Usage of Photosynthetic Artificial Leaves and Glucose Fuel Cells for Reduction of Greenhouse Gases

For hundreds of years the human population has been burning fossil fuels and removing important vegetation from our planet without as much as a blink of an eye. This in turn has caused the amount of greenhouse gases in the atmosphere to skyrocket to unforeseen levels. With large corporations like ExxonMobil refusing to set goals for emission standards, it's up to the bright young minds to innovate new ideas to reduce them. In 2014, 39.8 billion tons of CO_2 were emitted. The most effective greenhouse gas remediation strategies target this compound, since it is the most abundant and therefore the most damaging to the atmosphere, biosphere, and human society.

Photosynthesis is a natural phenomenon that removes carbon dioxide from the atmosphere. Climate models estimate that 30% of the carbon dioxide emissions caused by humans are consumed by the world's plants.

It has been suggested that growing more plants should ideally mitigate the overabundance of carbon dioxide. However, growing each plant requires a consistent supply of nutrients like phosphorus and nitrogen throughout its lifetime. It is also important to consider that most plants lose their leaves in the fall and thereby lose their ability to photosynthesize. A recent study predicted that plants would sequester less carbon dioxide over the next 100 years due to nutrient limitations in the soil, (Mascarelli). The simulations found that plants will absorb significantly less carbon dioxide than in previous eras due to projected nitrogen limitations in the northern hemisphere and phosphorus limitations in the tropics (Mascarelli).

An effective alternative to planting more trees and shrubs is widespread implementation of artificial leaves. These artificial leaves rely on the same basic principles of photosynthesis, yet do not need the attention and resources that generic plants would. These leaves will consist of a resin with embedded catalysts which mimic compounds used in photosynthesis. Essentially, the catalysts chosen will be replicating photosystems I and II in chloroplasts. Manganese catalysts will be used for light activated splitting of water. This mimics the photo excited locomotion of electrons within the thylakoid of a chloroplast. The electron transfer rates of the existing leaves have been shown to exceed the rates observed in natural photosynthesis (Ruhr). Unlike the existing artificial leaves, the end goal of these leaves will be to produce glucose, instead of simply splitting water into hydrogen and oxygen.

Prototypes of similar artificial leaves already exist; this new leaf takes the technology even further, and will mitigate CO_2 emissions and help people in the process. These newly innovated artificial leaves will have glucose fuel cells embedded into the resin. The fuel cells will immediately convert the energy from the monosaccharides produced into electrical energy which can be supplied to a local area such as a factory or home. The fuel cell uses solid-state materials since they are the most simple and reliable. The efficiency of the solid-state catalysts can be "improved further by roughening or grafting onto porous materials," (Ho). It has been found that a single glucose unit can produce 24 electrons. By using platinum electrodes, studies have shown to generate between 1-10 $\mu W\ cm^{-2}$ based on a minimal amount of glucose (Ho). Clusters of artificial leaves have the potential to produce great amounts of glucose and will thus result in a large power output. The inclusion of fuel cells creates an eco-friendly source of energy that has the potential to be used in personal or industrial settings.

In addition, ultra-thin wires resembling the stems of flexible vines will transfer the energy from the leaves. They will be covered by a bioplastic made from starch instead of a petroleum based plastic. Potato starch is considered a waste product in the agricultural industry, but is also the world's fourth largest crop. This will be a cheaper and eco-friendly substitute to high-density polyethylene. Over 100 million tons of non-biodegradable, petroleum based plastics are produced annually. Deviating from this practice will also help reduce greenhouse gases.

For example, a family can produce their own energy through the use of this green technology, which can be spread over their property in a fashionable manner. The natural beauty of the house will not be reduced as the leaves blend in with the environment. Large, unaesthetic solar panels, which often diminish the attractiveness of the house, can be replaced for the more natural looking leaves as well. Each home can serve as its own power station.

Another benefit of the artificial leaves is that the glucose produced does not necessarily have to be converted into electrical energy. There are over 810 million people who starve every day. Each year 2.6 million children die as a result of hunger-related causes. To combat this, people from third world countries such as Zimbabwe and Burundi can extract glucose from the leaves once it has accumulated. Since most people from these countries have a scarce supply of food, they can consume the glucose in order to continue internal bodily functions to maintain homeostasis. This technology could potentially save thousands of lives as it provides a source of energy for people in between the few small meals they have over a long period of time.

The leaves can be placed in overlapping arrangements on rooftop factories and attached to pipes and chimneys that emit immense amounts of CO_2. The wires transferring the electrical energy, which resemble flexible vine stems, can be wrapped around the respective areas to secure it in place while converging to an inverter. The inverter will change the DC electricity from the leaves to 120 volt AC which can then be connected to the dedicated circuit breaker in the electrical panel.

The production of this green technology will be cost effective as well. Once the technology has been perfected, there could be mass production of the artificial leaves. The catalysts and the glucose fuel cells will be positioned onto sheets of resin, and then they will be cut out into appropriate leaf-like shapes.

While artificial leaves are able to provide many benefits with infinite possibilities, there are some concerns to address. An issue to consider is the feasibility of using enzymes in varying environments. Since there is a risk of enzyme denaturation in extreme temperatures, the fuel cell needs to be covered by an insulator. The potato starch bioplastic used for the wiring could also be used to coat the fuel cell. Another possible issue with the artificial leaf is the degradation over time due to ultraviolet radiation. To resolve this issue, the artificial leaf could self-repair by mimicking the functions of organic vascular systems found in nature. More research would have to be conducted to understand the bioengineering behind this solution.

Artificial photosynthesis is a major asset in the future for alternative energy. These proposed leaves can serve a dual purpose of generating electricity and producing carbohydrates, affecting billions. The ultimate goal is to use the artificial leaves to recycle oxygen and reduce the overall level of greenhouse gases in the atmosphere while providing other benefits to society. No technology is perfect from the start, but through the implementation of artificial leaves, these goals and benefits go from plausible to within an arm’s reach.

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