Novel Method to Increase Energy Production from Microalgae

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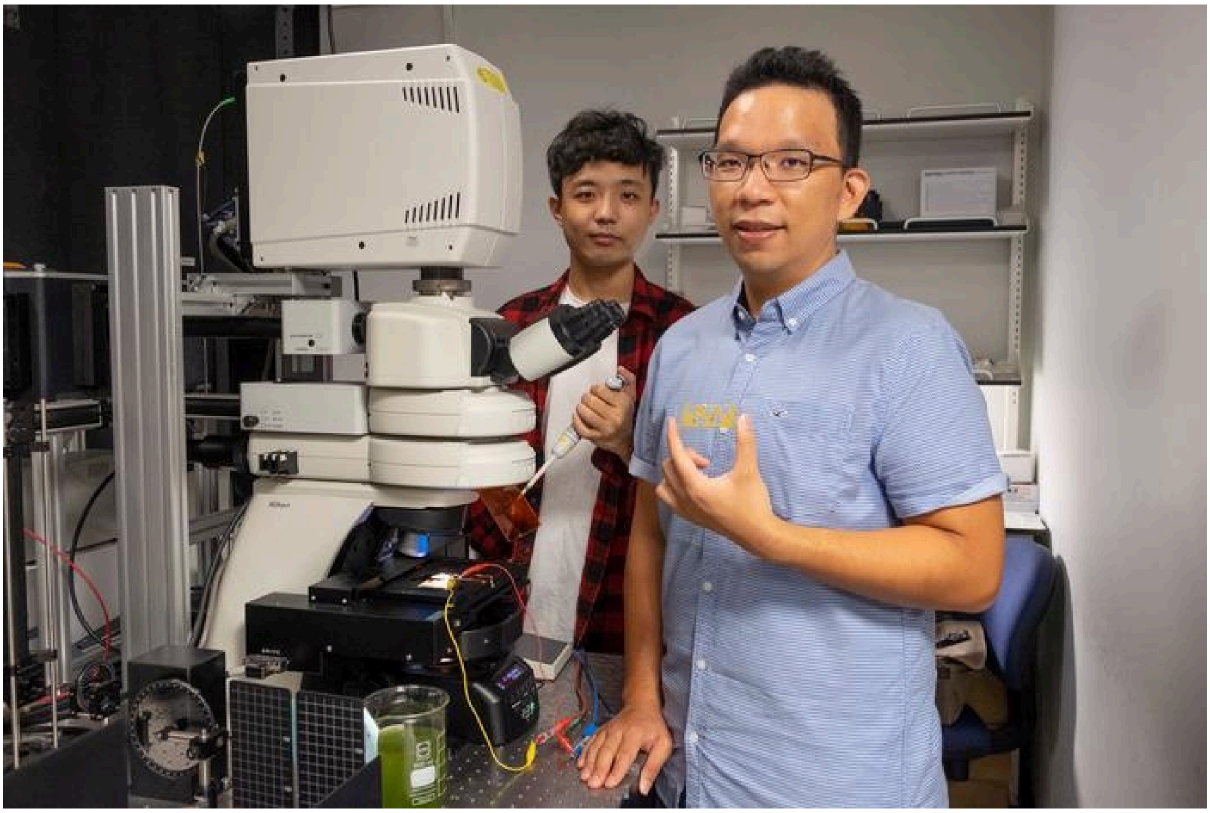
The multitude of common algae covering the surface of seas and ponds may be the solution to increasing the efficiency of artificial photosynthesis, enabling researchers to create more energy and cut wastage in the process.



In recent research from Nanyang Technological University (NTU), Singapore, scientists demonstrated a method to encase algae protein in liquid droplets, leading to an extraordinary improvement in the light-harvesting and energy conversion characteristics of algae by nearly three times.

This energy is created as the algae experiences photosynthesis, which is the process used by algae, plants and a few bacteria to harness solar energy and convert it into chemical energy.

By imitating how plants turn sunlight into energy, artificial photosynthesis may be a sustainable way of producing electricity that does not depend on natural gas or fossil fuels, which are non-renewable. Since the natural energy conversion rate from sunlight to electricity is not high, increasing the total electricity produced could render artificial photosynthesis commercially feasible.

The study, headed by Assistant Professor Chen Yu-Cheng from the School of Electrical and Electronic Engineering, explored a specific type of protein found in red algae. These proteins, called phycobiliproteins, are accountable for absorbing light within algae cells to trigger photosynthesis.

Phycobiliproteins are capable of harvesting light energy from the entire spectral range of light wavelengths, including those which chlorophylls are unable to absorb well, and turning it into electricity.

> *Due to their unique light-emitting and photosynthetic properties, phycobiliproteins have promising potential applications in biotechnology and solid-state devices. Boosting the energy from the light-harvesting apparatus has been at the centre of development efforts for organic devices that use light as a power source.*
>
> *Chen Yu-Cheng, Study Lead and Assistant Professor, School of Electrical and Electronic Engineering, NTU*

The team's study may pave the way towards a new, sustainable means of producing electricity from sunlight that does not depend on natural gas or fossil fuels, which are non-renewable. New bio-motivated technology based on phycobiliproteins could be used to create more effective solar cells and facilitate better efficiency within artificial photosynthesis.

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Using algae as the basis of biological energy is a widespread topic of interest in sustainability and renewable energy, as algae usage potentially decreases the number of poisonous by-products formed in the production of solar panels.

The study aids NTU's pledge to sustainability as part of its 2025 strategic plan, which aims to comprehend, articulate and resolve humanity's influence on the environment.

The findings have been reported in *ACS Applied Materials Interfaces*, and the study has been chosen as the cover of the scientific journal.

Tripling Artificial Photosynthesis Efficiency

Microalgae absorb the sunlight and turn it into energy. So as to increase the amount of energy that algae can produce, the team formulated a technique to enclose red algae within small liquid crystal micro-droplets that measure 20 to 40 microns in size and then expose them to light.

When the light reaches the droplet, an effect known as the "whispering-gallery mode" takes place, wherein light waves move around the curved edges of the droplet. Light is excellently captured within the droplet for a longer time, giving more chance for photosynthesis to occur, thereby producing more energy.

The energy produced during photosynthesis in the form of free electrons can then be trapped via electrodes as an electrical current.

The droplet behaves like a resonator that confines a lot of light. This gives the algae more exposure to light, increasing the rate of photosynthesis. A similar result can be obtained by coating the outside of the droplet with the algae protein too. By *exploiting microdroplets as a carrier for light-harvesting biomaterials, the strong local electric field enhancement and photon confinement inside the droplet resulted in significantly higher electricity generation.*

Chen Yu-Cheng, Study Lead and Assistant Professor, School of Electrical and Electronic Engineering, NTU

The droplets can be easily made in bulk inexpensively, making the research team's technique commonly applicable.

As said by Asst Prof Chen, the majority of algae-based solar cells yield an electrical power of 20-30 $\mu W/cm^2$. The NTU algae-droplet combination increased this level of energy production by nearly two to three times, compared to the energy production rate of the algae protein alone.

Converting "Bio-Trash" to Bio-Energy

Artificial photosynthesis seeks to reproduce the natural biological process by which plants turn solar energy into chemical energy. The goal is to create a way of producing energy that is reliable, renewable, and storable without affecting the environment in a negative manner.

One of the hurdles of artificial photosynthesis is producing energy as efficiently as other solar-driven energy sources, such as solar panels. On average, solar panels have an efficacy rating of 15 to 20% while artificial photosynthesis is presently projected to be 4.5% efficient.

Asst Prof Chen said: *"Artificial photosynthesis is not as efficient as solar cells in generating electricity. However, it is more renewable and sustainable. Due to increasing interest in environmentally-friendly and renewable technologies, extracting energy from light-harvesting proteins in algae has attracted substantial interest in the field of bio-energy."*

Asst Prof Chen visualizes one potential use case of "algae farms", where thickly growing algae in water bodies could in due course be integrated with larger liquid crystal droplets to form floating power generators.

The micro-droplets used in our experiments has the potential to be scaled up to larger droplets which can then be applied to algae outside of a laboratory environment to create energy.

Chen Yu-Cheng, Study Lead and Assistant Professor, School of Electrical and Electronic Engineering, NTU

"While some might consider algae growth to be unsightly, they play a very important role in the environment. Our findings show that there is a way to convert what some might view as 'bio-trash' into bio-power," added Asst Prof Chen.

Journal Reference:

Yuan, Z., *et al*. (2021) Light-Harvesting in Biophotonic Optofluidic Microcavities via Whispering-Gallery Modes. *ACS Applied Materials Interfaces.* doi.org/10.1021/acsami.1c09845.

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