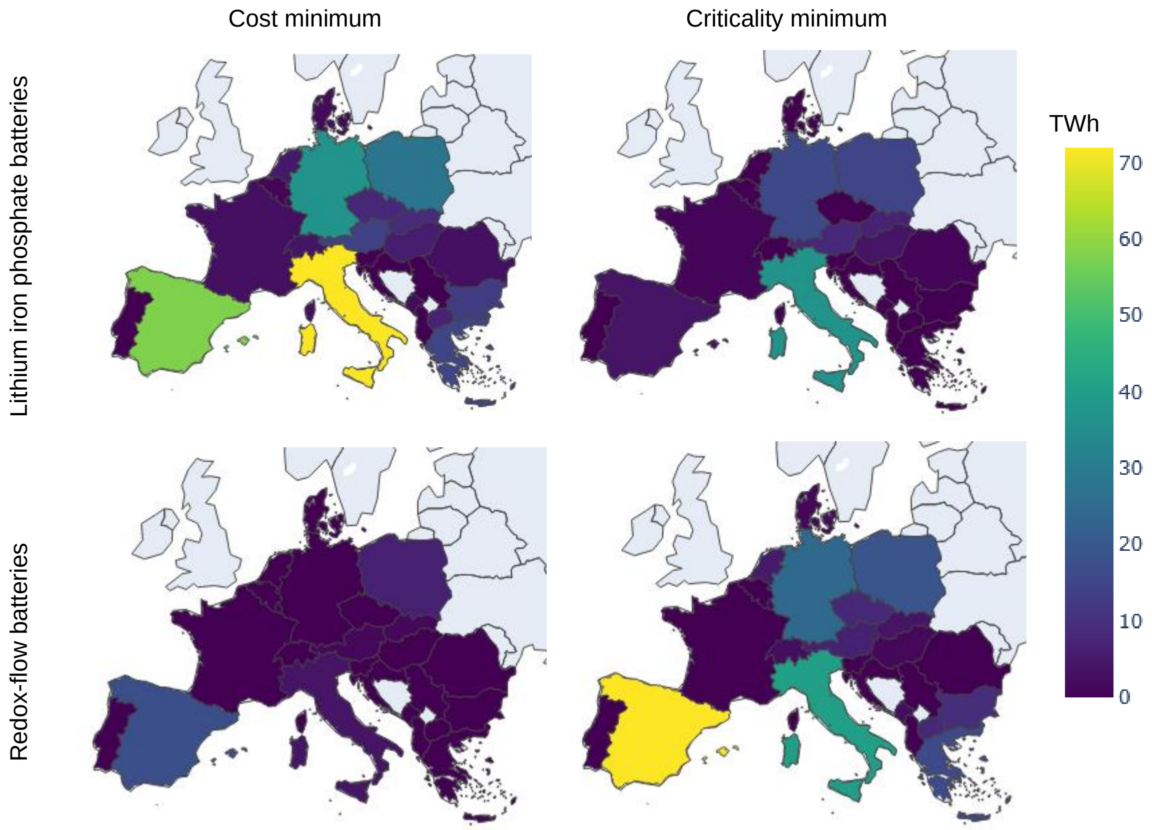

Figure 1: Power generation from lithium iron phosphate batteries (top) and redox-flow batteries (bottom) for energy systems with minimal system cost (left) and minimal criticality for an allowed cost increase of 2% opposed to the cost optimum (right).

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