Case for Change

Is our planet in trouble? How do we know? Getting to the Root of the Problem. Is it our fault?

Is Our Planet in Trouble?

This is the first and most basic question we need to answer. If we're not in trouble, then there's no point in writing this, and I can go take a hike. Or write about something else.

For the past 30 years, I've been growing more and more concerned about the future of our planet. As an engineer with a solid scientific background, and a passion for the outdoors, adventure and wildlife, I've been studying the issues of sustainability from different perspectives. To me, the math, science and data show unequivocally that we are on a bad path, a path to destroying our planet. And, when I say "destroying our planet", what I specifically mean is "rendering our planet unhabitable for life as we know it, including humanity". Obviously, the planet will go on just fine if we trash the surface. After a few million or billion years, it will likely recover, unless it doesn't, with an entirely different array of life. Who knows, maybe more dinosaurs?

Anyway, when I first realized there was a problem, I was mainly worried about uncontrolled population growth, and the possibility of running out of resources, in particular, fossil fuels, that are the foundation of our uncontrolled growth. After all, I was in the oil industry originally, so I had a pretty good understanding of that potential risk. I was already worried about too many people demanding too many resources, and when I went to China for a project, I saw first-hand how low the per-capita foot-print was in that already over-populated country. Everybody lived in high-density housing, tall cement apartment buildings with stair-only access unless they were moving furniture, in which case they could use the one elevator in the 12-story building. Laundry and shower down the hall, one per floor. Hanging clothes to dry in a window. Nobody had cars. The hospital had space for a couple vehicles in front, mainly ambulances. Everybody coveted cars, and I was constantly asked to describe my vehicles. It was both eye-opening and embarrassing, at least for me. I couldn't help but wonder what kind of energy demands would come from this country if everybody had a car and house like a lot of us westerners, yet I also felt that everybody on earth deserves to have an equal lifestyle, and I was uncomfortable being viewed as "privileged".

I didn't really wake up to global warming until perhaps 10 to 15 years ago, when the scientists' predictions about temperature increase started to become a reality, as opposed to a hypothesis. Reality is harder to argue with, or so one would think. The temperature is actually rising. Fast. We are losing wildlife at an unprecedented rate, so fast that the short span of existence of humanity on this planet, a mere sliver of time, relative to the existence of the planet, is being termed the "Anthropocene" era, in which mankind is rendering our planet increasingly inhospitable to an increasing array of inhabitants, including wildlife, plants, us humans and even all those single-celled organisms at the very bottom of the food chain, that make up the lion's share of biomass on our planet. Yet, I'm constantly amazed that humanity in general can manage to look the other way, ignoring or setting aside this terrifying reality, and the role we all play in it.

The first step in solving a problem is determining if there really is a problem and, if there is, then defining exactly what the problem is, and how to fix it, if it can be fixed. There seem to be plenty of people, around 60% in the U.S., that seem to feel that there is a problem with environmental sustainability on our planet, and they may do a little here and a little there to try and do better. But there seems to be a troubling lack of urgency, and most people don't really do much to make a difference. Some do more than others, like bothering to recycle, but many don't seem to think there's any point in bothering, because we can't do much to change things. Partly because they don't believe it's that big of a deal, or because they don't believe it's our fault, referring to us humans. It's gonna happen no matter what we do or don't do. Yes, the planet is dying, but we may as well enjoy life. Hell, we're here.

To me, ignoring problems is not who I am. I am a pro-active person at my core, and I can't turn the other way and feel good about myself. Once I understand that there is a problem, I have no excuses. I can't claim ignorance because I know. To ignore the problem or look the other way would make me complicit and accepting of the problem. That would in turn make me a part of the problem, a perpetrator and perpetuator of the problem, and not part of the solution we need. That feels lame and futile to me, and I don't want to be that person. I refuse to be part of the problem, and prefer to be part of the change for improvement. I want to help make things better. I feel really lucky to have been born into a middle-class family right here in the U.S.A. I have a wonderful life, with every opportunity to enjoy my family, recreation, and a fun and successful career. I do not take my luck or these opportunities for granted, and I believe all humans have the right to a happy and joyful life on this planet. I do not want my legacy to be part of the problem. I don't want to be remembered as just another loser who squandered the planet's future because I couldn't be bothered to make sensible changes to help. When I knew. I believe my children and their children and all subsequent generations have a right to a decent life on a decent planet. I strongly believe this is possible, if we make our changes now.

We are all in this together, and we can make a difference, if we at least try. We can't keep ignoring the issues and procrastinating. We have to do it now, to have any hope at all. We can make gradual changes to steer our climate in the right direction and keep our planet habitable for millennia to come, or we can ignore the issue and continue to run the planet to failure. It's up to us. The first way will give the future of humanity a happy and peaceful existence, in balance with our planet. The second way will leave our descendants a destroyed, apocalyptic mess to deal with in a struggle for mere survival, much less a decent and happy life. So, I ask, what's it going to be? Which future do you want to leave to our future descendants? Which person do you want to be? The one who tried? Or the one who couldn't be troubled to help? How do you want to be remembered?

How Do We Know?

Let's face it. Our planet is complicated. The environment is complicated. Our own bodies are complicated. I could go on and on. My point is, we'll never have a complete understanding of exactly how these complex systems work. We certainly understand many aspects of how complex ecosystems work, and we learn more every day, but we're a long way from a complete understanding. With respect to our own bodies, we still don't know exactly why cancer or dementia or autism or muscular sclerosis

attacks some people and not others. We can barely reach some parts of our planet, like the deep ocean trenches, which we're only beginning to explore. There are huge gaps in our understanding of the complex biological interactions in our hugely diverse ecosystem.

What happens when one or more species are driven to extinction? What happens to the web of life, and its resiliency to hold up under stresses that we humans impose every day? The poisons, the trash, the greenhouse gasses that are increasing the temperature of our planet? According to the World Wildlife Fund Living Planet Report 2020, we've already managed to decimate an average of 68% of the wildlife species on this planet since the first Earth Day in 1970, in just the past 50 years.[1] In North America the total bird population has declined by 29% since 1970, a loss of nearly 3 billion birds.[2] We've driven the Monarch butterfly population from a billion in the mid-90's to less than 50 million today.[3] And this is just one popular species that represents and entire group of insects, including bees, that the earth, and we humans, need in order to pollinate our food sources. And we've done all this damage with almost no understanding of the long-term impacts on the untold millions of ecosystems on the planet. And, at this point, it's fairly safe to say that there is probably no ecosystem left on the planet that has not been impacted by humans, whether we are aware of it or not. After all, the air and water we've contaminated flows pretty much everywhere, eventually. And we have no idea of the impact all this will have on us humans as a species.

We're even beginning to see impacts of global warming on contagions and previously eradicated diseases. In 2016, a boy was killed, along with 2,000 reindeer, after exposure to Anthrax that was released when melting permafrost exposed the frozen carcass of a reindeer that had been killed by the bacteria at least 75 years earlier.[4] Yellow fever and Zika virus are moving into new ranges as mosquitoes that carry the viruses migrate into warming regions. The number of cases from diseases carried by mosquitoes, ticks and fleas have tripled in the U.S. in the last 13 years, infecting humans and wildlife with Lyme disease. In Minnesota alone, the moose population plummeted by 58% in just 10 years, in the early 2000s from unprecedented tick populations, as many of 90,000 found in a single calf.

In the oceans, we have also lost half of the coral reefs in the past 50 years, from climate change, overfishing and pollution.[5] To make it worse, since the reefs support a huge array of aquatic diversity in the oceans, we are also losing these species as we lose the coral. And the excessive carbon dioxide that we are emitting to the atmosphere is causing higher concentrations in the ocean water, which is causing increased acidification, which in turn is weakening the shells of shellfish. This is really scary, because shellfish, along with diatoms, which also have exoskeletons, are at the bottom of the aquatic food chain. If we lose all the shellfish, what happens next? Which species will we lose to starvation? The whales? The salmon? The tuna? The cod fish? The seals? Some of them? All of them? After all, they need to eat, just like we do, and if we kill off their diet, they'll either have to find something else to eat, or starve to death. Either way, the ecosystem will be disrupted, since if species change their diets, that will impact yet more species in a never-ending cascade of impacts.

Again, getting back to the original question, how do we know if our planet is in trouble? Do we really and truly have a problem that needs to be solved? The environmental measurements and observations are mind-boggling, and they seem to come at us from all directions. It feels like every move we make has some kind of environmental impact, for better or worse, and it's nearly impossible to keep up with it all. One minute we hear about yet another species going extinct, yet another wildfire, yet another megastorm, and then the next we may hear some hopeful news about successful species

recovery, growth in renewable energy, some new invention, some new carbon absorber that will save the day.

So, should we be worried or not? Should we take climate change seriously or not? Should we do something about it or not?

I'm afraid the answers are yes, yes and yes. At least, that's my take. When we're decimating the life that makes up the intricate balance of ecosystems on the entire planet, while ignoring the problems and continuing with business as usual, we're in deep, deep trouble here. When we have a global emergency on our hands, and can't even convince ourselves there's a problem significant enough to bother solving, that's even scarier. We need to get busy, and we need to do it now. Right now.

Getting to the Root of the Problem

After several decades as an engineer, one of the most important things I have learned is that, in order to answer a complex question, we need to have a way to measure and define the issue numerically. The adage that "if you can't measure it, you can't control it" holds true for everything from losing weight to pitching a project to reducing our energy to saving the planet. For every project I pitched as an engineer, I had to know the cost of the project and the money, energy or water it would save. I couldn't just go into a room full of decision-makers and wave my arms around aimlessly about all the problems, without proposing specific solutions.

Yet, that's what it feels like we do when we talk about the environment. We just arm-wave about whatever problem we last heard about. It's like the old parody about the blind men describing an elephant. One describes the tail, another the trunk, another a leg, and yet another the massive torso. We get all this depressing news about extinction of yet another species, the last white rhino, ocean acidification, wildfires, forests scraped for date palms and cattle, the ocean full of plastics, even starving children in undeveloped countries. And, while we can, to some degree, connect some or all of this with environmental problems, which is definitely true, it's nearly impossible to define what we can do about it. How do you choose between all these issues? What can I personally do about that last rhino or wildfire?

At the end of the day, it turns out that all these various problems that suggest that our planet might be in trouble are actually mere indicators of problems, and not necessarily the underlying cause. We need to cure the disease, not just the

So, What is Carbon Dioxide Anyway?

Whenever the subject of global warming comes up, the terms "carbon dioxide", "CO_2" and "Greenhouse Gas" are usually not far behind. First of all, carbon dioxide and CO_2 are the same thing. CO_2 is simply a chemical abbreviation for carbon dioxide, and refers to a molecule that has one carbon and two oxygens. In the diagram, C stands for carbon and O stands for oxygen:

O=C=O

Greenhouse gasses are molecules that exist naturally as gas, or vapor, and tend to take up, or absorb, energy, and emit it slowly as heat over time. Greenhouse gasses other than CO_2 all have different amounts of heat that they store, depending on the molecule. To get all these molecules in equal terms, the heat carrying capacity of greenhouse gasses are typically converted into equivalent units of CO_2. Think of adding a penny to a nickel. To get the total cents you don't just add the coins together, because you'd get a meaningless answer. Two coins. How much is that? First you multiply the nickel by five to convert it into equivalent pennies. Then you add 1 cent and 5 cents to arrive at 6 cents, which is more useful than just saying you have two coins. CO_2 is used as a basis for greenhouse gas calculations because it's the most abundant greenhouse gas, by far. I use the terms carbon dioxide, CO_2 and carbon interchangeably, and they all mean the same thing, equivalent units of CO_2.

symptoms. Otherwise, the symptoms will just keep coming back, and will probably get worse with time. A nasty weeping sore that won't go away could mean melanoma, and it takes a lot more than a band aid to get rid of that. Getting back to the planet, wildlife loss is definitely a problem, but it's not necessarily a root cause. While it's definitely depressing to see loss of wildlife, and it may be tempting and even gratifying to save each species, one at a time, the demise of wildlife isn't killing our planet. Whatever is killing the wildlife is killing our planet. So, how do we get to the bottom of that?

If we're looking for underlying causes, the global temperature increase seems to be linked to a lot of the problems, from loss of wildlife as their environment becomes less hospitable, to increased wildfires, drought, which leads to water and food scarcity, glacial melting, which leads to sea level rise, and increasingly violent storm systems. If the temperature continues to rise, we can expect these problems to become worse. Yet, temperature doesn't feel like an actual underlying cause in itself. Something is causing the temperature to rise. Also, global temperature has risen and fallen constantly since the planet was formed. So, is the temperature rise really anything new or unusual? Is this simply part of a normal cycle for our planet? What, specifically, is causing the temperature to rise?

It turns out that a lot of natural things can cause the atmospheric temperature to rise. Carbon dioxide and other greenhouse gasses are known to hold heat in our atmosphere until they break down, many years after release. While we humans don't have too much control over volcanoes, plate tectonics, planetary wobble or proximity to the sun, we are definitely complicit in how much carbon dioxide we spew into the atmosphere with our daily activities. So then, the question becomes, how much of this temperature rise is due to carbon dioxide from human activity, compared to all the other possible causes? This is a hugely important question. If it turns out that the temperature is rising because of mainly natural forces, then all the greenhouse gas reduction in the world won't change things, and we might as well live and let live, knowing that future generations will suffer, but we can't really do much about it, so why bother? On the other hand, if it turns out that mankind's release of additional greenhouse gasses is causing the temperature increase that will doom future generations, then we have a serious ethical obligation to do something about it. Don't we? So, let's see if we can answer this important question. Because it's important.

While the indicators were enough to convince me personally that our planet is in trouble, I still needed specific connections between humans and the underlying cause, which is temperature increase, which is caused by carbon dioxide. The internet

Hasn't the Planet Always Had Atmospheric CO_2 Variation?

500 million years ago, the atmospheric CO_2 concentration was a whopping 4,000 ppm, which is ten times higher than the 400 ppm that's jacking up the temperature today. The concentration gradually reduced over millions of years, reaching around 400 ppm around 3 million years ago, and then dropping to the range of 180 to 300 ppm for the past 2 million years. While the planet was just fine with teeming life at 400 ppm of CO_2, we have to understand that at that time the planet was a completely different place than today. Beech trees grew near the poles, and the equators were much too hot to support the life forms that exist today, including humanity.[6] At least, not without air conditioning. Sea level was 50 to 60 feet higher than it is today. The microbes that consumed the CO_2 from the atmosphere over millions of years were gradually buried by sediment, becoming the fossil fuel bearing formations that mankind is now burning for energy, releasing all this sequestered CO_2 in a relatively miniscule amount of time, just a couple hundred years. While the planet will once again survive just fine, if these emissions continue unchecked, life as we know it, including mankind, are unlikely to survive.

There are other natural sources of CO_2 that have nothing to do with human activity. One of the most commonly cited is volcanos. In the past, volcano eruptions have certainly caused short-term climate impacts, mainly right after they blow, but overall, they release less than 1% of total CO_2.[7]

abounds with data from credible sources, so I started digging around. As I researched, I thought about how much easier it is to pull data from the internet compared to 40 years ago, when I was just starting my career. Instead of heading to the library, and of ordering volumes and volumes of government and scientific references, I could simply google world population by year, carbon dioxide by year, and global average temperature. All this data has been meticulously gathered by scientists all over the world since the mid-19th century, and even before. Atmospheric CO_2 concentration is available by year for the past 850,000 years, thanks to ice cores from Greenland glaciers and the polar ice caps, that maintain a record of atmospheric gasses when they freeze. With all this data, I began to look for relationships by plotting it in different ways. I can't help it. I'm one of those weird number geeks who gets a thrill out of analyzing data and looking for relationships and trends. I know, scary.

First, I wanted to see for myself if the temperature increase that we are seeing now is really all that unusual. Some of the news we see says that it is, and other news says that it's not. Also, I wanted to know if carbon dioxide in particular was a significant cause of temperature increases. To find out, I plotted the data for atmospheric CO_2 concentrations[7] for the past 850,000 years to present, shown in Figure 1.

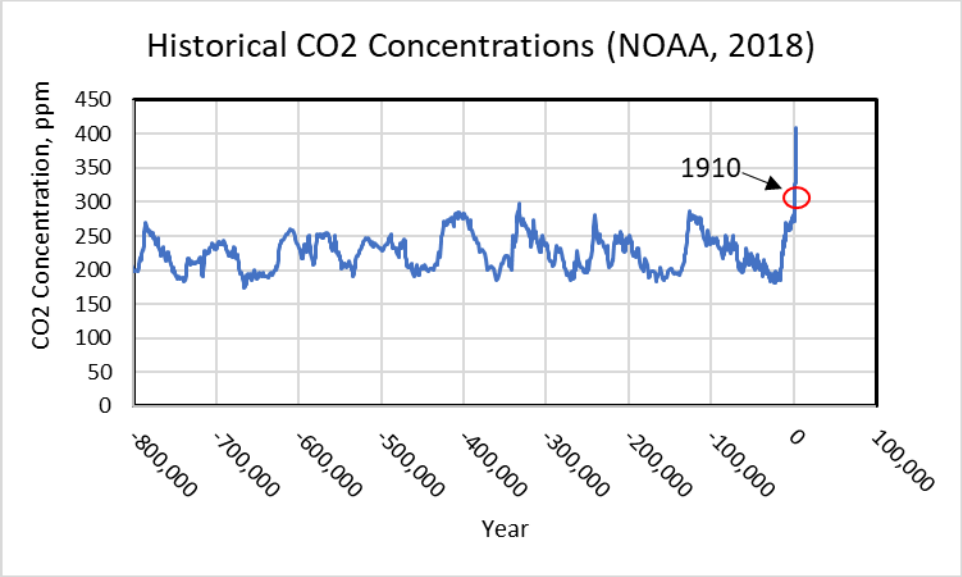

Figure 1 - Atmospheric CO_2 Concentrations from 800,000 B.C. to Present.

This graph[8] shows that the CO_2 concentration has indeed been fluctuating for the past 800,000 years, mainly in the range of 200 to 250 ppm, on cycles that last about 100,000 years. There are some periods where the concentration dipped below 200 ppm, and rose above 250 ppm, but the concentration didn't rise higher than 300 ppm in all that time, until 1910, which is when we humans started burning fossil fuels with abandon, marking the rise of the industrial revolution. This graph illustrates a few things very well. First, it's fascinating to me how much of an impact we've made on the CO_2 concentration in our atmosphere in such a short period of time, essentially a sliver of time, compared to the natural trends over the previous hundreds of thousands of years. Like, Wow! To think us tiny little human maggots could cause that kind of impact on an *entire planet*? You gotta hand it to us humans, that's for sure! Second, our planet's natural geologic activities and weather patterns certainly affect the CO_2 concentration in the atmosphere. However, these natural cycles don't seem to account

for the extreme increases we are seeing now. Since it's probably safe to say that human influence on the atmosphere was fairly minimal, since global population was low, and we didn't yet have the technology to get really aggressive with fossil fuels, the sudden and timely rise above the usual fluctuations might actually be from burning of fossil fuels.

Taking it a step further, I wanted to see if higher atmospheric CO_2 concentrations can actually lead to higher atmospheric temperatures. To get a sense of this, I simply plotted CO_2 concentration and temperature on the same graph. Since it's easy to find good data for temperature from 1850 onward, and I already had the above CO_2 data, I plotted from 1850 to present. Also, 1850 predates the increase above 300 ppm CO_2 by 60 years, so the graph, Figure 2, includes a decent baseline of data prior to the increases since 1910.

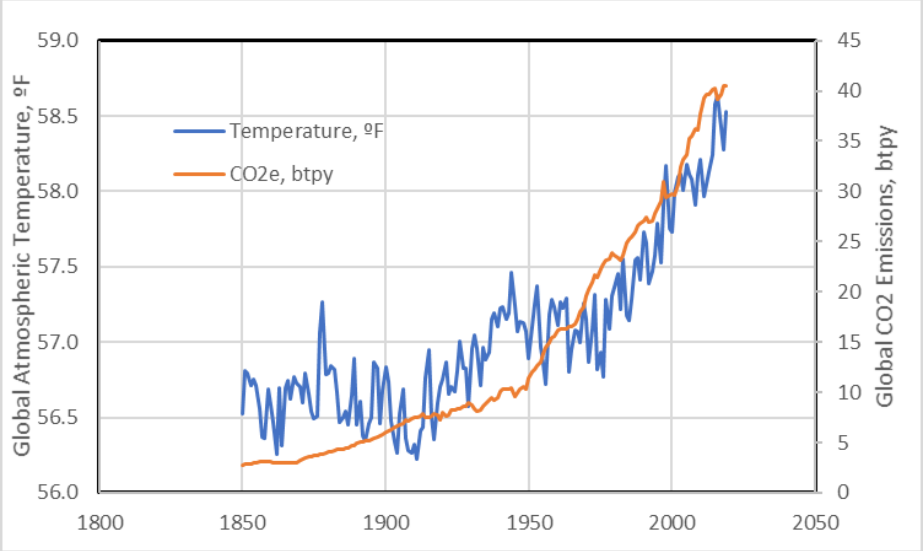

Figure 2 - Atmospheric CO_2[8] and Global Temperature[9] from 1850 to Present.

Figure 2, which takes a closer look at the recent past two centuries, shows that, prior to 1910, the temperature was fluctuating from year to year, but didn't really start rising until around 1910. The CO_2 concentration was rising prior to 1910, but at a much slower rate than in the second half of the 20th century. The more gradual rise in early years suggests that we were certainly emitting significant CO_2 into the atmosphere, which makes sense, since we were beginning to burn more fuels, a mix of wood, whale oil and fossil fuels, to fuel our growing population. However, the increased CO_2 emissions didn't really begin to impact the atmospheric temperature until around 1910. From approximately 1910 onward, the global temperature, while fluctuating from year to year, has been on a definite increasing trend. This suggests that either the CO_2 concentration prior to this time wasn't enough to increase the temperature, or that the natural sinks for CO_2 emissions on the planet, the ocean and the forests, were still taking up CO_2 at a sufficient rate to delay an increase in temperature.

Figures 1 and 2 help us get closer to what we're looking for, which is an underlying base cause for temperature increase on the planet that we can measure and possibly control. We can now see that the global atmospheric temperature is indeed higher now than at any time in the past 8,000 centuries, and we can see that the temperature has risen notably since 1910. We can also see that both CO_2 concentration and temperature are increasing, and that their rate of increase seems to be accelerating

in the past few decades. If temperature increase is causing the climate-related problems we are seeing on the planet, then CO_2 may be a significant underlying cause. To find out, I next plotted global temperature against the atmospheric CO_2 concentration for the same time period, 1850 - 2020, shown in Figure 3.

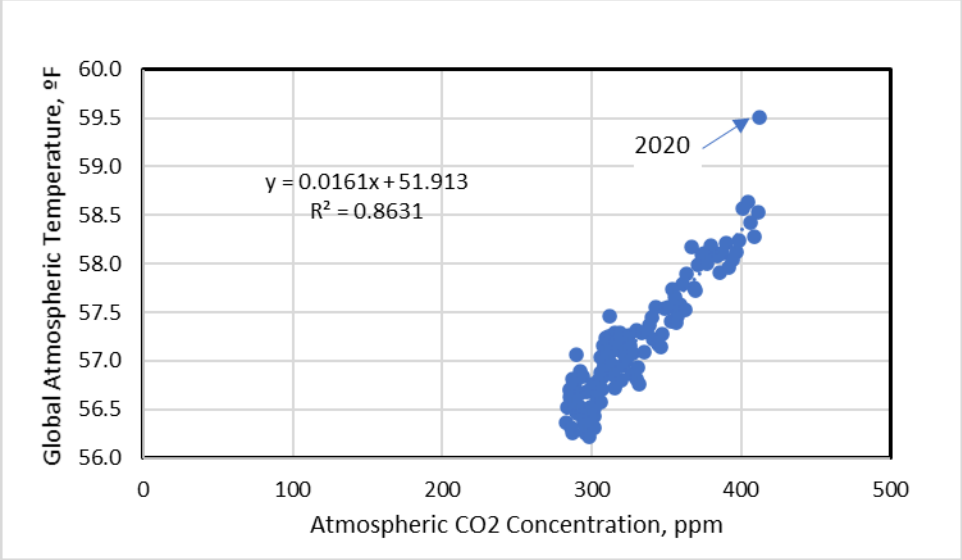

Figure 3 - Global Atmospheric Temperature vs CO_2 Concentration, 1850 – 2020.

This relationship, between temperature and CO_2 concentration, tells us that temperature definitely increases as CO_2 increases. Also, it aligns with the commonly accepted scientific knowledge that CO_2 is a greenhouse gas that increases atmospheric temperature at a predictable rate, which is based on physical atomic principles.[10,11] Considering the complexities of our planet, this is a shockingly straight-forward relationship. The equation on the chart describes the best fit straight line through the data points, each of which represents one year of average temperature and CO_2 concentration of that particular year. This is known as a regression fit, and is a basic statistics tool that is available on any spreadsheet.

The R^2 (r-squared) value on the graph is the regression coefficient for this particular set of data. A regression coefficient is a measure of how well the data points fit the line, statistically. A coefficient of 0 would mean there is no relationship at all between the two variables, in this case, the temperature and the CO_2, or that CO_2 has

How on earth (pun intended) can a measly 400 ppm of CO_2 change the temperature so much?

After all, 400 ppm, or 400 parts per million, is only 0.04% of the earth's atmosphere, which is nothing compared to the major components of the atmosphere, which are nitrogen, at 79%, and oxygen, at 21%. It turns out to be all about infrared energy waves. Energy from the sun enters earth's atmosphere in the form of these infrared waves, and then is ultimately reflected back into the atmosphere after it reaches the surface. Both oxygen and nitrogen are small, simple molecules with only two atoms in them, and they only absorb a tiny range of waves, so the reflected energy just blasts right past them and back out into space. On the other hand, greenhouse gasses, such as CO_2, hold energy because they absorb a huge range of infrared waves, and then they hold that energy and vibrate, spewing it out as heat in all directions, so that about half the energy stays in the atmosphere, warming it, while the rest blows on out into space. Of course, we need *some* greenhouse gas to maintain a livable temperature. With no greenhouse gas at all, it would be a lot colder around here, below freezing, which would also suck for life as we know it. The reason mankind and all the wildlife evolved on this planet in the first place is the delicate balance of heat-trapping gasses in our atmosphere, that we are now destroying. That Goldilocks thing.

nothing to do with increasing temperature. At the other extreme, a coefficient of 1.0 would mean the relationship is perfect, or that CO_2 was the sole underlying cause of the temperature increase. In Figure 3, the regression coefficient is 0.86, which means that the atmospheric CO_2 concentration is about 86% of the underlying cause of temperature increases on the planet. Of course, I'm aware that it's much more complicated than that, and any trained statistician will probably blanch when they read this boiled-down explanation, but I am trying to find general relationships that will help us, without digging too deeply into the intricate mathematical details of a regression analysis. After all, human beings have approximately the attention span of a goldfish, maybe about 10 seconds, so too much detail is going to be lost on most readers. Since I don't want to lose readers over this important issue, I'm choosing to keep it simple. For our purposes, it's close enough to say that atmospheric CO_2 concentration is about 86% of the underlying cause of temperature rise on our planet, and it's also fair to say that around 14% of the temperature increase is from other factors, most likely geologic factors that are mentioned above, such as volcanoes, tectonic plate movement, etc.

Is it Our Fault?

Now that we've found a plausible, identifiable, measurable, underlying cause for the temperature increase that is creating havoc on our planet, we still aren't completely clear on why the CO_2 is increasing. After all, a volcano, or even leaks in the oceanic trenches, could release lots of CO_2, methane, and other greenhouse gasses, couldn't they? And the CO_2 that's released when we burn fossil fuels could be just a small portion of that, right? Actually, it turns out that we've been tracking CO_2 from fossil fuels separately from that released from natural causes. We can do that pretty easily, because when we burn fossil fuels, the amount of CO_2 released is really simple to calculate, because all the carbon in the fuel turns into CO_2, so it's just a mass balance that a high school chemistry student can do, if they pay attention in class. To see if our fossil fuel emissions could be causing the increases in atmospheric CO_2, I plotted the atmospheric concentration against human-caused CO_2 emissions[12] in Figure 4.

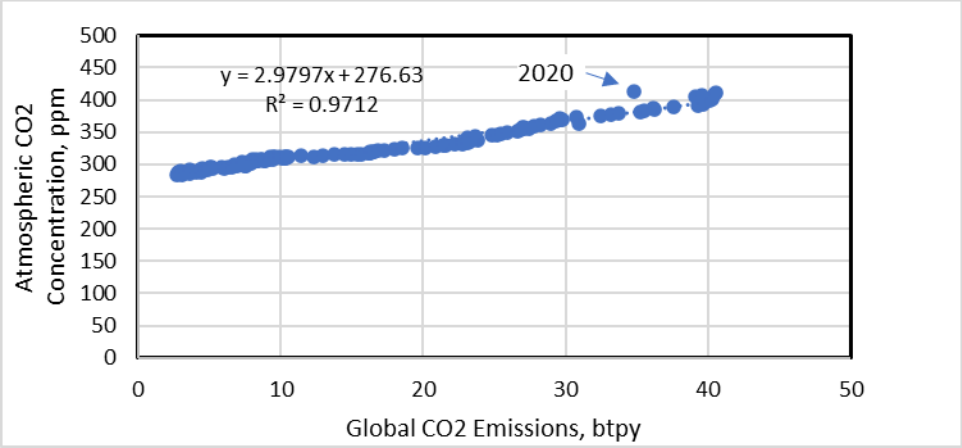

Figure 4 - Atmospheric CO2 Concentration vs Global CO2 Emissions, 1850 – 2020.

Figure 4 is hard to argue with, because it shows an obvious increase in CO_2 concentration in the atmosphere, that increases with increasing emissions from human activity, including fossil fuels and land

use. Fossil fuels is direct burning of fossil fuels, while land use includes our agricultural practices, peat bog and forest decimation, mining and construction, to name a few practices that impact the ability of land to absorb CO_2. The regression coefficient of 0.97 means that fossil fuel emissions are about 97% of the reason that the CO_2 concentration is increasing in our planet's atmosphere. The anomalous point for 2020 is marked on the graph for reference; in 2020, the atmospheric CO_2 concentration increased, as the CO_2 emissions decreased because of less travel due to COVID 19. This is a potentially scary point, because a break from the trend may indicate the beginning of a tipping point in our atmosphere, if atmospheric CO_2 increases with lower CO_2 emissions. I hope that's not the case, but time will tell.

If human CO_2 emissions are causing increases in atmospheric CO_2 concentration, which is leading to increased temperatures that are causing global warming, then the next obvious step is to see what direct impact human CO_2 emissions has on the temperature. This more direct relationship, shown in Figure 5, accounts for all human activity specifically, in a plot of fossil fuel emissions and human land use on atmospheric temperature.

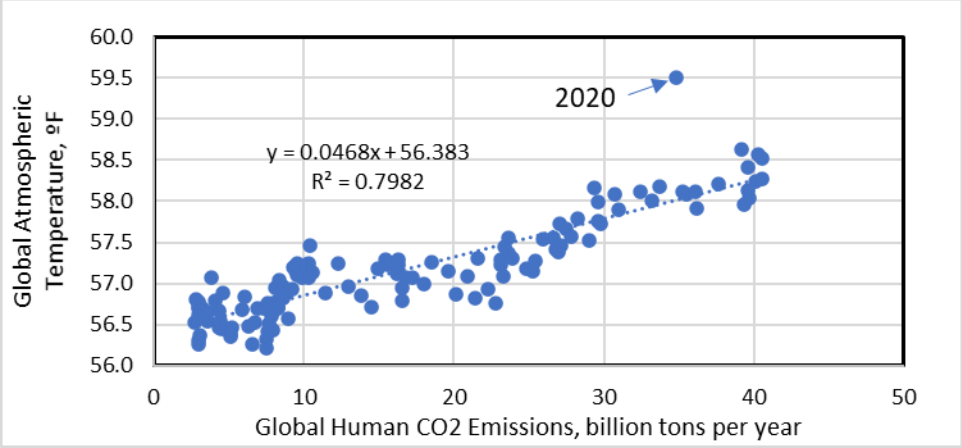

Figure 5 - Annual Global Atmospheric Temperature vs Global CO2 Emissions, 1850 – 2020.

This trend has more scatter in it, because it combines more direct relationships between fossil fuel emissions and atmospheric CO_2 concentration with temperature and atmospheric concentration, into a more general and very useful relationship between atmospheric temperature and human-caused CO_2 emissions. The lower regression coefficient of 0.798, which we'll just round to 0.8, means that human-caused fossil fuel emissions is about 80% of the cause of global warming. This trend is a bit looser (eg, more scatter) than the closer, or tighter, relationships between atmospheric CO_2 concentration and fossil fuel emissions or

What About the Other 20%?

There are many natural forces that cause variations in global temperature and climate. Among the known factors are plate tectonics, earthquakes, and ocean currents, which drive the glacial and interglacial cycles, planetary precession, or wobble, eccentricity, axial tilt, proximity to the sun, which varies according to where our planet is in its elliptical orbit, variation in solar radiation, and the albedo effect, which falls out of the glacial cycles, to name just a few examples. Certainly, a massive volcano or a big old comet can really wonk things up good. There are also impacts that have yet to be discovered. All told, these make up about 20% of the temperature change we are seeing, and there's not much mankind can do about this stuff, unless we can manage to explode a comet out in space with a suicidal comet blaster, like in *Armageddon*. Or not, like in the more recent *Don't Look Up*. On the other hand, the 80% of temperature change that is caused by our emissions is something we can do something about, since we're the ones that are causing it. At least in theory.[13,14,15,16,17]

between atmospheric temperature and atmospheric CO_2 concentration, because it combines the other natural factors that contribute to atmospheric CO_2 and temperature. Overall, these natural factors that lead to global warming make up about 20% of the reason for temperature increases, while human activity makes up the lion's share, about 80%.

Personally, I find these relationships between human CO_2 emissions and global warming both depressing and encouraging. It's depressing to think our fossil fuel emissions are truly the biggest reason for global warming, that us little itty-bitty humans are actually capable of killing our planet with our activities and our technology. I love technology. It just makes life so fun and convenient. Refrigerators, laptops, cell phones, penicillin, painkiller, anesthesia, good wine, planes, trains and automobiles, the list goes on and on. Organic leafy greens from Mexico in the middle of winter, oh my! At the same time, it's encouraging to see that our emissions are specifically the main reason for global warming, because it means that if we're really the reason for the temperature increase, then we might be able to reverse the trend. At least, in theory. That is, if we can muster the will and the spine to do so.

Next, let's figure out what we need to do. And how to do it. And then let's do it. This is important. It's about balancing with our planet. The only planet we have. We really need to do this. Together. As a human species. We are the most intelligent species on the planet. How hard can it be?

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