Solar heat integration in calcination processes

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The cement industry needs novel alternatives for thermal substitution and carbon capture. The integration of solar thermal heat and thermochemical storage can play an important role, providing heat at very high temperatures between 900 °C and 1500 °C for continuous processes.

What is the cement process?

Cement manufacturing is divided into five sub-processes, quarrying, raw material preparation, clinker burning, cement preparation and dispatch, whereas the clinker burning is identified as the key process for high temperature solar heat integration.

Thereby, the raw material (mixture of limestone, clay, and marl with additive materials like sand, iron oxide or bauxite) is fed to a state-of-the-art multiple-stage cyclone preheating system (temperatures 350°C – 1000°C), where the significant calcination process ($CaCO_3$ → $CaO + CO_2$) takes place at around 900 °C. The subsequent process of sintering is done in the rotary kiln at around 1250 to 1450 °C to produce clinker (main part of cement).

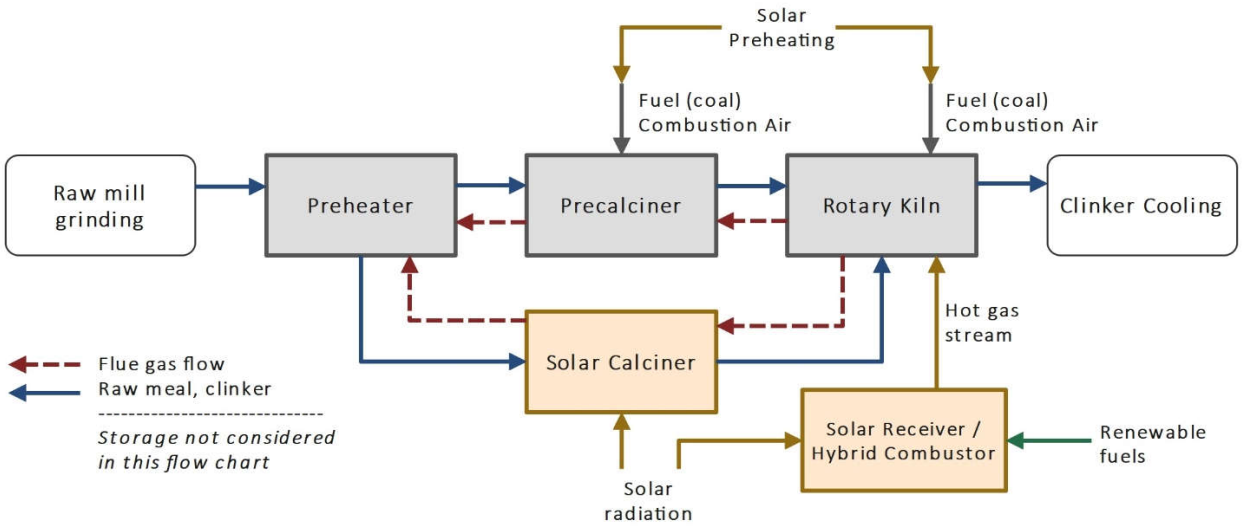
The required thermal energy (85 % of the total energy demand, 3.5 – 5.2 GJ/ton clinker) is provided by two fossil burners, the main firing at the end of the rotary kiln and the second firing at the end of the calciner. The resulting hot exhaust gases by combustion are in counterflow to the solid particles through the entire kiln system.

CO2-footprint of cement industry

The global cement production today accounts for 8 % of the anthropogenic CO_2-emissions. One-third of CO_2-emissions are caused by burning the fossil fuels needed to provide the thermodynamic conditions for the calcination and sintering process. However, two-thirds arise from the chemical reaction itself and are declared as unavoidable emissions.

What makes it suitable for solar integration?

Concentrated solar power (CSP) may prove to be a successful technology to reduce the carbon footprint. Carbon capture technology and utilization (CCU) are necessary to sequestrate the unavoidable emissions. Of great interest, but so far only research on a small scale, is the substitution of fossil by solar thermal energy for the calcination process. In addition, thermochemical storage will play a crucial role in ensuring the continuous process.



Source: Fraunhofer Chile

Solar heat integration options

The solar integration can take place through several of the individual successive processes of the clinker burning (preheater, precalciner, rotary kiln), which require thermal heat.

The substitution of the thermal energy from the conventional fossil fired rotary kiln and precalciner can be done by using heat generated from a solar tower. As heat transfer fluid (HTF), a mixture of water vapor and carbon dioxide (use the greenhouse gas effect) can be used to reach ultra-high temperatures.

Alternatively, the precalciner can be replaced by a solar calciner, where the raw material is heated up and calcinated directly by concentrated solar. The solar implementation in these two processes would have the most impact in fossil fuel reduction but conclude in bigger challenges as higher temperatures are needed.

Furthermore, solar hybrid combustion solutions with alternative green fuels (renewable syngas or hydrogen) are possible to replace the burner flame.

The preheating system and raw material preparation (drying, grinding) are already so far energetically optimized by heat recovery systems from the exhaust gas stream of the rotary kiln.

Anyway, solar integration in auxiliary processes to the kiln system like preheating of combustion air and fuel, can be conceivable. Regarding all these, a stepwise solar hybridization into existing cement plants is required, as well as a storage system to achieve higher solar fractions and to operate the cement process continuously.

Status quo in solar integration

A decade of very hot solar thermo-chemistry research has been done on testing solar calciner on lab-scale. Today is beginning to yield the first pilot projects in partnerships with cement companies and firms willing to try out novel solar alternatives. Some of the promising projects are established by Synhelion and Heliogen, which are trying to decarbonize high temperature heat demand industry processes, as the cement industry.

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