Department of Chemical & Biomolecular Engineering

CHBE Team 10
Optimized Zinc Ore Refinement for Battery Grade Zinc

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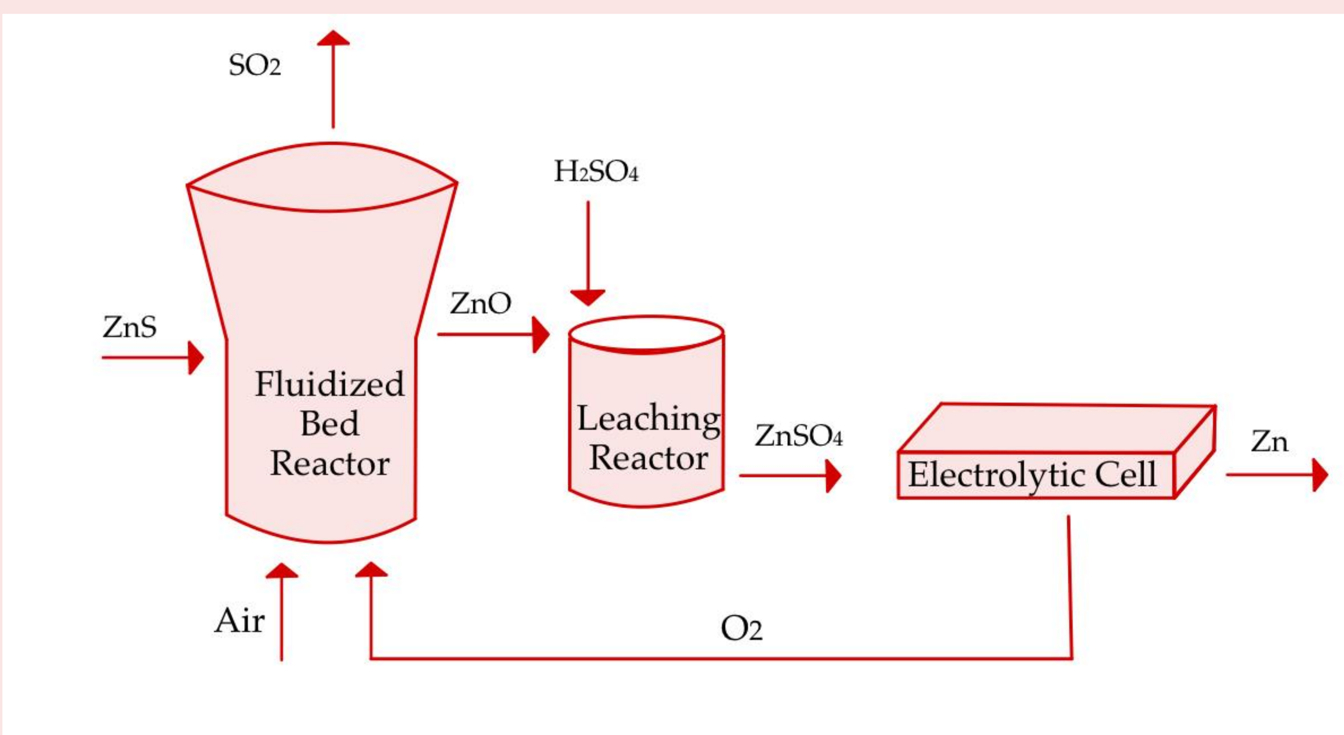
Project Description

The goal of this project was to design and simulate a zinc refining process. According to the US Geological Survey, **America mines over 700,000 tons of zinc per year**, but **only refines less than 200,000**, creating a large opportunity for domestic refineries. Zinc has many modern industrial applications, including the emergence of zinc-based battery storage technologies, making it the **fourth most used metal** in the world with a **global production estimate of 13.9 million metric tons of zinc per year**. Zinc-based batteries offer comparable efficiency and energy density to Li-ion, but are **safer, cheaper and better for the environment**, making them perfect for grid-storage applications. In this project, a zinc refining process is designed, optimized, and analyzed **to produce a target of 100,000 tons of refined zinc per year.**

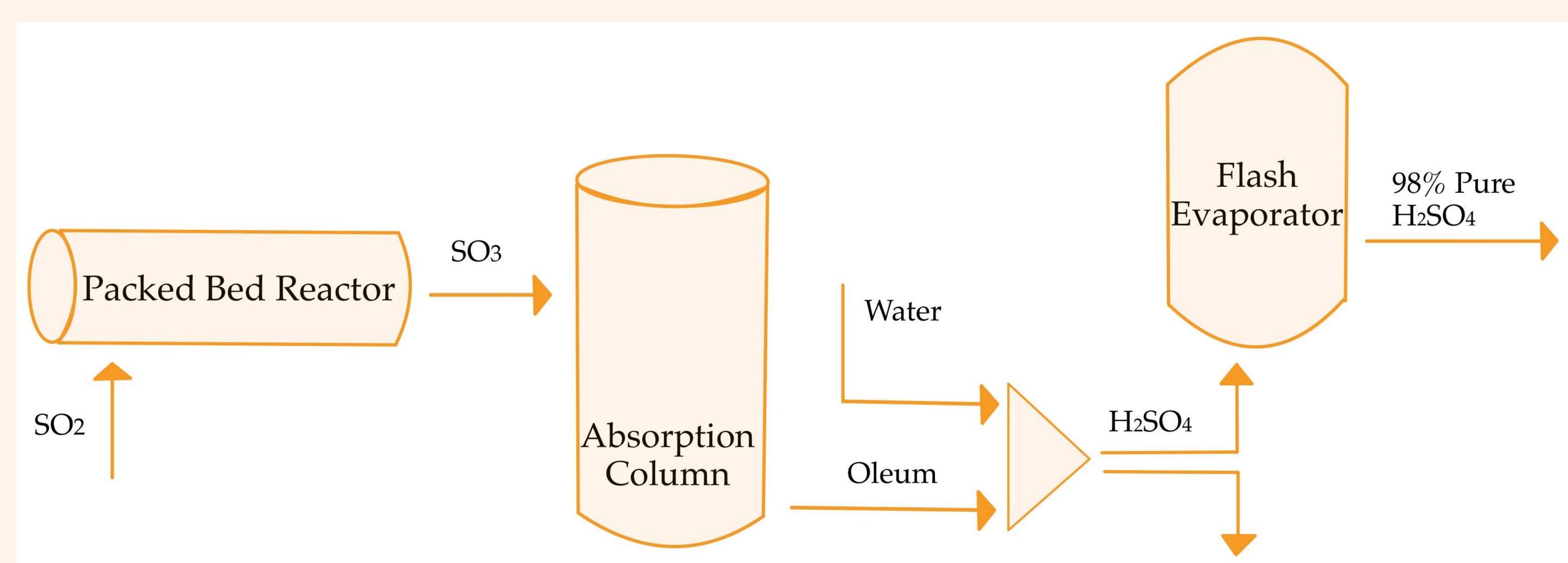


Zinc Refining

1. Zinc ore, primarily sphalerite (ZnS) is reacted with air and recycled oxygen in a **Fluidized Bed Reactor (FBR)**. This reaction produces Sulfur Dioxide gas and Zinc Oxide.
2. The zinc oxide is then fed to a **leaching tank**, where it is reacted with sulfuric acid to form a zinc sulfate solution.
3. The zinc sulfate solution then enters the electrolytic cell, where a current is applied in order to deposit pure zinc on the cell's cathode.

Sulfuric Acid Purification

1. Sulfur dioxide produced in the gas stream of the FBR flows through a **packed bed reactor (PBR)** in the presence of a vanadium pentoxide catalyst to from sulfur trioxide
2. Sulfur trioxide flows through an **absorption column** to dissolve into sulfuric acid, forming oleum, and then combining with water to form twice as much sulfuric acid
3. Sulfuric acid is split to the leaching process and **flash evaporator**, where it is purified into a sellable product and used as a recycle stream to reduce raw material costs



References

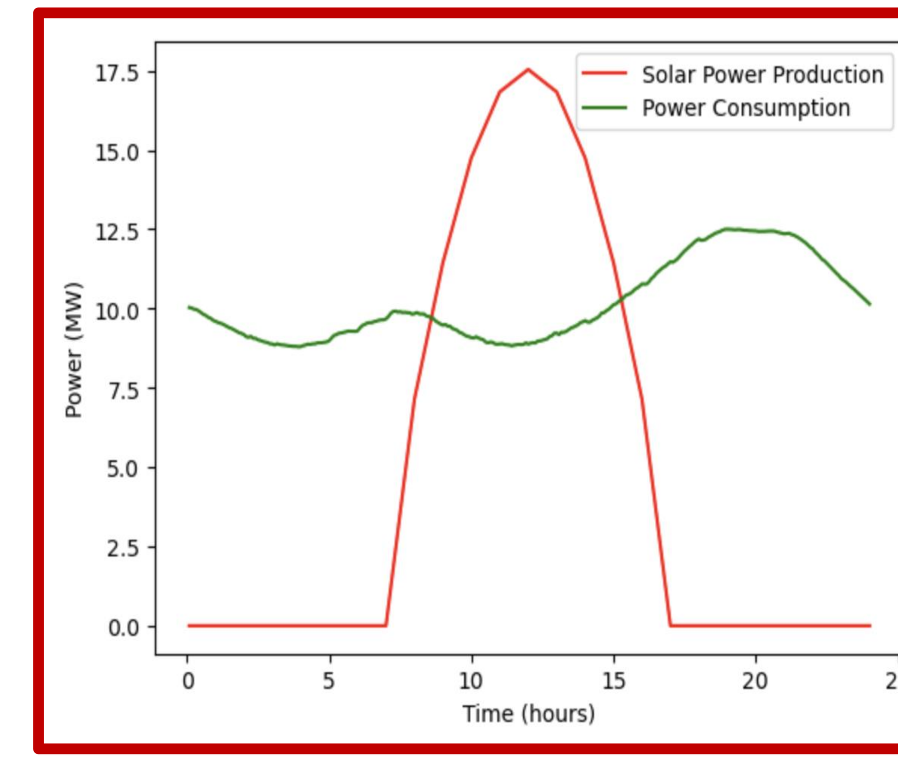
1. Tolcin, A. Zinc Statistics and Information. https://www.usgs.gov/centers/national-minerals-information-center/zinc-statistics-and-information (accessed 2025-04-22).
2. Today's Outlook | Demand. https://www.caiso.com/todays-outlook (accessed 2025-04-21).

Sustainability

Our zinc refining process is designed with strict environmental controls to minimize harmful emissions, particularly sulfur dioxide (SO_2) and sulfuric acid (H_2SO_4). By recycling potential SO_2 emissions to produce sulfuric acid, both used internally in our process and sold, the process enhances profitability while drastically reducing pollution. Emissions from the flash separation step, the only significant source, are exceptionally low, 0.003275 kmol/hr of SO_2 and 9.386×10^{-6} kmol/hr of H_2SO_4, which is **only 0.465% and 0.0357% of EPA limits**, respectively. This margin will ensure long-term environmental compliance as our facility ages.

Battery Application

The minimum battery capacity for zinc-based batteries can be modeled based on the difference in power demand and photovoltaic (PV) power production throughout the day. Power demand data was normalized for 10,000 homes with an average energy demand of 30 kWh per day. The fixed tilt PV array was modeled with a 20% efficiency over 25 acres based on solar irradiance data in California . Storing this energy demand requires **37.4 MWh batteries** containing **30.48 tons of zinc per battery**. Throughout the course of a year our zinc refining process can produce over **3000 batteries** with a total energy capacity of **120 GWh**.



Economic Analysis

Operational Cost

This process incurs significant raw material and utility expenses, particularly during the roasting and leaching stages. The primary input, zinc sulfide with iron sulfide impurities, is priced at approximately $1,300 per ton. Including air and water, the total raw material cost is approximately $200 million per year. Utility requirements for process heating and cooling duties require an additional $3 million annually.

Process Profit

Revenue is generated from the sale of purified zinc and sulfuric acid, totaling approximately $273 million per year. After operation, labor and material costs, the estimated **annual profit is $35 million**, yielding a **payback period of 1.19 years** and a **profit margin of 12.8%.**