16th International Conference on Greenhouse Gas Control Technologies **GHGT-16**

23-27th October 2022, Lyon, France

Application of Decision Support Tool (DST) based on Analytical Hierarchy Process for the Screening of Carbon Capture Technologies

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Abstract

Carbon capture, utilization, and storage (CCUS) will play an important role in achieving the path to net-zero emissions [1]. There are many carbon capture technologies available today and the diversity of technology options can be classified as post-combustion, pre-combustion, oxy-combustion. Despite the fact that there are extensive works of literature available for the capture technologies, there is a lack of a comprehensive database or source which provides a detailed technical, environmental, and economic evaluation of the carbon capture technologies under the same basis. One of the most complete studies available so far is the technical report from IEAGHG [3] which followed up the most suitable technologies for CO_2 capture via evaluation of technical and economic aspects. Among the key recommendations of this report stands the advice to compare different technologies according to a consistent costing methodology. Also, the technologies may have different levels of maturity and the choice of the right capture technology for a given industrial site is associated with CO_2 concentration in the flue gas, the existence of impurities, operating pressure, etc., making an optimal decision between available technologies challenging and tedious.

In this regard, a decision support tool (DST) based on the Analytical Hierarchy Process (AHP) with a double-weighted matrix [2] is presented for the evaluation of well-suited capture technologies based on the specific inputs provided by the tool user. The DST is being developed in the framework of the PROCURA (Power to X and carbon capture & utilization roadmap for Belgium) project which aims to develop and provide a clear roadmap of CCUS technologies for all sectors in Belgium, establishing required steps by 2030 to reach carbon neutrality by 2050. The DST is incorporated with an extensive database coming both from literature and from detailed in-house models based on process simulations and economic analysis. These in-house models (still partially under development) are due to become a key highlight and innovation of the proposed DST as they provide a detailed evaluation of the capture technologies.

The purpose of this tool is to evaluate and rank various technologies in terms of three main criteria: engineering, economics, and environment. There are numerous key performance indicators (KPIs) under each criterion as presented in Figure 1 where the user preferences are introduced to the tool in two steps. First, preferences among, economic, engineering, or environment with respect to the others are indicated by the user using a scale varying from 1 (equal interest) to 9 (extremely favored). Then, KPIs under each criterion such as Technology Readiness Level (TRL), CO_2 capture rate, capture cost per ton of CO_2, etc. are evaluated against each other by the user. These preferences (for both criteria and KPIs) are then converted to score weights via AHP and the ranks of each technology will be calculated. Lastly, the most suitable CO_2 capture technologies are screened and recommended to the user considering all criteria and indicators. An example of the technology rank graph is presented in Figure 2.

The decision support tool is envisioned to deliver an easy-to-use data overview and assist the user to select the most promising options for the available carbon capture technologies in line with the user requirements. Currently, in-house models such as chemical absorption (using monoethanolamine), physical absorption (using dimethyl ether of polyethylene glycol) and CO_2 capture with membrane are available and the present tool's database can be further developed as a practical assessing tool with detailed results from a wide range of simulations including absorption, adsorption, cryogenic and membrane technology etc. as well as life cycle assessment (LCA) studies, social impacts, and industrial data. Moreover, as technologies ranking strongly depends on the estimated plant size, in-house models are being adapted to small, medium, and large-scale industries on the basis of their point-source CO_2 emissions. This will make the tool more accurate according to the user's requirements. Furthermore, a specific focus is set on the development of an open-source platform where verified data can be updated regularly to guide final decision-makers to accelerate carbon capture demonstration and short- to mid-term deployment for various industries. A case study for an industrial CO_2 emitter in Belgium will be presented to illustrate the tool and its applications. The goal is to develop this DST as a widely applicable and user-friendly tool for the site-specific evaluation of CO_2 capture technologies at one platform.

Keywords: Decision Support Tool (DST), Carbon Capture, Utilization and Storage (CCUS); Analytical Hierarchy

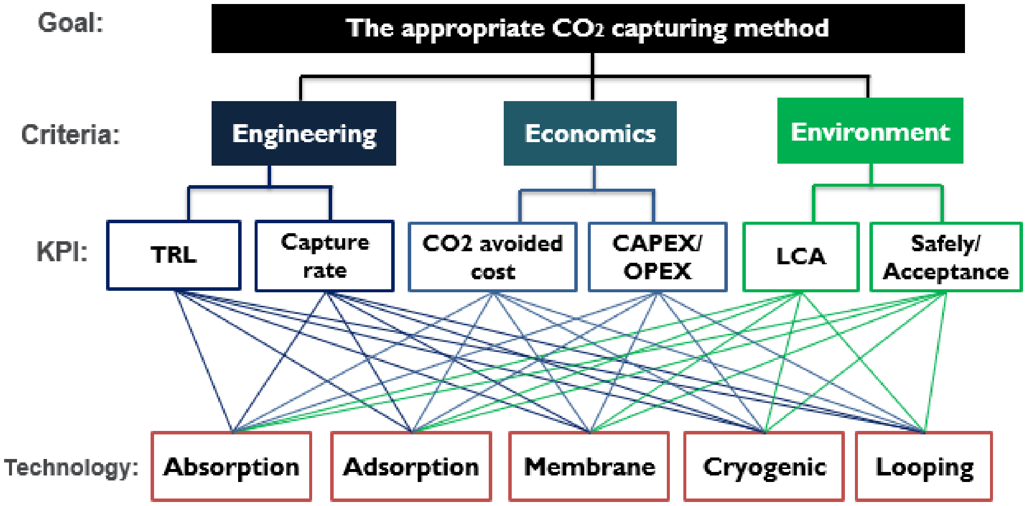

Figure 1: A schematic diagram of analytical hierarchy of Engineering, Economics and Environment criteria with its Key Performance Indicators (KPIs)

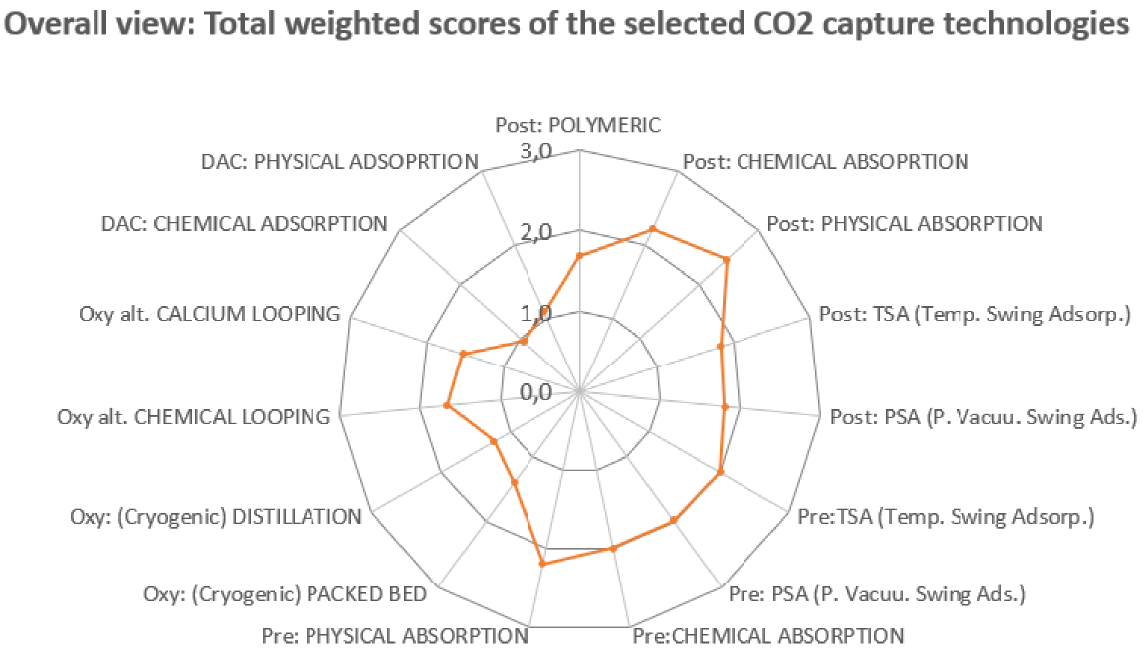

Figure 2: A graphical presentation of ranked technologies based on user preferences

References

[1] IEA (2020), Energy Technology Perspectives 2020, IEA, Paris https://www.iea.org/reports/energy-technology-perspectives-2020
[2] Saaty TL. (1980) Analytic hierarchy process. New York, NY: McGraw-Hil
[3] IEAGHG (2019), 2019-09 further assessment of emerging CO_2 capture technologies for the power sector and their potential to reduce costs