IEAGHG 8th Post Combustion Capture Conference

16th to 18th September 2025 Marseille, France

Deploying Direct Air Capture in Europe: Yes, but how, where and when?

Oumaima Rhalem[a], Sigrid Aunsmo[b], Sigmund Holm[b], Shamim Homaei[c], Kang Qiu[b], Asgeir Tomasgard[c], Rahul Anantharaman[b], Matteo Gazzani[a,*], Simon Roussanaly[b,*]

[a] *Copernicus Institute of Sustainable Development, Utrecht University, Utrecht, the Netherlands*
[b] *SINTEF Energy Research, Trondheim, Norway*
[c] *NTNU, Trondheim, Norway*

Corresponding author's e-mail address: simon.roussanaly@sintef.no, m.gazzani@uu.nl

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Abstract

While the International Energy Agency forecasts that approximately 1 $GtCO_2/y$ will have to be removed via Direct Air Capture (DAC) by 2050 . While this sets the global target and the importance of DAC in achieving net-zero ambition, the question of how to best achieve that target at the global and continental level remains to be answered.
Indeed, this rollout does not only depend on the cost of direct air capture technology but also its surrounding system, which includes the energy and power system, CO_2 storage availability, deployment of CO_2 transport and storage infrastructure, and even air characteristics (for example, temperature and humidity). To complicate this further, some of these characteristics vary significantly within a year and geographically (for example, temperature, electricity price, etc.) and will change significantly in the coming decades (for example, electricity prices and emissions). Hence, while several works have looked at the rollout for DAC, integrating these aspects to the right level of detail has been a challenge.

This work thus seeks to develop a plan for such a rollout at the European level by integrating fit-for-purpose representation of, for example, these different aspects:

- The DAC performances are based on the detailed model from Wiegner et al. for sorbent-based DAC [1] and An et al. for solvent-based DAC [2][3].
- The EMPIRE model [4] is used to develop different scenarios of electricity price and CO_2 intensity per European country, by 5-year investment periods until 2050 and with an hourly granularity within a year.
- Variations of relevant air characteristics (temperature and humidity) within a year are based on European meteorological data set [5].

- The CO_2 transport and storage infrastructure is modelled using the iCCS tool for techno-economic and environmental evaluation of CCS value chain [6].

The EnergyModelX model [7] is used to integrate these aspects with the aim of minimising the DAC rollout cost, as illustrated in Figure 1. The results will include optimal DAC rollout strategy, net removed emissions level, and associated cost, as well as the impact of possible constraints such local burden of DAC rollout on the regional power sector or the lack of European collaboration.

While a least-cost deployment forms the base case, several scenarios investigating different allocation approaches between countries (cumulative per capita emissions, ability to pay, equal per capita) will also be presented and discussed (see Figure 2).

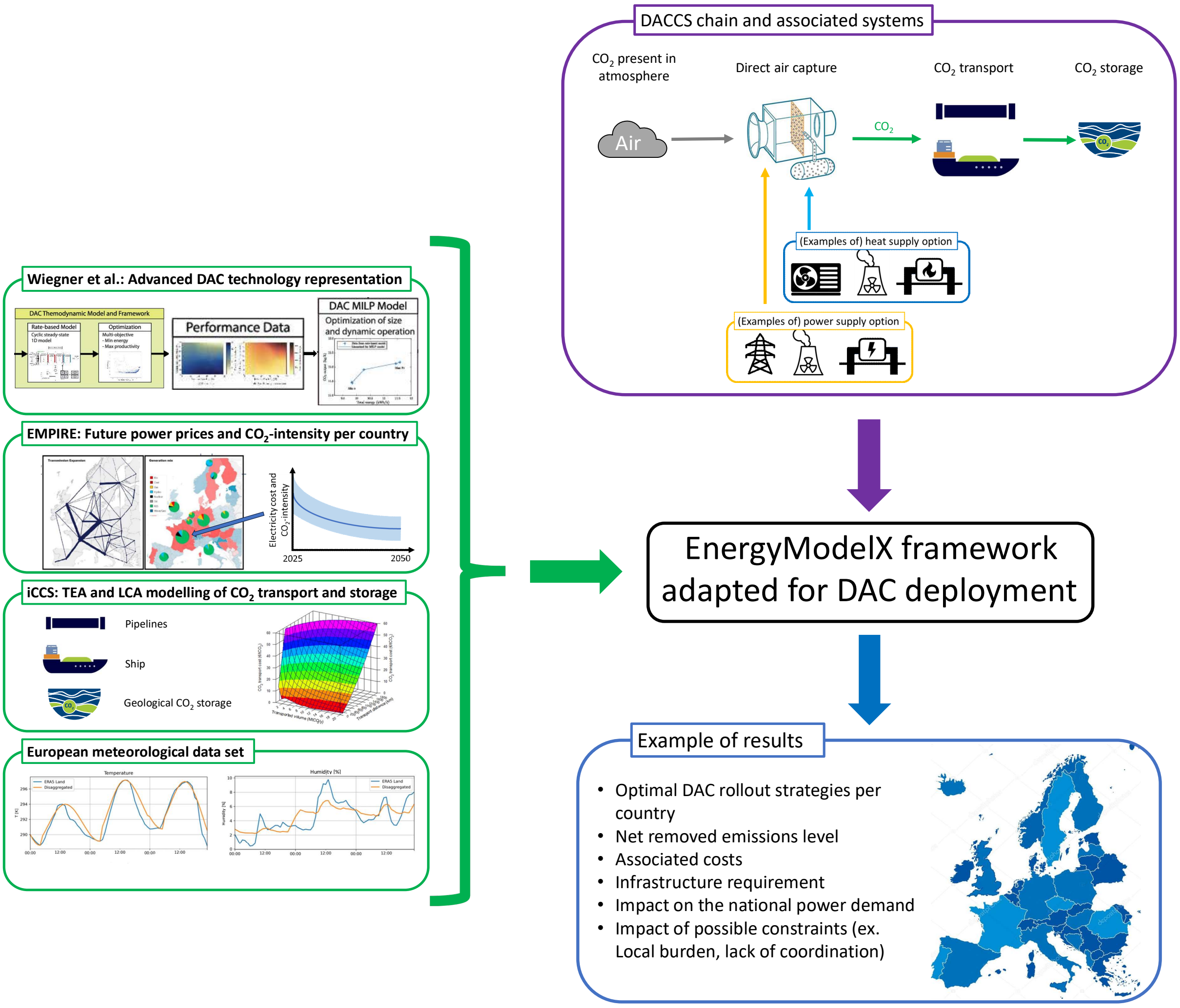

Figure 1: Schematic illustration of the integration of the fit-for-purpose modelling of relevant aspects via the EnergyModelX tool to understand the optimal rollout of DAC across Europe

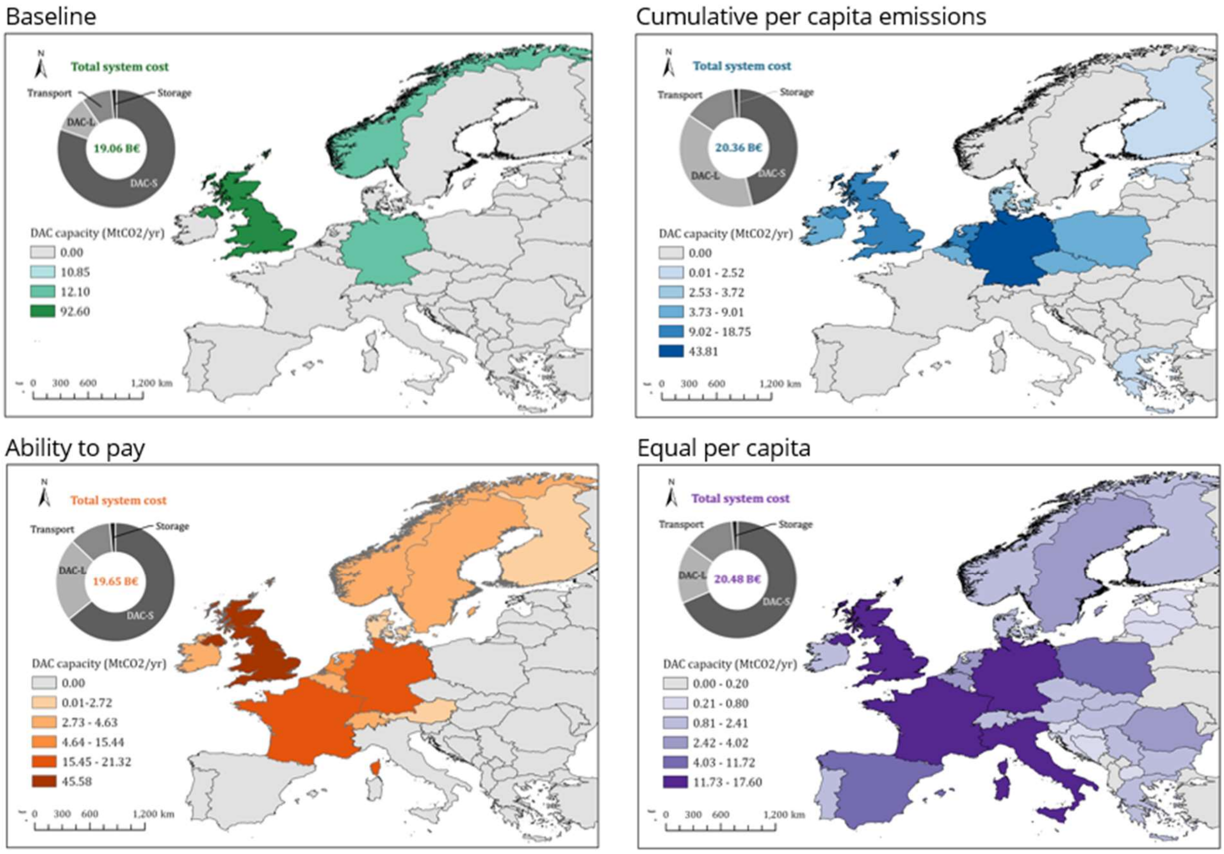

Figure 2: Optimal DAC rollout in 2050 depending on different scenarios.

Keywords: Direct Air Capture (DAC); Techno-economic analyses; Risk and value chain assessments, and system analyses.

ACKNOWLEDGEMENTS

This work was supported by the project "The Norwegian Continental Shelf: A Driver for Climate-Positive Norway" (NCS C+) funded by the Research Council of Norway (328715) under the green platform program.

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