The Climate Change Crisis

A HiveMind White Paper

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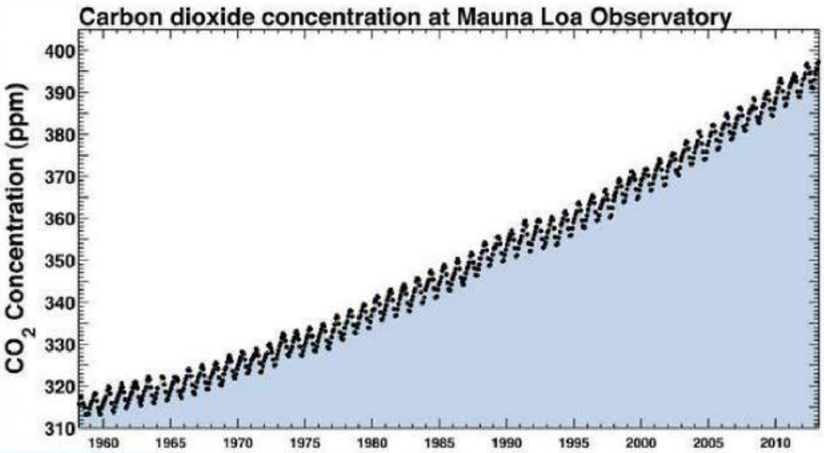
Tipping Point: The Paris Agreement:

The Paris Climate Agreement in 2015 was a triumph after decades of trying to get the leaders of the world's economies to hammer out a consensus to mitigate — though not fully avoid — catastrophic climate change. One hundred and seventy five parties (The European Union's twenty-eight member states signed as a single entity) agreed to limit global temperature rise to under 2 C.

The goals were audacious: CO2 and other greenhouse gas emissions needed to peak by 2020 and then decline precipitously to zero by 2050. That would be met by limiting emissions and increasing renewables by several orders of magnitude. Drawdown technology to remove CO2 and other greenhouse gases from the atmosphere was never mentioned.

A global agreement to address CO2 emissions and climate change was long overdue after decades of lost opportunities. Surprisingly, by 1957 the vast majority of the data about the relationship between atmospheric CO2 and the planet's temperature had already been collected. By 1979 the data had been analyzed and had proved a conclusive linear correlation between atmospheric CO2 and a warming climate. Indeed, there was a push to include CO2 emissions in the Clean Air Act in 1963 and the EPA first warned of the negative effects of climate change in 1979.



Flash forward eighteen months after the signing of the Paris Agreement, and the euphoria has largely deflated after a series of setbacks: it took six months for the parties to actually sign the nonbinding agreement in 2016, President Trump announced the US withdraw in 2017, and in 2018, global CO2 emissions increased more than 2%

CO2 Pledges & Policy.

Damage Done: Two Trillion & Rising

Since 1820, industrial societies have emitted over two trillion tons of CO2 and other greenhouse gases into the atmosphere. The planet has warmed 1.2 C (2.1 F) since then (1.62 F since 1980 alone) making the earth the warmest it's been in 130,000 years. The oceans — a key sink for absorbing CO2 — are the most acidic they been in 800,000 years. The billions of tons of additional CO2 reacts with carbonate molecules dissolved in seawater and this reaction causes the water to become more acidic.

For some perspective on the asymmetry between changes in climate and culture, 130,000 years ago hippos lived in what's now England, the American Midwest was a desert, and seas were twenty feet higher. Civilization at that time consisted of Homo Sapiens competing with Neanderthals, Denisovans, and hyenas for food.

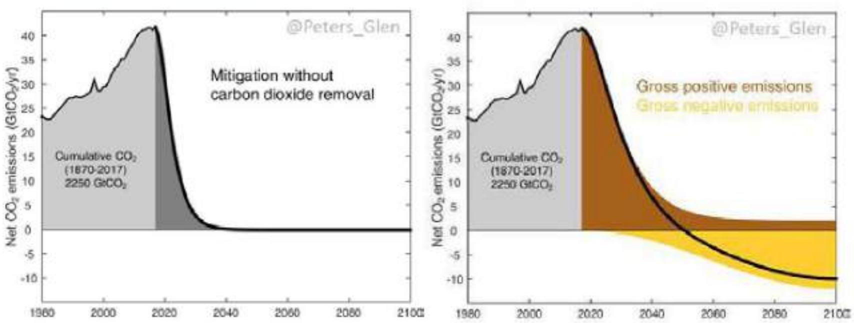
Why hasn't the change in climate fully impacted us yet? It will; we're simply enjoying the delay between turning the thermostat up and overheating. Because CO2 stays in the atmosphere for thousands of years, by the end of this century temperature will rise enough to melt Arctic glaciers and Greenland permafrost, day time highs will shoot up twenty degrees Fahrenheit on any given day, and oceans will be so acidic that sea water dissolves corals, oyster shells, and plankton that manufacture much of the oxygen we breathe.

Big Oil Gets Woke: Shell Sky Scenario:

On March, 2018, Royal Dutch Shell Oil in conjunction with MIT released Sky Scenario: Meeting the Goals of the Paris Agreement. The Sky Scenario advocates six major pivots each tantamount to a worldwide Manhattan Project. It calls for a massive sale up of technology to drawdown three trillions tons of CO2 and other greenhouse gases after "over shooting" the Paris Agreement's goals. This will be accomplished by the global deployment of 10,000 carbon capture and storage facilities. At current population growth through 2100 that would equal one facility for each million people on the planet drawing down 10,000,000 tons at each site.

The Sky Scenario doesn't mince words when it comes to the urgency of this deployment: "achieving netzero emissions in just 50 years leaves no margin for interruption, stalled technologies, delayed deployment, policy indecision, or national back-tracking."

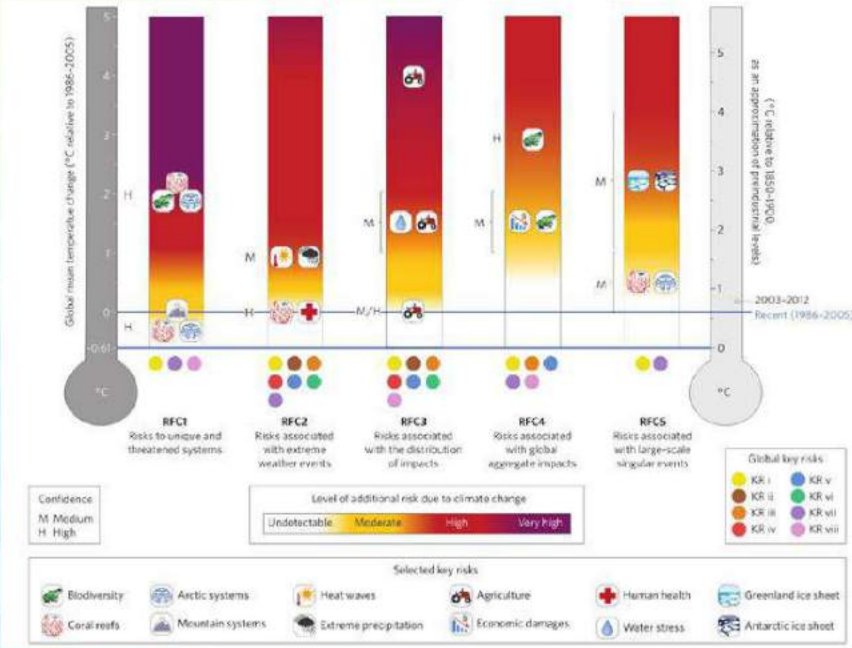
Another startling admission is that without CO2 drawdown and sequestration, emissions would have to drop off a cliff starting today.



Download Shell Sky Scenario Here: https://www.shell.com/promos/meeting-the-goals-of-the-parisagreement/_jcr_content.stream/1530643931055/d5af41aef92d05d86a5cd77b3f3f5911f75c3a51c1961fe1c981daebda29b726/shell-scenario-sky.pdf

IPCC: Circles of Climate Change Hell

On October 8th, 2018, the United Nations' Intergovernmental Panel on Climate Change (IPCC) released a shocking report blandly titled "Global Warming of 1.5° C." In it, thousands of scientists lay out the nearly order of magnitude difference in risk and damage between 1.5 C and 2 C rise in temperatures. It also addressed the massive gap between what was promised at Paris, what has been delivered so far, and puts a drop-dead date for emissions at twelve years. The levels of risks were put into a single graph called "Burning Embers" as a kind of Dante's circle of climate change hell.



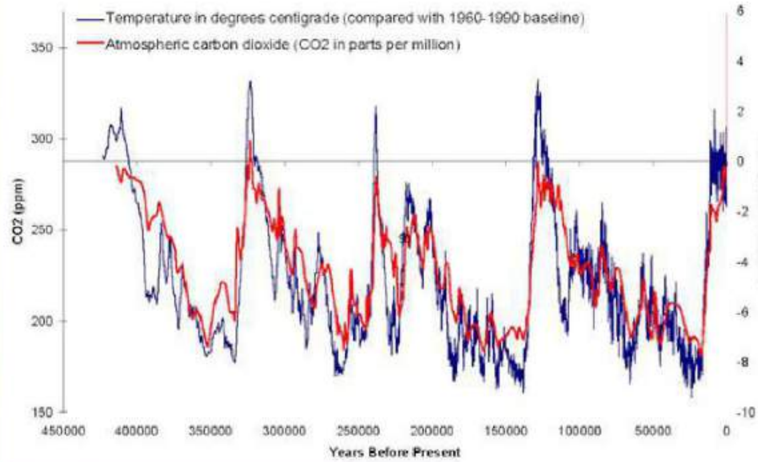
Download IPCC Report Here: https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

Download visual synopsis of the difference between a 1.5 C rise & 2 C rise Here: https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

The first level ***Risk to Unique and Threatened Systems*** clearly shows that arctic ice, coral reefs, and biodiversity will significantly decline and possibly disappear by the middle of the century. The far end of the spectrum is sinisterly titled: ***Risks Associated with Large-Scale Singular Events***. These are "tipping points," whereby a series of incremental changes pushes a regional system over a threshold, at which point it shifts globally during a period of rapid, discontinuous, and sometimes irreversible change. The iconic example here is "disintegration of the Greenland and West Antarctic ice sheets leading to a large and rapid sea-level rise."

The report marks the first time the United Nations entity has even mentioned let alone called for massive scale up of drawdown technologies and deployment. "We have not identified any pathways that get to 1.5°C without carbon dioxide removal," stated Jim Skea, co-chair of IPCC Working Group III.

Within twelve months, drawdown technology had gone from zero to the only solution that can save the planet from catastrophic climate change in the very short time frame we have left.



The Drawdown Solution

A Brief History of Drawdown Technology:

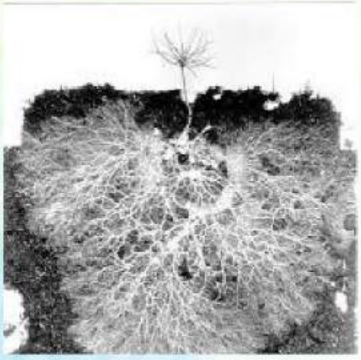
Drawdown technology isn't new. It's been globally deployed for over one hundred years. In fact, 60% of the nitrogen in your body is the result of drawdown technology called the Haber Bosh Process. German scientist Fritz Haber invented the process in 1905 and won a Nobel Prize in 1918 for creating a reliable method to pull nitrogen out of the atmosphere and turn it into ammonia to be used for fertilizer. Bosch won a Nobel Prize in 1931 for perfecting the process. The increase in crop production from ammonia based fertilizer allowed the world's population to increase from 1.6 billion to 7 billion and the process now produces 450 million tons of nitrogen fertilizer per year.

Three Types of CO2 Drawdown Technology:

Drawdown technologies falls into three categories: carbon capture and storage (CCS), mechanical direct air capture, and biological capture. Carbon capture and storage scrubs the emissions directly from a site such as coal plant. Though this is needed to limit emissions, smokestack capture has some significant limitations: it can only capture CO2 from the original site, cannot capture all the CO2 emitted, and is expensive.

Mechanical direct air capture has the advantage of being able to capture CO2 from anywhere, but often use fossil fuels to power the process and even worse sometimes uses the captured gases to extract more fossil fuel as in CO2 fracking. These sites are essentially giant air sucking fans, and the idea of tens of thousands of these stretching across the landscape isn't an inspiring vision of the future. This type of technology also faces the Valley of Death: a lag time of tens of years and billions of dollars to go from the current pilots to global scale up. As the IPCC Report makes clear, by then will be too late.

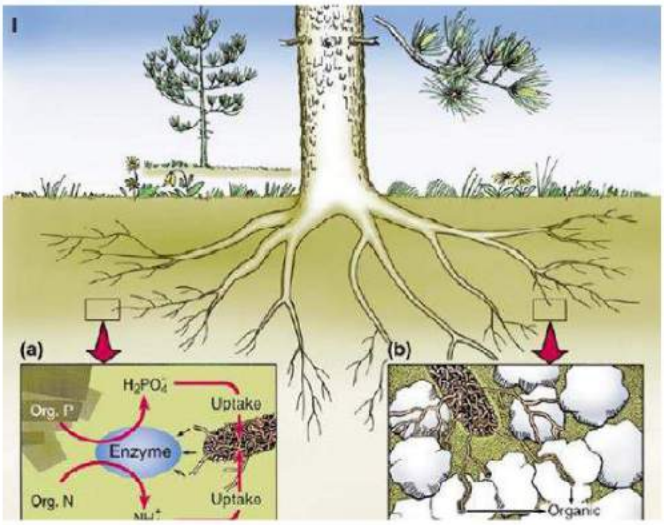
Mycelium is the most promosing form of biological capture and provides several advanatages over other drawdown technologies: it doesn't require new infrastructure, can be inoculated in most biomes using no special equipment, has no negative side effects, and is powered by photosynthesize through its symbiotic relationship with plants. It's also proven in the field and ready for global scale up with minimum capital investment.



How Mycelium Sequesters CO2 & Inhibits N2O

Mycelium: The Missing Link Between Plants & Soil

Over 1.3 billion years ago, Fungi left the oceans and colonized the land preparing the way for plants and animals by breaking down rock into soil. Mycelium produces oxalic acid (two carbon dioxide molecules joined together with two hydrogen molecules) making calcium and other minerals available to plants and animals. This ability of mycelium to turn rock into soil continues to this day. The plant breathes in CO2 and out oxygen, turns the CO2 into carbon for structure and sugars for energy, and trades almost half of its carbon and sugar to mycelium in exchange for rate limiting nutrients like phosphorus, nitrogen, and water.



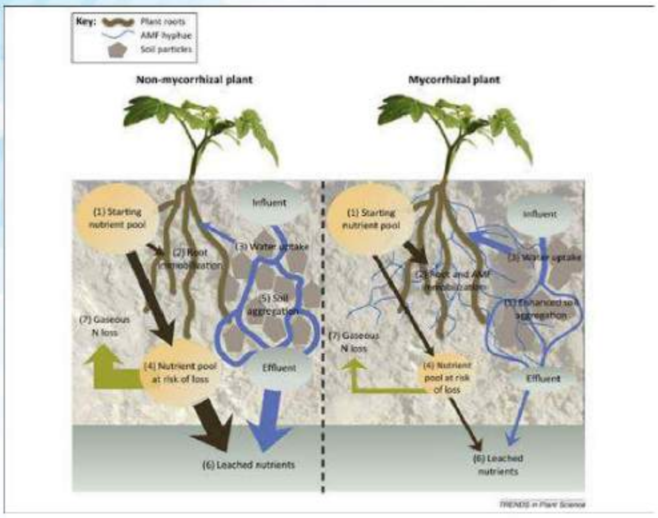
Mycelium & CO2 Sequestration

There are thousands of peer-reviewed papers on mycelium's role in CO2 sequestration in soils. Three podcasts give excellent overviews of this process in laypeople's terms: Suzzane Simard's How do Trees Collaborate and How Trees Talk to Each Other, and Paul Stamet's Six Ways Mushrooms Can Save the World.

How Do Trees Collaborate?: *https://www.npr.org/2017/01/13/509350471/how-do-trees-collaborate*
How Do Trees Collaborate?(Audio): *https://www.ted.com/talks/suzanne_simard_how_trees_talk_to_each_other/transcript?language=en*

Mycorrhiza is Latin for fungus-root and was first discovered in the 1800s though its role in soil enrichment wasn't fully understood until twenty years ago Mycelium merge with the plants roots at a cellular level and extends their reach one hundred fold through filaments one tenth the size of a human hair. A single pinch of healthy soil contains seven miles of mycelium.

This symbiotic relationship with mycelium enables the plant to better contend with diseases and parasites, compete for space and sunlight, invest extra energy in the production of flowers or cones, successfully reproduce, and replace growth lost to insects, animals, storm breakage and seasonal defoliation.



There are thousands of peer-reviewed articles on mycelium's ability to sequester CO2 and inhibit N2O production and release by outcompeting N2O producing microbes. We will succinetly review three here.

The first article, "*Roots and Associated Fungi Drive Long Term-Term Carbon Sequestration in Boreal Forests,*" was published in Science magazine in 2014 and addresses mycelium's ability to enable trees to capture more CO2 and convert it into carbon and sequester it in a matrix in the soil. The entire article is available online.

Roots and associated fungi drive long-term carbon sequestration in boreal forest: *https://www.ncbi.nlm.nih.gov/pubmed/23539604*

The study shows that the soils of boreal (temperate) forests act as a carbon "sink" trapping greater than 50% of terrestrial carbon. Previously it was believed that above ground plant litter was the principle source of carbon, and that as plant matter degraded it released carbon back into the atmosphere. This is one study of a growing body of research that shows mycelium trap a huge amount of carbon in the soil.

The second article, *Soil as Carbon Storehouse: New Weapon in Climate Fight* was published in the Yale Environment 360 in 2014. It quotes a number of leading climate change researchers who all make the connection between the ability of soil to store enough carbon to stop global warming, mycelium, and its ability to store both carbon and inhibit N2O release into the atmosphere.

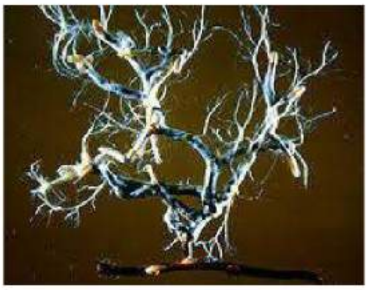
Soil as Carbon Storehouse: New Weapon in Climate Fight? https://e360.yale.edu/features/soil_as_carbon_storehouse_new_weapon_in_climate_fight

"Supply-side approaches, centered on CO2 sources, amount to reshuffling the Titanic deck chairs if we overlook demand-side solutions: where that carbon can and should go," says Thomas J. Goreau, a biogeochemist and expert on carbon and nitrogen cycles who now serves as president of the Global Coral Reef Alliance. Scientists say that more carbon resides in soil than in the atmosphere and all plant life combined; there are 2,500 billion tons of carbon soil compared with 800 billion tons in the atmosphere and 560 billion tons in plant and animal life. And compared to many proposed geoengineering fixes, storing carbon in soil is simple: It's a matter of returning carbon where it belongs. One promising strategy, says Goreau, is bolstering soil microbiology by adding beneficial microbes to stimulate the soil cycles where they have been interrupted by use of insecticides, herbicides, or fertilizers."

"An important vehicle for moving carbon into soil is root, or mycorrhizal fungi, which govern the give-and-take between plants and soil. The most common mycorrhizal fungi are marked by threadlike filaments called hyphae that extend the reach of a plant, increasing access to nutrients and water. These hyphae are coated with a sticky substance called glomalin, discovered only in 1996, which is instrumental in soil structure and carbon storage.

"In research published in Nature, in January, scientists from the University of Texas at Austin, the Smithsonian Tropical Research Institute, and Boston University assessed the carbon and nitrogen cycles under different mycorrhizal regimens and found that plants linked with fruiting, or mushroom-type, fungi stored 70 percent more carbon in soil. Lead author Colin Averill, a fourth-year graduate student at the University of Texas, explains that the fungi take up organic nitrogen on behalf of the plant, out-competing soil microorganisms that decompose organic matter and release carbon. He says this points to soil biology as a driver of carbon storage, particularly "the mechanisms by which carbon can stay in the ground rather than going into the atmosphere."

The final paper, *Arbuscular mycorrhizal Fungi Reduce Nitrous Oxide Emissions from N2O Hotspots* was published in the New Phytologist on December 5th, 2017. The other articles touch on this, but this study lays out how mycelium inhibits N2O, a greenhouse gas with 300 times the heat trapping capacity of CO2.



Arbuscular mycorrhizal fungi reduce nitrous oxide emissions from N2O hotspots: https://www.ncbi.nlm.nih.gov/pubmed/29206293

Included is the synopsis.

- Nitrous oxide (N2O) is a potent, globally important, greenhouse gas, predominantly released from agricultural soils during nitrogen (N) cycling. Arbuscular mycorrhizal fungi (AMF) form a mutualistic symbiosis with two thirds of land plants, providing phosphorus and/or N in exchange for carbon. As AMF acquire N, it was hypothesized that AMF hyphae may reduce N2O production.
- AMF hyphae were either allowed (AMF) or prevented (non AMF) access to a compartment containing an organic matter and soil patch in two independent microcosm experiments. Compartment and patch N2O production was measured both before and after addition of ammonium and nitrate.
- In both experiments, N2O production decreased when AMF hyphae were present before inorganic N addition. In the presence of AMF hyphae, N2O production remained low following ammonium application, but increased in the non AMF controls. By contrast, negligible N2O was produced following nitrate application to either AMF treatment.
- Thus, the main N2O source in this system appeared to be via nitrification, and the production of N2O was reduced in the presence of AMF hyphae. It is hypothesized that AMF hyphae may be outcompeting slow growing nitrifiers for ammonium. This has significant global implications for our understanding of soil N cycling pathways and N2O production.

HiveMind's One Stop Solution For Catastrophic Climate Change:

HiveMind uses a blend of dozens of mycelium species that have been proven to capture significant amounts of CO2, inhibit N2O release, and safely sequester them in a mycelium matrix in the soil. We have two of the world's top ten CO2 emitters as clients, Shell Oil and Cummins Diesel, and have completed pilots for Cummins and will complete our first pilot for Shell, a mycelium inoculated green roof on a gas station in London, in January of 2019.

HiveMind's technology has been verified by Europe's top industrial process agency, EEVS Insight Ltd (Energy Efficiency Verification Specialists) is the UK's leading provider of IPMVP-based performance analysis and verification services for any sustainability project, product, service or investment.

Squaring the Circle: Solving the Problem of Global Scale & Cost:

Critics claim that nearly the entire landmass of a country like England would be required to store enough greenhouse gases to make them carbon neutral. With a new understanding of how mycelium interacts with plants, carbon and nitrogen, we can solve the problem of scale without displacing people.

HiveMind sequestered 135 metric tons of CO2e in four inches of soil on a 500 square feet green roof at Cummin's Huddersfield diesel plant. Our data from over a dozen sites in the US give an average of 100 tons CO2E sequestered per 1,000 square feet on a standard sedum roof of four inches. There are 43,560 square feet in an acre, so it's possible to sequester 4,300 tons of CO2e over ten years on acres of land. Central Park is 840 acres so it's possible to sequester 3.6 million tons of CO2e in a space the park's size. That's the carbon footprint of 180,600 Americans. We believe that's a better solution than a park full of giant air sucking fans.

HiveMind's per ton cost is $11 compared to $100 per ton for mechanical capture. Our margins are 45% and will only fall to 40% with scale up.

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