

Research Project #17

Experimental and Simulative Development of an Efficient Direct Air Capturing (DAC) Process (IET-4 & IMD-2)

Direct Air Capture (DAC) comprises technologies designed to separate CO₂ from ambient air, thereby generating negative emissions. These negative emissions can offset CO₂ from hard to abate sectors and can therefore play a vital role in meeting the climate targets of the Paris Agreement. [1]. The latest IPCC report further highlights the importance of employing DAC to achieve these targets [2]. Consequently, there is currently considerable public interest in this technology, although several research challenges remain in order to further advance its development.

The DAC technology with the highest Technology Readiness Level is the adsorption-based approach. A key area for improvement lies in the adsorbents used in DAC systems. Adsorption capacity, selectivity toward CO₂, and long-term stability are of central importance for overall process performance. To date, energy demand and costs represent the main hindrance to a global roll-out of DAC. Since the range of commercially available adsorbents remains limited to a single material, the production of novel adsorbents at a scale that allows thorough testing is essential. Moreover, bench-scale testing can provide new insights into the heat and mass transfer characteristics of these adsorbents, which cannot be investigated adequately at lab-scale.

Such a bench-scale “mini-plant” is currently under construction at the Institute of Energy Technologies (IET-4), which is specially designed based on preliminary process analysis [3] and to be commissioned in 2026. Standard as well as novel solid sorbents will be tested, which are being developed and produced in small to medium-sized batches at the Institute of Energy Materials and Devices (IMD-2). This interdisciplinary approach is required to identify most promising operation and respective materials since optimization is only possible in a holistic view.

Within the framework of this interdisciplinary PhD project, a further milestone in DAC research is to be achieved, building upon the recent studies already completed. The research will cover multiple levels, including material synthesis, experimental characterization in lab- and bench-scale, and process simulation.

Tasks to be completed during this PhD project include:

- Production of sorbents on a kilogram scale with reproducible quality and in a form suitable for use in the DAC miniplant.
- Operation of the DAC pilot plant using the self-produced sorbents as well as reference materials and characterization of their performance under operating conditions.
- Thermodynamic modeling of the DAC process with varying material properties and operation conditions.
- Development of an energy-optimized operational strategy and respective material requirements for large-scale DAC plants based on the insights gained.

The overarching goal of this project is to advance the understanding of the sorbents utilized and to enhance the overall DAC process, thereby increasing the technical efficiency and economic viability of DAC technology.

Location of the HITEC Fellow	Forschungszentrum Jülich, Institute of Energy Technologies - Electrochemical Process Engineering (IET-4), Director: Prof. Dr. Ralf Peters https://www.fz-juelich.de/en/iet/iet-4
Partners of the HITEC Project	Forschungszentrum Jülich, Institute of Energy Materials and Devices – Materials synthesis and Processing (IMD-2), Director: Prof. Dr. Wilhem Albert Meulenber https://www.fz-juelich.de/en/imd/imd-2
Specific requirements	Background in chemical engineering, material engineering, mechanical engineering, environmental engineering or comparable First Lab experience First modelling experience preferable
For project specific questions please contact	Dr. Nils Beltermann, IET-4, n.beltermann@fz-juelich.de Dr. Stefan Baumann, IMD-2, s.baumann@fz-juelich.de

- [1] United Nations Framework Convention on Climate Change, Paris Agreement, United Nations, 2015
 [2] IPCC, Synthesis Report of the IPCC Sixth Assessment Report (AR6): Climate Change 2023
 [3] A. S. Jajjawi et al., Exploring Weather Impacts on Direct Air Capture Through Process and Techno-Economic Modeling, 2025