Flexible energy systems for planning the world’s main copper mines considering geographical conditions

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Energy systems of the future will be highly renewable, but building the required infrastructure will require vast amounts of materials. Particularly, renewable energy technologies are more copper-intensive than conventional ones and the production of this metal is intensive in energy and emissions. Moreover, as mineral resources are being depleted, more energy is required for their extraction, with subsequent increase in environmental impacts. Highly stressed and uncertain water resources only worsen this situation.

In this work, we will first provide a comprehensive review of the limited available energy planning approaches on copper mines, including transferrable learnings from other fields. Our second contribution is to compare the influence of different geographical locations on the optimal design of energy systems to supply the world’s main copper mines. For this, we use a linear energy system optimization model, whose main inputs are hourly time series for solar irradiation and power demand, and projections for energy technology costs and ore grade decline. Our third contribution is to propose a multi-vector energy system with novel demand-side management options, specific to copper production processes, including water demand management, illustrated on a case study in Chile (where mining uses a third of the nationwide electricity).

In the first part, the review, we learned that energy demand models in copper mines have only coarse temporal and operational resolutions, and require major improvements. Also, demand-side management options remain unstudied but could promise large potentials. In general, the models applied in copper energy planning seem overly simplistic when contrasted to available energy decision tools.

For the second part, we observed that in most locations, using local photovoltaic power not only lowers future electricity costs but also compensates for increased energy demand from ore grade decline. Some regions gain a clear competitive advantage due to extremely favorable climatic conditions.

In the third and final part, regarding the demand-side management, we saw how the geography and the spatial design of the mines strongly influence the available options and their performance. Jointly planning flexible water and energy supply seems to be particularly attractive. Also, there is
space for smart scheduling of maintenance of the production lines, the hardness of the rock feed, oxygen production, and the hauling (rock transport) fleet.

As an outlook, we highlight the need for consideration of lifecycle impacts as a design goal, and to further develop demand model's and their flexibility on the mining side. We expect that implementing these smarter approaches will help secure a cleaner material supply for the global energy transition.