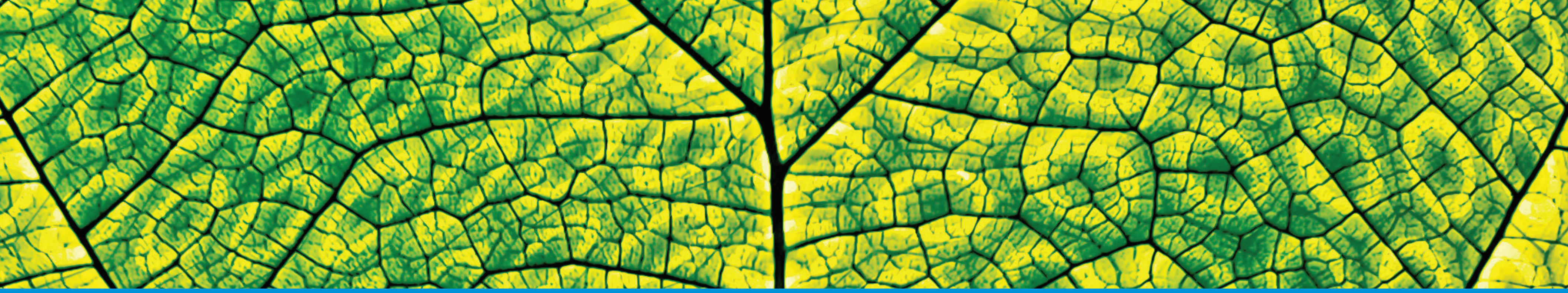
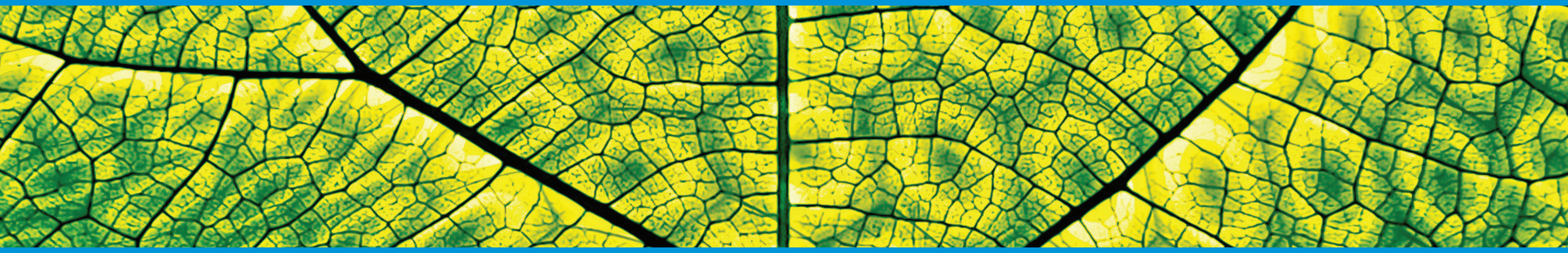


ARTIFICIAL PHOTOSYNTHESIS MAY PLANT THE SEEDS FOR A MORE SUSTAINABLE FUTURE



Fossil fuels are finite resources which are becoming controversial at times due to concerns over pollution and global warming. While in no short supply, coal can be deleterious to humans, animals and the environment. Wind turbines are unsightly to many and mar bucolic landscapes. Huge expanses of farmland must be dedicated to corn, which could be used for food or for planting other crops, while today's solar cell technology is cost-prohibitive for many and often inefficient. This is where a new ground breaking technology comes in artificial photosynthesis offering a potentially game-changing new path out of our energy quagmire.

By now, we are all familiar with the ubiquitous solar panels shining on rooftops, a somewhat stark signal of our growing interest in alternate sources of energy; however there are some significant advantages that artificial photosynthesis has over the photovoltaic cells used in solar panels in their current incarnation. For one, the direct translation of sunlight to electricity in photovoltaic cells renders solar power time-and-weather sensitive; thus, reducing its usefulness and efficiency and increasing its cost. Conversely, artificial photosynthesis would be capable of generating a fuel with storage potential.

While the majority of extant methodologies which generate alternate energy do not have the potential to produce more than a single type of fuel, this is not the case with the photosynthetic process. The means of generating fuel can be adjusted so the reactions occurring via the interplay of light, CO_2 and H_2O culminate in the production of liquid hydrogen, which can be used in a way akin to gasoline in hydrogen-powered engines, it can also be channeled into a fuel-cell model. This creates electricity by reversing the photosynthetic process through the amalgamation of hydrogen and oxygen into water.

Furthermore, the photosynthetic process is capable of producing electricity, comparable to what we derive from the grid, hydrogen fuel cells can be used to run the necessary components of daily modern life such as water heaters and air conditioning.

Today, large-scale hydrogen energy faces a major problem: how to effectively produce liquid hydrogen in an environmentally-friendly manner. The answer to this may be found in artificial photosynthesis. Another potential output of this process is methanol. As opposed to emitting pure hydrogen in the photosynthesis process, the photoelectrochemical cell could be used to produce methanol fuel. Traditionally, obtained from the methane inherent in natural gas, methanol fuel is a common component added to commercial-grade gasoline to facilitate a more salubrious burn. In fact, some vehicles are even able to run solely on methane gas.

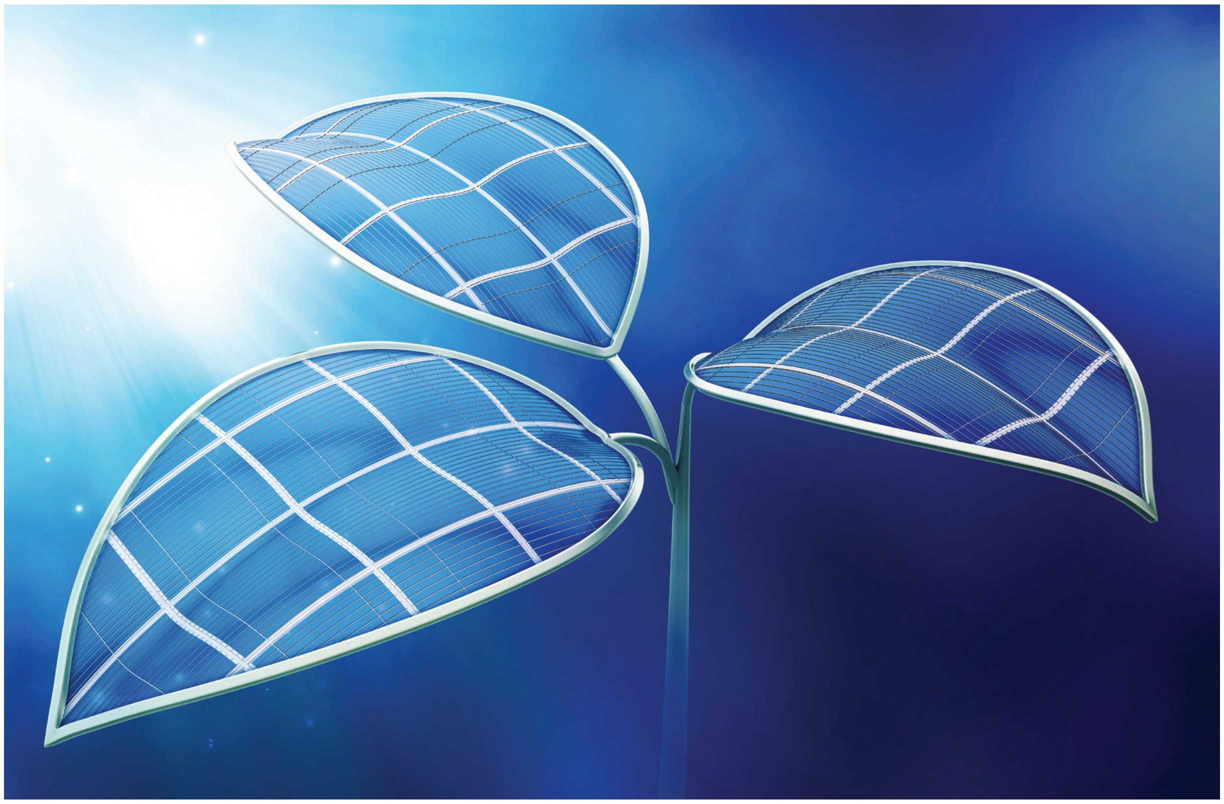
Finding a way to manifest clean fuel without having to grapple with any deleterious by-products, such as greenhouse gasses, has been the Holy Grail, so highly sought in the alternate energy arena. It could well be that artificial photosynthesis leads us out of the wilderness to finally discover an energy source that seems straight out of a science-fiction utopia. Amazingly, it would sustain itself without the usual toil of mining, drilling, or growing. Furthermore, with the world's abundance of water and carbon dioxide, this elixir of power appears to be infinite and possibly even more cost efficient than other energy sources. Unbelievably, this type of photoelectrochemical reaction could actually take away huge quantities of noxious CO_2 from the air while producing fuel.

I know what many of you must be thinking; when it seems too good to be true, it usually is. There has to be a catch. But is there? The only downside here is that this technology isn't quite ready to be put into use at this time. There are also many barriers blocking the path to employing artificial photosynthesis on a mass scale. In order to duplicate the natural photosynthesis synonymous with plants, a system of energy conversion must be capable of achieving key, primary objectives. It must harvest sunlight as well as rend water molecules. This would most likely need to be cocooned in some version of nanotube which simulates the structure of a "leaf". Chlorophyll is the catalyst which plants use to bring this process to fruition by enveloping sunlight, along with an assortment of enzymes and proteins that break down H_2O molecules into hydrogen, electrons and oxygen. CO_2, with the aid of electrons and hydrogen, produces carbohydrates while releasing oxygen.

In order for an artificial photosynthetic system to serve human needs, the output must change in accordance with the goal. The culmination of the reaction would, instead of releasing oxygen, consist in the expulsion of liquid hydrogen (or maybe methanol). The result being that this hydrogen could be used as liquid fuel or funneled into a fuel cell. The difficulty lies not in getting the process to produce hydrogen, because this is already present in the water molecule, nor is capturing sunlight a challenge as today's solar-power systems already accomplish that task. The obstacle lies in splitting the water molecules to obtain the necessary electrons to allow the chemical process which precedes the hydrogen. The requisite water stirring needs an energy input of approximately 2.5 volts, so the process demands a catalyst to set the whole thing in

motion. This impetus sparks a chemical reaction helped along by the sun's photons.

Some of the most outstanding advances surrounding artificial photosynthesis occurring over the past decade revolve around several viable catalysts including manganese, which is the catalyst at the photosynthetic heart of plants. One atom of manganese sets into motion the natural process which uses sunlight to divide water. Manganese's role in an artificial system is a biomimetic approach which imitates the biological processes inherent to plant



life. Then there is dye-sensitive titanium dioxide, which is a stable metal that can be used as an effective catalyst. Finally, one of the more newly discovered catalysts in the field is cobalt oxide which has proven to be dependable and an extremely efficient impetus for artificial photosynthesis. Fortunately, cobalt oxide happens to be an extremely prolific molecule and is already a common industrial catalyst in other areas.

It seems that humans, while at the top of the evolutionary ladder, still have a lot to learn by emulating the world of flora and other simple life forms. The possibilities of perfecting artificial photosynthesis on a massive scale would be astronomical and offer a virtually perfect environmentally sustainable and renewable source of energy which could potentially power our homes, businesses, vehicles and lives by mimicking natural occurrences of plants and other organisms.

Scientists around the globe are hard at work looking for the best way to transform solar energy into a limitless photosynthetic fuel source. Scientists are even performing such cutting edge experimentation as finding out that nanometer-scale spherical gold particles could absorb visible green light and transfer photo-excited protons and electrons. New studies go one step further by using the same method to convert CO_2 into complex hydrocarbon fuel molecules, such as propane and methane. These are then homogenised by mixing green light with the gold nanoparticle, an ionic liquid. This approach also enables ethylene, acetylene and propene to be photosynthesised. These are complex molecular configurations which could someday facilitate viable energy storage in fuel cells.

However, in the abovementioned method, as in other means used to generate artificial photosynthesis, the benefits of these discoveries depend on its transferability to practical application in real-world situations. Researchers concede, in that respect, there is still a need to refine the ability of gold nanoparticles to instigate these chemical conversions and a quest to delve deeper into figuring out how possible future applications could work best. While there is still a long road ahead on the path to reaching the pinnacle of artificial photosynthesis, it will probably be a decade before practical CO_2-fixation, fuel-formation technologies become economically viable. That being said: the future of artificial photosynthesis looks as bright as the sun and the seeds have already been planted today for the success of this futuristic fuel tomorrow.

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References

https://www.chemistryworld.com/features/taking-a-leaf-out-of-plants-books/3010612.article

https://science.howstuffworks.com/environmental/green-tech/energy-production/artificial-photosynthesis.htm

https://www.sciencealert.com/new-artificial-photosynthesis-breakthrough-uses-gold-to-turn-co2-into-liquid-fuel

https://futureoflife.org/2016/09/30/artificial-photosynthesis/

https://singularityhub.com/2018/02/25/artificial-photosynthesis-is-solar-energys-forgotten-cousin-and-its-making-a-comeback/

https://www.technologyreview.com/s/601641/a-big-leap-for-an-artificial-leaf/

https://www.thegreenage.co.uk/tech/artificial-photosynthesis/

https://www.sciencedirect.com/topics/chemistry/artificial-photosynthesis

https://newscenter.lbl.gov/2019/06/17/here-comes-the-sun-a-new-framework-for-artificial-photosynthesis/

https://oilprice.com/Energy/Energy-General/Artificial-Photosynthesis-A-New-Renewable-Energy-Source.html

https://news.illinois.edu/view/6367/789800

https://blogs.anl.gov/solar-energy/artificial-photosynthesis/

https://www.downtoearth.org.in/news/climate-change/scientists-convert-co2-to-solar-fuel-with-artificial-photosynthesis-57709

https://www.businessinsider.com/new-artificial-photosynthesis-uses-gold-turn-co2-into-liquid-fuel-2019-5

https://www.goodnewsnetwork.org/scientist-invents-way-trigger-artificial-photosynthesis-cleans-air-produces-fuel/

https://www.theverge.com/2012/5/10/3011669/nocera-mit-first-low-cost-artificial-leaf

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