Studying the integration of solar energy into the operation of a semi-autogenous grinding mill. Part I: Framework, model development and effect of solar irradiance forecasting

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Grinding is one of the most energy-demanding processes of copper mines. Declining ore grades and harder rocks will further intensify this demand. Periods of stressed copper prices, high energy costs and climate change mitigation targets additionally motivate the search for alternative energy sources in mining. In Chile, many copper operations are located in the Atacama Desert, hence solar energy systems are an attractive solution. However, the mineral hardness is variable and uncertain in time and space, which adds challenges to planning energy systems with high solar shares. More specifically, here a stochastic optimization model is developed. It sizes the solar photovoltaic (PV), battery energy storage system (BESS) and the contracted power, based on the solar radiation, mineral hardness, and costs. Using Markov Chains, different years of solar radiation are generated from historical records. These solar scenarios are used to test the impact of individual years with long periods of cloudy/rainy days on the sizing of the system, in contrast to planning with an average year or planning with many-year time horizons in a stochastic approach. The novelties lie in the developed model, and in understanding the impact of the uncertainty and variability of rock hardness and solar irradiation on the optimal sizing of the PV-BESS system and the power capacity contract. Furthermore, the impact of a larger variability of ore hardness is evaluated in one scenario. PV-BESS can cost-effectively provide energy to the grinding mill. Different planning approaches lead to significant differences in the recommended power supply. In contrast to planning with the

average solar year, using a conservative solar year (many cloudy days) yields significantly smaller sizes of PV and BESS (20% and 55%) and a higher reliance on the grid (larger contracts and imports); and the stochastic approach follows a similar line (10% and 25% smaller). Despite its increased grid dependency, the one-year stochastic approach provides more robust solutions regarding costs and sizes (avoiding penalties). The variability of the rock hardness also impacts the size of all components of the PV-BESS system, especially the battery energy capacity. Its relevance for battery sizing motivates to perform further studies with a focus on the uncertainty and variability of the ore.