High-Temperature Copper Ore Processing with Solar Thermal Heat

Typical energy consumption by conventional beneficiation and flotation methods:

- *30-80 kWh/t mostly provided by fossil fuel*

Temperature range for the new solar thermal heat processing:

- *900-1000°C*

Industry field:

- *copper industry*

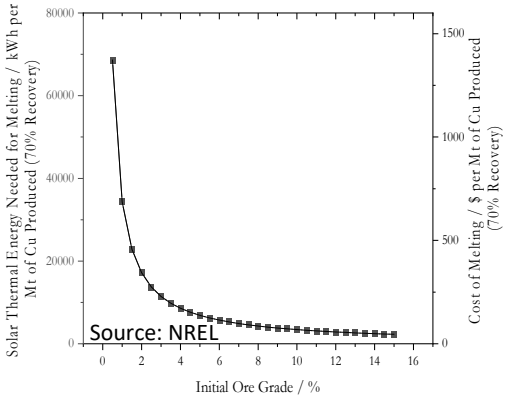
Countries with high potential:

- *Chile, Peru, China, USA, Australia*

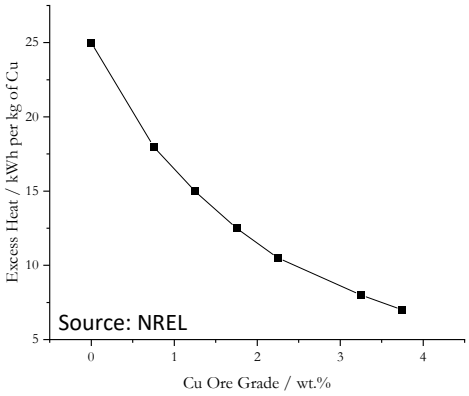
Character of new process:

- *molten-state, continuous process*

Source: Rob Lavinsky, iRocks.com – CC-BY-SA-3.0, https://www.mindat.org/photo-48265.html



Preliminary cost analysis for the ore melting using solar thermal heat



Function of energy required for Cu extraction process vs. Cu ore grade.

What is the Cu ore upgrading process?

Low grade Cu ore out of an open-pit mine (usually only at < 0.7 wt.% of Cu for US mines) needs to be concentrated before fed into a Cu smelter for efficient smelting because the energy required for smelting decreases exponentially as the ore grade increases. Today the Cu extraction industry typically demands an ore grade with > 25 wt.% Cu. This process from 0.7 wt.% to > 25 wt.% costs about $1000/Mt of Cu.

To concentrate the raw ores, conventional processes (e.g., beneficiation and water-based froth flotation) usually consume fossil fuels because of the lack of easy access to electricity at remote mine sites. Therefore, there is a great economical opportunity for more efficient and sustainable Cu ore upgrading.

Where is this process used?

The leading countries in terms of Cu mine production are Chile, Peru, China, Democratic Republic of the Congo, United States and Australia. The process is used before Cu smelting and final refining.

What makes it suitable for solar integration?

Almost all the leading countries for Cu production have high direct normal irradiation (DNI), e.g., northern Chile, southeastern Peru, northwestern China, southwestern USA and central Australia. It provides a fundamental alignment between market and technology.

The use of solar thermal heat to provide the process heat could help the industry reduce the carbon footprint to power the conventional Cu ore upgrading processes at remote mine sites.

The new process resembles the density separation during froth floatation but in a molten state after the solar process heat melts the raw ore. Preliminary cost analysis shows that the cost of melting using solar thermal heat at an estimated $0.02/kWh is cost-competitive to traditional process and the cost can be drastically reduced when the initial ore grade increases. Therefore, the ideal way to implement is to utilize traditional methods to slightly concentrate the low-grade ore (where cost is the lowest) and use solar process heat to continue processing to a much higher ore grade.

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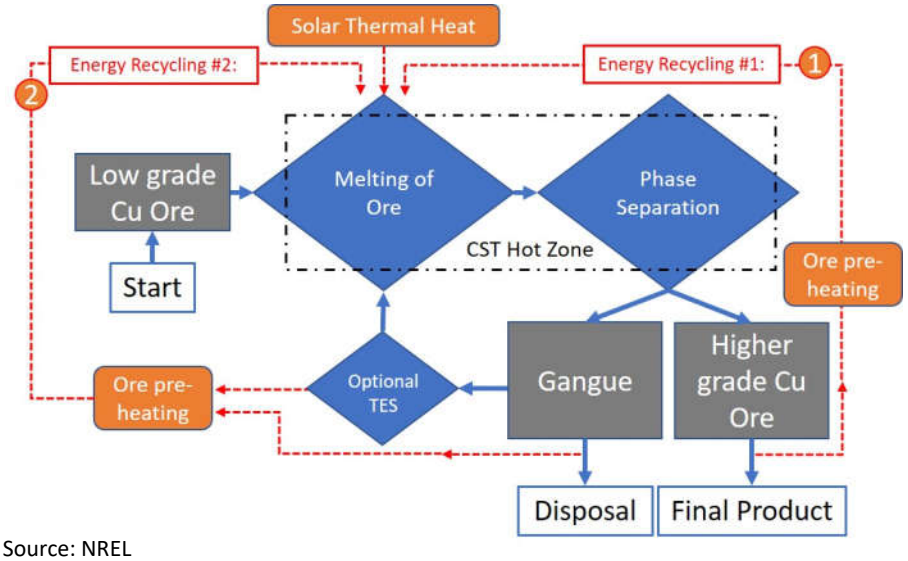

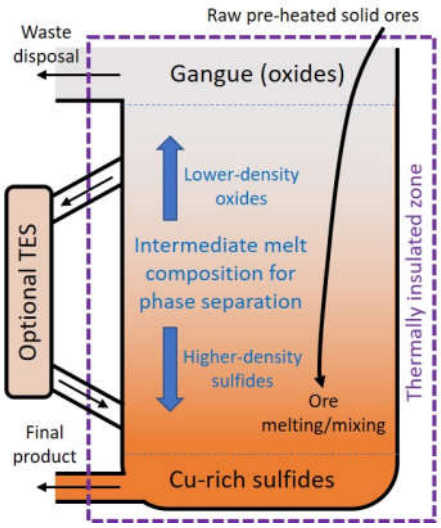

Source: NREL

Summary of requirements for solar systems providing heat for this process

User side heat transfer fluid:
- *molten ore will serve as HTF*

Estimated operating temperature:
- *900-1000°C*

Estimated power level required:
- *<150 kWh/Mt of Cu production*

Required continuity of heat supply:
- *medium continuity needed*

Available backup heat supplies:
- *to be defined*

Heat storage options:
- *Feasible, depends on final concept*

Working principle

This is a new area of exploration. Conceptually, the molten-state process will be integrated with a receiver (e.g., a cavity receiver for smaller scale demonstration at ~100 kW). The heat will be used to melt the ore without a second HTF and the density separation will occur to produce upgraded Cu-rich sulfides as final product and oxide-rich "gangue" to be disposed.

The processed ore product and gangue waste will be removed from the reactor and cooled for collection. The latent heat and sensible heat during cooling will be used to preheat the upcoming fresh raw ore to achieve better thermal management and thermal energy recycling.

Status quo in solar integration

There is no demonstration of this new molten-state Cu ore upgrading technology so far.

Currently, NREL, MIT and Heliogen have a concept for the technology. Potential future work include (1) verification of the phase separation process and its efficiency using a high-flux solar furnace at NREL and (2) larger scale demonstration at Heliogen. First analyses for the integration of solar thermal energy in Cu-ore processing were performed by the CEDER (Centro de Desarrollo Energético) of Antofagasta (Chile) using a lab-scale solar rotary kiln.

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Prepared by Youyang Zhao, Craig Turchi
NREL