TECHNOLOGICAL BREAKTHROUGHS: THE PAST, PRESENT AND FUTURE

Diana Ivakhnenko

Educational and Research Institute of Energy Saving and Energy Management, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Carbon dioxide (CO_2) is a natural part of the atmosphere, yet its excessive concentration threatens both the environment and human health. Studies show that indoor CO_2 levels above 1000 ppm can lower the quality of sleep and cause fatigue, dryness, or breathing discomfort (Liu, Lin & Zhang, 2023).

As global emissions continue to rise, it becomes essential not only to reduce new CO_2 output but also to capture and reuse what already exists in the air. This approach – known as Direct Air Capture (DAC) – has inspired innovators worldwide, including Ukrainian entrepreneurs working to make the planet cleaner.

In 2019, Ukrainian engineer Yurii Hartskiy founded Carbominer, a startup the name of which literally means *"carbon miner."* The idea came from a personal concern – his daughter's health and the quality of the air she breathed (Yermolenko, 2025). Realizing the wider potential of this problem, Hartskiy set out to design a technology capable of extracting CO_2 directly from the atmosphere and turning it into a useful product.

Soon after its creation, Carbominer reached the finals of ClimateLaunchpad 2019**,** being recognized as one of the most promising green-tech startups in Europe.

Carbominer focuses on developing Direct Air Capture units that can remove CO_2 from the air and deliver it directly to greenhouses or vertical farms, where CO_2 accelerates plant growth. Unlike industrial systems, Carbominer's approach is decentralized: its compact modules can be installed on-site, eliminating the need to transport compressed CO_2 from factories (Carbominer, n.d.-a).

The company's broader mission is to make DAC technology affordable, local, and environmentally clean, combining business efficiency with ecological responsibility.

Carbominer's system uses liquid absorbents that selectively capture CO_2 from ambient air. When saturated, the absorbent is regenerated with low-energy heating, releasing pure CO_2 for reuse (Carbominer, n.d.-b).

A key innovation is the plan to power these systems with solar panels, ensuring that air capture does not rely on fossil energy. The integration of renewable power sources helps make the process nearly carbon-neutral and suitable for operation in remote agricultural areas.

This combination of on-site production and renewable energy use places Carbominer among the most sustainable DAC developers in the world (Carbominer, n.d.-c).

Carbominer has already tested pilot systems in Ukraine and Europe, proving their efficiency under real conditions. The next step is commercial scaling and cooperation with partners in agriculture, construction, and energy.

The company also explores how captured CO_2 can be used to produce synthetic fuels and eco-friendly building materials, turning carbon into a valuable industrial feedstock rather than waste.

Despite the progress, DAC remains energy-intensive and costly. Because CO_2 forms only 0.04 % of the air, huge volumes must be processed to capture meaningful amounts. Without renewable power, such systems can even emit more CO_2 than they remove (Keith, Holmes, St. Angelo & Heidel, 2021).

Economic challenges also persist: carbon credits and global policies are still developing, and large-scale adoption will require both government incentives and cheaper materials (Gambhir, Realmonte & Nemet, 2024).

Still, the benefits of DAC are undeniable. It can operate anywhere**,** remove historical emissions, and provide CO_2 for industrial reuse**.** When combined with renewable energy – like Carbominer's planned solar-powered modules – it can achieve net-negative emissions (Keith et al., 2021; Gambhir, Realmonte & Nemet, 2024).

Carbominer's local, modular approach makes the technology more flexible and sustainable, showing how carbon capture can evolve into a profitable, environmentally friendly industry (Carbominer, n.d.-a; Carbominer, n.d.-c).

Direct Air Capture and carbon utilization mark a turning point in how humanity interacts with the atmosphere. By transforming CO_2 from a harmful gas into a valuable resource, companies like Carbominer prove that innovation and environmental care can go hand in hand.

Though challenges remain, the combination of renewable energy, scientific progress, and human creativity brings us closer to a future where clean air is not only a right but also a renewable resource.

References:

Carbominer. (n.d.-a). *About us.* Retrieved from https://carbominer.com

Carbominer. (n.d.-b). *Technology*. Retrieved from https://carbominer.com/technology

Carbominer. (n.d.-c). *Implementation.* Retrieved from https://carbominer.com

Gambhir, A., Realmonte, G., & Nemet, G. F. (2024). *Environmental Science & Technology*, ***58***(3), 1271–1280. Retrieved from https://doi.org/10.1021/acs.est.3c08269

Keith, D. W., Holmes, G., St. Angelo, D., & Heidel, K. (2021). *Energy & Environmental Science*, *14*(12), 7063–7090. Retrieved from https://doi.org/10.1039/D1EE03523A

Liu, X., Lin, Z., & Zhang, Y. (2023). *CO_2 levels and human health in buildings. Buildings*, ***13***(11), 2768. Retrieved from https://doi.org/10.3390/buildings13112768

Yermolenko, K. (2025, April 21). *Vydobuvach vuhletsyu: ukrayintsi stvoryly startap, yakyy vytyahaye CO_2 z povitrya* [*Carbon extractor: Ukrainians create startup that extracts CO_2 from the air*]. *Hmarochos.* Retrieved from https://hmarochos.kiev.ua/2025/04/21/vydobuvach-vugleczyu-ukrayinsczi-stvryly-startap-yakyj-vytyagaye/