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Review

Alternatives for oxygen-selective membrane systems and their integration into the oxy-fuel combustion process: A review

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ABSTRACT

Coal-fired power plants are considered to be one of the industrial technologies with a substantial contribution to climate change. In order to reduce their environmental impact, carbon capture and storage have acquired importance as a future clean coal technology in short and medium term. Concerning the closer-to-market options for CO_2 capture, oxy-combustion is seen as one of the promising zero-emission plants due to the possibility of its suitability in existing boilers. This technology uses oxygen as the oxidant for combustion, providing a raw CO_2 product which contains mainly water vapor, oxygen and nitrogen. Currently, cryogenic air separation is the only available mature option on a commercial scale. However, this system involves a high capital investment and an energy penalty in the oxy-fuel process, thus hindering its full-scale commercialization. As oxygen transport membranes offer significant advantages compared to the previous alternative, this option is foreseen as a candidate for its replacement. This work includes a review of this system and focuses on the study of the possible alternatives for integration into the oxy-fuel combustion process. As a result of this research, the compiled information has been homogenized, providing a completed base data related to operating parameters, required equipment and location of the combustion process for each studied alternative.

1. Introduction

Currently, the control of greenhouse gas (GHG) emissions in order to prevent their adverse effects on the global climate has become one of the most complex challenges worldwide. According to scientific studies and the different organisms and international agencies, such as the Intergovernmental Panel on Climate Change (IPPC) or the International Energy Agency (IEA), this environmental situation stems mainly from the growing energy demand and demographic development. As of today, fossil fuels represent the dominant energy source that drives the global economy. More than 60% of the world's primary energy demand is fulfilled by fossil fuels, where the electricity and heat production sectors are the principal contributors to carbon emissions [1].

In response to this environmental concern, the international community has agreed on measures that counteract this problem through different summits and conferences over several decades. The Conference of Parties (COP-21) held in Paris came to a historic agreement whose main goal was to limit global warming to 1.5 °C. From a technical point of view, the possible technological options to achieve the set aim are summarized in Fig. 1 [2–3].

In November 2017, the last summit on climate change took place in Bonn. In this meeting, a sustainable world strategy was agreed where renewable energy will be promoted instead of the use of fossil fuel for primary energy production [4]. However, studies suggest that the improvement in energy efficiency of processes and the carbon dioxide capture and storage (CCS) are alternatives that could minimize CO_2 emissions in the short and medium term [1,3,5]. Currently, CCS techniques have not been implemented on a large scale because it is necessary to reinforce a series of technological challenges: social acceptance, economic and legislative aspects and contribution to research and development. The main technological close-to-market options for CO_2 capture are: (a) Pre-combustion (CO_2/H_2 separation). This option consists of the decarbonisation of the fuel prior to the combustion. Firstly, the coal is gasified to produce synthesis gas ($CO + H_2$). Then, the CO is transformed into CO_2 by the water-gas shift reaction, and finally, before the combustion of the H_2, the CO_2 is captured. The high partial pressure of CO_2 makes easier its separation form H_2. Theoretically, pre-combustion could entail a cost 38–45% and 21–24% lower than post-combustion and oxy-combustion respectively [6]. However, it implies important changes in the case of retrofitting of existing facilities and

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