Breakthrough artificial photosynthesis comes closer

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Imagine we could do what green plants can do: photosynthesis. Then we could satisfy our enormous energy needs with deep-green hydrogen and climate-neutral biodiesel. Scientists have been working on this for decades. Chemist Chengyu Liu will receive his doctorate on 8 June for yet another step that brings artificial photosynthesis closer. He expects it to be commonplace in fifty years.

In fact, we can already achieve photosynthesis as green plants can. Solar energy converts CO_2 and water into oxygen and chemical compounds that we can use as fuel. Hydrogen for example, but also carbon

compounds like those found in petrol. But the costs are higher than the value of the fuel it yields. If that changes, and we can scale up this artificial photosynthesis gigantically, then all our energy problems will be solved. Then CO_2 emissions from energy production will become negative.

Promising, but we are not there yet

Although it sounds promising , we are not there yet. Chengyu Liu, one of the dedicated researchers working on artificial photosynthesis: "Now that this subject is such a hot topic worldwide, I think the first real application of this will be a fact within twenty years." But that's not all, he continues: "After the introduction of a new technology like this, it always takes decades before it becomes common practice. It was the same after the invention of the steam engine in the nineteenth century. I suspect it will be another thirty to fifty years before it is used industrially on a large scale."

Real green hydrogen

We already have cars running on hydrogen, with only water as the exhaust gas. But it takes a lot of energy to make that hydrogen. The "green hydrogen" we produce nowadays, only means that we get the energy to produce it out of a windmill or solar panel, and not from coal, gas or oil. With photosynthesis, that energy comes directly from the sun, without a solar panel having to supply power first.

No fake trees, but huge surfaces needed

What would our world look like when artificial photosynthesis would be the standard? Would we have artificial trees with artificial leaves everywhere to meet our energy needs? "Indeed you need huge surfaces

to catch the light, CO_2 gas and water (vapor). This can be done, for example, in the form of solar panels on roofs. Or we could place photosynthesis-boxes in the desert, working during the day and collecting water vapor in the evening. There must be much more different ways to use this kind of set-up. Once we successfully solve the price problem of the reactions itself, the next step will be the optimization of devices for large scale applications."

Liu already totally envisages it: "It would be great if we could use seawater, because it is not scarce. We would then use a device that produces energy very cheaply with free sunlight, free seawater and free CO_2. Fossil energy would be far too expensive in comparison."

Two components: Water splitting and CO_2 reduction

Artificial photosynthesis, like the natural variant in green plants, consists of two parts. One is water splitting into hydrogen and oxygen. The other one is carbon dioxide reduction into energy-rich hydrocarbons. The target is to achieve these two parts in one system that on the one hand reduces the CO_2 content of the air, and on the other hand produces fuels and oxygen.

The ideal catalyst: efficient, cheap and readily available

In his Ph.D. research, Liu focused on the first part of water splitting, which produces hydrogen and oxygen. A reaction accelerator or catalyst can help make that reaction more energy-efficient. Liu: "Among other things, I have developed strategies to design more efficient catalysts. The ideal catalyst is not only efficient, but also cheap and readily available. It should not be a rare metal, for example, that you have to get from somewhere with a lot of environmental damage."

One of the best moments

Finding the ideal catalyst is one of the greatest challenges in the research field, says Liu. "One of the best moments in my research was when I found a new strategy to design a catalyst for hydrogen production, right in a pH neutral environment."

Liu's research provided new design rules and ideas on how to achieve efficient artificial photosynthesis. "The results provide fundamental understanding as well as a practical strategy for finding new catalysts for water oxidation. I hope to continue my research. Eventually, I would like to be one of the researchers who achieve a complete system of artificial photosynthesis."

Promoter Bonnet does see Liu being there when researchers make a complete system of artificial photosynthesis realistic. "My feeling is that if people find a way to realize efficient artificial photosynthesis one day, or a way to make an artificial leaf, Chengyu could be one of them. He has the passion, the understanding, the excellent scientific attitude and he has received excellent training."

Provided by Leiden University

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