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A comprehensive review on high-temperature fuel cells with carbon capture

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HIGHLIGHTS

- High-temperature fuel cells as CO_2 concentrators are presented.
- Developments of high-temperature fuel cell integrated CO_2 capture processes are reviewed.
- Technical and economic evaluations on fuel cell hybrid systems with CO_2 capture are discussed.
- Challenges and future prospects of fuel cell with CO_2 capture are suggested.

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ABSTRACT

High-temperature fuel cells and their hybrid systems represent one of the most promising technologies with high conversion efficiency. The configuration of such kind of system could facilitate an easy capture of CO_2. Several novel CO_2 capture strategies have been developed based on high-temperature fuel cells, such as solid oxide fuel cell (SOFC), molten carbonate fuel cell (MCFC) and direct carbon fuel cell (DCFC). However, related review which focus on their system integration and performance evaluation is still rare. The aim of this study is to improve interest in high-temperature fuel cell with CO_2 capture by providing an overview of the status of such kind of cutting-edge technologies. To approach this goal, the major strategies and technologies for fuel cells and their hybrid system with CO_2 capture have been reviewed. Simultaneously, the characteristics of fuel cell technologies are summarized and the technical and economic performance of the fuel cell with CO_2 capture are explored and discussed as well. The existing challenges that required to be overcome in fuel cell with CO_2 capture technology are highlighted with aspects on fuel cell module scale-up, cost, safety, reliability and capture energy, etc. Finally, opportunities for the future development of high-temperature fuel cell with CO_2 capture technologies are discussed. The conclusion remarks of this investigation indicate that fuel cell integrating CO_2 capture process is a promising route to sustainable future, and could even be more effective if fuel cell technology can be commercialized.

1. Introduction

Carbon dioxide (CO_2) as a primary greenhouse gas (GHG), has caused a significant effect on climate change and drawn a widespread attention in the past decades [1]. According to statistics from the IEA (International Energy Agency), global energy-related CO_2 emission in 2019 reached about 33 gigatonnes (Gt), following two years of increases.[2]. Hence, reducing CO_2 emissions has become the unanimous choice of science and technology communities and governments worldwide. Huge technological effort is ongoing towards efficiency improvement of conversion systems, to reduce fossil fuel consumption. However, efficiency enhancement or new technology for fossil fuel conversion is still insufficient to achieve the CO_2 emissions reduction goal [3]. Although there is an increasing interest to use renewable energy such as solar, wind, geothermal and biomass, their proportion in world electricity generation by source is still very low (only 6.3% in 2014) [4]. Carbon Capture and Storage (CCS) represents an invaluable technology and among the only ones able to sustain the fossil fuel energy economy which cannot be replaced in short-term [5,6].

CCS can be defined as the combined process of separating CO_2 from

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