The Climate Restoration Imperative

WHAT IT MEANS, WHY IT MATTERS,
HOW WE CAN MAKE IT HAPPEN

Peter Fiekowsky
with Carole Douglis

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Prologue: A Tale of Two Futures

IT'S NEW YEAR'S DAY, 2050. Last month, December 2049, NASA's observatory on Mauna Loa, Hawaii, reported that atmospheric carbon dioxide (CO2) has dropped back below 300 parts per million (ppm) for the first time since 1910—finally returning to levels that humans have survived long-term. We're back in the climate range in which humanity has spent its history. We made it. The age of climate catastrophe is over.

People celebrate with fireworks and parties across the globe. We have overcome the existential threat posed by runaway climate change and restored a climate that will allow humanity to survive and to flourish.

Farmers know when to plant again. Harvests are reliable again. The coral reefs are well on the road to full recovery. So are the fisheries on which so much of humankind depends. The hellscape of huge wildfires that once dominated the American West is a fading memory. The one billion men, women, and children who live in regions of Asia, Africa, and the Americas that were threatened by catastrophic flooding and who expected to become climate refugees can now remain home in safety.

From this vantage point, it's difficult to recall a time when the concept of "climate restoration" was an unfamiliar one. Decades ago, during the first half-century of "climate action," few in the scientific community discussed climate restoration. It wasn't until 2015 that anyone proposed it as a serious policy goal. It wasn't until 2021 that a concerted effort was launched to convince policy leaders to make it a priority. Yet now, just 29 years later—it has been accomplished!

Unfortunately, that future is far from guaranteed. A different future—one you've likely heard about many times and perhaps promoted—is the one we're collectively driving toward.

IT'S NEW YEAR'S DAY, 2050. The goals set by the 2015 Paris Accords on climate change have been achieved. In just 35 years, net greenhouse-gas emissions have been reduced from their peak in 2019 to net-zero.

People celebrate with fireworks and parties across the globe. After 200 years of living with the environmental impacts of the Industrial Revolution, including 60 years of dire warnings about the threat from excessive CO2, the trend toward global warming has stabilized. The human population has also stabilized, as demographers predicted, at around nine billion—15 percent higher than in 2020.

Yet the readings from the observatory at Mauna Loa tell scientists that the global level of atmospheric CO2 is now 460 ppm. A T-Rex would love this level. But it's 50 percent higher than the highest humans have lived with throughout our evolution and history.[1*] It's 67 percent higher than 280 ppm, the "pre-industrial" average, at which agriculture and the early civilizations of humankind were able to develop and flourish.[2]

The great coral reefs are gone, as high water temperatures and acidity have persisted. The oceans are largely devoid of their once-vast fish populations. Gone, too, are most of the old-growth forest and rainforests that once occupied large stretches of the planet's surface. Most were razed to grow food for the nine billion; some have been destroyed to provide living space for the hundreds of millions

* The source notes appear at the back of this paper, beginning on page 46.

of climate refugees caused by an average global sea level rise of about two feet (two thirds of a meter). Gone, too, are the Arctic ice pack, the indigenous peoples who inhabited it, and the polar bears, sea lions, and many other species that lived in the far North.

This, then, is the climate and population "stability" that the international community set as its goal at Paris back in 2015.

But will humanity long survive on a planet where the climate patterns that all living things have relied on for 12,000 years have been permanently changed; where the last of the large fish and wild animals are on a path to extinction; and where human activity has taken over nearly all the land needed for diverse ecosystems?

We might, but we might not. We don't know. We can't know. The path we've taken is a risky one, from which there may be no way back.

Climate Change and Cognitive Dissonance

THE SECOND SCENARIO described above—the one in which we achieve net-zero emissions, yet still suffer unpredictable and potentially disastrous long-term impacts from climate change—is rarely invoked in the popular discourse. Yet it's all too plausible.

In private conversations, I've heard many scientists and other experts acknowledge the possibility of hideous social dislocations and possible extinction of the human race even if we achieve net-zero emissions by 2050. But very few are willing to say so in public. Instead, nearly the entire climate community continues to publicly insist that meeting the Paris goals will avoid the worst effects of climate change. Whatever happens, we can say it could have been worse.

Later in this paper, I'll discuss some of the reasons for the gap between the public positions of most climate experts and the facts they'll acknowledge behind closed doors. But first, I want to address the skepticism you are likely feeling. If you are like most people concerned about the climate, you may be shocked and disturbed by the dire sketch painted of a zero-emissions future. You may be muttering to yourself, "This can't possibly be correct." You may be tempted to dismiss my message and turn away to other activities.

Confusion and denial are normal reactions to new information or views that conflict with long-held views or beliefs. If you've taken a psychology class, you may recall that psychologists call this phenomenon cognitive dissonance.[3] It's a state of psychological distress people experience when confronted by new information that contradicts what they already know, believe, or value. It's painful to hold incompatible ideas and disturbing to face alternatives to a long-held, strongly espoused belief.

People experiencing cognitive dissonance commonly do one or more of three things to relieve the pain: They attack the speaker who is delivering the message that causes the pain; they dismiss the message itself as false; or they decide to simply stick to their previous belief without even considering the evidence for the message.

I've experienced each of these three responses when I speak about the inadequacy of the Paris goals and the urgent necessity of climate restoration.

Millions of us all over the world have come to recognize and care about the seriousness of the climate change threat. That's a great thing. However, some of the things we "know" about climate change aren't quite true.

As I’ve already suggested, one of these mistaken beliefs is the idea that the Paris goal of net-zero carbon emissions is sufficient to solve the climate problem for humanity. I’ll be offering substantive information to show why this belief is wrong—dangerously so.

Of course, I’m not the only person to realize that the net-zero goal doesn’t go far enough to protect the future health and happiness of humankind. This is a realization that is gradually being shared by increasing numbers of thoughtful individuals.

However, many of those who have begun to acknowledge the inadequacy of the Paris goals have moved on to embrace a second false belief—the idea that there is no alternative path we can take that will restore a truly healthy climate in the foreseeable future. They run the risk of succumbing to a deadly form of fatalism, assuming that net-zero emissions is the best we can do and that any vision of a better future is a mere fantasy.

My message to you is that this second belief is just as flawed as the first—that there are specific, concrete steps we can take that can bring about a restoration of the kind of healthy climate humankind has flourished under for ten thousand years. What’s more, I will show that climate restoration is not only feasible, but, once started, will pay for itself.

Again, it’s very possible that your reaction to this message may be one of shock, disbelief, and even anger. You may say “Restoration is impossible!” and ignore the data I’ll offer in support of restoring the climate.

If so, I suggest that you allow yourself instead to acknowledge that you are experiencing cognitive dissonance. That may give you the space to seriously consider the possible future I'm presenting.

I invite you to contemplate this suggestion. After all, it's arguable that our most important job as members of the human race is to ensure the survival of our species. Hoping that we might survive with 50 percent higher CO2 and a population ten times higher than the stable levels from before the industrial era is too risky. Moving from hope to science, confidence, and planning is urgently required.

In this introductory white paper—and in the book-length discussion that will follow—I'll explain how we can realize the first scenario described earlier, in which climate restoration is achieved by the year 2050. I do support the protocols for reducing carbon emissions laid out in the Paris Accords. But I also contend that they are not remotely enough to secure a healthy future for our species. I argue that simply following the Paris guidelines and hoping for the best is not a responsible option. There is a better goal, and there are better paths to achieve it.

My Journey to Climate Restoration

A BRIEF ACCOUNT of how I came to understand both the seriousness of our current climate disaster and the hopeful possibility of a climate restoration program may help you begin to overcome the cognitive dissonance that my first few remarks have likely triggered.

In my career as a scientist, engineer, philanthropist, and social activist, I've long been exposed to information about the impact of a changing climate on the human environment. But for decades, I actually avoided getting involved in efforts to address the climate change dilemma.

In 1975, I was an undergraduate at MIT when I first learned about global warming. I remember sitting on a sofa in the dorm one evening reading stories about climate change in Science News and Scientific American. The message was simple: Since carbon dioxide levels in the Earth's atmosphere were rising, average temperatures across the planet were growing warmer. This was not surprising to me. Even then, it was well understood that CO_2 is what we call a greenhouse gas. Like everyone else, I'd been in a greenhouse and felt its cozy warmth even on a frosty mid-winter day.

Even then, the underlying math was reasonably clear. Scientists knew that pre-industrial levels of atmospheric CO_2 had been significantly lower than current levels. Recent studies continue to confirm this, pinning down the normal pre-industrial range at between 275 and 280 ppm. By 1958, when chemist Charles Keeling developed the first instrument capable of reliably measuring atmospheric CO_2, the average level had already reached 318 ppm.[4] By 1975—just sixteen years later—CO_2 levels had increased to 330 ppm, well beyond levels humanity had ever survived long-term. In my lifetime the average level rose almost 16 ppm in 16 years, about one ppm every year.[5]

The obvious implication of these findings was that reducing the level of new CO_2 emissions into the atmosphere—for example, by transitioning away from carbon-burning fossil fuels to renewable energy—would not be sufficient to restore a fully healthy climate. Since CO_2 lingers in the air for millennia, even if humankind could somehow switch over to clean energy immediately, we'd also have to pull a lot of CO_2 out of the atmosphere if we hoped to return to the pre-industrial levels below 300 ppm.

But as I read those articles back in 1975, I wasn't particularly alarmed. It seemed obvious to me that someone would take care of the problem of atmospheric CO_2. After all, we humans had recently completed six successful missions to the moon, each of which had required that we solve technical problems far more complex and challenging than removing CO2 from the atmosphere. In fact, NASA improved CO2 removal technology for the mission, starting from what submarines had used for decades.[6] What's more, the newly-created Environmental Protection Agency (EPA) was then hiring chemical engineers and other experts to work on programs to remove toxic chemicals from the ground. I assumed that similar programs would be launched to get the excess CO2 out of the air in the last decades of the century, thus restoring our climate and creating a new set of scientist-heroes for the world to admire and honor.

Of course, this would take time. But the articles I read showed that the Earth's atmosphere was big enough to handle what we were putting into it, at least in the short term. It had been clear for ten years that the year 2000 was a likely tipping point when the CO2 problem would start threatening human survival.

That was 25 years in the future. For a teenager, the 25 years to the end of the century was a lifetime away. I remembered that President John F. Kennedy had made his famous speech challenging America to land a man on the moon in 1961—just eight years before Neil Armstrong took his first steps on the lunar surface. It seemed reasonable that a society that could land people on the moon within eight years could achieve the needed CO2 removal in much less than 25 years.

One of the fundamental things most of us learn as infants is that adults will generally do what's needed to take care of us, even if we don't understand what's happening. That deep assumption becomes wired into our rapidly developing brains, and it remains a powerful subconscious influence on our worldview at least until something happens to shatter it.

So in 1975, as a 19-year-old, I "knew" without thinking about it that somebody smarter than me, the adult in the room, would take care of the CO2 problem.

So I stayed out of the way. I continued to pursue my major in astrophysics, enjoying the challenges of studying the chemistry and physics of a galaxy called M87, 50 million light-years away. And I put the problems of climate change here on planet Earth out of my mind.

To Leave Our Children a World We're Proud Of

AFTER GRADUATION, I worked in astrophysics at NASA, then on improving semiconductor manufacturing at an artificial intelligence (AI) lab. Later I started my business, Automated Visual Inspection, based on some advances I made in AI and machine vision.

At the same time, I became deeply involved in volunteer work in poverty reduction with a citizen advocacy organization called RESULTS.[7]

RESULTS was taking on seemingly impossible goals and meeting them, one after another—although at the time I was too naive to appreciate how impossible they really were. For instance, UNICEF had promised in the seventies to vaccinate all the world's children by 1990. By 1985, more regions were getting vaccinated, but the global vaccination rate was still below half, with no way in sight to achieve UNICEF's goal. RESULTS got involved. We convinced Congress to provide the funding that made it possible to raise the child immunization rate to 85 percent—short of the 100 percent promised, but enough to profoundly change the world. That rate held steady for 30 years, until a slight dip during the COVID pandemic.

Another cause led by RESULTS was microcredit, the ingenious financial tool developed by Nobel Prize winner Muhammad Yunus, which empowers people to lift themselves out of poverty through small loans designed to help them start or expand businesses. RESULTS helped launch the Microcredit Summit Organization that set the goal of providing access to microcredit for half of the world's poorest people—five hundred million people—and to do it within ten years. Technically, we fell short; it took 11 years to reach the five hundred million mark. Again, RESULTS helped to change the world.

Yet another example: In the 2000s, RESULTS helped organize campaigns that convinced international policymakers to fund treatment for tens of millions of people living with HIV/AIDS. This effort played a major role in turning around an epidemic that had taken millions of lives, terrified countless more, and had seemed insurmountable for nearly two decades.

Those campaigns taught me the power of setting a specific, ambitious target for any important project. As I tell the people I work with, If your goal is so vague that you can't fail—if you promise simply to "try"—then you can't succeed. If you wish to accomplish something important, then you need to risk failure.

Today I have a sticky note on my computer monitor that says, "Whatever you make doable ends up being done." Making it doable means having a specific, measurable goal and specific milestones that take you there.

A meaningful mission statement that serves as a North Star is also an invaluable tool for those who want to make a real difference. While working with RESULTS on the HIV/AIDS challenge, I created my personal mission statement: "To leave our children a world we're proud of." For the last 20 years, I've selected the projects I engage in based on whether or not they are critical to that mission.

What Is Our Climate Goal?

AROUND 2010, I noticed that our progress in reducing hunger and poverty was faltering after forty years of remarkable gains. I realized that two factors were driving this trend: population and global warming.

The famous 1972 report Limits to Growth, commissioned by a quasi-governmental organization called the Club of Rome, had pointed out that, on the then-current path of population growth, economic expansion, and increasing pollution, sometime around the year 2000, things would start collapsing—big things, like ecosystems, economies, and societies.[8] Like many of my contemporaries, I found the study highly convincing, even obvious. It seemed to me self-evident that uncontrolled exploitation of natural resources driven by unlimited population growth could only lead to environmental calamity. By 2010, the worsening trends I perceived largely reflected the kind of resource-shortage disaster that Limits to Growth had predicted.

But climate change, which had not figured in the Club of Rome's calculations, was also playing a part. It was making growing seasons more erratic and food harder to produce. It was exacerbating disasters like droughts, floods, and hurricanes and making portions of the planet unlivable. Shorelines were changing; coral reefs were dying.

Meanwhile, the human population had doubled again between 1975 and 2010, exacerbating conflicts over water and other resources. In fact, the world's population, which had remained largely stable for eons prior to industrialization, had soared 10-fold—from about 700 million in 1750 to more than 7 billion.[9] Together, climate change and the vast scale of human impact were threatening the collapse of ecosystems and climate systems worldwide.

I realized that, on the world's current course, my personal goal was likely to go unmet—along with the goals of billions of other people from every walk of life. One outgrowth of that realization was my decision to get involved in addressing the issue of climate change. It appeared that no collection of "adults in the room," in government or anywhere else, had taken it upon themselves to solve it.

I was not the only RESULTS volunteer with that insight. A couple of years earlier, Marshall Saunders, a real estate developer in San Diego and a good friend and protégé of mine at RESULTS, had established the Citizens Climate Lobby (CCL).[10] His intention was to produce the same kind of world-changing impacts in climate that RESULTS had helped achieve in poverty and hunger. I was delighted that, finally, after 45 years, someone was really taking on climate change in a meaningful way. I became a supporter of CCL.

But after three years, with the number of CCL members having grown from two people to two hundred, I got the sense that no real impact was being made. So I got more involved. I asked my friend Mark Reynolds, the executive director of CCL, "What is the goal of CCL and the climate movement? What are you using as a specific measurable target, and what's your deadline for achieving it?"

Mark thought about this query, and rather than make up an answer, he said, "Good question, Peter! That's your job now. Talk with Dr. James Hansen, who's on our board. Figure out the answer and report it to us."

Dr. Hansen is a physicist and a former director of NASA's Goddard Institute. Shortly thereafter, he and I had lunch, and

I posed the same question I'd asked Mark. I was floored when he said simply, "I don't know."

Hansen went on to explain that, although the essential physics of climate change was clear, despite hard efforts by CCL and other organizations, there appeared to be no chance that Congress or the president would take effective action to address the problem. The best future he could imagine was that we might get CO2 back to 350 ppm by the end of the century. (By 2010, the average level was approaching 390.)

I was disturbed by this answer. "Dr. Hansen, 350 ppm would be a likely death sentence for humanity, wouldn't it?" I asked.

He confirmed that it would. "But if we actually got there," he said, "we could see where to go next."

My instincts, honed through my business career and my years as a volunteer activist, kicked in. I don't get involved in companies or projects that aren't designed to succeed. For a time, I abandoned climate again, putting my focus on expanding RESULTS' health and poverty work into Africa.

But the next spring, my daughter came home from college, brimming with excitement over the things she was accomplishing, proud of achievements at school, and overflowing with plans for the future. Was I willing to fail her? How could I leave her, her brother, and everyone else's children a world in which humanity might not survive rather than one we can be proud of?

That was the moment when I finally committed to the concept of climate restoration. I didn't relish the idea of having to convince experts like Dr. Hansen to join me. But I realized that someone had to take on this challenge. I went on to create the Foundation for Climate Restoration and to launch the large-scale education and lobbying effort of which the paper you are reading represents a part.

Today's Inconvenient Truth

When we look at the universe of climate activists—including concerned scientists, government officials, and engaged citizens—their overwhelming goal has been, and continues to be, the reduction of carbon dioxide emissions. Today, specifically, the almost universal goal is to reduce emissions to net zero by 2050. Net zero means that whatever CO2 human activity continues to emit, we'll compensate for it by withdrawing that amount of CO2 somewhere else.[11]

There's a widespread impression that the net-zero emission goal is an explicit commitment found in the Paris Climate Accords. That's not quite correct. The actual objective stated in the agreement (Article 2, paragraph 1a) is "Holding the increase in the global average temperature to well below 2^{o}C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5^{o}C above pre-industrial levels." Elsewhere in the agreement (Article 4, paragraph 1), it is stated that the parties "aim . . . to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century," as a way of achieving the temperature goal. This is another way of saying "net-zero emissions by 2050."

Thus, the actual Paris goal is to limit global warming; the means of pursuing that goal include net-zero emissions. It's a subtle but important distinction. Many countries, provinces, and cities have adopted net zero as a goal, but no such goal is explicitly mandated in the Paris Accords.

At net zero, which is also sometimes called "the draw-down point," CO2 levels will be stable.[12] The climate will stop warming, the oceans will stop getting more acidic, and storms will (probably) stop getting worse. There's also a chance that, according to the Paris goals, the increase in average global temperature levels can be kept below 2 degrees Celsius—perhaps even below 1.5 degrees.[13]

There is an understandable historic reason for the net zero goal. Fifty years ago, when global warming started getting attention, achieving net zero would have kept our planet livable. Unfortunately, we have held to that goal almost like a religious dogma, even as the world has changed radically. In that time, the world's population has doubled yet again.[14] In the same period, CO2 has gone from arguably safe levels to levels that are warming the planets rapidly and thus pose an unpredictable and unprecedented risk to human survival; and our ecosystems are collapsing before our eyes. Evidence from the daily headlines even suggests that our political and social systems may be collapsing in synchrony under the environmental pressures that climate change is producing.

It's time to acknowledge the inconvenient truth that climate scientists and activists have failed to confront: Meeting the goal of net zero by 2050 in no way guarantees the survival of human society as we know it or even that of homo sapiens as a species. This reality is acknowledged by the scientific community, not expressly but by its silence. No scientist I know will publicly affirm that achieving the goals set by the Paris Accord will provide humanity with a flourishing future or even with a clear path to survival.

Thus, we can reshape the world economy to achieve net zero—we can make a complete transition to renewable energy, with the electric grid largely running off solar, wind, and batteries; we can make all our vehicles run on electricity; we can completely eliminate fossil fuels and stop destroying forests tomorrow—but the ecosystems we depend on will still continue to collapse.

That's because, even without further carbon emissions, there will still be a trillion tons—that is, 1,000 billion tons—of excess CO2 lingering in the atmosphere for a millennium or longer.[15] (As I'll explain a little later, some other greenhouse gases, such as methane, play a lesser but meaningful contributory role in the crisis we are now facing.) And since nature and the laws of physics don't care whether a greenhouse gas is newly emitted or a legacy of past activities, temperatures will continue to climb, the oceans will continue to warm, the poles will continue to melt, and sea levels will continue to rise, even once the net zero goal is reached.

The Paris Accords and other climate agreements were designed to limit the "worst effects" of climate change, or, as some have written, to "avoid a climate disaster."[16] William Nordhaus, the Nobel Prize-winning economist who helped define the goal of limiting global warming to 2 degrees Celsius in 1977, selected this target because he considered it the level most likely to maximize economic growth (as measured by global GDP) even in the face of agricultural decline due to rising temperatures. Nordhaus was not applying the perspective of a physical scientist or an environmental expert, nor did he address the broader goal of human thriving. As befits an economist, his focus was strictly on GDP growth.

It's also important to note that Nordhaus did not have access to today's data about the impact of CO2 emissions. As far as he knew, the long-term warming we faced would be a quarter of what history now tells us.[17] We've collectively put our faith and energy into achieving their 1980-era target of net zero, failing to face the reality that net zero is now woefully inadequate.

Why do I say that net zero is a recipe for human disaster? Climate history tells the story.

Humans and the ecosystems we rely on require a reasonably stable climate similar to the one in which we evolved and have flourished. This stability is what enabled us to develop agriculture and civilizations. Until 100 years ago, we always lived in a world where atmospheric CO2 levels remained below 300 ppm.[18] Therefore we know that 300 ppm and lower is proven safe for humanity. Nothing higher passes that test.

Today, CO2 levels are around 420 ppm. They are rising about 2.5 ppm each year—twice as fast as they were in 1975.[19] Not surprisingly, this acceleration correlates with the doubling of our population since then. Meeting the Paris goal of net zero emissions by 2050 will see CO2 level off at about 460 parts per million.* That's more than 50 percent higher than human beings ever survived.[20]

This is not to say that planet Earth has never experienced higher CO2 levels. The last time CO2 levels reached anything close to the Paris goal of 460 ppm was about 3 million years ago, during the Pliocene epoch.[21] This was long before modern humans evolved—the oldest known evidence of homo sapiens is a number of fossil skeletons from Africa that date back about 200,000 years.[22] During the Pliocene, temperatures much warmer than today's fostered a remarkably uniform planetary fauna featuring large mammals like mastodons and giant camels from Spain to China and even as far north as the Arctic. Most significantly, global sea levels were likely 30 to 60 feet higher than today's, or even more.[23] Unless we reduce the

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* Here's how I calculate this: The average CO2 level is currently about 420 and rising 2.5 ppm a year. While we are heading to net zero, the level will still be rising, but more slowly. Let's say emissions reach 0 net ppm a year by 2050. That means that ppm rise will fall to zero as well. Thus, the rise will average out half-way between those levels, 1.25 ppm a year. 1.25 ppm x 30 years = 37.5 ppm. Today's 420 + 37.5 added over the 30 years takes us 457.5 ppm by 2050.

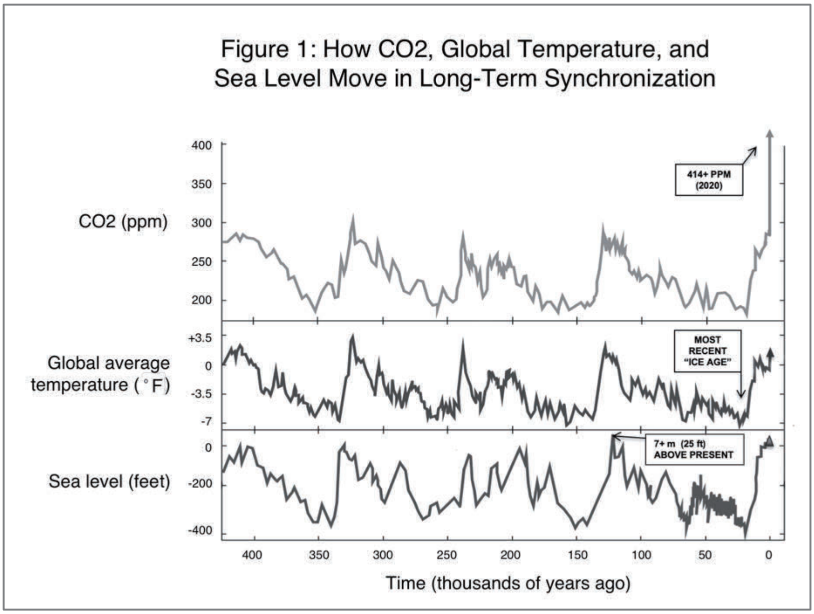
CO_2 level, we'll eventually experience that same sea-level rise again, submerging hundreds of coastal cities.

Could eight billion humans survive conditions so radically different from those that enabled the development of agriculture and the rise of modern civilization? I have not found a single scientist willing to answer that question with a forthright Yes.

Let's consider another CO_2 target widely used by climate activists. In 2008, Dr. James Hansen wrote a famous paper suggesting that 350 ppm is the highest CO_2 level likely to support the ecosystems we depend on long term.[24] Many activists and scientists have seized on 350 ppm as a benchmark for safe carbon levels. It appears to be the tipping point above which the polar ice caps melt and Earth enters what some call the "hothouse Earth" state.[25] The number is even the name of an active organization working for the energy transition.[26]

Unfortunately, we blew past that target in the late 1980s.[27] So even 350 ppm would require a lot of CO_2 removal. Achieving net zero emissions won't get us there.

But is 350 ppm the right target to aim for? Do we really want to focus our efforts on achieving the highest level that might enable humankind to survive? Wouldn't it be wiser to shoot for the level within which humans have historically survived—namely, below 300 ppm? This is a topic of debate in the scientific community. I've encountered a number of scientists who publicly advocate the mainstream 350 goal, while privately acknowledging that the below-300 goal would be safer for humanity.



My friend John Englander compiled three parallel graphs from well-known data published by Dr. Jim Hansen (Figure 1).[28] The image covers the period of the last four ice ages (out of the ten ice ages Earth has experienced in the last million years). The top graph shows CO2 levels; the middle graph shows average temperatures. The bottom graph indicates ocean levels. Taken together, the three show that, as CO2 levels rise, the planet heats up, glaciers melt, and the melt water raises the sea level. (Note that there is a lag time between rise in CO2 concentrations and the rise in sea level and average temperatures.) This simple pattern repeats, one ice age after another.

As a scientist, I like graphs, because they present numerical data and the relationships among them in a form that is intuitively clear and easy to grasp. Remember that the

Paris Accords in effect call for stopping CO2 rise at 460 ppm in 2050, and that that level is 50 percent higher than any previous level shown in Figure 1. Looking at these graphs, it seems clear to me that under the Paris Accords we should expect a significant increase in global temperatures and sea levels. The last 400,000 years of history makes the future look far more dire than the scientific language usually used by climate experts—for example, in the reports issued by the IPCC. (The IPCC is the UN-sanctioned Intergovernmental Panel on Climate Change, considered the final authority on climate. Their reports present the consensus of thousands of climate scientists.)

Perhaps this is why no scientist I know will defend the claim that humankind is likely to survive if we limit our climate efforts to meeting the Paris goals. It's also why I sometimes refer to the Paris Accords as "the Paris Suicide Pact." The people who created and signed that agreement are well-intentioned, and the goal of reducing net carbon emissions is implicitly for the survival and wellbeing of humanity. However, an implicit goal is not clear enough. It will not inspire the new actions needed to achieve the goal. If we really want to ensure the survival and flourishing of our species, we must explicitly define that goal and commit ourselves to reaching it.

Beyond Net Zero: Embracing Climate Restoration

I HOPE I'VE OPENED your mind to the possibility that achieving the net zero goal set by the Paris Accords is not enough to guarantee a healthy, sustainable future for humankind. We need to go further, by reducing the level of atmospheric CO_2 to the below-300 ppm level in which our species originally evolved and has historically flourished. This is the goal of climate restoration.

Which leads to the next big question: Is climate restoration actually possible? Or must we resign ourselves to restricting our climate efforts to pursuing the net zero goals set by the Paris Accords, and then hoping for the best?

To answer this question, let me start with a crucial point. As a technological, social, and political project, climate restoration is not in opposition to the Paris Accords—rather, it begins with the current journey to net zero emissions in 2050 that the Paris Accords launched. In other words, it supplements and completes the essential work that Paris began.

This is not the place for a detailed analysis of current progress toward the net zero goal. However, in my view, the IPCC is getting its job done. The transition to clean energy is far from complete, but all the major technological and economic breakthroughs required to make it happen have already fallen into place. It seems clear that humankind will largely abandon the use of fossil fuels by 2050, as Paris promised.

That reality sets the stage for the rest of our climate project—climate restoration. And as with most big projects, the focus in the final stage will need to be very different from the focus in the earlier stages up to now. Clean energy sources like those spotlighted by the IPCC are not directly involved in climate restoration. Instead, we'll need to turn our attention to a series of new technological solutions that are not even mentioned by the IPCC.

The good news is that these new technological tools are well advanced in their development. They are not based merely on guesswork or theory; they have been tested, developed, and even deployed to varying extents. The climate restoration chess board is already almost set for success.

The promise of climate restoration is reflected in the growing interest it is beginning to attract from scientists, activists, business people, and policy makers. Many have attended a series of climate restoration forums organized by the Foundation for Climate Restoration, along with an original climate restoration conference in Rome in 2018. Pope Francis validated climate restoration in 2020, saying that "Climate restoration is of utmost importance, since we are in the midst of a climate emergency."[29]

Nonetheless, although we are surely near the point where climate restoration will achieve the breakthrough into public consciousness that it deserves, we are not yet there. Many people are still grappling with the cognitive dissonance caused by the confusing messages sent by the well-intentioned policy makers who came up with the Paris Accords. Hundreds of books, thousands of scientific articles, and countless film, television, and audio programs have informed the public about the importance of the energy transition and the net zero goal. By comparison, the attention so far dedicated to climate restoration has been a mere trickle.

I hope the message I'm delivering here will help to change all that.

Climate Restoration: Goal and Timetable

THE GOAL OF CLIMATE RESTORATION is to restore the safe, healthy levels of greenhouse gases last seen on Earth over a century ago and do it by 2050, while we still can—while ecosystems, political, economic, and social systems are still relatively strong. Going beyond climate actions that focus on

Table: Comparing the Goals of the Paris Accords and Climate Restoration		
	Paris Goals	**Climate Restoration**
First proposed	1977 by Nobel Prize-winning economist William Nordhaus	2015 by scientist, engineer, and entrepreneur Peter Fiekowsky
Defined goals	Holding the increase in global average temperature to below 2 degrees Celsius	Restoring atmospheric CO2 level below 300 ppm by 2050
Stated purposes	To strengthen the global response to climate change and to avert its worst effects	To enable the survival and flourishing of humans by restoring an atmospheric level of CO2 that humans have survived long term
Methods	Reducing CO2 emissions with target of net zero by 2050; also removing some CO2 from the atmosphere	Removing one trillion tons of excess CO2 from the atmosphere
Metrics	Average global temperature; reference variously defined	CO2 ppm as measured at Mauna Loa
Projected outcome	Atmospheric CO2 level peaks at 460 ppm, 50 percent higher than the pre-industrial average	Atmospheric CO2 level and average global temperature return to pre-industrial levels

mitigating disaster—like those recommended by the Paris Accords—the goal of climate restoration is to enable my children and yours, and generations beyond, to survive and flourish. (See the table above, which summarizes the differences between the goal set by the Paris Accords and the goal set by climate restoration.)

In technical terms, restoring the climate means reducing atmospheric carbon dioxide from today's 420 ppm to below 300 ppm by 2050. This will require removing roughly a trillion tons of carbon dioxide that we've already pumped into the air and that would otherwise remain in the atmosphere far beyond our lifetimes, as well as removing any continuing emissions while we head to zero emissions.

To meet this goal, we expect to use the decade of the 2020s to scale up carbon removal technologies, then the following 20 years (2030 to 2050) operating these technologies at full tilt. Restoration will require us to remove at least 50 gigatons (Gt) of CO_2 from the atmosphere each year. (A gigaton equals one billion tons.)

At this rate, the trillion tons (50 Gt per year times 20 years) of legacy CO_2, plus additions made between now and then, will be gone—done, finished, completed—by 2050.

The task sounds gargantuan. And we need to carry it out at the same time we complete the work involved in the ongoing energy transition from fossil fuels to renewables. Yet in this book I will show you that both the technological capabilities and the financing mechanisms to carry out these tasks already exist. They've mostly flown under the radar due to our single-minded focus on emissions reduction This focus has left us blind to restoration options.

The technologies to be used in climate restoration are varied, but they have one thing in common: They all represent adaptations of natural processes that have taken place on planet Earth in current and previous geological eras.

Think back to Figure 1. You saw there that atmospheric CO_2 levels have risen and fallen significantly and repeatedly over the last 400,000 years, playing a major role in precipitating the last four ice ages. During that time, while humans were evolving, those CO_2 levels never previously rose as high as they are now. But it remains true that wide variations, from 300 ppm down to about 180 ppm, have occurred naturally over time. This means that nature herself has removed a trillion tons of CO_2 from the atmosphere, and has done so repeatedly. The methods that look viable today are the ones that nature evolved. In retrospect, that is not surprising--this is not the first time nature has faced a climate crisis and resolved it.

However, nature was not in a hurry to remove geologically relevant amounts of CO2. Using modern technological tools, we can do the same on an accelerated timetable. For our survival, we now need to do so roughly a thousand times faster—in effect, restoring CO2 levels intentionally in roughly the same time frame that we raised them accidentally.

Note, by the way, that the Paris Accords do acknowledge the need to remove existing CO2 in the atmosphere. Although the accords emphasize reducing future emissions, they also endorse "removals by sinks of greenhouse gases" (Article 4, paragraph 2), and they refer to another international agreement—the 1992 United Nations Framework Convention on Climate Change—for a definition of these "sinks." That convention defines "sinks and reservoirs of all greenhouse gases" as "including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems."[30] Thus, the basic approach to climate restoration—removing excess CO2 from the atmosphere—is sanctioned by the Paris Accords, although few people realize this.

Making the Difference: Three Criteria for Climate-Restoration Solutions

SCIENTISTS AND ENGINEERS have developed and demonstrated four major technologies for reducing greenhouse gas levels that reproduce large-scale natural processes. Not only that: The Big Four, as I call them, require little if any government funding. They can be financed through large, existing markets. For these reasons, they hold enormous promise as vehicles for achieving climate restoration.

My book-length discussion of climate restoration will delve in much more detail into each of the Big Four solutions. Please note that these are not the only available methods for removing carbon from the atmosphere. I focus on the Big Four because they meet three crucial criteria for real climate restoration solutions: *They are permanent, scalable, and financeable. In* fact they are the only ones I've seen so far to meet those criteria.

Permanent: This means that the CO2 removed by the technology stays securely out of circulation for at least a century. For example, turning CO2 into limestone or other rock is permanent, as nature has stored 99 percent of earth's carbon there.[31] Similarly, ocean photosynthesis turns CO2 into biocarbon that commonly remains suspended deep in the ocean for thousands of years.

By contrast, most land-based carbon is short-lived. Most biocarbon on land is exposed to oxygen and rots in a matter of decades, failing the permanence test; wildfires can turn whole forests back into CO2 in a flash. Good forestry and agriculture processes support soil-based carbon such as trees, roots, and biochar, all of which are valuable indicators of a healthy ecosystem, but they don't produce permanent carbon sequestration.

There are a number of other carbon-capture pathways that also fail the permanence test. Direct air capture (DAC) technology is popular in the media and in Congress, garnering billions of dollars of commercial and government funding. DAC concentrates pure CO2 for industrial purposes, and sometimes for pumping underground. The permanence of the CO2 it purifies depends on how it's used. Some is used for fizzy drinks and in greenhouses, where the CO2 ends up back in the atmosphere in short order. Most industrial purposes, such as creating carbon-neutral fuel or plastics are wonderful advances, but are not permanent. Synthetic fuel, for example, ends up being burned in engines. DAC advocates hope that, in the future, financing will be available to allow pumping the CO2 underground permanently, but such a multi-trillion-dollar mechanism has not yet been seriously proposed,

Scalable: This means that the climate restoration technology could be scaled up within a decade to remove and store at least 25 Gt of CO2 per year. As I'll explain, making limestone from CO2 for use in building materials is eminently scalable. So is fostering photosynthesis in the ocean.

Methods that may seem attractive but are not scalable include approaches that compete for significant land acreage needed for food or forest production, such as afforestation or bioenergy production using carbon capture and storage (BECCS).[32] Although not scalable for climate restoration, these methods may be valuable for environmental and other reasons.

Financeable: This means that funding for the technology is already available or is ready to be mobilized. A climate restoration method is particularly financeable when it produces something that can satisfy a large existing market. Thus, the Big Four methods that generate products like construction materials or seafood meet the criterion of financeability.[33]

It may seem counterintuitive to look for climate restoration solutions for the benefit of future generations in the workings of the free market, which is organized primarily for quarterly and annual profits. But a growing number of business leaders and investors are motivated by a passion to restore the climate for their children while also providing products and services to large groups of customers. As they step forward, they will fund more businesses that fulfill our common desire for a flourishing humanity.

Financially, it would be quite easy for world governments to complete climate restoration by 2050, acting on the will of the people rather than the commitments of corporate leaders. I calculate that we could finance the restoration of our climate to pre-industrial levels by mid-century for as little as $2 billion per year. ($1 billion per year would finance methane removal; the other billion would be invested in synthetic limestone and ocean pasture restoration.) In global terms, this is a trivial amount, approximately the annual budget of Fort Worth, Texas, or the equivalent of two days of revenue for Apple.

The problem with government financing of climate restoration is not the economic cost but the political will, which is starting at roughly zero today. This is why I think it's more practical to rely on solutions supported by the free market. Could a handful of billionaires take it upon themselves to restore the climate? How dangerous could it be to have wealthy families tackling the problem without permission or approval from international bodies yet to be authorized? These are concerns that some environmentalists have raised and that must be addressed. It will be important for the scientific community to engage in supporting climate restoration to help allay such fears.

Climate Restoration versus Climate Profits

Carbon dioxide removal (CDR) is now becoming big business. Can profitable CDR companies play a meaningful role in restoring the climate? Only if they fulfill the three criteria.

Knowing my interest in climate restoration, people send me their ideas for carbon removal and things to make out of captured carbon every day. I've received scores of emails from entrepreneurs and companies that have invented a process for using CO2 to make carbon fiber for use in manufacturing cars or airplanes, for instance. Many others have written to me about their new technique for turning CO2 into bioplastic, clothing, and all manner of other consumer goods. Still others collect CO2 for piping into greenhouses. A number of companies now extract carbon dioxide from the exhaust of power plants and factories, where the gas is concentrated for industrial uses. Others are building large fan-like machines that can draw it directly from the air.

All of these ideas from the world of "carbon tech" are intriguing, and many could be profitable. After all, the raw material, CO2, is usually free once you have built the technology to capture it and pay for the energy required. The products turned out at the other end can be of high value, such as graphene (used in making semiconductors and other electronic components), carbon nanotubes (also used in electronics as well as in fibers and composite materials)—even diamonds.

I appreciate the inventiveness of these efforts, and I wish the entrepreneurs success. But let's be clear: The markets for these products are too small to make a measurable impact on the climate. When someone claims they will, ask them for the numbers. We need to remove seven tons of CO2 per year for every man, woman, and child—the equivalent of 14 pounds per day. Besides rock for concrete and water for farming, do you know of any products that we use in such quantities?

We should understand that profitability and restoring the climate are separate goals which overlap only in rare cases. The climate will be restored when we remove a trillion tons of

CO_2. Removing a small fraction of that isn't bad, but will make no measurable difference to climate restoration. If your ship is sinking, pumping out one or two percent of the water inside is not going to keep it afloat and may well distract you from preparing and firing up the large pumps.

What makes the methods I call the Big Four so promising is that they meet all three of the criteria I've named—they are permanent, scalable, and financeable. And they're all progressing now.

The Big Four Climate Restoration Methods

EACH OF THE BIG FOUR methods deserves a thorough explanation, and it will receive one in the book-length version of this paper. But for now, let's take a quick look at how the four work and how they all represent clever human adaptations of processes long ago "invented" and honed by Mother Nature—an approach known as biomimicry.

Synthetic limestone manufacture. Nature has permanently stored 99 percent of Earth's carbon in the form of limestone.[34] The calcium carbonate made by shellfish and corals eventually sinks to the seafloor, where it becomes limestone. This has been happening for over a billion years. Recently engineers have learned to mimic the chemistry that oysters, mussels, and corals perfected. Companies in the United Kingdom, the United States, and Australia have developed ways to use captured CO_2 to produce synthetic limestone—high-quality rock that can substitute for the aggregate from quarries that is now used to make roadbeds and concrete.[35] The first synthetic limestone plants are beginning operations in 2021-2022. The manufacture and sale of carbon-negative limestone could be scaled up within a decade to pull up to 50 Gt of CO_2 per year from the atmosphere. The global market would therefore finance CO_2 removal simply through the purchase of aggregate rock.

Great demand for rock exists, and synthetic limestone could satisfy it. We collectively purchase seven tons of rock for every person on our planet, every year. It's a trillion-dollar industry.[36] Harnessing this business to climate restoration will be a huge win / win for business and for the planet.

Seaweed permaculture. Kelp and other seaweeds, called macro-algae, can grow as much as two or three feet a day, swiftly building their tissues from sunlight and CO_2.[37] Kelp forests once lined many of the earth's coastlines, pulling down more CO_2, acre for acre, than the rainforests of the Amazon, while also providing shelter for fish and other sea creatures. When the seaweed dies in the course of its natural life cycle, it tends to sink, taking the carbon it contains to the ocean depths, sequestering it far from the atmosphere for hundreds or thousands of years.

Unfortunately, as the ocean waters warm and currents change, natural kelp forests are struggling now, as are the fisheries they sustain. However, marine specialists have figured out how to enable these important ecosystems to rebound at the coastlines and also grow in the open ocean.

Visionaries are constructing marine permaculture arrays—light, latticed structures made of tubes—to which seaweed can attach in mid-ocean.[38] The seaweed that grows in these "ocean forests" provides food and shelter for fish, shellfish, and other marine animals. It also draws down considerable CO_2. I consider this tech financeable because about half the seaweed production would be harvested for commercial purposes. Kelp is a common ingredient in a host of consumer products, from toothpaste and shampoo to puddings and cakes. The other half would be sunk, along with the CO_2 it captured. Estimates suggest that, at scale, seaweed permaculture could capture enough CO_2 to reduce the atmospheric excess by close to 20 percent over 20 years.[39]

Ocean pasture restoration (OPR). Also called ocean iron fertilization or ocean eddy fertilization, OPR mimics in a controlled fashion the process that cooled the Earth 10 times in the last million years during the lead-up to ice ages.

This powerful approach utilizes nature's fastest large-scale carbon removal pathway and can be scaled up rapidly, with important benefits to restoring ocean and fishery health while "farming" eddies that make up only about two percent of the ocean's area. It became controversial for a variety of reasons. The primary one is the simple fact that it removes CO_2 from the atmosphere without reducing emissions. Some people claim, understandably, that this CO_2 level restoration could constitute an unethical threat to the UN-sanctioned zero-emission climate goals. In my full-length study of climate restoration, I'll discuss the controversy in more detail, and explain why some of the world's most distinguished climate scientists share my belief in the potential value of OPR. In this paper, I'll offer just a basic explanation of how it works.

Over the last million years, as shown in Figure 1, an ice age started roughly every hundred thousand years. Nature then pulled massive amounts of CO_2 out of the atmosphere via photosynthesis by phytoplankton (microalgae) in the ocean.[40] As the phytoplankton and the animals it feeds die, their remains sink to the low-oxygen deep ocean or the ocean floor. As our planet entered an ice age, the CO_2 level would fall by nearly half, to about 180 ppm. Eventually, ocean currents would change, oxidize the suspended biocarbon, releasing massive amounts of CO_2, and atmospheric CO_2 and temperatures would rise once again. Roughly a trillion tons of CO2 would get stored in the lead-up to and during an ice age, then released several thousand years later.

While plans on land require rain blown from the ocean to grow, ocean plants require nutrients washed and blown from the land to grow. In much of the ocean, the limiting nutrient is iron, and, for several reasons, the amount of iron in the oceans has been decreasing for the last 150 years.

In recent decades, scientists have noted a global decrease in both iron and phytoplankton (and the marine food chain of which it forms the base). We see this in large parts of the ocean, including areas that contain the other nutrients phytoplankton need.[41] In the 1980s, ingenious researchers proposed a way to use biomimicry to solve this problem. When trace amounts of iron-ore dust are added to iron-poor ocean areas, photosynthesis increases rapidly. Just as on land, the phytoplankton "vegetation" produced then becomes food for the animal kingdom, specifically fish. Well-fed fish produce both well-fed coastal populations and prosperous fishing industries— both of which appear inclined to fund this ocean restoration approach. The plankton and fish also feed whales, which also contributes powerfully to restoring ocean health.

Most germane for the climate, phytoplankton pulls significant amounts of CO2 from the atmosphere—probably enough to complete climate restoration by 2050.

So much sunshine falls on the world's oceans that, in principle, phytoplankton could bloom throughout the ocean and clear out all the excess CO2 in the atmosphere in a year. That's neither desired nor likely to happen. But if just one or two percent of the ocean bloomed with microalgae thanks to ocean pasture restoration, the trillion tons of excess carbon could be drawn from the skies within 20 to 30 years.

Acceleration of natural methane oxidation. With the ability to remove CO_2 by increasing two kinds of ocean photosynthesis as well as by manufacturing rock, we're all set to restore the climate, right? Not quite. There's one more challenge to solve, which has to do with the melting Arctic.

Methane is the main component in the natural gas you may use for cooking or heating. It is produced when vegetation decays in wetlands, or in the ancient vegetation that eventually turned into coal and oil. Methane has a short half-life in the atmosphere—about eight years, compared to a millennium for CO_2. But a ton of methane causes about 120 times more warming than a ton of CO_2. The latest IPCC report estimates that atmospheric methane produces 30 percent of today's warming.[42]

Methane escapes from many places, including wetlands, rice paddies, livestock, waste dumps, and leaks from countless industrial sites around the globe—especially oil-fields, refineries and gas pipelines. Because of the variety and widespread nature of methane sources, it's difficult to reduce emissions to a significant degree.

Here is where the connection to the melting Arctic comes in. I'm sure you've heard of the demise of sea ice and the opening of chasms in formerly solid permafrost. The reports tend to ignore something even more frightening: the possibility of a rapid spike in temperatures from a methane "burst" released by permafrost melting beneath the Arctic Ocean. Earth has seen it happen before. Some 56 million years ago, the Paleocene-Eocene Thermal Maximum (PETM), as scientists call it, wiped out about 30 percent of all species then alive.[43]

Climatic conditions during the PETM were close to our own, though CO_2 is actually rising 10 times faster today. Some scientists fear that a large methane burst could send temperatures so high so rapidly that it has the potential to cause another extinction event. The parallels to today's swiftly rising CO_2 levels and the ongoing loss of 95 percent of Arctic ice are striking.[44]

What keeps me up at night is the fact that, in 2019, in the shallow East Siberian Sea, scientists observed massive ("bucket-size") methane bubbles streaming up from the ocean floor to its surface.[45] That area of ocean (the East Siberian Arctic Shelf) contains an estimated 1400 Gt of methane under the seabed; experts think that 50 Gt (eight percent of the total) could be released in a blast.[46] If that happened it could double or quadruple today's level of global warming within a year.

So far, many scientists say only a small burst is building. But what if history does repeat itself, and tens of gigatons of methane—the warming equivalents of trillions of tons of CO_2—are released? How would we ensure our children's survival?

Fortunately, there is a likely solution. Nature continually oxidizes methane in the atmosphere, breaking this super-potent greenhouse gas down into water and CO_2.[47] (Yes, CO_2—but remember that CO_2 has less than one percent of the heating power of the same weight of methane.) Over the last couple of years, I've assembled a team of leading chemists and other experts who previously analyzed how methane oxidizes over the ocean. Through geomimicry, they have replicated the process in the lab. Using this method, we are working on a way to double the background rate of methane oxidation.

What we call enhanced atmospheric methane oxidation (EAMO) adds a fine mist of iron chloride molecules to those that form naturally in salty sea air. The air then acts as a sponge, soaking up methane and oxidizing it. A burst, were it to happen, would be oxidized rapidly, reducing both its maximum level and duration. I think of EAMO as an "insurance policy" against ecosystem damage from a methane spike. Current estimates are that this insurance will cost about $1 billion per year, primarily for the iron chloride. Testing of this chemistry is progressing as of this writing.

There's a considerable side-benefit to providing this insurance policy against a possible methane burst. According to our group's calculations, even if the burst does not occur, doubling today's methane oxidation rate would pull greenhouse-gas warming back to 2005 levels—essentially rolling the climate-change clock back 15 years. Cutting methane in half translates to reducing CO2 by 44 ppm.* This reduction would in effect take us from about 420 ppm of CO2, where we are now, down to 380 ppm, where we were in 2005.

These are conservative figures. Using estimates from the 2021 IPCC AR6 report, which recalculates the impact of atmospheric methane, halving atmospheric methane this year would roll global warming a decade further—to where it was in 1995.[48] Either of these outcomes would be excellent for humanity and nature. In addition, using a natural pathway to methane oxidation, they would cost a small fraction of one percent of what we're investing in clean energy now.[49]

Methane oxidation is a real opportunity for an industry leader committed to climate restoration and humanity's survival to embrace, support, and invest in.

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* Doubling methane oxidation reduces atmospheric methane by half. Molecule for molecule, methane produces 44 times the amount of warming than CO2. So reducing methane by 1 ppm is the equivalent of reducing CO2 by 44 ppm. Today's CO2 is 420 ppm, minus 44 ppm = 376 ppm. That was the CO2 level in 2004. (Methane was slightly lower then, so the result is actually equivalent to the 2005 level.)

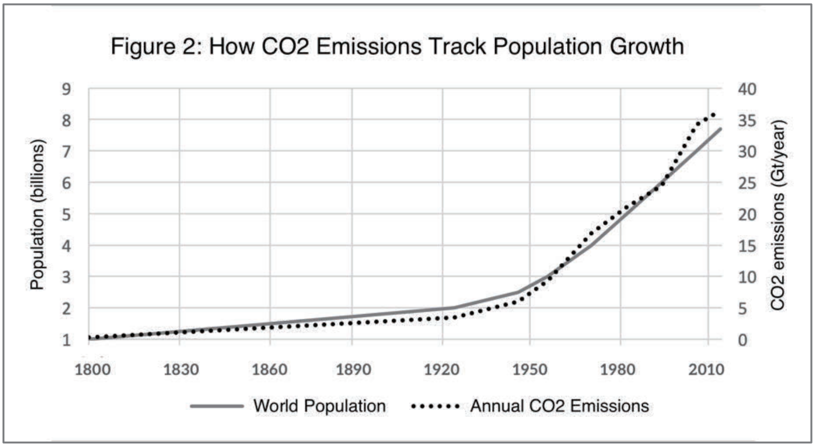
Getting Our House in Order: Moving to Smaller Families

AIMING TO RESTORE a global population level that was sustainable for millennia is another insurance policy for humanity flourishing.

Before the Industrial Revolution, world population had been nearly stable for many millennia. Women had on average about five children, and on average two would survive to adulthood. However, from 1700 until recently, population increased exponentially as we decreased child mortality by a factor of 50 without a corresponding decrease in birth rate. Population is now 10 times the pre-industrial figure.[50]

A diverse population is a gift to humanity. But today's high population puts strains on natural resources and on the environment that sustains us.[51] This is especially urgent in our era of climate change. Levels of carbon emissions and resource use closely track population growth. This means that doubling the number of people—which generally means doubling the use of resources such as land and clean water—has led to doubling the rate of carbon emissions. As obvious as that sounds, the closeness of the correlation startled me when I looked up the numbers and graphed them (Figure 2).[52]

However, after studying the trends and speaking with population experts on several continents, I have good news here, too. If we simply encourage a norm of small families, without any coercion or pressure, the global population will return to a size that was sustainable for thousands of years.



Few are aware of it, but the global trend is heading in the right direction, and has been for 60 years. Average family size worldwide has dropped from 5.2 children per woman in 1960 to 2.4 today.[53] Today, women in 30 high-income countries are choosing smaller and smaller family sizes—an average of under 1.5 children per woman. If we continue this trend so that 1.5 becomes the average worldwide—and keep that as the norm for roughly a century—we will return to a population that Earth has sustained long-term.

People sometimes ask me, "What's the most important thing I as an individual can do for the climate?" I have a ready answer: "Plan a small family, with one or two children and encourage your family and friends to do so." Having one fewer child reduces your carbon footprint more than anything else you can do as a private citizen. It's far more impactful than becoming vegan, giving up air travel, or installing solar panels on your home.[54]

I would never shame a friend who isn't vegan. In the same way, I would not shame a friend who chose to have a large family. (I myself have two children, now adults.) But I urge people committed to impactful climate action to plan for small families and to encourage their friends to do the same. Small families are good for the climate.

Smaller families also lead to healthier economies—the Asian Tigers of Singapore, Hong Kong, South Korea, and Taiwan are a case in point. As poor countries reduce their birth rates, their economies flourish with increased public and private investment in each child—the so-called demographic dividend. With fewer children, there are more resources available for building social and economic infrastructure. If someone were to ask my advice, I would support policies that nudge people toward smaller families, such as reduced child credits after a first child.

By contrast, coercive policies such as China's old one-child policy tend to backfire. China's birth rate was falling fast before the one-child policy, and it dropped even further and faster after that policy was eliminated.

Taking climate restoration seriously requires strengthening our commitment to the sustainable population path.

Five Myths That Stand in the Way of Climate Restoration

I HOPE THIS PAPER has helped you see that insuring humanity's collective survival requires climate restoration. There's much more to say about all the topics I've raised so far, and the forthcoming book will delve into them in depth.

However, you may be hesitant to dive deeper into the climate restoration story because of certain misleading ideas many people have been exposed to and repeat. I'd like to take a little time to address those myths in the hopes of clearing your way on this journey.

Myth 1: *"Reducing carbon emissions to net zero is job one. Anything else is just a distraction."*

This myth may have been true fifty years ago, when CO2 levels were still within humanity's historical range—but no longer. In fact, this myth is dangerous, as if the captain of a sinking ship should tell his crew to patch the leaky boards in the ship—and order them not to bother with running the pumps to keep the ship from foundering. Just as patching leaks on a ship that has already taken on water won't refloat it, stopping emissions alone won't restore a safe climate.

The simple scientific reality is that, to ensure a future environment in which we know humankind can safely thrive, we need to remove the excess CO2 we have already spewed into the atmosphere. Stubbornly prioritizing net zero is counterproductive because it delays implementation of the required scale of CO2 removal.

Myth 2: *"There are no silver bullets for the climate, only silver buckshot."*

The idea behind this myth is that it's dangerous to put faith in any "big idea" for climate restoration. While this may be true when it comes to reducing emissions, it doesn't apply when it comes to climate restoration. The fact is that nature has used two or three large-scale processes to restore the Earth's climate and reduce high CO2 levels, including the storage of carbon in limestone and in the oceans, triggered by minute amounts of iron dust. If we think of these as "nature's silver bullets," their success in the past history of the Earth shows that it would be wise for us to use them to address the current emergency.

Myth 3: *"Climate restoration is geoengineering. We got into this climate mess because technology poured CO2 into the air. How can we expect technology to get us out?"*

Geoengineering refers to any deliberate, large-scale human intervention in natural systems in an effort to counteract climate change. Climate restoration is, by definition, a particular form of geoengineering designed to ensure the flourishing of humanity.

Many people oppose geoengineering because they think that any attempt to improve the climate will probably make it worse. But as we've seen, there's no evidence that humanity can survive without climate restoration. The geoengineering issue comes down to a philosophical question as to whether humans should seek to actively restore the climate or passively hope that nature will restore it. As a father, a grandfather, and a proud member of the human race, I believe in actively ensuring our survival, especially using nature's proven methods.

Myth 4: *"Climate restoration lets the fossil fuel companies off the hook."*

Underlying this myth appears to be the belief that fossil fuel companies caused global warming and that shaming them or eliminating them will fix it. But finding fault doesn't reduce CO2 levels. Only action will do that—specifically, the replacement of fossil fuels with clean energy sources. That transition is already under way, in part with the involvement of oil companies, using their global infrastructures for handling large quantities of materials. Much of the new offshore wind turbine capacity, for example, is being installed by oil company offshoots who are skilled at handling ocean-based heavy machinery.*

Climate restoration is about guaranteeing the future of our species. It is not about picking energy winners and losers, or about punishing corporations for their bad actions in the past.

Myth 5: *"Climate restoration may all be well and good, but it needs a lot more study before we can do anything about it."*

The good thing about this myth is that it starts with a recognition of the need for climate restoration. The question is how to make it happen both quickly and safety. Since we are running out of time to preserve our critical ecosystems, action is needed if we want to preserve a viable world for the next generation.

Fortunately, all of the climate restoration solutions I've described work initially on a local scale. Therefore, any problems that may arise will also be local, which will allow us time to correct them. This again is how nature works, testing out evolutionary developments locally, with successful ones gradually spreading widely.

The atmosphere and oceans are too complicated and fast-changing for theory alone to tell us how to successfully restore the climate. Only scaling up CO2 and methane removal in the same way nature gradually introduces new systems will teach us how to do it safely and efficiently.

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* Full disclosure: In my work as a scientist and climate activist, I have sometimes worked with oil companies to develop plans for complying with the Paris Accords and other programs for implementing the transition to renewable forms of energy. For example, I assisted Royal Dutch Shell in designing their "Sky Scenario," released in 2018 (https://www.shell.com/energy-and-innovation/the-energy-future/scenarios/shell-scenario-sky.html).

"All things are impossible until they happen," goes one of my favorite quotes, "and then they become inevitable."[55]

Climate Restoration—An Inspiring Goal for Our Time

I SPOKE EARLIER of goals that have inspired me and many others to achieve what would not happen otherwise. Those of us who want future generations to flourish in the kind of natural environment enjoyed by humans throughout our development must now focus our attention on the goal of climate restoration.

Yes, it's a big job, one that poses genuine challenges—technological, economic, political. But the biggest challenge is simply mustering the will to make it happen. Remember that President John F. Kennedy announced the American moonshot program before the necessary technology even existed. He defined a goal and asked the nation to commit itself to achieving that goal without anyone knowing how it could happen![56] But the goal was inspiring, and the nation achieved it in less than a decade, in the process developing thousands of innovations that were needed to make that success possible.

The good news is that the technology of climate restoration is much further along than the technology of space flight was in 1961 when the moonshot goal was announced. New technologies will surely emerge that will allow us to achieve the goal of climate restoration even faster and more easily. What is needed now is a collective commitment to prioritize humanity and to restore the climate and population to conditions that allowed us to flourish.

We only get one chance to preserve humanity. We can continue hoping that humanity will survive with a hot climate suitable for dinosaurs, collapsing ecosystems and a population ten times higher than was stable for millennia--or we can be the adults in the room and plan our collective return to safety. As responsible citizens, let's choose the goal that gives us certainty: climate restoration.

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About the Authors

PETER FIEKOWSKY is an MIT-educated physicist and engineer, a serial entrepreneur, a philanthropist, and a social innovator. He has worked at NASA and the Fairchild/Schlumberger Artificial Intelligence Lab in Palo Alto; taught at MIT; and developed his own machine vision company, Automated Visual Inspection LLC (AVI). He holds 27 patents and is on the board of Solar Capex, a fintech company dedicated to tripling the rate of investment in solar projects.

A decade ago, when it became clear that global warming would endanger humanity's future, Fiekowsky began working on climate restoration. Organizations Fiekowsky has built to help achieve this goal include:

- The Foundation for Climate Restoration (FCR), which works with scientists, innovators, policymakers, citizens, faith leaders, activists, and students to create the understanding and policy needed to further climate restoration. The Foundation has been instrumental in the adoption of climate restoration as a goal by both the Vatican and the United Nations.
- Methane Action (MA), a nonprofit organization dedicated to solutions that will reduce atmospheric methane concentrations to pre-industrial levels.

- Methane Oxidation Corporation (MOC), which is enabling companies to neutralize their carbon footprint through the active reduction of atmospheric methane.
- The Stable Planet Alliance, which is working to frame the next set of UN Development Goals under the umbrella of achieving a healthy, sustainable population by 2100.

Fiekowsky has also been an investor in and advisor to many companies working in the climate restoration field. He lives with his wife Sharon in Los Altos, near his grown son and daughter in the heart of Silicon Valley.

CAROLE DOUGLIS is an award-winning journalist who has specialized in writing about climate, biodiversity, and sustainability since the 1990s. Her work has been published in *The Atlantic, Harper's, Psychology Today*, and in National Geographic Society (NGS) books. She holds a B.A. *magna cum laude* from Harvard University and an M.A. in international relations from the Fletcher School of Law and Diplomacy.

A bold vision of a future in which humankind can truly thrive

People around the world recognize the dire threat posed by climate change. Governments, businesses, and individuals are making commitments to shift to renewable energy sources, trim consumption, and otherwise reduce their carbon footprints.

But what if these steps are woefully inadequate to ensure the future health—or even the survival—of the human race? What if the most popular goal being pursued by today's climate activists—net-zero carbon emissions—is actually a recipe for human disaster?

That's the warning being sounded by scientist, engineer, and entrepreneur Peter Fiekowsky . . . along with an urgent call to refocus our rescue efforts on a much bigger, bolder, yet fully achievable goal—the goal of *restoring the climate* to the healthy state that will allow human beings to thrive.

Scientific data show that humans evolved and thrived in a world where atmospheric CO2 levels were below 300 parts per million (ppm). Meeting the goal of net-zero emissions will leave us with a dangerous level of about 460 ppm. We need to do much better—to return the world to climate conditions that we *know* are healthy for humans.

In this white paper, adapted from a forthcoming book, Peter Fiekowsky explains the science behind climate restoration, describes the technologies that can make it a reality, and offers an inspiring vision of a world in which our children and our children's children can have a real chance to survive and to thrive.

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