Title
Sink or Source: Turning Greenhouse Gases into Renewable Energy

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SINK OR SOURCE:

Turning Greenhouse Gases into Renewable Energy

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Figure 1: The Amazon as a whole is increasingly deteriorating at the hands of anthropogenically caused wildfires, though the volume of carbon emissions is greater in the eastern region of the forest than the west.

Before human impact on the planet dramatically shifted planetary systems away from energy equilibrium, every forest consumed more carbon dioxide than it emitted. Trees are universally associated with photosynthesis, held in high esteem for "breathing" the air we can't in order to produce a livable environment for land animals. The conversion of CO_2 to oxygen was, after all, needed in order for complex life to develop in the first place. However, in the anthropocene, the new geological era in which human actions have a distinct impact on environmental cycles, Earth is becoming an unlivable environment for trees.[1]

According to a study on greenhouse gas concentration, human-caused greenhouse gas emissions are the primary cause of climate change.[2] Almost 25 million acres of forest were reduced every year from 2015 to 2020, and this trend continues—due to patterns of increased urbanization and burning of fossil fuels, deforestation is ever-increasing. With the increasingly perpetuated deforestation brought about by climate change, two of the world's largest groups of tropical rainforests now emit more carbon than they absorb: the forests of Southeast Asia and the Amazon rainforest.[3] Regardless of whether it is even possible for forest restoration to revitalize this striking decline, a solution entirely separate from reforestation currently exists: the conversion of greenhouse gasses to usable, marketable and sustainable consumer products. Through catalysis, some of the most harmful greenhouse gasses can be converted to renewable fuels. Herein lies the potential to lift the burden of processing CO_2 from trees while simultaneously producing an alternative to the fossil fuel burning that pushes forward their demise.[4]

Self-Perpetuating Deforestation

Climate change has imposed unruly, raging wildfires that sweep across large areas of the world's most significant forests. In the Amazon rainforest, the function of trees has turned on its axis; instead of ridding the air of CO_2 and emitting oxygen, these trees are now ablaze with flames. Wildfires can be beneficial to certain ecosystems, but when they are this abundant and ongoing, they become destructive systems of biodiversity-degrading ruin: the Amazon is now a system that creates CO_2 rather than processing and dispensing with it. The byproduct of photosynthesis is oxygen. The byproduct of large-scale fires is an outpouring of CO_2 at a scale that natural environments are not equipped for.[5]

What's more, the mass death of trees due to wildfires creates a secondary implication for increased CO_2 emissions: soil decomposition. The burning of trees causes a self-perpetuating cycle of continuous temperature increase: when trees die in larger numbers, they emit copious amounts of CO_2, which causes heightened planetary heating due to the greenhouse effect. In addition to fire smoke, the death of trees causes CO_2 emissions as soil breaks down the plants' organic matter to repurpose them, emitting carbon as a byproduct. This causes the planet to severely warm up, leading to more fires and, hence, the increased CO_2 emitted from fire smoke and soil decomposition. This is an example of a positive feedback loop, a type of system that has become a recurrence in the progression of environmental degradation and climate change effects. A disturbance to a natural system spurs a positive correlation between its addition and a change that happens because of it, which in turn causes the original occurrence to increase.[5]

When a system photosynthesizes to the degree that it intakes and converts more CO_2 than it produces, it is classified as a carbon sink.[5] A single living tree is an example of a carbon sink, however small trees become a paradox at the hands of wildfires. Southeast Asian forests overall now have a net output of carbon dioxide, as does the Amazon rainforest. What will become of humans if the organisms that keep us alive can no longer tolerate Earth's condition?

FEATURES

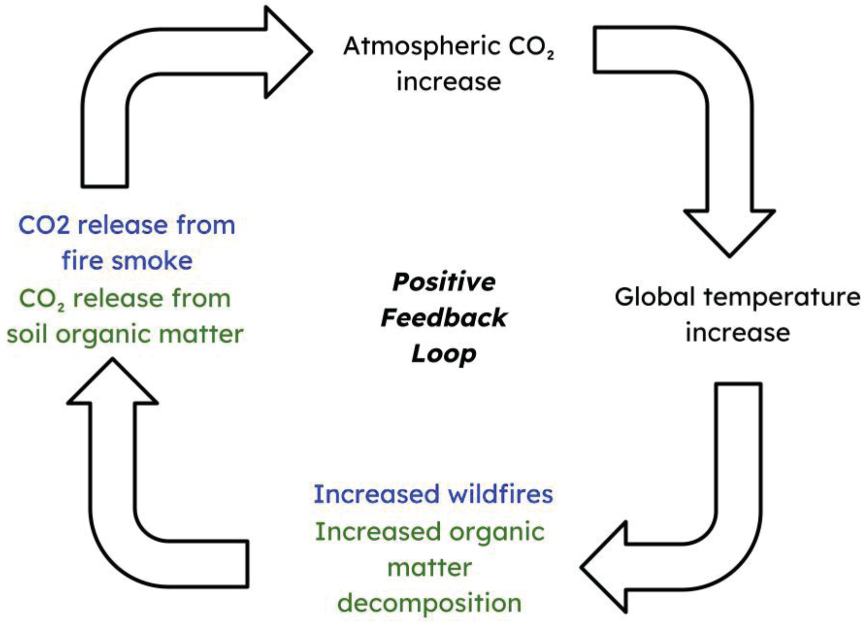

Figure 2: Increased CO_2 concentrations feed back into the systems that spurred these initial climbing numbers. The way soil decomposition and wildfires emit greenhouse gases and perpetuate planetary warming make them both examples of positive feedback loops.

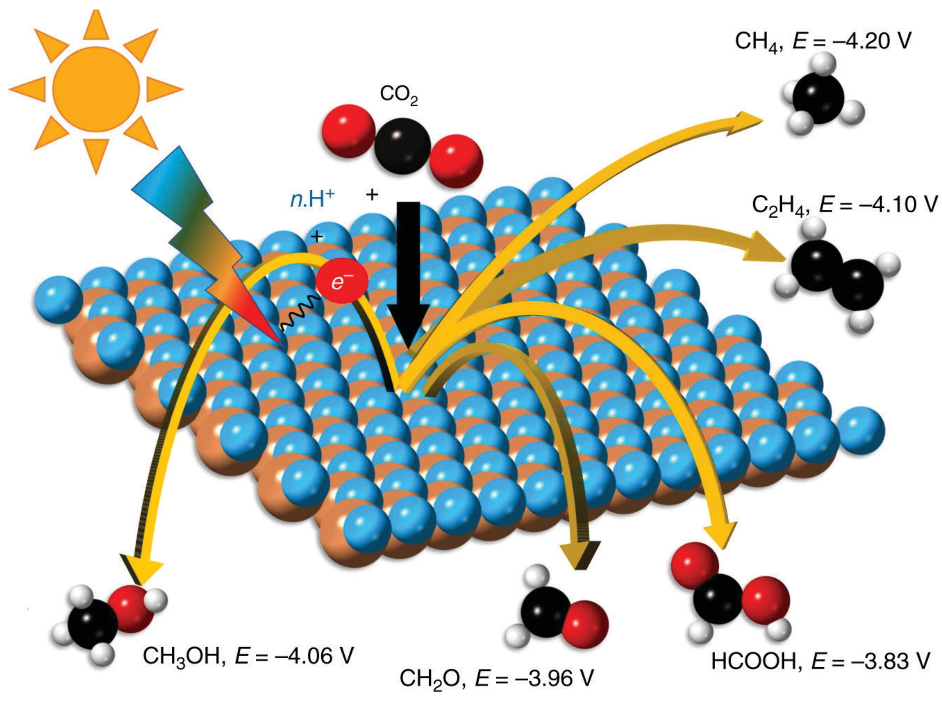

Figure 3: Photocatalysis, the type of reaction behind photosynthesis, combines the properties of carbon dioxide and the power of the sun to form new chemical compounds. Alcohols and hydrocarbons can be produced from this process—most notably in the context of CO_2 to produce ethanol, the ethylene that then becomes ethanol when combined with OH and H.

Trees' regulatory properties

Trees, such as the vast array that characterizes the Amazon rainforest, are helpful in performing heat transfer, keeping the temperature of the planet within a healthy boundary for life on Earth. Trees increase the height and thickness of the troposphere, the layer of the atmosphere that shields Earth from temperature extremes.[3] Trees also move water from land to the atmosphere by taking in water from soil and emitting it as water vapor from their leaves—a process called evapotranspiration.[6] As vegetation decreases in forests, these areas' capacity for evapotranspiration decreases significantly. According to a study on the deforestation and carbon output of the Amazon, between 25% to 30% of global rainfall can be attributed to this crucial element of the water cycle.[7] The Amazon rainforest, defined by its moist, tropical climate, dries and becomes even more susceptible to wildfire as trees' heat-regulating and precipitation-enabling qualities dwindle.[3,7]

Earth's Energy Equilibrium

The reason the climate warms is that Earth diligently does its job of maintaining the equilibrium of planetary energy balance. The world needs to expel as much heat as it receives, and the addition of greenhouse gasses into the atmosphere disrupts this equilibrium. When solar radiation comes into the earth's atmosphere, an equal amount of energy is thrown back to space as the amount absorbed, preventing earth from becoming a sink of ceaselessly compounding heat energy. The cycle of equilibrium has Earth's best interests in mind, but the unnatural increase in greenhouse gasses sabotages the usefulness of this phenomenon.[8] Due to heat-trapping and absorptive nature of greenhouse gases alone, less energy leaves Earth as they become more abundant. In addition to this simple correlation is the effect of planetary energy balance: Earth heats up to emit an equal amount of energy to that which it's being bombarded with. The thickening layer of greenhouse gases looming above is slowly making the heat transfer to Earth a one-way trip: rather than escaping the atmosphere and restoring the balance as intended, this energy gets reflected back to Earth, increasing the planetary heating of the greenhouse effect.[9]

Given that the surplus of greenhouse gasses hinders effective climate regulation, two ways to solve the issue become apparent: stopping the production of greenhouse gasses, and removing greenhouse gasses from the air before they can join Earth's well-meaning (but greenhouse effect-reinforcing) regulatory cycle. Each method indirectly helps to free Earth to carry out its intended function of equilibrium, but it isn't common for progress toward both of these goals to be made at the same time. However, the direct conversion of greenhouse gasses into clean energy is not only entirely possible, but already being done.

Photocatalytic Carbon Dioxide Conversion

Air Company, founded in 2017, uses photocatalysis to convert CO_2 into vodka and perfume.[10] If these products alone were created through this process, photocatalytic carbon conversion would already be a nifty and exciting method of useful carbon capture. However, the process carries the premonition of a climate-healthy future: ethanol is a biofuel.

CO_2 can be converted to ethanol through photocatalysis. The high-energy operation of catalysis is performed in order to manipulate the chemical arrangement of compounds. Photocatalysts absorb and utilize solar energy in order to induce chemical reactions. Rather than conducting energy from induced electricity, all they need is light from the sun to render through chemical manipulation a new, useful substance from the carbon dioxide that increasingly afflicts the atmosphere. Semiconductors are materials that can harness solar light.[4] According to a study done in 2022, the metals that are able to perform this function to produce ethanol from CO_2 are those whose ability to increase chemical reaction speed, or their catalytic potential, aligns with the energy needed to convert CO_2 to ethanol.[11],[4]

Electrons themselves, combined with the spaces they make as they move around, can capture and redistribute photons from the sun, harnessing them as energy. The holes made by this "electron jumping" effect cause water molecules to chemically rearrange into hydrogen ions (H+) and hydroxyl radicals (OH). Photoexcited electrons and CO_2, after some ensuing instability, become stable OH and H molecules. When OH, H, and another byproduct—ethylidene—are left, the resulting chemical compound is C_2H_6O—ethanol, a compound that , aside from being in high demand in cosmetic, medical, and other commercial industries, is a fossil-fuel alternative to jet fuel. Considering that the use of ethanol as fuel has a net zero CO_2 output, only 30% less energy production efficiency than gasoline makes the trade of gasoline for ethanol-based fuel worthwhile.[4]

Catalytic Methane Decomposition

Though converting CO_2 to biofuel is a momentous stride toward a society that functions on net zero emissions, carbon dioxide is not the only greenhouse gas the atmosphere harbors in excess.

In fact, though CO_2 is more abundant than methane (CH_4), methane's greenhouse effect is more than 20 times stronger. The greenhouse gas methane consists of one carbon atom and four hydrogen atoms. The strength of the bonds between these atoms is immensely strong when compared to other molecular interactions, afforded by the structural symmetry and bonding style between carbon and hydrogen atoms in methane. Catalysis is needed to break these bonds and isolate the hydrogen. In its pure form, hydrogen can be used as a renewable fuel with water as its only byproduct. The catalytic decomposition process usually involves metals, a nonrenewable resource that causes greenhouse gas emissions upon extraction. Not only is this new method safer, but it has no inadvertent negative environmental consequences inherent to the processes involved, a predicament that the technology involved with CO_2 catalysis has yet to solve.[12]

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