Net benefits and phase shifts of global warming potential of post-combustion carbon capture technologies in energy-intensive industries

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Introduction

Nowadays, Life Cycle Assessment (LCA) is recognised as the most reliable method to evaluate the environmental impacts of post-combustion carbon capture technologies, to compare the environmental impacts of processes without and with carbon capture technologies, or to compare different carbon capture technologies [1]. This approach comprehensively considers all stages from raw material extraction to final disposal, providing decision-makers with a thorough assessment of environmental impacts [2].

However, there remains uncertainties regarding the net benefits of post-combustion carbon capture technologies in terms of climate change i.e. Global Warming Potential (GWP). The potential mechanisms and pathways of environmental burden shifting are not yet fully understood, making it challenging to accurately assess the long-term environmental impact of these technologies.

Given the urgency of climate change and the fact that CO_2 capture is one of the main ways to reduce CO_2 emissions, at least during the transition period, in-depth research into the life cycle impacts of post-combustion carbon capture technology is crucial. This study aims to provide valuable insights for policymakers and industry stakeholders, contributing to the development of more effective climate change mitigation strategies and facilitating the transition to a low-carbon economy.

Methods

This work followed the process shown in Figure 1 for literature search, screening and data acquisition. The time framework of publications is 2015-2024.

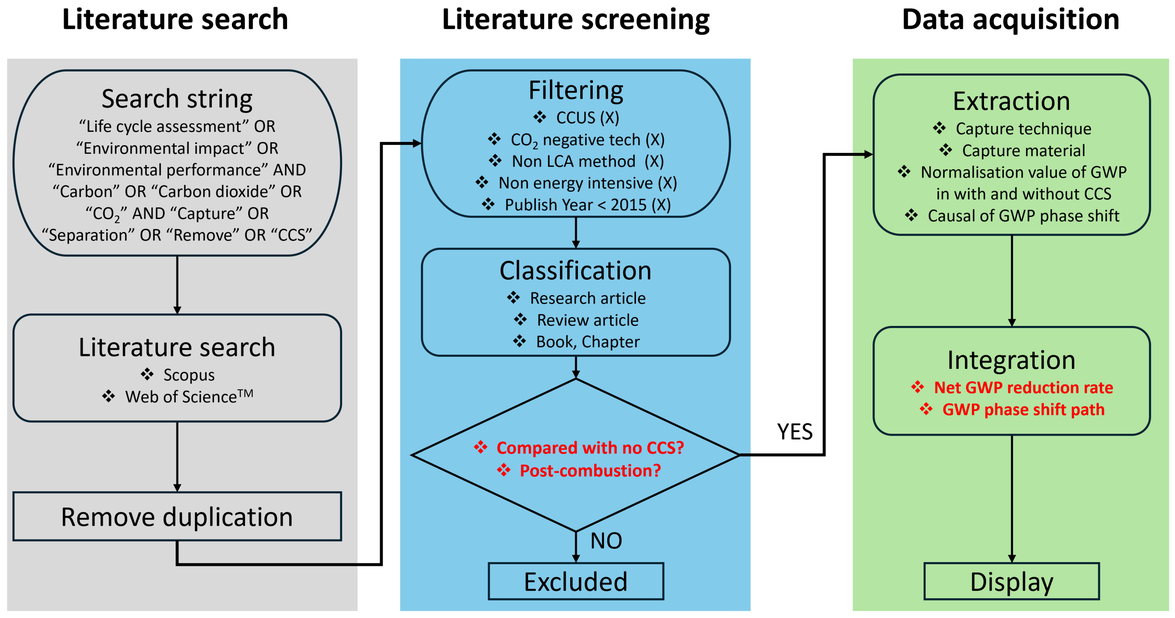

Figure 1: *Flow chart of screening process and methodology for quantitative metadata acquisition.*

Results

Net GWP benefits

The net GWP reductions rate for the four post-combustion carbon capture technologies (absorption, adsorption, membrane separation, and calcium looping) are shown in Figure 2 and range from 50 to 90 per cent overall. The figure also shows the subtypes of each capture technology. Overall, the differences between technologies and their subtypes are not significant.

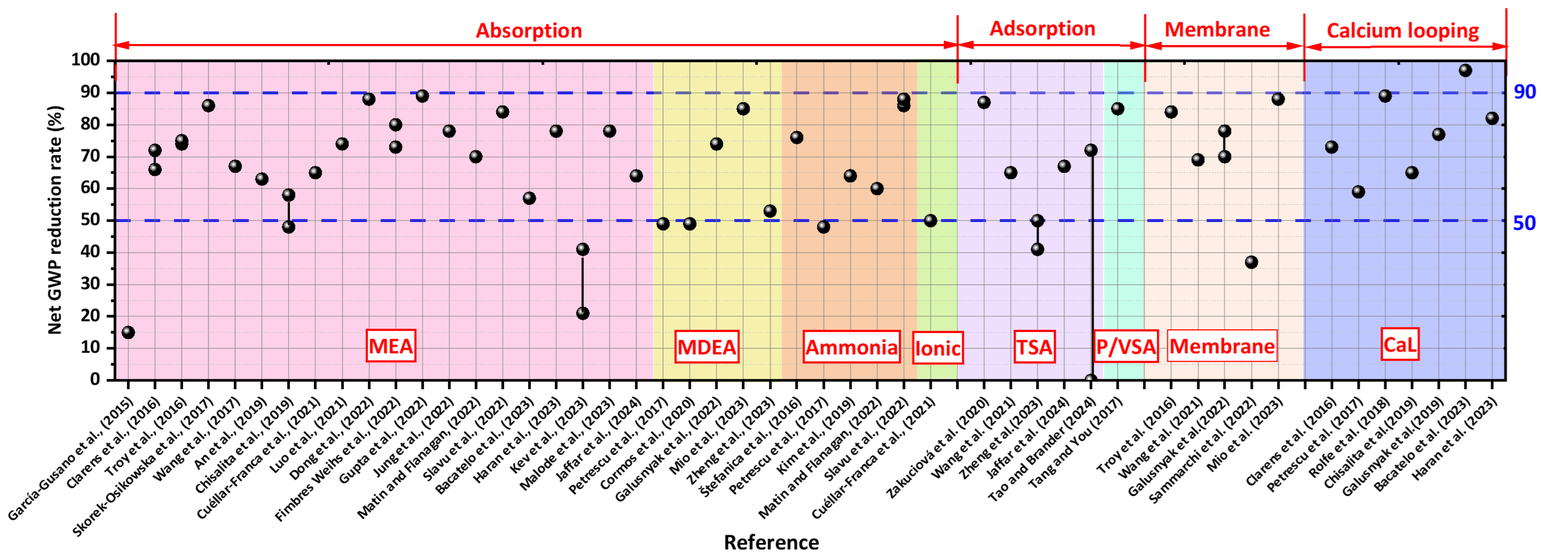

Figure 2: *Compilation of net GWP reduction rates for four carbon capture technologies.*

GWP phase shifts

The four perspectives (global, life cycle, technology and mechanism) of the phase shift in carbon capture technologies are shown in Figure 3. It shows that, from a global perspective, the GWP shifts from the operational phase to upstream and downstream stages. From a life cycle perspective, it shifts from the use and operation phase to the other four life cycle phases. From a technology perspective, it shifts from the CO_2 capture phase to the other eight phases. Finally, from a mechanism perspective, the root cause of this shift is the increased demand for materials and energy in phases other than the CO_2 capture phase.

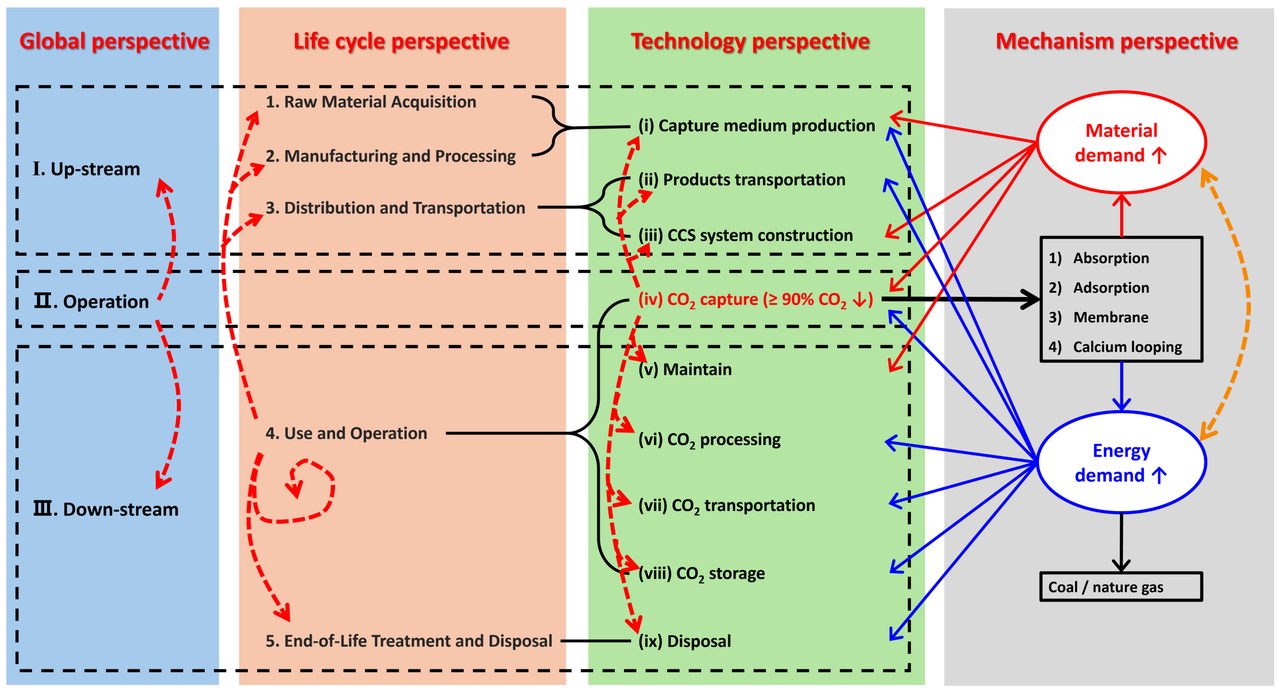

Figure 3*: GWP phase shift paths (red thick broken lines with arrow) of four CO2 capture techniques from global perspective, life cycle perspective, technology perspective, and mechanism perspective.*

Conclusion

Net GWP reductions for all four post-combustion technologies (absorption, adsorption, membrane separation, and calcium looping) are well below the typical 90% capture rate, sometimes to 50%, due to life cycle shifts driven by material and energy demands outside the capture stage.

References

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[2] Cuéllar-Franca, R. M., & Azapagic, A. (2015). Carbon capture, storage and utilisation technologies: A critical analysis and comparison of their life cycle environmental impacts. J. CO_2 Util., 9, 82-102.

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