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The evaluation of oxy-fuel combustion deployment at the Mirfa Plant in UAE

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Abstract

Oxy-fuel combustion is currently one the promising options for carbon capture. Nonetheless, there are some technical barriers that hinder the deployment of the technology in commercial scale, being the oxygen production the most energetic costly step.

There is an opportunity to overcome this issue by using waste oxygen produced at the Mirfa Plant situated in Abu Dhabi, UAE. The facility currently produces gaseous nitrogen for injection into on-shore reservoirs and its waste stream rich in oxygen is vented to the atmosphere. This work focuses on finding a better application for the waste stream based on oxy-fuel technologies simulated in Aspen Plus.

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Keywords: Aspen Plus; ASU; carbon capture; CCS; CPU; oxy-fuel.

1. Introduction

Research studies have long identified greenhouse gas (GHG) emissions to be associated with global warming [1, 2]. The temperature of the planet has been increasing to dangerous levels specially in the last few decades due to intense human activity. The energy demand is increasing in such an unsustainable way that green technologies are not developed enough to keep up with this growth, making us rely on the burning of fossil fuels, thus emitting even more

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GHG into the atmosphere. Public awareness impacted the legislation in well-developed countries and contributed to make global leaders discuss the issue in the last few years. For instance, many talks have taken place during the COP-21 in Paris in 2015 where specialists have agreed that reducing GHG emission must be achieved as soon as possible. However, 41% of the currently global energy demand is still supplied by coal-fired power plants [3]. Global leaderships are encouraging the use of non-fossil fuel sources, such as nuclear energy, tidal, wind, solar and biomass [4] but it is unlikely that other alternative energy will completely substitute fossil fuels in the near future, mainly because the technology maturity is not capable yet to supply the increasing energy demand. Therefore, we must develop technologies to mitigate CO_2 emissions from carbon-intensive fossil sources.

One approach named Carbon Capture and Storage (CCS) plays an important role in recovering CO_2 from fossil fuel-fired power plants flue gas and transporting it to suitable storage locations rather than being released into the atmosphere. The three most studied techniques to provide energy and capture carbon dioxide from the industrial flue gas are classified as post-combustion, oxy-combustion and pre-combustion technologies [5].

Pre-combustion technology is based on converting the fuel into a mixture of CO_2 and hydrogen, usually denominated as syngas [6]. Amongst the major challenges of developing this technology there is the maturity readiness which hinders considering pre-combustion technologies for industrial application. Post-combustion technology, on the other hand, comprises the removal of CO_2 from the flue gas after the combustion take place. It differs from the oxy-combustion approach in the very combustion step where the hydrocarbon fuel reacts with air rather than an oxygen-rich environment, which results in a flue gas composition where carbon dioxide accounts only for 10 to 20% (differently from oxy-combustion where the flue gas is composed basically by CO_2 and vapour). Yet, research demonstrated that post-combustion technologies are, so far, the most economically feasible alternative to be deployed industrially [7]. Amongst the techniques to remove carbon dioxide from the flue gas, there are amine scrubbing, membrane separation and adsorption on solids or in liquids as the ones generally studied.

At last, oxy-combustion technologies rely on the combustion of fuel in the presence of pure oxygen rather than air. In such technology, the air is previously separated in an Air Separation Unit (ASU) into nitrogen and oxygen highly pure streams. The oxygen stream is then mixed with the recycled flue gas stream necessary to maintain the adiabatic flame temperature (ATF) in a reasonable level inside the boiler and also make up the missing N_2 volume [8]. Hence, the combustion takes place in a nitrogen-free environment generating flue gas rich in CO_2 and vapour, from which CO_2 may be easily dissociated by cooling processing followed by cryogenic separation [9]. Since the oxy-fuel combustion consists of using oxygen instead of air as the oxidant gas, it results in producing a CO_2-enriched flue gas that facilitates further purification in addition to reducing nitrogen oxides formation. On the other side, the main drawbacks of this technology are that the cost and energy demanded during the air separation process and the cryogenic separation are specially high, the technology is yet not mature to be scaled up industrially and several modifications would be necessary in current power plants facilities in order to incorporate such method [10]. Nonetheless, optimizing a power plant based on oxy-combustion might overcome some of these obstacles and be an alternative to the current post-combustion technologies on the market.

As aforementioned, one of the main challenges within this technology is the production of oxygen, which can be obtained whether by adsorption or cryogenic means with Air Separation Units (ASU). There exists an opportunity, at Mirfa Plant situated in Abu Dhabi, of utilizing waste oxygen produced from air separation unit, which provides gaseous nitrogen (GAN) for injection into on-shore gas reservoirs located in Habshan. This large quantity of high purity oxygen could be utilized for oxy-fuel power plant with CCS, which results in reducing the cost of operation and energy consumption of air separation units in addition to providing a stream of CO_2 that can be used for EOR activities. The Mirfa plant, which started operation in June 2011, consists of two identical air separation trains producing 670,000 Nm3/h of GAN at a purity of less than 10 ppm oxygen in nitrogen, while the remaining stream composed by 71%mol oxygen is vented to the atmosphere.

This work focuses on finding a better application for this oxygen. Since most of the energy to produce pure oxygen is saved by using the waste oxygen from Mirfa Plant, oxy-fuel technologies might be a better alternative than post-combustion technologies. Ultimately, the techno-economic evaluation results should assess the feasibility of deployment of such technologies.