EIC COMMUNITIES

Article, 26 September 2024

From CO2-made milk to phone-charging waste streams: when pollution is an asset

Microbial fuel cell, hydroponics, new-generation membranes, and much more. When "deep tech" turns carbon dioxide and nitrogen compounds into assets and brings us closer to the day when we drink carbon dioxide (CO_2)-made milk and recharge our phones from wastewaters.

Diego Giuliani

Imagine **savouring an ice cream made from air**, **recharging your smartphone through plants**, **growing vegetables from your waste streams**, and flying on planes powered by recovered carbon emissions. This is not a sci-fi scenario but **a near-future reality that scientists and researchers are working to make possible**. Producing milk from CO_2 while reducing pollution, cutting heavy industries' emissions to turn them into renewable fuel, and **harnessing the magic of plants to feed modern cities and produce bio-electricity** are some of the extreme challenges, taken up by a bunch of "deep tech" projects falling under the umbrella of what insiders call the EIC- CO_2 and nitrogen portfolio. "Our goal is to foster and leverage a circular approach to transform actual waste such as carbon dioxide and various nitrogen compounds found in water, air and soil into useful feedstocks. The waste streams that portfolio projects work on belong to the 'family' of GHG emissions"," states Francesco Matteucci,

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Programme manager on Advanced Materials for Energy and Environmental Sustainability for EIC Communities, the EU-project funding research and deep tech projects.

The common thread among the eight projects within this portfolio is the challenge of **turning problems into viable and sustainable solutions, by capturing and converting carbon dioxide and nitrogen compounds**. "Whether electrochemical, photochemical, biological, or thermochemical, the conversion technology was our primary categorisation criterion," explains Matteucci. "But as **our aim is to create a sustainable value chain for this 'carbon and nitrogen circular economy,'** during the evaluation phase we also took into account the ability of these projects to manage and valorise the waste inputs, reuse or avoid the use of critical raw materials, fully implement a circular approach, and integrate the whole technology into the industrial system."

Providing cheap and healthy food, while cutting livestock's carbon emissions and addressing the scarcity of available land for pastures is among the goals of Hydrocow. Coordinated by Arttu Luukanen, the project owes its name to its ambition of "engineering a microbe that converts carbon dioxide and hydrogen produced from water using electricity, into beta-lactoglobulin". In other words: **producing milk from CO_2 and electricity, removing the cow from the process**. "We are trying to build a mechanism for the microbes to express proteins, and the first one that we are targeting is beta-lactoglobulin, a major constituent of milk," he explains. It's too early to say what this "animal-free milk" will taste like, adds Arttu, but "**as it will be based on a very pure form of this protein, there should be no palatability issues**." His optimism is bolstered by the encouraging experience of Solar Foods, the Finnish food technology company that he works for as Senior Vice President, Space and Defence: "Solein is a protein produced by a naturally occurring bacterium and made from natural single-cell organisms, which are grown in a fermentation process. Water is split with renewable electricity into hydrogen and oxygen. As a carbon source, the microbes use CO_2 gas that is captured from the atmosphere, and thanks to this protein **we have already created ice-cream, snacks and excellent pasta**. A professional chef works with our food team to develop delicious recipes using it."

Producing food, but not only, is also the mission of Mi-Hy, another project in the EIC- CO_2 and nitrogen portfolio. In the words of its coordinator, Rachel Armstrong, its aim is to take up the challenge of "**feeding modern cities, reducing their waste and producing bioelectricity** at the same time, by **merging the technologies of hydroponics and microbial fuel cells**." As hydroponics is a system that allows plants to grow in water only, she explains, "to optimise it, we work with both parts of the plant system: the first one is its green part that captures carbon dioxide, fixes it through sunlight and turns it into biomass, which is basically what we eat. But for it to be good and tasty, we also need to deal with the other part of the plant, which is the root system, and **this is where most of the Mi-Hy technology is situated**."

This is where comes into play the microbial fuel cell, a technology designed over 100 years ago by the British botanist and mycologist Michael Cressé Potter and then further developed to increase its ability to produce electricity. "It's on **a bioelectrical system which, much like a car battery, is made of two chambers**: a negative and a positive one, respectively the anode and the cathode. **On the anode side, we feed bacteria which clean the water and make electricity out of the organic waste**. The leftovers form a sludge that can used as biofertilizer." Unlike traditional hydroponics, which depends on chemical fertilisers to supply plant nutrients, this innovative system not only **powers its own LEDs but also generates valuable and sustainable resources through a complex process**.

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Just as valuable is the **renewable fuel for planes**, trucks and other vehicles, that the EU project DAM4CO2 aims at producing, **through the conversion of CO_2 emissions**. The key, says its European coordinator Alessio Fuoco, is a **new generation membrane, "that will basically act as a filter** but at a molecular scale: it will let through the CO_2 molecules, but retain those of nitrogen and other compounds." The process is far more complex, but to make it simple, he explains, "when moving in the membrane, the CO_2 will bump into a catalyst and get converted into fuel." **Compared to the existing methods**, which capture carbon dioxide only when its concentration is extremely high and require dedicated separation facilities, this solution would not only **cut the energy consumption of the whole process**, but also **be operable in much smaller, more versatile and scalable units**. "It's not a tool that you will have at home," adds Fuoco. "But it could be installed in waste disposals producing biomethane, in high-polluting industries that most need to be decarbonised, and any other setting where the CO_2 level in flue gases is between 5% and 20%."

The **potential for almost unlimited future applications** is also common to the solutions developed by Mi-Hy and Hydrocow. "It's something that is not going to end here. If we manage to modify the organism to produce this milk protein, then the question will be: 'What other proteins can we produce? '**It could be other food proteins, like egg proteins, but also collagen, leather or ingredients for the pharmaceutical industry,**" notes Luukanen. "If we scale up our solution, **it could be installed in every major industrial hydroponic system.** By making locally produced bioavailable nitrogen and generating bioelectricity, it would reduce both the demand for fertilizers and the carbon consumption of the hydroponics needed in Europe to have year-round vegetables," concludes Mi-Hy's Armstrong, before adding: "**One day, we might not only charge our phones with it, but even have public urinals growing tomatoes!**"

Photo credits: HydroCow - https://www.hydrocow.eu/

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