DECISION SUPPORT TOOL (DST) FOR CO_2 CAPTURE TECHNOLOGIES USING ANALYTIC HIERARCHY PROCESS (AHP)

Topic: Energy – Generation and Storage, energy and chemical engineering

S. KIM, R. BONANNO and G. LEONARD

Chemical Engineering, University of Liège, Belgium

Abstract

There is ever-increasing pressure to reduce greenhouse gas emissions from industrial sectors due to the global warming effects. Carbon Capture, Utilisation, and Storage **(CCUS)** are considered a crucial strategy for achieving CO_2 emission reduction targets. There are many technology options available to treat CO_2-containing streams. However, the choice of the right technology for CO_2 capture is closely linked to several criteria: the concentration of CO_2 in the flue gas, the presence of pollutants, pressure conditions, etc. So, it may be not immediate and tedious to make an optimal choice between available technologies. A **decision support tool (DST)** is developed to **assess** and **compare** widely available CO_2 capture technologies in terms of **engineering**, **economics** and **environment criteria** as well as **key performance indicators (KPIs)** such as Technology Readiness Level (TRL), CO_2 capture rate, capture cost per ton of CO_2, etc.

Background

The **Analytic Hierarchy Process (AHP)** is a multi-criterion mathematical decision-making method that was introduced by Saaty[1]. It is a structural way of representing multi-criteria problems with sets of criteria and alternatives as presented in Figure 1.

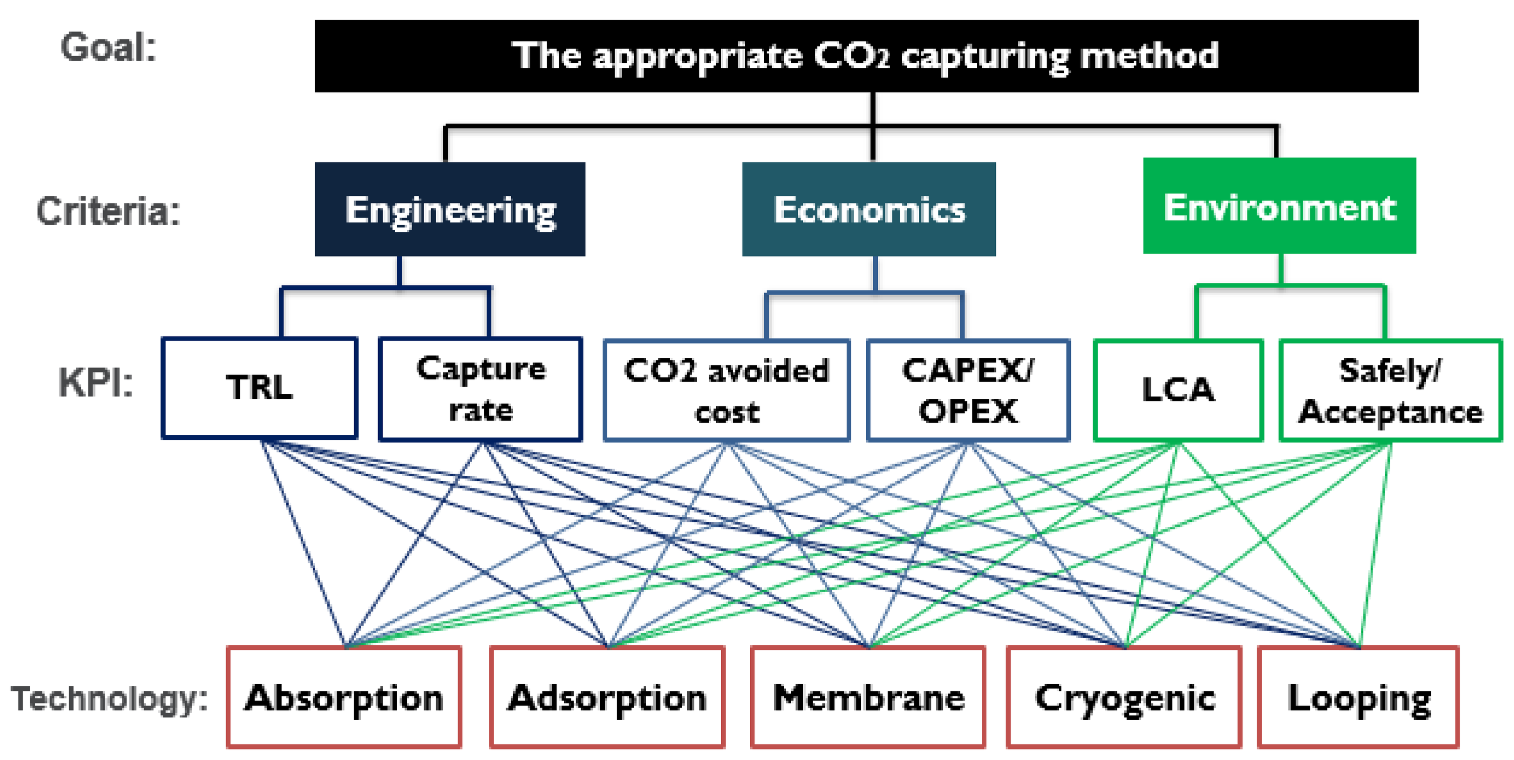

Figure 1: A schematic diagram of analytical hierarchy

The DST is based on the concept of AHP and can be used to provide a consistent and robust selection approach to CO_2 capture technologies; **Tradeoffs** between technology selection **criteria/KPIs** can be displayed as weights to guide decision-making processes. A summary of criteria and its KPIs used in the DST is presented in Table 1.

Table 1: A summary of criteria and its KPIs for the DST

KPI / Criteria	Engineering	Economics	Environment
KPI 1	TRL	CO2 avoidance cost	LCA score
KPI 2	Capture rate	CAPEX per kg of CO2 captured	Safety Issue
KPI 3	SOx NOx	OPEX per kg of CO2 captured	Public acceptance

Under the Engineering criterion, its associated KPIs are Technology Readiness Level (TRL), CO_2 capture rate while SOx NOx KPI evaluates technology's capability to handle contaminants. The Economic criterion consists of avoidance cost, CAPEX, and OPEX while the Environmental criterion contains Life Cycle Assessment (LCA) score, safety issue, and public acceptance to assess capture technologies.

References

[1] Saaty TL. Analytic hierarchy process. New York, NY: McGraw-Hil; 1980

[2] Osman, A.I., Hefny, M., Abdel Maksoud, M.I.A., Elgarahy, A.M. and Rooney, D.W., 2021. Recent advances in carbon capture storage and utilisation technologies: a review. *Environmental Chemistry Letters*, *19*(2), pp.797-849.

CO_2 capture options

There are three approaches to capture CO_2 and namely, post-combustion, pre-combustion, and oxy-combustion as presented in Table 2 (Osman et al. [2])

Table 2: Technical options for CO2 capture

Combustion/ Technology	Descriptions
Oxy	• Typical operating pressure and % of CO_2: **1 bar, 75-95%** • E.g. Chemical Looping
Pre	• Typical operating pressure and % of CO_2: **10- 80 bar, 20-40%** • E.g. Physical solvents, Membrane Systems, Pressure (and/or Temperature) swing adsorption
Post	• Typical operating pressure and % of CO_2: **1 bar, 3-15%** • E.g. Amine solvents, Solid sorbents, Ionic liquids, Metal Organic Framework (MOFs), membrane
DAC	• Typical operating pressure and % of CO_2: **1 bar, 400 ppm** • E.g. Climeworks, Carbon Engineering and Global Thermostat

In addition, Direct Air Capture (DAC) can also be an import part of technology options to mitigate climate changes. In the DST, various CO_2 capture technologies are assessed and compared via AHP.

DST description and Results

The tool allows users to express preferences in two steps: first, select which criteria among, economic, engineering, or environment are preferable. Then, inside each criterion, there are KPIs to be evaluated against each other by the users. The preferences are expressed on a scale of 1 to 9 where 1 means equal importance while 9 refers to the extreme favor.

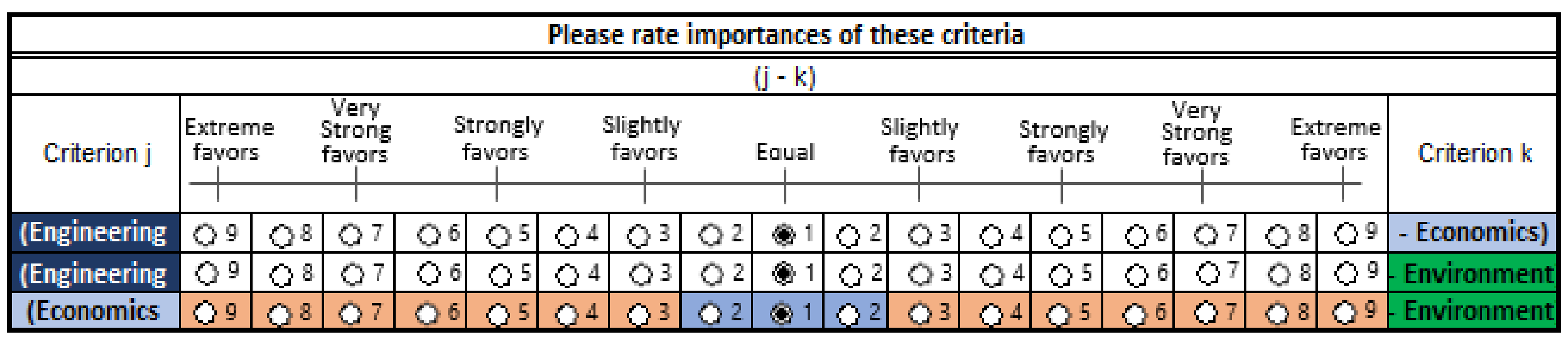

Figure 2: A scale system used in the DST (For criteria)

Users will select the preferences as shown in Figure 2 for both criteria and KPIs. These preference scores will be used to calculate weights as presented in Saaty[1] and then will be used to calculate the overall score (over a total score of 3) of each technology. The ranks of the technology are presented in Figure 3.

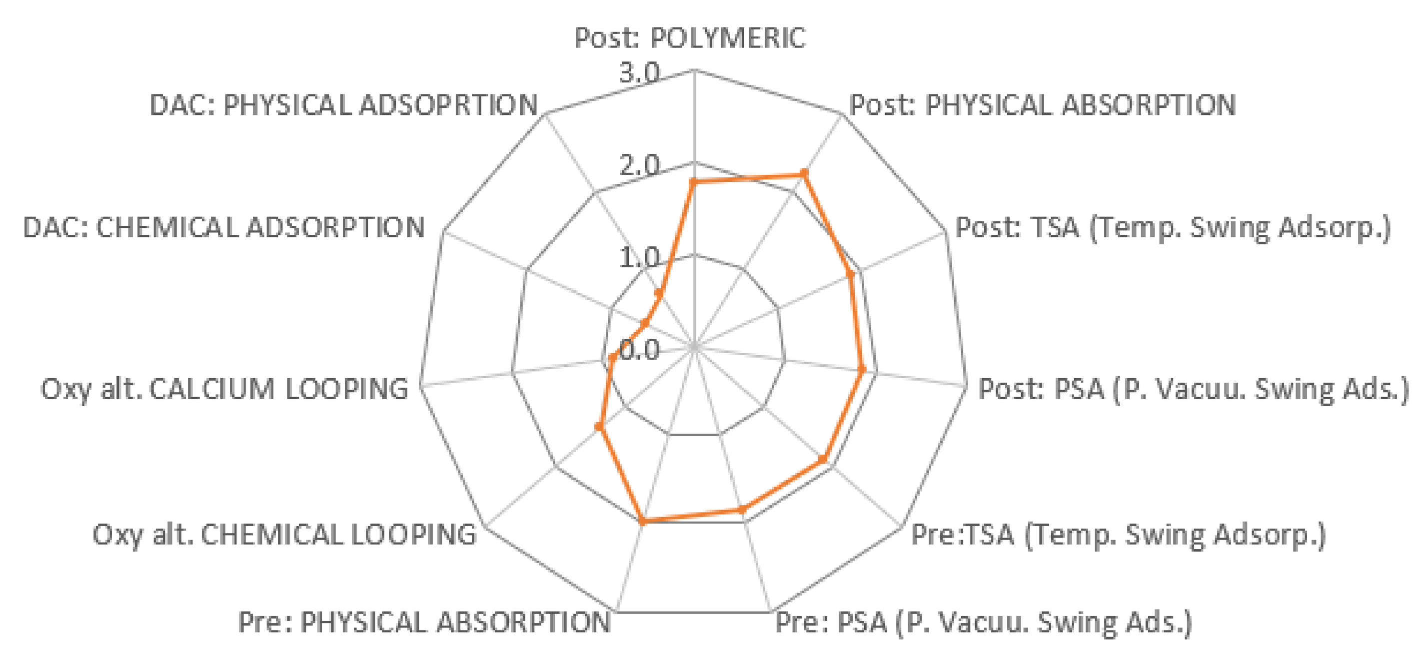

Figure 3: A rank of the selected CO_2 capture technologies based on user preferences

Conclusions and perspectives

This work presents an overview of the available technologies for CO_2 capture and guides the user towards a more conscious choice in line with the user's needs. The model is currently based on literature data. In future works, the DST database will be updated using modeling results and can be further developed as a practical assessing tool with a detailed database, LCA studies, and industrial data.

*The authors are grateful to the Belgian Energy Transition Fund which supports this research within the project PROCURA