International Journal of Greenhouse Gas Control 114 (2022) 103605

Contents lists available at ScienceDirect

International Journal of Greenhouse Gas Control

journal homepage: www.elsevier.com/locate/ijggc

Thermodynamic challenges for CO_2 pipelines design: A critical review on the effects of impurities, water content, and low temperature

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ARTICLE INFO

Keywords:
Carbon dioxide
CO_2 transport
CCUS
Corrosion
CO_2 pipeline
Water content

ABSTRACT

Environmental issues related to climate change have constantly been increasing in the last years, and global emissions must be managed wisely, adopting the most powerful and effective strategies available. Carbon Capture Utilization and Storage (CCUS) is claimed as a solid climate mitigation strategy for the most challenging emissions and the production of blue hydrogen. The development of an international CO_2 transportation network is considered a necessary cross-cutting topic in the whole Carbon Capture and Storage sector. CO_2 pipeline development is an essential aspect for the realization of most decarbonization CCS projects. Large-scale CCS projects will require the management and transport of CO_2 in the presence of impurities at lower costs than traditional CO_2 pipelines utilized for Enhanced Oil Recovery (EOR). Thus, the accuracy of modelling carbon dioxide in the presence of other components needs to be assessed. Corrosion prediction and control are strongly related to water content and introduces uncertainties in terms of costs and corrosion risks, especially in the presence of other components and possible cross-chemical reactions. In this work, the process and flow assurance challenges related to the design of a CO_2 pipeline have been reviewed in terms of impurities, water content, and corrosion, as well as low-temperature scenarios. The main scope of this paper is to analyse the aspects that can be improved and the ones that need for further research from a thermodynamic point of view. This will help the design of a next generation of CO_2 pipelines with low CAPEX (capital expenditure) and OPEX (operating expense), suitable for large-scale CCS projects and meeting the Paris Agreements.

1. Introduction

The development of an international CO_2 transportation network is considered a necessary cross-cutting topic in the Carbon Capture and Storage sector. CO_2 pipeline development is an important aspect for the realization of most decarbonization CCS projects. Carbon Capture Utilization and Storage (CCUS) is claimed as a solid climate mitigation strategy in particular for the most challenging missions. Most greenhouse gas emissions in the atmosphere over the last 150 years are addressable to human activities (Solomon et al., 2007). Heavy industries are responsible for 20% of global emissions today, more than 50% of which are related to steel and cement industries (Global CCS Institute 2020). Electricity production generates the second-largest share of greenhouse gas emissions. In the United States, more than 60% of electricity comes from burning fossil fuels, mainly coal and natural gas (EPA 2021). In the International Energy Agency (IEA) Sustainable Development Scenarios (SDS), carbon capture utilization and storage (CCUS) accounts for 9% of the cumulative emissions reductions needed globally by 2050 (International Energy Agency 2019). Since hydrogen is considered the fuel of the future, the interest in its development has increased during the last years. The production of hydrogen is called "green" when entirely produced from renewable energy sources and "blue" when it is obtained with steam methane reforming (SMR) associated with CCS (Simpson and Lutz, 2007, Barelli et al., 2008). Hence, due to the low cost of blue hydrogen, if compared with green hydrogen (IEA 2020), in the near term, CCS will play an essential role in the development of blue hydrogen production since SMR is an assessed and reliable technology. However, the high costs of the CCS technologies have lowered commercial development (Heuberger et al., 2016). The key aspects for the development of CCUS projects are related to costs, incentives, and public perceptions (Cox et al., 2020, Viebahn and Chappin, 2018). The captured CO_2 for large CCS projects can be

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https://doi.org/10.1016/j.ijggc.2022.103605
Received 3 May 2021; Received in revised form 29 October 2021; Accepted 4 February 2022
Available online 9 February 2022
1750-5836/