Development of granules for storage of high-temperature solar energy via reversible carbonation-calcination

Project suitable for Bachelor Thesis, Semester Project or Master Thesis

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www.prec.ethz.ch/staff/postdocs.html/www.prec.ethz.ch/staff/doctoral-students.html	
Working place:	Laboratory ML K28
Starting date:	Flexible
Grading criteria:	http://www.prec.ethz.ch/documents/grading_criteria.pdf

1. Background

High-temperature concentrated solar heat can decarbonize many industrial processes like solid waste gasification, cement manufacturing, mineral and metallurgical extraction, power generation, and allow advanced solar fuel synthesis. The integration of a heat storage within the plant allows to operate the downstream process also during off-sun periods, with great positive impact on the overall plant efficiency (see Figure 1). The state-of-the-art, commercial thermal energy storage systems employ materials with high heat capacity, like molten salts, that are limited to a working temperature of around 600°C - too low to operate the above-mentioned processes. The endothermic/exothermic effect of reversible carbonation-calcination reactions occurring between CO_2 and some solid metal oxides (i.e. CaO, SrO and BaO) can be exploited to store/release solar heat at temperatures higher than 600°C. This concept, known in general as thermochemical energy storage, also allow to store more energy per unit mass or volume than sensible and latent energy storage technologies [1]. Metal oxides, when exposed at high temperatures, usually suffer of thermal sintering that inhibits their storage/release heat capacity over consecutive cycles. The method of mixing reactive metal oxides with sintering-resistant additives has been demonstrated capable to provide stable performance over long-term heat storage/release cycling. Also, having available the reactive metal oxides in form of granules, instead of powders, enables further prevention against thermal sintering and higher performances of thermochemical storage reactors with packed-bed configurations.

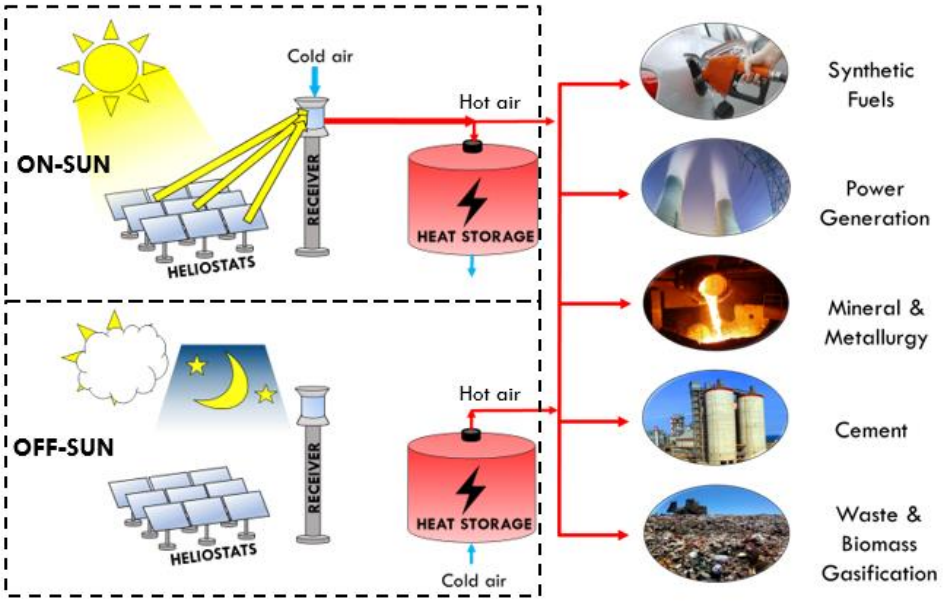

Figure 1. High-temperature industrial processes driven round-the-clock by solar heat.

2. Objective

Preparation of novel formulations of granules for thermochemical heat storage applications based on reversible carbonation-calcination of CaO, SrO and BaO, and characterization of their performance over multiple consecutive heat storage/release cycles.

3. List of Assignments

1. Literature review (see list of References below).
2. Lab introduction and safety briefing
   Contact: Philipp Haueter, https://prec.ethz.ch/staff/person-detail.html?persid=105648
   Bulfin Brendan, https://prec.ethz.ch/staff/person-detail.html?persid=241010
3. Synthesis of CaO, SrO and BaO granules via a granulation method developed in-house, with the inclusion of selected sintering-resistant additives in different concentrations.
4. Investigation of material cycling performance by thermogravimetric analysis (TGA) after variations of synthesis and operating parameters (e.g. type of precursors, presence of pore former, thermal pre-treatment conditions, operating temperature).
5. Characterization of physical and chemical properties of the materials via different analytical techniques (e.g. SEM, EDX, XRD).
6. Seminar (date to be determined towards end of semester).
7. Report: 2 hardcopies +1 e-copy (MS-Word + PDF format + CD with raw data)

Note: List of assignments serves as guideline; adjustments may be required according to progress and results.

4. References

[1] Pardo, P., Deydier, A., Anxionnaz-Minvielle, Z., Rouge, S., Cabassud, M., Cognet, P., 2014. A review on high temperature thermochemical heat energy storage. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2013.12.014

[2] André, L., & Abanades, S. (2017). Evaluation and performances comparison of calcium, strontium and barium carbonates during calcination/carbonation reactions for solar thermochemical energy storage. Journal of Energy Storage, 13, 193-205.
https://doi.org/10.1016/j.est.2017.07.014

[3] Gigantino, M., Kiwic, D., & Steinfeld, A. (2019). Thermochemical energy storage via isothermal carbonation-calcination cycles of MgO-stabilized SrO in the range of 1000–1100° C. Solar Energy, 188, 720-729.
https://doi.org/10.1016/j.solener.2019.06.046

[4] André, L., Abanades, S., & Flamant, G. (2016). Screening of thermochemical systems based on solid-gas reversible reactions for high temperature solar thermal energy storage. Renewable and Sustainable Energy Reviews, 64, 703-715.
https://doi.org/10.1016/j.rser.2016.06.043