

ALGAE IS THE NEW GREEN



HYPER
GIANT

THE MOST EFFECTIVE ANSWER TO CLIMATE
CHANGE COULD BE 1.5 BILLION YEARS OLD.
SURPRISE: IT'S NOT TREES, IT'S ALGAE.



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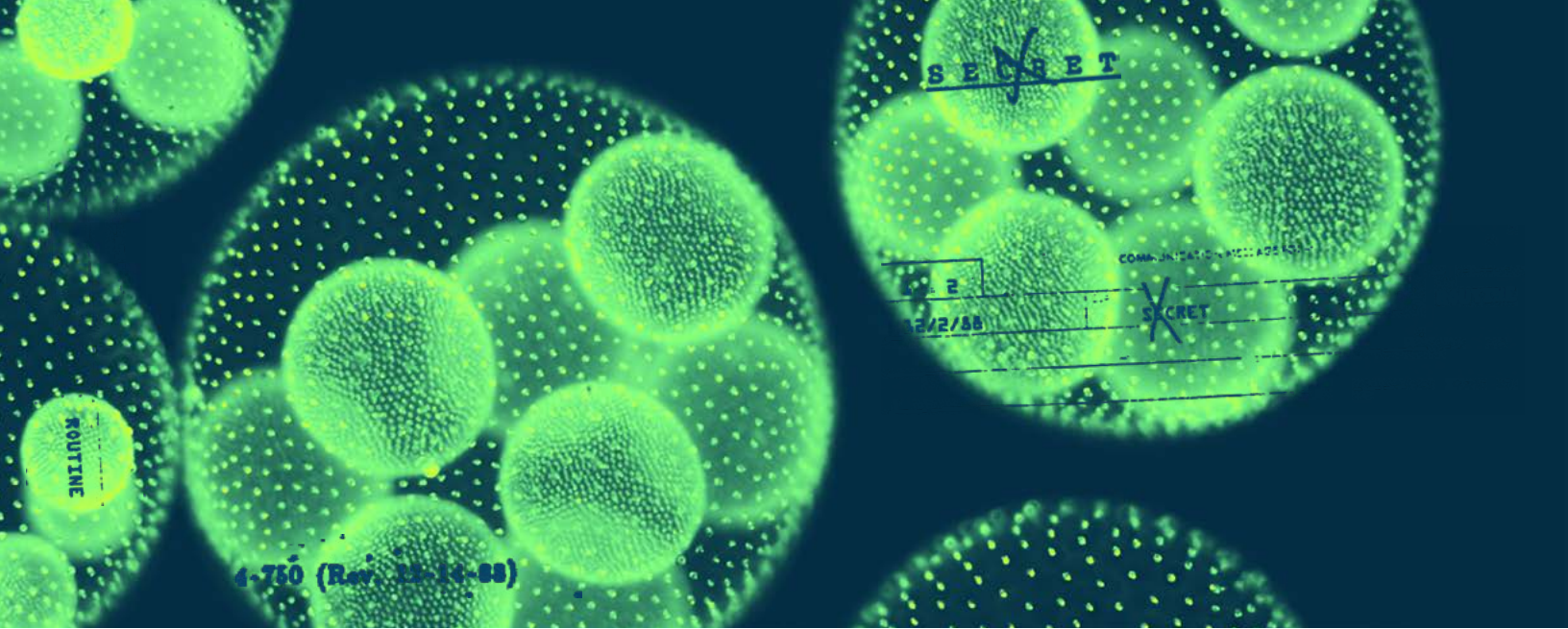
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We are at a critical inflection point in the trajectory of our species where our carbon emissions are creating costly and dangerous living conditions that pose a significant threat to the future health, productivity, and livelihood of the world’s population. Carbon emissions have reached record highs in the past few years, and the US economy could suffer economic losses as high as \$520 billion yearly due to climate change.¹ Trees have long been touted as a powerful tool for carbon reduction, and recently the directive to “plant more trees” became the most visible answer to addressing our climate change goals. However, it is a solution that comes with notable economic and social costs; plus, the requisite runway of time may be too long to stop the crisis.

The surprising answer, in addition to planting more trees, could be found in algae. The amorphous plant that grows in fresh and saltwater captures and transforms carbon at a rate substantially higher than trees, while needing far less space. Products like AI-powered bioreactors will help algae to capture carbon at optimal rates in the necessary timeline. And, that’s just a small part of the algaenomics movement, which is focused on new and innovative ways to use algae.

This white paper outlines the global context around climate change and carbon emissions, the variety of carbon solutions currently being discussed and then explores the potential of algae and its many uses in addressing the carbon emissions crisis.

THE CONTEXT

01

SCIENTISTS UNANIMOUSLY AGREE ON LINK BETWEEN GLOBAL WARMING AND CARBON EMISSIONS

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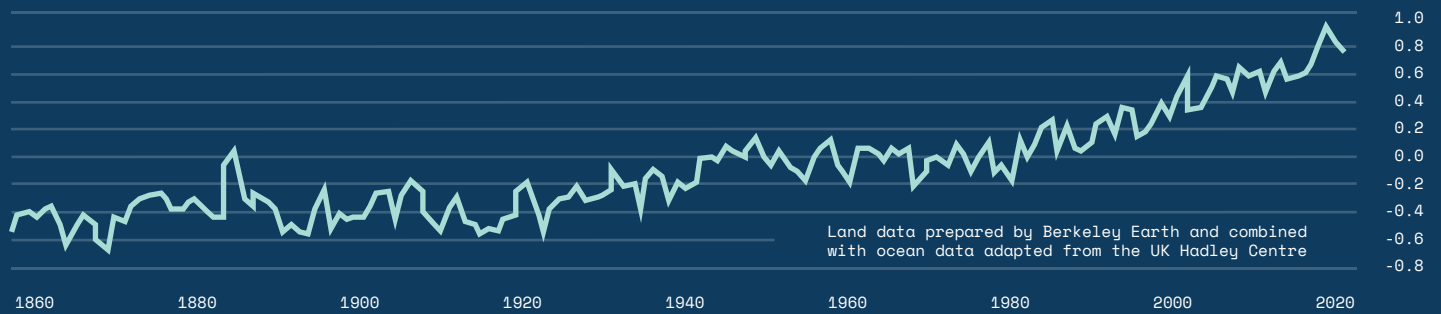
A multitude of scientific studies show that at least 97 percent² of actively publishing climate scientists agree that climate-warming increases over the past century are extremely likely to have been caused by human activities. In addition, a majority of leading scientific organizations worldwide have publicly endorsed this position.

The global temperature has risen significantly over the past 150 years³ in alignment with the onset of the industrial revolution. Substantial temperature increases have occurred since the 1950s⁴, reaching record levels in 2018⁵.

ANNUAL TEMPERATURE ANOMALY

GLOBAL AVERAGE TEMPERATURE 1850-2018

Source: [Temperature Map](#)



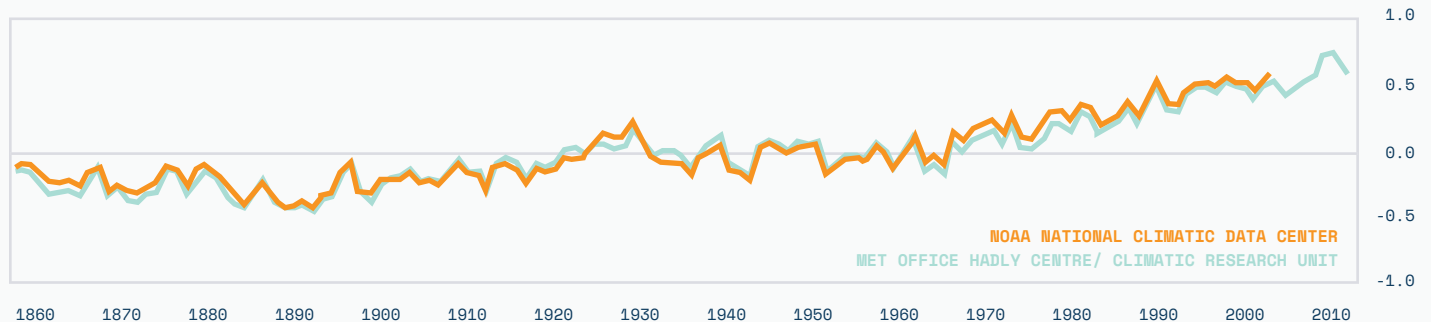
Similar dramatic increases in carbon emissions⁵ are correlated to manufacturing advances in the steel, electric, and automobile industries. Carbon dioxide is released into the environment when humans burn gasoline, natural gas, and coal to generate electricity and operate cars, trains, ships, and aircrafts⁷.

Note: Carbon emissions refers to carbon dioxide, which is a greenhouse gas. Carbon dioxide (CO₂) is the baseline greenhouse gas that is used as a benchmark for other greenhouse gases.⁸

These greenhouse gases form a layer that metaphorically serves as a blanket, keeping heat from dissipating and ultimately causing global warming. Scientists overwhelmingly agree with the connection between carbon emissions and rising global temperatures, with 97% publicly acknowledging that they are a major factor responsible for increased heatwaves, droughts, and rising sea levels. The countries that rank highest in manufacturing⁹, such as China, the United States, and the member states of the European Union, emit the most greenhouse gases¹⁰.

A WORLD OF AGREEMENT: TEMPERATURES ARE RISING

GLOBAL TEMPERATURE ANOMALY (°C)



Source: <https://www.c2es.org/content/international-emissions/>

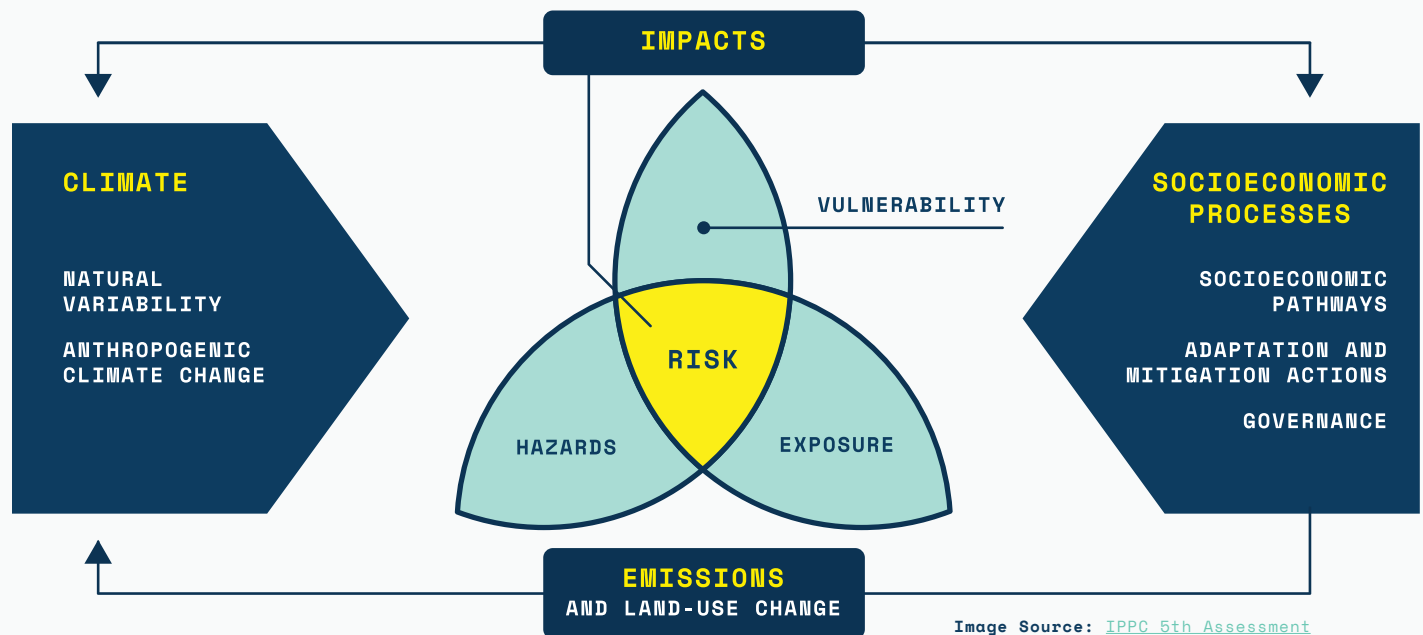
Temperature data showing rapid warming in the past few decades, the latest data going up to 2018. According to NASA data, 2019 was the warmest year since 1880, continuing a long-term trend of rising global temperatures. The 10 warmest years in the 139-year record all have occurred since 2005, with the warmer being the five most recent years.

CARBON EMISSIONS ARE HAVING WIDESPREAD IMPACTS ON THE ENVIRONMENT AND HUMANKIND

The impact of climate change on natural systems is strongly supported by extensive and far-reaching data. Evidence also attributes some impacts of climate change to human systems, with a major or minor contribution of climate change distinguishable from other influences.¹¹

The Intergovernmental Panel on Climate Change (IPCC), the United Nations body for assessing the data related to climate change, has been studying impacts, adaptation, and vulnerability caused by global warming over the past two decades. It is their assessment that it is at least 95 percent probable that man-made emissions

of greenhouse gases are the main cause of global warming since 1950. Further recent climate changes have had widespread impacts on human and natural systems, as reported by the Fifth Assessment Report of the IPCC.



The IPCC's summary of Interactions: Human interference with the climate system is occurring, and climate change poses risks for human and natural systems (Figure SPM.1).

According to a summary by MyClimate.org and many other bodies of evidence, the direct effects of climate change include:

- Rising maximum temperatures
- Rising minimum temperatures
- Rising sea levels
- Higher ocean temperatures
- An increase in heavy precipitation (heavy rain and hail)
- Shrinking glaciers
- Thawing permafrost

The indirect consequences of climate change, which directly affect us humans and our environment, include:

- An increase in hunger and water crises
- Decrease in quantity and quality of water sources

- Health risks associated with rising air temperatures and heatwaves
- Increasing spread of pests and pathogens
- Loss of biodiversity and natural ecosystems due to species extinction
- Lowered crop yields
- Ocean acidification due to increased HCO₃ concentrations in the water as a consequence of increased CO₂ concentrations
- The need for adaptation in all areas (e.g., agriculture, forestry, energy, infrastructure, tourism, etc.)
- Economic implications of dealing with secondary damage related to climate change

Source: [Myclimate](#)

WHY DOES BIODIVERSITY MATTER?

Diverse ecosystems create the fundamental necessities that human beings depend on to survive, such as fresh water, pollination, soil fertility and stability, food and medicine. Extinction weakens the stability of these ecosystems. A UN report released in May 2019 from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) warns that wildlife is declining at unprecedented rates while the rate of species extinction is accelerating.

Source:

<https://www.conservation.org/blog/why-is-biodiversity-important>

<https://www.un.org/sustainabledevelopment/blog/2019/05/nature-decline-unprecedented-report/>

https://climatetrust.org/biodiversity-and-meeting-our-paris-climate-goals-go-hand-in-hand/?gclid=EAIaIQobChMI5NiH49-15AIViYvICH0LRg5rEAAVASAAEgJ-KPD_BwE

HUMANITY MUST STOP THE PACE OF WILDLIFE EXTINCTIONS – OR FACE EXTINCTION.

ACCORDING TO THE UNITED NATIONS

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According to Ahmed Djoghlaif, the executive secretary of the Convention on Biological Diversity – an international treaty adopted in 1992 under the auspices of the United Nations Environment Program – at least 40 percent of the world's economy and 80 percent of the needs of the poor are derived from biological resources.”



GONE UNCHECKED, CLIMATE CHANGE WILL RESULT IN SIGNIFICANT ECONOMIC LOSSES

Global warming will have a substantial impact on global economies. Researchers say that all told, a persistent increase in average global temperatures of 0.04°C per year, in the absence of mitigation policies, will reduce world real per capita GDP by 7.22% by 2100.

Source:

<https://blogs.ei.columbia.edu/2019/06/20/climate-change-economy-impacts/>

<https://nca2018.globalchange.gov/>

<https://www.nature.com/articles/s41558-019-0444-6>

The temperature increases will result in extreme weather events and surging sea levels that will cause significant damage to property and infrastructures, create risks to the population's health, lessen

human productivity, weaken energy and water supply, and negatively impact sectors such as agriculture, fisheries, forestry, and tourism, and ultimately disrupt global trade and supply chains.



HOW CLIMATE CHANGE IS IMPACTING AMERICA'S FARMERS

CASE STUDY: 001

Nearly a dozen states in the Midwest are economically dependent on agriculture.

As of June 2019, extreme rainfall events have increased 37 percent in the Midwest since the 1950s, and this year, the region has experienced above normal amounts of rain and snowmelt that have caused historic flooding. Many fields have washed away, and livestock have drowned; Nebraska alone lost \$440 million worth of cattle, and as of March, Iowa had suffered \$1.6 billion in losses.

In addition to flooding, increased heat and drought will likely reduce crop yields. According to a 2011 National Academy of Sciences report, for every degree Celsius the global thermostat rises, there will be a 5 to 15 percent decrease in overall crop production. Many commodity crops such as corn, soybean, wheat, rice, cotton, and oats do not grow well above certain temperature thresholds. In addition, crops will be affected by less availability of water and groundwater, increased pests and weeds, and fire risk. And as farmers struggle to stay afloat by finding ways to adapt to changing conditions, prices will likely increase and be passed along to consumers.

Source: <https://blogs.ei.columbia.edu/2019/06/20/climate-change-economy-impacts/>



Some companies and governments have already been impacted by climate change-related losses. A Morgan Stanley report states that climate disasters have cost North America \$415 billion in the past three years, much of that due to wildfires and hurricanes. Globally the costs reach \$650 billion.¹²

For example, secondary impacts from 2017's Hurricane Harvey have created an estimated \$125 billion in losses for Texas. Similarly, hard disk manufacturer Western Digital Technologies saw major losses in 2011 after production was impaired by flooding in Thailand.

Note: It is not yet possible to directly link climate change to hurricanes; warmer temperatures and higher sea levels are known to enhance their intensity and destructiveness.

Further, a 2018 survey of 7,000 companies conducted by the Carbon Disclosure Project (CDP) estimates that if business continues as usual, almost half of the world's largest corporations would suffer losses of a trillion dollars due to climate change, starting in 2023. The CDP cites Alphabet (Google's parent company) as an example of a company at risk of climate change loss due to likely having to address cooling costs for data centers as temperatures rise.¹³

With overwhelming data from scientists, and an increasing awareness of the threat to the safety and livelihood of future generations and our economies, both countries and corporations are recognizing the need for change and urgency of action.

RISK TO TELECOMMUNICATION COMPANIES

CASE STUDY: 002

A 2018 study found that over 4,000 miles of fiber optic cable as well as data centers, traffic exchanges, and termination points – the lifeblood of the global information network – are at risk from sea level rise. According to NOAA's sea level rise projections, this infrastructure could be underwater by 2033 because most of it is buried along highways and coastlines. When it was built 25 years ago, climate change was not a concern, so while

the cables are water resistant, they are not waterproof. Cities such as New York, Miami, and Seattle and large service providers including CenturyLink, Intelliquent, and AT&T are most at risk.

Source: <https://blogs.ei.columbia.edu/2019/06/20/climate-change-economy-impacts/>



NATIONS COME TOGETHER TO LIMIT GLOBAL WARMING WITH THE PARIS AGREEMENT

In 2015, 200 governments met at the United Nations Framework Convention on Climate Change (UNFCCC) to stem global warming by setting goals specifically on carbon capture and reduction of emissions.

The resulting agreement set a goal to limit global temperature rise to 1.5° C, well below 2° Celsius (the temperature benchmark set before the beginning of the Industrial Revolution). The agreement focused on restricting harmful greenhouse gas emissions to stave off the worst impacts of climate change on health, food security, and extreme weather.

As of 2019, 196 states plus the European Union have ratified the agreement.¹⁴

A study by the University of Cambridge and cooperating institutions finds that abiding by the Paris Climate Agreement, thereby limiting the temperature increase to 0.01°C per year, reduces the loss substantially, to a 1.07% reduction to inflation-adjusted per capita GDP by 2100.¹⁵

THE SOLUTIONS

02

THE RACE IS ON TO CREATE MORE EFFICIENT WAYS TO REDUCE CARBON AND REACH GLOBAL TEMPERATURE GOALS

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To achieve the Paris Agreement objectives, countries submitted carbon reduction targets and commitments for curbing emissions through 2030, including both economy-wide carbon-cutting goals and the individual commitments of some 2,250 cities and 2,025 companies¹⁵.

Current efforts in the US to reduce carbon emissions are focused on renewable energy sources, such as wind and power, stopping deforestation, restricting super-pollutants such as hydrofluorocarbons (HFCs), and increasing energy efficiency.

Glen Peters, research director for the Center for International Climate Research (CI-CERO) and coauthor of a new study on the challenges of meeting the Paris Agreement goals says that developed countries need to “develop low, zero, or even negative

carbon emissions energy technologies that can be deployed at scale in the developing world".¹⁷

This underscores the need to focus on multiple and breakthrough solutions to meet the Paris Agreement imperatives.

STAYING BELOW 2 DEGREES OF GLOBAL WARMING

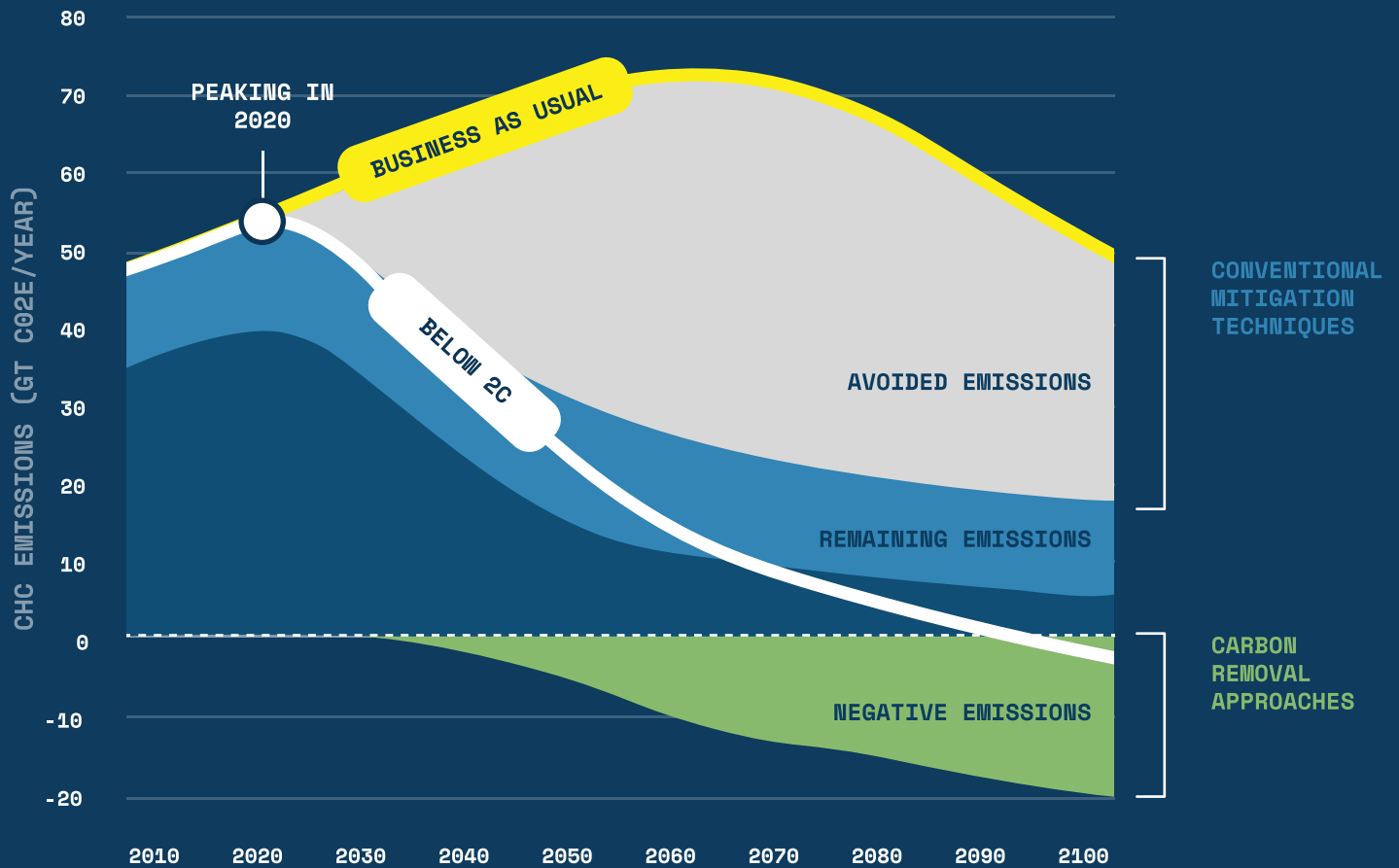


Image Source: <https://www.wri.org/our-work/project/carbon-removal>

Note: This is a notional scenario consistent with an at least 66 percent chance of limiting global warming to below 2°C. Some residual gross greenhouse gas emissions (both CO₂ and non-CO₂) will remain at the end of the century even with ambitious climate action because they are too difficult or costly to remove entirely. Once negative emissions exceed those that remain net zero emissions is reached. Faster and/or deeper emission reductions could reduce the role for carbon removal; slower and/or weaker emission reductions would increase the need for carbon removal.

Many researchers believe it will require not just reducing carbon dioxide but actually removing it from the atmosphere. A new wave of carbon removal technologies are seeking ways to remove, store, and reuse carbon in the movement to stop rising global temperatures.¹⁸

CARBON CAPTURE AND STORAGE (CSS) VS CARBON CAPTURE AND SUSTAINABLE UTILIZATION (CCU)

Carbon Capture and Storage technologies rely on capturing carbon dioxide from the air and storing it underground. With CCS, the captured material is injected deep underground into geological formations, such as abandoned coal mines, where it can stay for millions of years.

Carbon Capture and Sustainable Utilization is the process of capturing carbon dioxide to be recycled for further usage.

While both offer a response to the global challenge of significantly reducing greenhouse gas emissions from major stationary (industrial) emitters, many scientists, entrepreneurs, and environmentalists believe Carbon Capture and Sustainable Utilization (CCU) is a superior solution as it turns the carbon dioxide into products that add value to the economy.

Source: https://www.eurekalert.org/pub_releases/2019-04/agu-nsh042319.php



THERE ARE CHALLENGES TO DEVELOPING CARBON REMOVAL OPTIONS THAT CAN SCALE - FORESTS ARE NOT THE MAGIC BULLET

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The question now is which methods will deliver carbon removal at the scale necessary to remove billions of metric tons of carbon dioxide.

Forests are one of the most widely recognized solutions for carbon removal. Forests cover a third of the world's land¹⁹ and absorb as much as 30 percent of our carbon emissions²⁰ naturally through photosynthesis. The photosynthesis process removes carbon dioxide and stores it in wood and soil as it converts light energy into chemical energy to create fuel for trees activities and growth.



There is evidence that leveraging forests for carbon removal could result in the removal of hundreds of millions of metric tons per year. The World Research Institute estimates that about 3 metric tons of carbon dioxide can be removed per year for every acre of temperate forest that is restored without exorbitant expense (they estimate less than \$50 per metric ton), while creating cleaner water and air at the same time.²¹

While stopping deforestation, restoring existing forests, and managing forests to encourage more carbon removal are all recommended, a popular study suggests new tree planting is the most viable option to affect climate change.

According to a [new analysis](#) by ecologist Thomas Crowther and colleagues at ETH Zurich, a Swiss university, there is enough room in the world's existing parks, forests, and abandoned land to plant 1.2 trillion additional trees, which would have the CO2 storage capacity to cancel out a decade of carbon dioxide emissions.²²

While first widely shared in the press as the next big climate change solution, the study has since been met with criticism. The study did not (nor did it aim to) look at how long it would take to make the reductions or consider the challenges convincing private landowners to plant.

Other scientists believe it could take hundreds of years²³ before new plantings

could scale back carbon dioxide levels to the levels the study suggests. "If the goal is removing carbon dioxide from the air in our lifetimes, planting trees is not going to

cut it," says Dan Habb, Head of R&D at Hypergiant Industries, an AI company building machine learning solutions to accelerate climate change solutions.

Other challenges with forestation include the displacement of land used for farming, scientific and technological difficulties in measurement and monitoring, and limited public funding for carbon-beneficial land management, says a World Research Institute (WRI) Working Paper.

**IF THE GOAL IS REMOVING
CARBON DIOXIDE FROM THE AIR IN
OUR LIFETIMES, PLANTING TREES IS
NOT GOING TO CUT IT.**

DAN HAAB - HEAD OF R&D AT HYPERGIANT INDUSTRIES

“

OTHER CARBON REMOVAL METHODS



Farms:

Soils can store carbon, but overfarming has created a carbon deficit. Composting and cover crops can close the gap and build soil carbon. WWI estimates that with more than 900 million acres of agricultural land in the United States, even relatively minimal increases in soil carbon could be impactful. Farmers and ranchers also benefit from better soil health and crop yields. The challenges are difficulty monitoring and measuring and unpredictability from year to year.



Bioenergy with Carbon Capture and Storage (BECCS):

BECCS is the process of using biomass for energy in the industrial, power, or transportation sectors; capturing the embodied carbon before it is released back to the atmosphere; and then storing it either underground or in long-lived products like concrete. If BECCS causes more biomass to grow than would otherwise, or more carbon to be stored where it would otherwise be released back into the atmosphere, it can provide net carbon removal.

Biomass makes up 50 percent of the renewable energy sources in the EU. Fuels derived from trees and plants—called biomass—qualify as “carbon neutral.” Ironically, this means that throughout Europe, countries and utilities are reaching their carbon-reduction targets by importing wood pellets from the United States and burning them in place of coal.

An increasing body of peer-reviewed science finds several issues with forest-derived biomass. The demand for woody biomass is a threat to forests around the world. Bioenergy is economically uncompetitive compared with genuine clean energy technologies like solar and wind without massive subsidies, and due to the mature nature of bioenergy technologies, unlikely to experience significant cost reductions in the future.

OTHER CARBON REMOVAL METHODS



Direct Air Capture:

Direct air capture is the process of chemically scrubbing carbon dioxide directly from the ambient air, and then storing it either underground or in long-lived products. This new technology is similar to BECCS, except that it removes carbon from the atmosphere instead of reducing emissions. On the downside, the technology remains costly and energy intensive. Direct air capture also requires substantial heat and power inputs—scrubbing 1 gigaton of carbon dioxide from the air would require about 7 percent of all projected US energy production in 2050. The technology would also need to be powered by low- or zero-carbon energy sources to result in net carbon removal. It is still a new technology, and companies are working on these challenges.



Seawater Capture:

Seawater capture extracts carbon dioxide from seawater. By reducing carbon dioxide concentration in the ocean, the water is able to draw in more carbon from the air. Seawater capture will face added complexities of technology deployment in harsh maritime environments.



Enhanced Weathering:

Weathering is a process whereby minerals naturally react with carbon dioxide, turning carbon from a gas into a solid. It typically takes a long time—on a geological timescale. Now scientists are working on speeding up the process, especially by enhancing the exposure of these minerals to CO₂ in the air or ocean. Scientists have shown that enhanced weathering is possible, but there is more work to be done to map out cost-effective and prudent applications of this approach.

Source: Excerpted from <https://www.wri.org/blog/2018/09/6-ways-remove-carbon-pollution-sky>

ALGAE: THE MAGIC ANSWER?

03

THERE IS ANOTHER CARBON REMOVAL SOLUTION THAT COULD CHANGE THE GAME: ALGAE

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A growing community of scientists, researchers and entrepreneurs have been studying and deploying algae as an alternative method to remove carbon from the atmosphere. A plant typically found in aquatic areas, algae uses a photosynthesis process similar to that of trees to absorb carbon. Ironically, one of the oldest plants in the world could be the solution to our carbon emissions problem. Algae potentially eliminates many of the challenges associated with the most popular existing methods and other new utilization methods being developed.

ALGAE FUN FACTS – A SUPER PLANT

- Thrives in freshwater or saltwater and can also be found growing on tree trunks, animal fur, snowbanks, stones and in soil, including desert crusts and mud.
- Endures a range of temperatures, oxygen or carbon dioxide concentrations, acidity, and turbidity.
- Occurs in a variety of forms and sizes, from a single cell organism to multicellular; lives in colonies; or takes on a leafy appearance as in the case of seaweeds such as giant kelp.
- Picoplankton are between 0.2 to 2 micrometers in diameter, while the fronds of giant kelp are as large as 60 meters in length. It can reproduce through asexual or vegetative methods and via sexual reproduction.
- They produce about half the oxygen in Earth's atmosphere.
- Petroleum is partially derived from ancient algae deposits.
- Produces about half of all the oxygen produced on the planet.

Source: [LiveScience](#)

[Mitigation and Adaptation Strategies for Global Change, Chapman, R.L.](#)

Algae has strong potential for scalability since it can survive in extreme temperatures and can be farmed on land that would not be valuable for farming. And because algae are tiny plants that can be produced in seawater, they can be also grown in significantly higher quantities per square foot than land crops²⁶.

THE BENEFITS OF ALGAE FOR CLIMATE CHANGE – EFFICIENT REUTILIZATION

One of the strongest cases for deploying algae in the fight against global warming is that it not only takes carbon out of the air but it also is the most efficient at storing carbon dioxide and can be easily used in a variety of other sustainable and commercial products or materials – from tennis shoes to steel alternatives to veggie burgers. And, unlike trees, algae can do all this without taking up vast amounts of land and freshwater that otherwise fuel natural forests and agriculture.

When algae absorbs carbon dioxide from the atmosphere, power plants, or steel processing exhaust, it can be converted into algae oil. This in turn can be used to produce carbon fibers economically, as initial analyses show.²⁴ These fibers can then be used to make both lightweight and high-strength materials that are carbon neutral.



PLASTICS APPLIED TODAY IN THE MAKER MOVEMENT

CASE STUDY: 003

Dutch designers Eric Klarenbeek and Maartje Dros use algae to create polymers that can replace plastic in 3-D printing.

“In principle, we can make anything from this local algae polymer: from shampoo bottles to tableware or rubbish bins,” says the firm’s project coordinator, Johanna Weggelaar. “Our goal is to ultimately turn an industrial manufacturing process – a source of pollution that contributes to global warming – into a way to subtract CO2 from the atmosphere. Using algae as a raw material would turn any mode of production into a way to help the environment.”

“

They are starting with the maker economy, building a network of object manufacturing and sale shops to use the process. They have set up an Algae Platform in collaboration with Atelier Luma in the South of France to develop products and explore application with local designers around the world.

They also worked with American company Ecovative Design, a biomaterials company that develops sustainable alternatives to conventional plastics, resins and foams. The studio has developed a commercial line of mycelium products called Krown. The DIY kits allow consumers to grow their own lamps, tables, or biodegradable picnic items.

Source: [Fast Company](#), [Dezeen](#)

A team of researchers at the Technical University of Munich (TUM), led by Professor Thomas Brück, have developed a methodology for the efficient production of algae (which has been endorsed by the IPPC) and the exploration of economic models for scaling its utilization. They have found that carbon fibers derived from algae have the same properties as conventional fibers and can be used to make both lightweight and high-strength materials that are carbon neutral. Plastics made as a result of TUM's algae's carbon dioxide removal process can also be easily returned to the atmosphere through recycling (waste incineration plants following a few years of use).²⁶ On the other end of the spectrum, carbon fibers are strong enough to replace structural steel. In fact, solid carbon fiber is the second most stable form of carbon²⁷ on the planet after diamonds.

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ALGAE] PLANTS
WHICH TOGETHER
WOULD COVER THE
SIZE OF ALGERIA
WOULD OFFSET ALL
CO₂ EMISSIONS FROM
AIR TRANSPORT.

PROFESSOR THOMAS BRÜCK, TUM

SUSTAINABLE FASHION:

AN ALGAE T-SHIRT THAT GOES FROM WEAR TO COMPOST IN 12 WEEKS

SIDEBAR



Future-focused men's apparel brand Vollebak has created a T-shirt made from wood fiber and algae that can turn into plant food in 12 weeks in the comfort of your backyard. At \$110, it's an investment in the earth's future. According to the website, the T-shirt biodegrades in the earth in 12 weeks and turns into worm food – you can either bury it in your garden or put it out with the compost.

Source: [Vollebak](#)



AI HAS TREMENDOUS POTENTIAL TO ADVANCE THE DEVELOPMENT OF EFFICIENT, ADOPTABLE CLIMATE CHANGE SOLUTIONS

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There are a number of algae bioreactors in development and use today that increase the scalability of and efficiency of algae as a harvestable biomass and a tool for carbon sequestration. Looking forward, the application of AI to the bioreactor process can accelerate our ability to learn how to scale algae production and experiment with different (or accelerate) ways to use algae that is both good for the environment and good for the economy.

HOW TO MAKE ALGAE BIOMASS

Bioreactors are the machines that allow humans to process algae for both carbon removal and for creating the algae material that can then be used to make food, fuel, fertilizer, foam, or any number of other uses. Bioreactors consist of interconnected closed tanks that hold water and form a closed system that prevents pollutants from entering and limiting evaporation. Algae flows from one tank to another, fueled by a blower that pumps filtered air in the system. There are two outputs. The oils attached to algae are then put through different processes to make biofuels or plastics. Then there is the algae itself, which is dried into a powder that can be used for nutrients or fibers.



Universities, governments and corporate research programs have been developing bioreactors since the late 1950s. All of them work on the basic premise of capturing carbon from the atmosphere and sequestering in algae byproducts. When the algae absorbs the carbon, it thrives and grows. The bioreactor then converts carbon dioxide into carbon-rich lipids to create biofuel that can be cultivated far biomass and used in production.

Historically, it has been difficult to optimize algae growth and output from existing bioreactors or processes. Plus, the solutions have been labor intensive with hard to control waste outputs.

However, HyperGiant Industries, an artificial intelligence (AI) company that works with companies and governments to create smarter solutions and tackle the world's most challenging problems has created an AI-powered bioreactor to tackle current model deficiencies.

HyperGiant has built a next-generation algae reactor focused on leveraging machine learning to accelerate algae's power to solve climate change. It sees the bioreactor as a platform to experiment with more sustainable and innovative ways to scale algae utilization. The AI-enhanced bioreactor uses machine intelligence to automate production, optimize output, and reduce maintenance. The current scalable model could range from something small enough to sit on your counter to feed your daily smoothie habit all the way through to commercial construction where reactors are used in enterprise level developments skyscrapers.

THERE EXISTS AN INTERESTING OPPORTUNITY TO CHANGE THE WAY WE LIVE IN CITIES. THIS IS ABOUT CHANGING THE WAY WE CONSUME FOOD, PRODUCTS, AND FUEL."

BEN LAMM - HYPERGIANT CEO

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For example, its current prototype product is a controlled closed system model that taps into the Heating, Ventilation and Air Conditioning (HVAC) in office buildings. It uses the building exhaust as a point of reference for CO2 density, and it thrives in the carbon-rich dirty air that comes from exhaust pipes. As the bioreactor harvests algae, it releases it out of the system into compacted algae-based pucks (the size of a hockey puck) that can be used for a variety of use cases including food production, biochar, biofuel, etc.

Hypergiant's bioreactor comes paired with a mobile application that provides the status of the bioreactor, detects anomalies, and provides current and historical reporting of CO2 sequestration and biomass production. A cloud-based infrastructure connects the bioreactors, allowing them to learn from each other, optimize for new environments, and provide global insights. Using machine intelligence algorithms, the team can scan the satellite imagery of a city and create an algorithm that segments pixels into vector objects to be classified. Machine intelligence can use heat maps from pollution concentration to prioritize algae farm locations as well.

"We want to modularize and shrink the components themselves to make them as efficient as possible and spread them across as many use cases as possible, from the hobbyist 3-D printing their own parts who may want to buy a kit and put it up in their garage all the way through to commercial construction, where we can put reactors on the tops of big skyscrapers," says Lamm. "We are focused on targeted growth and the farming of algae in places where you need a lot of biofuel."



BIOFUEL COMPLEXITIES

A great deal of attention has been paid to algae's potential as a source of biofuel production.²⁷

Biofuels, which include any fuel made from a living organism—offer a more sustainable alternative to carbon-producing fossil fuels like petroleum, coal, and natural gas. Other leading biofuel sources include plants like soybeans or corn and animal waste.

Algae's relatively high oil content and rapid biomass production makes it an attractive method for carbon dioxide consumption.

The US government first explored algae as a petroleum alternative during the energy crisis in the 1970s. It abandoned the project in the 1990s²⁸ because it was unable to make it competitive with the pricing of petroleum. However, with the rising costs of petroleum and imperative for clean energy, oil companies such as Exxon and venture capital firms are pouring money into solving the algae as fuel equation. While progress is being made, the industry recognizes it's a long journey to profitability. The algae oil extraction is a costly process and

difficult to scale. The Energy Biosciences Institute (EBI) in Berkeley projected that development of cost-competitive algae biofuel production will require long-term research, development, and demonstration. While some organizations believe that the potential for algae-based biofuels is overblown²⁹, companies, researchers, and the US government continue to support long-term R&D exploration³⁰ of algae-based biofuels as a future source of power generation, as we strive to meet emissions-reduction goals and find breakthroughs for commercially viable clean energy.

WHAT IS BIOMASS?

Biomass is any organic matter—wood, crops, seaweed, animal wastes—that can be used as an energy source. Biomass is a renewable energy source because its supplies are not limited. We can always grow trees and crops, and waste will always exist. Due to its ability to grow fast and store energy, Algae has become one of the most interesting long-term, sustainable sources of biomass and oils for fuel, food, feed, and other co-products.

Source: <http://lsa.colorado.edu/essence/texts/biomass.html>

<http://allaboutalgae.com/benefits/>; <https://link.springer.com/article/10.1007/s11027-010-9255-9>



SUSTAINABLE SNACKING: KELP JERKY – DOING GOOD WHILE TASTING GOOD

SIDEBAR

Seaweed farming recently made headlines for its potential to reverse climate change through carbon sequestration. That's just one of the reasons Akua is passionate about kelp farming. Akua creates foods that can feed the planet sustainably while reversing climate change and restoring health to our world's oceans. According to its website, kelp farming is a zero-input crop that

requires no fresh water, no fertilizer, no feed, and no arid land to grow. Kelp also filters carbon and nitrogen from the water, and creates new jobs for our coastal communities. They source seagreens from a network of regenerative ocean farms along the northeast coast of the US. Blended with shiitake mushrooms, you can get your umami on.

Source: [Akua](#)

COMMERCIALIZATION OF ALGAE UTILIZATION

While both public and private organizations are working on algae as an alternative power source, many innovative companies are already commercializing the output of algae fibers in ways that are impacting everyday consumption while solving for climate change. One of the leading innovators is Bloom, a company that makes a foam from algae that is used for surfboards and shoes (whose soles are typically made from petroleum). Companies using the algae foam for shoes include Merrell, Adidas, and H&M. During the harvesting of the algae, the Bloom technology cleans the water and puts it back into the freshwater ecosystem, resulting in 225 bottles of filtered water³¹ returned to the environment and 21 balloons of CO₂ kept from entering the atmosphere. At the same time, these foam soles have a better recycling profile than plastics.

CHALLENGES OF RECYCLING FOAM FROM ALGAE

Bloom foam can technically be recycled, which is progress, but there is still a long way to go in terms of making algae foam recycling a reality. Foam releases ethylene-vinyl acetate (EVA), volatile organic compounds that pollute air and water. While Bloom's algae-EVA blend was tested to show it is 20 to 41 percent less

environmentally harmful than pure EVA, Bloom still isn't recyclable, as it can't be melted and reprocessed into new material.

Source: [Outside](#)



ALGAE OFFERS HUGE POTENTIAL AS A CARBON-NEUTRAL SUSTAINABLE SUPERFOOD

Algae with its high protein content and nutritional value can be used as food for both humans and animals as feedstock. The health food industry has long used spirulina, and NASA adopted it as a nutritional supplement for space missions. This is because spirulina is packed with vitamins and antioxidants and is a superior source of omega-3s. Essentially it is the most protein-rich resource that can be grown per area, whether plant- or animal-based. Articles in the United States [National Library of Medicine](#) (NLM) also document its clinical applications as an anti-inflammatory.

Blue Majik, a proprietary strain of blue-green algae developed by nutrition company E3 Live, has propelled algae into the mainstream. It's used in the Instagram-friendly "blue magic" smoothies, "mermaid bowls," and "unicorn lattes" that are growing in popularity behind the plant-based diet trend.

Photo source:

<https://www.womenshealthmag.com/food/a21991341/blue-majik-benefits/>



Many food innovators have even bigger plans for algae as a food source. With its ability to grow extremely quickly in almost any environment, algae is a crop with minimal space requirements and upkeep, yet it yields maximum nutritional output. "It makes a promising and sustainable nutrition solution," reports Brian Kateman in [The Guardian](#).

Photo source:

<https://www.instagram.com/p/BvtmeAjFkFR/>

SUSTAINABLE PRINTING: ALGAE TAKES BLACK INK INTO THE GREEN

SIDEBAR

Algae can be used to make paper, and now Colorado-based company Living Ink is turning the plant into a more sustainable alternative to mainstream inks, which use a petroleum-derived base. In fact, the pigment that produces traditional black ink is carbon black, made from a heavy petroleum that the International Agency for Research on Cancer (IARC) classifies as a known carcinogen. Living Ink's Algae Black is made from a sustainable algae farm.

Source: [Cosmetics Business](#)





Rebecca White is one of the rising innovators in the space. White is a research scientist at [iWi](#), a nutrition company that runs one of the largest algae farms³². iWi has algae farms in Texas and New Mexico, with a mission to accelerate algae's po-

tential as a solution for the food security of our planet. Population projections show that we will need a 70 percent increase in food supply by 2050 to feed the planet, and an August 2019 [United Nations report](#) warned of a looming food crisis.

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PLANTING AS MANY TREES AS POSSIBLE WOULD REDUCE THE AMOUNT OF GREENHOUSE GASES IN THE ATMOSPHERE BY ABOUT NINE GIGATONS EACH YEAR, ACCORDING TO PAMELA MCELWEE, A PROFESSOR OF HUMAN ECOLOGY AT RUTGERS UNIVERSITY AND ONE OF THE REPORT'S LEAD AUTHORS. BUT IT WOULD ALSO INCREASE FOOD PRICES AS MUCH AS 80 PERCENT BY 2050.

THE NEW YORK TIMES

iWi's two farms host 48 ponds about the size of a football field. They harvest the algae and turn it into algae oil and subsequently sell it as supplements. iWi is working on turning the remaining proteins and carbohydrates into protein products with a commercially viable taste profile.



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SEVENTY PERCENT OF THE WORLD'S AVAILABLE FRESHWATER IS USED FOR AGRICULTURE AND RAISING LIVESTOCK. LIVESTOCK AND THE FOOD THEY CONSUME GENERATE 14 PERCENT OF ALL GREENHOUSE GAS EMISSIONS FROM HUMAN-RELATED ACTIVITY, CONTRIBUTING TO CLIMATE CHANGE, MORE DROUGHTS, AND LAND EROSIONS. IT'S A VICIOUS CYCLE THAT EXPERTS SAY WE ARE RUNNING OUT OF TIME TO BREAK.] WE NEED A FARMING REVOLUTION," SAYS MIGUEL CALATAYUD, THE CEO OF IWI.

MASSIVE SCIENCE

Other companies are working with similar goals for algae as a scalable superfood.

[Triton Algae Innovations](#), an algae nutrition company, is working on a project that will make an algae product that can be used to make foods such as pasta and veggie burgers. According to an article in [Forbes](#), the company has an algae-based heme that is the same complex that makes the Impossible Burger "bleed" but without the genetic engineering.

SUSTAINABLE BEAUTY: SKINCARE THAT IS OCEAN DEEP

Algae is full of skin-beneficial vitamins and antioxidants, and it is a powerful antibacterial. While many companies use algae as a skincare ingredient, One Ocean also uses it to save the environment. Cosmetics and personal care brands rely heavily on water, both in manufacturing and as part of the product's formula. By sustainably producing its algae in a biotechnology lab in Europe, One Ocean neither depletes the critical water supply nor the carbon-absorbing ability of the ocean.

Source: [One Ocean](#)



ALGAE FOOD ENTREPRENEURS GROW GLOBALLY WHILE FEEDING LOCALLY

The Novotel Hotel in Bangkok is operating an urban algae farm on its roof in partnership with algae startup EnerGaia, a producer of spirulina-based food and supplements.

As reported by the Bangkok Post, Founder and CEO Saumil Shah started EnerGaia after first working for GE on an algae-based biofuel project in Thailand. He left GE to start a company using algae as fish feed when he saw more immediate commercialization opportunities. He then moved to Bangkok and shifted to human food after his fish food facility in Thailand was destroyed in the 2011 flood.

The company raised a Series A funding of \$3.65 million in 2019, fueling his vision to transform the spirulina market into a sustainable, accessible, and profitable solution for future resource scarcity caused by the world's reliance on water and land-intensive food production. Shah is banking on spirulina becoming a staple food item that moves out of the health food store and into the grocery store.³³



EnerGaia installed algae bioreactors on the hotel roof to produce spirulina that gets sold in the hotel café. The hotel roof farm was just the beginning. He envisions putting bioreactors in unused spaces – rooftops, vacant parking lots – to make urban farming of spirulina more accessible.

The company has since expanded to Indonesia, India, Bangladesh, and Vietnam. EnerGaia also works with the Bill & Melinda Gates Foundation to foster spirulina production in rural areas, such as one program that supplements rural farmers' incomes in Bangladesh.

Shah told the Bangkok Post that one bioreactor tank takes up just one square meter of space and can produce \$600 a year in income. According to the article, “microentrepreneurs’ can receive financing and training from EnerGaia to begin their farm, eventually selling the spirulina back to EnerGaia while keeping some to eat.”

This demonstrates the efficiencies of using algae bioreactors to supply local food, and sets the path for other algae benefits such as energy and power generation to be localized, using minimal space required in urban areas and at a relatively low cost, while also capturing carbon dioxide from the air.

Image Source: <https://www.treehugger.com/green-food/thai-startup-growing-spirulina-bangkok-rooftop-garden.html>

Source: <https://www.bangkokpost.com/business/1623214/green-movement-energaia-bets-on-spirulina>

CONCLUSION

04

The optimal time to plant trees to address our current climate crisis was decades ago. Now algae has become one of the few truly viable alternatives to planting trees, and it's beginning to grow as a commodity market. Leading algae-preneuers are finding innovative solutions to capture carbon, recycle the by-products, and invent new market products that take advantage of the environmental outputs of bioreactors and algae farms.

Individuals should: Look to algae as a potential food resource, consider the purchase of products created with algae, and support local and federal efforts to adopt algae methods of carbon absorption and sequestration. And, because it helps too: Go out there and plant a tree, be part of an ocean cleanup, or work for companies that are making progressive change in our world.

The world's problems can be solved by two things: collective action, and technology that improves upon dated ways of doing things and puts humans first. Everyone can be a part of this change and support those companies leading the way.

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