

A novel process to capture and convert CO₂ from air

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Credit: AI-generated image ([disclaimer](#))

As CO₂ emissions continue to grow, the world is becoming ever more reliant on the removal of carbon dioxide from the atmosphere to achieve urgent climate targets. Direct air capture (DAC) is a promising novel technology for the extraction of carbon dioxide from ambient air via liquid or solid sorbents. The CO₂ provided by this process can be either

stored in geological formations or used as feedstock for the production of carbon-neutral fuels and energy carriers. For his PhD-research, Francesco Sabatino designed and optimized processes for the production of synthetic natural gas from carbon dioxide captured from air and renewable hydrogen.

The necessary growth of renewable energies calls for the development of measures to balance the inherent fluctuations associated with sources such as solar and [wind energy](#). In this regard, power-to-X (PtX) is often brought up when discussing the future renewable energy system. PtX refers to technologies that convert electricity into a variety of fuels or energy carriers through a two-step process. Hydrogen is initially produced via water electrolysis and converted to a gaseous or liquid energy carrier by synthesis with CO or CO₂. The chemical bonds of these carriers would provide a very efficient and scalable way to store and transport large amounts of renewable energy.

Moreover, the complete decarbonization of our society will not take place overnight, with some sectors (such as aviation) requiring a crucial technological leap to become fully independent from carbon sources. The utilization of dense [energy carriers](#) produced from atmospheric carbon and [renewable hydrogen](#) would reduce or even eliminate the emissions of distributed and difficult to decarbonize sources such as the one associated with the [transport sector](#).

Direct air capture

Direct air capture (DAC) is still a very expensive technology with a high potential for improvement. The high cost of current DAC processes would place a considerable weight on the economics of any CO₂ capture and utilization system. Therefore, the first objective of Sabatino's PhD research was to optimize DAC processes in order to reduce their costs. In collaboration with his team, he investigated the most mature and

effective DAC processes, which capture CO₂ via aqueous solutions of potassium hydroxide or through adsorption on different solid materials. In addition, he also designed new processes based on electrochemical technologies, which are particularly interesting as they can be easily integrated with renewable energy sources, since the only energy input is electricity. Sabatino simulated these systems with detailed process models and optimized their performance through genetic algorithms.

Sabatino used data retrieved from patents or published papers to accurately simulate these processes and validate my models. "I found that all technologies have the potential to achieve costs lower than 200 \$/ton CO₂, thanks to rigorous optimization and smart design. However, processes adopting solid-sorbents generally perform better, provided that high mass transfer rates are achieved."

Optimal processing

The second objective of his research was to identify an optimal process integration between DAC and the methanation of carbon dioxide. The sorbent regeneration requires considerable energy, while the reaction of CO₂ with hydrogen is exothermic, that is, it releases heat. Sabatino investigated different integration strategies to identify and quantify the synergies that can arise from a smart combination of CO₂ capture and its conversion. He developed a kinetic model to describe the adsorption and desorption of carbon dioxide on potassium carbonate and implemented it in an existing reactor model.

Sabatino found that a great reduction of the energy demand can be achieved through efficient heat integration. Generally, overall auto-thermal operation can be attained, meaning that no external heat has to be provided to the DAC units. Moreover, a novel and intensified process in which the capture and conversion of the [carbon dioxide](#) are carried out in the same reactor provided the best results, thanks to a more efficient

heat integration and avoidance of CO₂ compression.

More information: Direct Air Capture and Methanation: Process design and development. [research.tue.nl/en/publication ... sign-and-development](https://research.tue.nl/en/publication/.../sign-and-development)

Provided by Eindhoven University of Technology

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