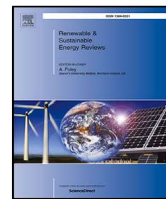




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Solid–gas reactors driven by concentrated solar energy with potential application to calcium looping: A comparative review

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ABSTRACT

The calcium looping process, based on the reversible calcination–carbonation reaction cycle of CaCO_3 – CaO , is an emerging and promising technology for thermochemical energy storage in concentrating solar power plants. In this process, concentrated solar energy is used to carry out the endothermic solar-driven calcination of CaCO_3 with formation of CaO and CO_2 as products in a solid–gas reactor. In this review, a number of experimental studies of solid–gas reactors driven by concentrated solar energy are discussed, with a particular focus on solar reactors for calcination of CaCO_3 or with that potential application. The solid–gas reactors for solar-driven calcination of CaCO_3 reported in the literature achieved a total efficiency of 16.6%–88% for a mass flow rate up to 25 kg h^{-1} and a power up to 55 kW. Also, a detailed comparison of the different types of solid–gas reactors driven by concentrated solar energy is provided by outlining their advantages and disadvantages according to several relevant criteria. This review is intended to be a valuable tool for the selection of a reactor configuration for future studies related to solar-driven calcination of CaCO_3 .

1. Introduction

Concentrating solar power (CSP) systems rely on using an optical system to concentrate solar energy collected in a larger aperture area into a smaller receiver area [1]. At the receiver, the energy is supplied to a heat transfer medium or directly to a thermodynamic cycle. Concentrated solar energy (CSE) is unique among the renewable energy sources because it can easily be coupled with thermal energy storage (TES), making it highly dispatchable and resilient to demand peaks, supply shortages, and the variable nature of solar energy [2,3]. The key categories of TES for CSP systems are: sensible TES, e.g. molten salts and packed beds; latent TES, e.g. encapsulated phase change material; and thermochemical energy storage (TCES), e.g. carbonates, hydroxides, and metal redox [4].

The major commercial solution used nowadays is molten-salts technology, which accounts for 75% of the globally installed TES capacity [3]. However, the nitrate-based molten salts that are currently used as heat transfer fluid have several disadvantages: corrosiveness, the maximum working temperature ($\sim 560 \text{ }^\circ\text{C}$) needed to prevent decomposition, which limits the system efficiency, and the significant energy

consumption required to keep the molten salts at temperatures over $220 \text{ }^\circ\text{C}$, to avoid solidification [5].

In contrast, TCES is an option for storing energy via reversible chemical reactions, allowing higher energy densities than other storage solutions, with the additional possibility of reactant storage at ambient temperatures [4]. These advantages allow extending the storage period beyond the one enabled by molten-salt systems and making TCES a solution for long-term energy storage [2,5,6]. TCES relies on using CSE to carry out an endothermic reaction. The reaction products can then be stored and used when needed by carrying out the exothermic reaction that releases the stored energy. The main current disadvantage of TCES is its low technology readiness level (TRL) of 4–5 [5].

Several reversible reactions have been proposed for TCES, mainly based on carbonates, hydroxides, metal redox, hydrides, sulfur, methanol, and ammonia [5]. One of the most promising systems relies upon the calcination–carbonation reversible reaction of CaCO_3 – CaO , known as the calcium looping (CaL) process (Fig. 1). In this system, CSE is used to carry out the endothermic calcination reaction that releases

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