FutureMetrics™ LLC
8 Airport Road
Bethel, ME 04217, USA

Business-as-Usual will Lead to Catastrophic Climate Outcomes

May 1, 2023

By William Strauss, PhD

Atmospheric concentrations of carbon dioxide (CO_2) hit another new record high on April 28, 2023, of 425.01 parts per million (ppm). The implications are dire.

This white paper makes it clear that urgent meaningful action on carbon emissions policy is needed.

Figure 1[1] below shows CO_2 concentrations in the atmosphere over the past 800,000 years. The temperature variations from the long-term average over that span of time are also on the chart (black line). When historical CO_2 levels rose rapidly due to natural forces temperatures spiked until CO_2 levels dropped.

The red line at the far right shows an extremely rapid rise in CO_2 concentration to unprecedented levels within an unparalleled short span of time (see Figure 2 below). Given historical temperature responses to much lower maximum CO_2 levels, it begs the question: Will the resulting rise in temperature be significantly higher this time?

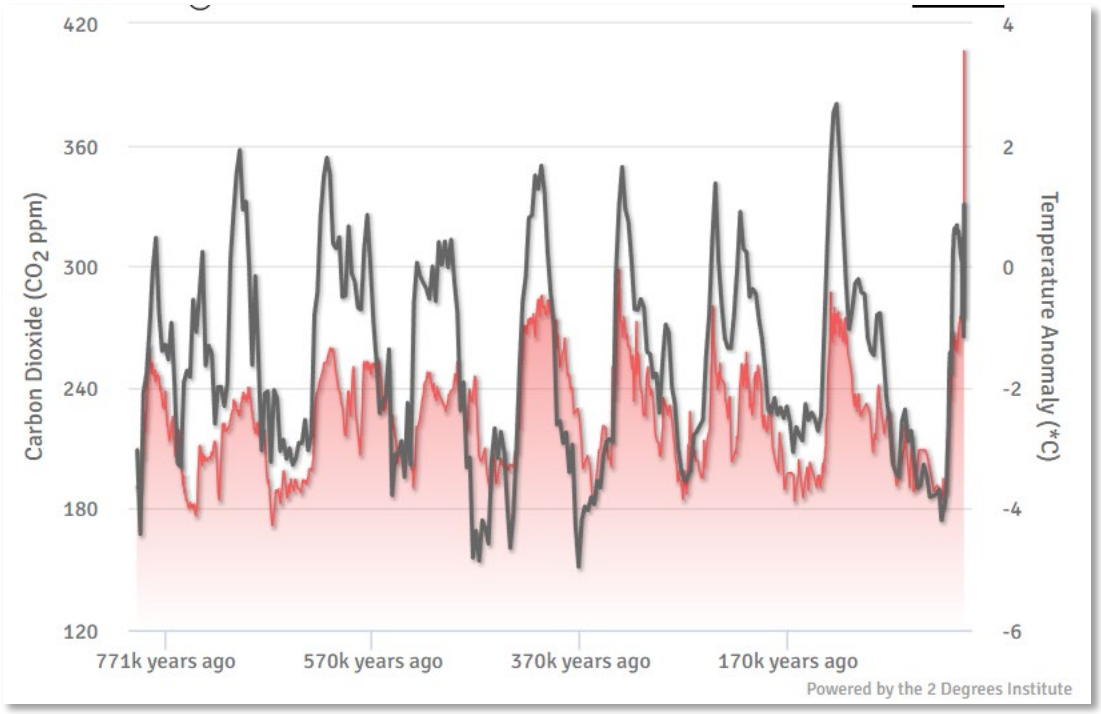

Figure 1 - CO2 Levels for the Past Million Years and Temperature Anomalies

[1] This chart screenshot and two others used in this white paper are powered by the 2 Degrees Institute https://www.2degreesinstitute.org/. The interactive chart can be found on the FutureMetrics homepage. The charts are highly interactive and can show many climate-critical parameters.

The likely answer is yes!

As Figure 2 below shows, CO_2 levels for the last 1000 years had plateaued at an average of around 280 ppm. Over the past 150 or so years, CO_2 levels have risen at rates and to levels that are nowhere to be seen in the historical record that includes humans and their ancestors.

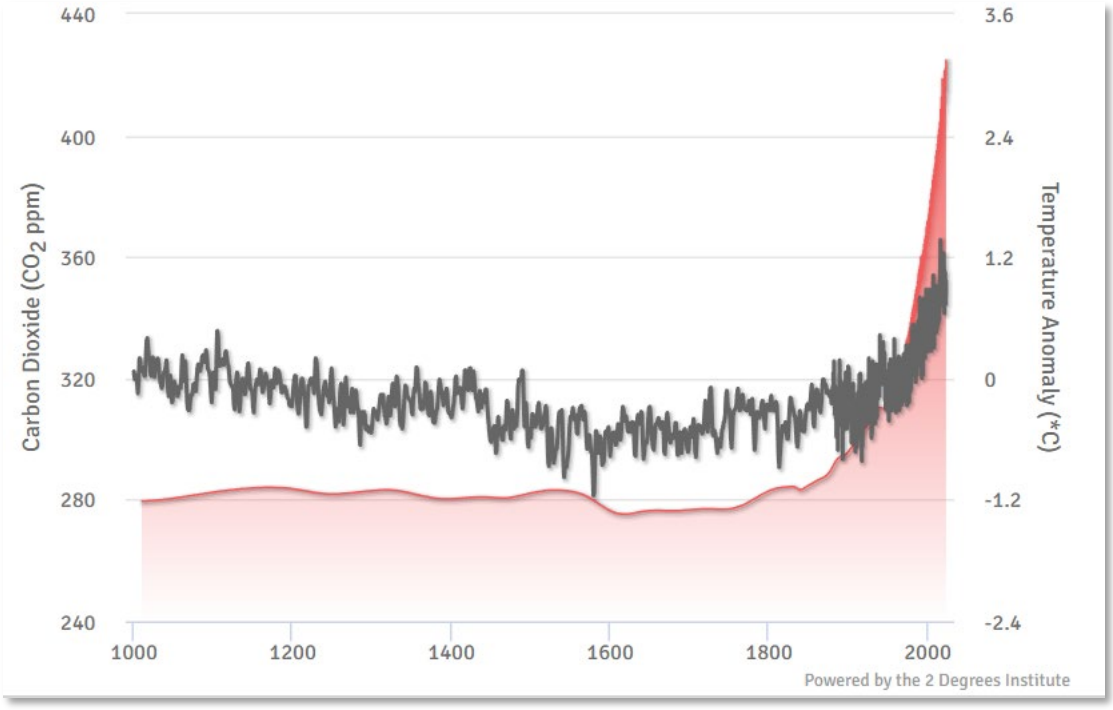

Figure 2 - CO_2 Levels and Temperature Anomalies for the past 1000 years

CO_2 is called a "greenhouse gas" because, just like the glass or plastic roofs in greenhouses, CO_2 prevents solar energy in the form of heat from escaping back into space. The relationship between higher atmospheric CO_2 levels and less solar energy escaping is a scientific fact.

The impact of the rapid increase in atmospheric CO_2 levels is that the atmosphere and the oceans are storing more heat. The rate of increase is extremely rapid.

The complex nonlinear[2] feedback loops that govern ecological equilibrium make it very challenging for most people to understand the dynamics that are causing the climate chaos[3] that is already unfolding. And linear systems do not govern how the earth's systems work.

> *"Linearity is a trap. The behavior of linear equations is far from typical. But if you decide that only linear equations are worth thinking about, self-censorship sets in. Your textbooks fill with triumphs of linear analysis,*

[2] In mathematics and science, a nonlinear system is a system in which the change of the output is not proportional to the change of the input. Wikipedia discussion is HERE.

[3] Chaos in this sentence is defined as both unpredictable outcomes in the real world, and as a mathematical understanding of complex systems. See HERE for Wikipedia discussion of chaos theory.

its failure buried so deep that the graves go unmarked and the existence of the graves goes unremarked. As the 18th century believed in a clockwork world, so did the 20th in a linear one." Ian Steward, *Does God Play Dice? The Mathematics of Chaos*, 1989.

Complex models using massive computer power produce climate forecasts. A precise forecast of the future climate due to the rapid changes in climate forcing inputs is challenging.

But there is no lack of consensus: If we keep doing what we are doing, the future will not be what we want it to be.

Zooming in on the last few months of data, Figure 3 below shows the new record high in CO_2 levels reached just two days ago (this paper was published on May 1, 2023). This is not the first new record high in 2023. There have been several including the April 17 high shown in the chart. And it is likely that there may be more as 2023 unfolds because previous peaks in the seasonal cycle have been in May.

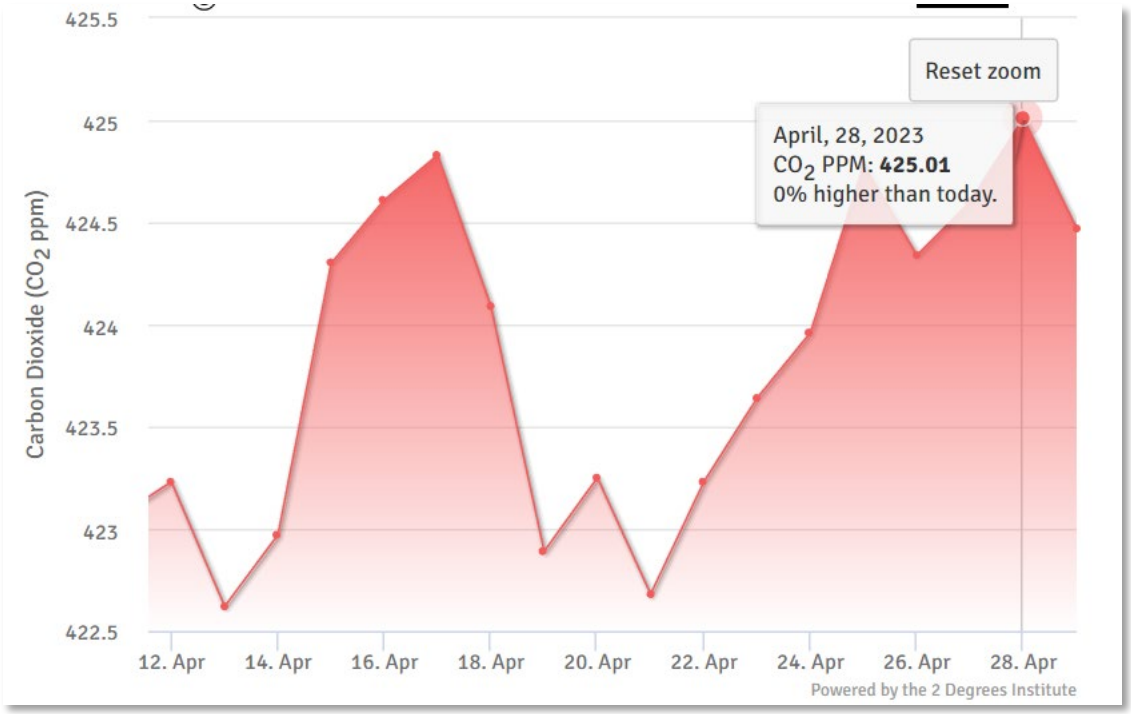

Figure 3 - Temperature Anomalies for the Past Two Months Showing New Record High CO_2 Level

This new high of 425 ppm is approximately double the average over the last 800,000 years and about 125 ppm higher than the highest peak in that time span.

It is not volcanoes, sun cycles, or any other natural influence that is causing this change in CO_2 concentration. It is the use of fossil fuels.

Mining minerals, including hydrocarbons, is part of how humans have created the civilization we enjoy. But we are at a hydrocarbon turning point that could not be more critical.

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Over the past 150 or so years, the use of petroleum, coal, and methane (commonly referred to as natural gas) has caused the carbon in those fuels to be converted into CO_2 during combustion.

That carbon was originally captured over a very long geological span by the natural balance between plants and air breathing organisms. Over many millions of years, much of the dead biomass transformed from carbohydrates into hydrocarbons that became part of the earth's geology.

We are now releasing millions of years of captured carbon over a span of hundreds of years. The impact on earth's systems is highly disruptive and the consequences are and will be negative.

When emissions cause negative consequences, they are called pollution.

Many of the by-products of industrialization have been regulated to preserve a healthy environment. Some pollutants were early to be regulated because they produced obvious dirty air and dirty water that had a direct impact on quality of life. The impacts of some pollutants are more "in your face" than others. Higher carbon dioxide levels have no direct sensory input to humans. There is no sensory perceptible signal to respond to! Without data and analysis, the link between CO_2 emissions and the more frequent and more extreme weather resulting from climate change would not exist.

But even without the alarms being sounded by most climate scientists, it is becoming more obvious now that CO_2 emissions are creating "in your face" consequences.

The signal that is becoming perceptible to even those that cannot grasp the complexity of earth systems science (or are in willful denial) is not dirty air and water, the signal is the rapidly increasing cost of doing business-as-usual in a world in which the probability of adverse unpredictable events is increasing rapidly.

Figure 4 below is produced by the experts that quantify risk for insurance companies. Higher risk means higher insurance cost. The higher the insurance cost, the higher the cost of doing business. This is a direct threat to profits and the viability of some firms. Depending on the degree of dependence on fossil fuels, the already increasing risk premium from the consequences of climate change will have a multiplier that it greater than one for those exposed to the uncertainty of the fossil fuel future.

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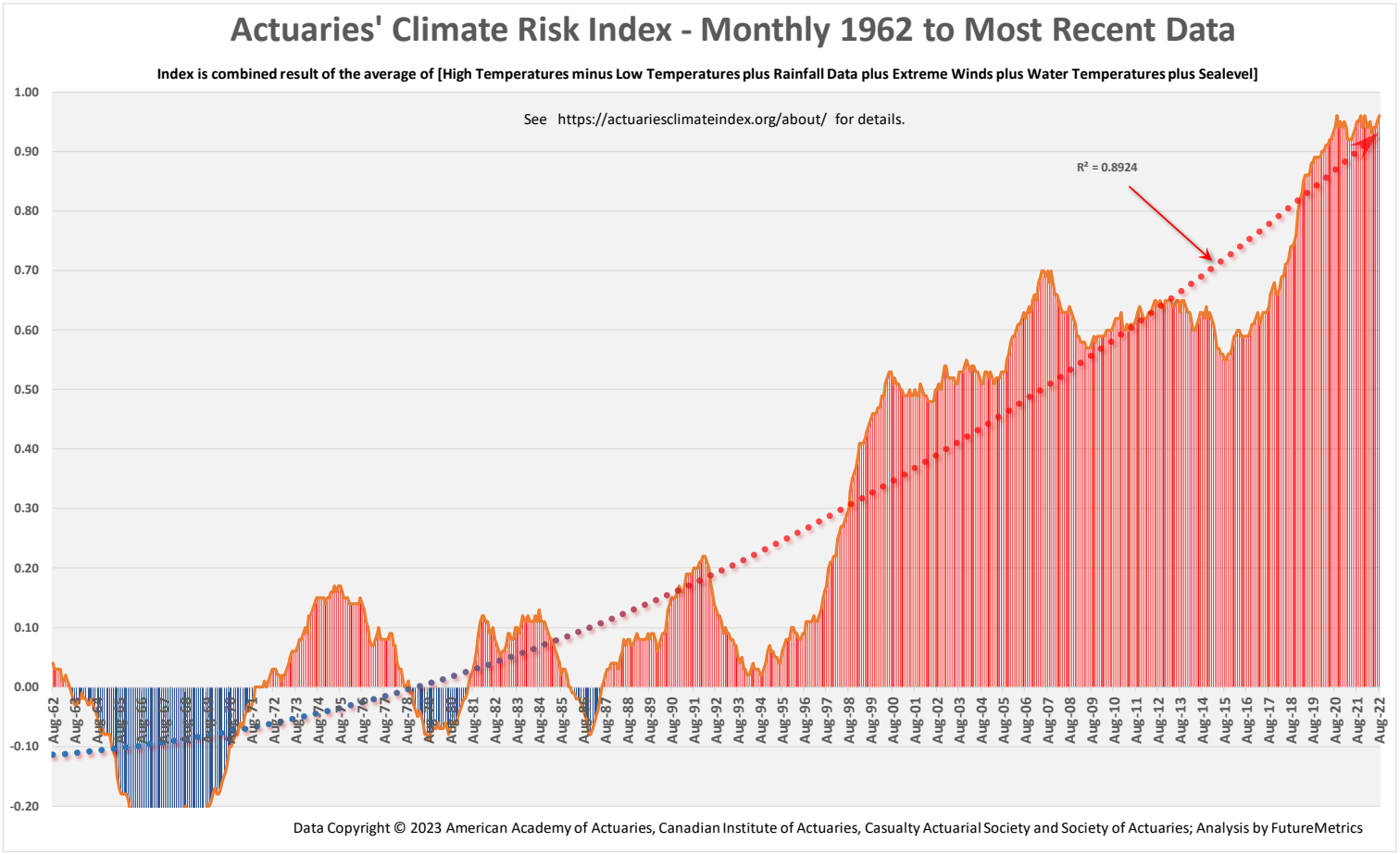

Figure 4 - Climate Risk Index

So, there is growing business-related pressure for somehow mitigating the impacts of climate change.

The BIG question is can that pressure and the overwhelming and compelling scientific forecasts about the dire consequences of unfettered rapid climate change translate into meaningful action.

Before this white paper concludes with thoughts on that critical question, it will review a few more charts to help those with a lingering hesitancy to grasp the need for urgent action.

Figure 5 below shows the rapid exponential increase in the tonnes per year of CO_2 from fossil fuel combustion. Plotted with that time series is the NOAA data on land and sea temperatures.

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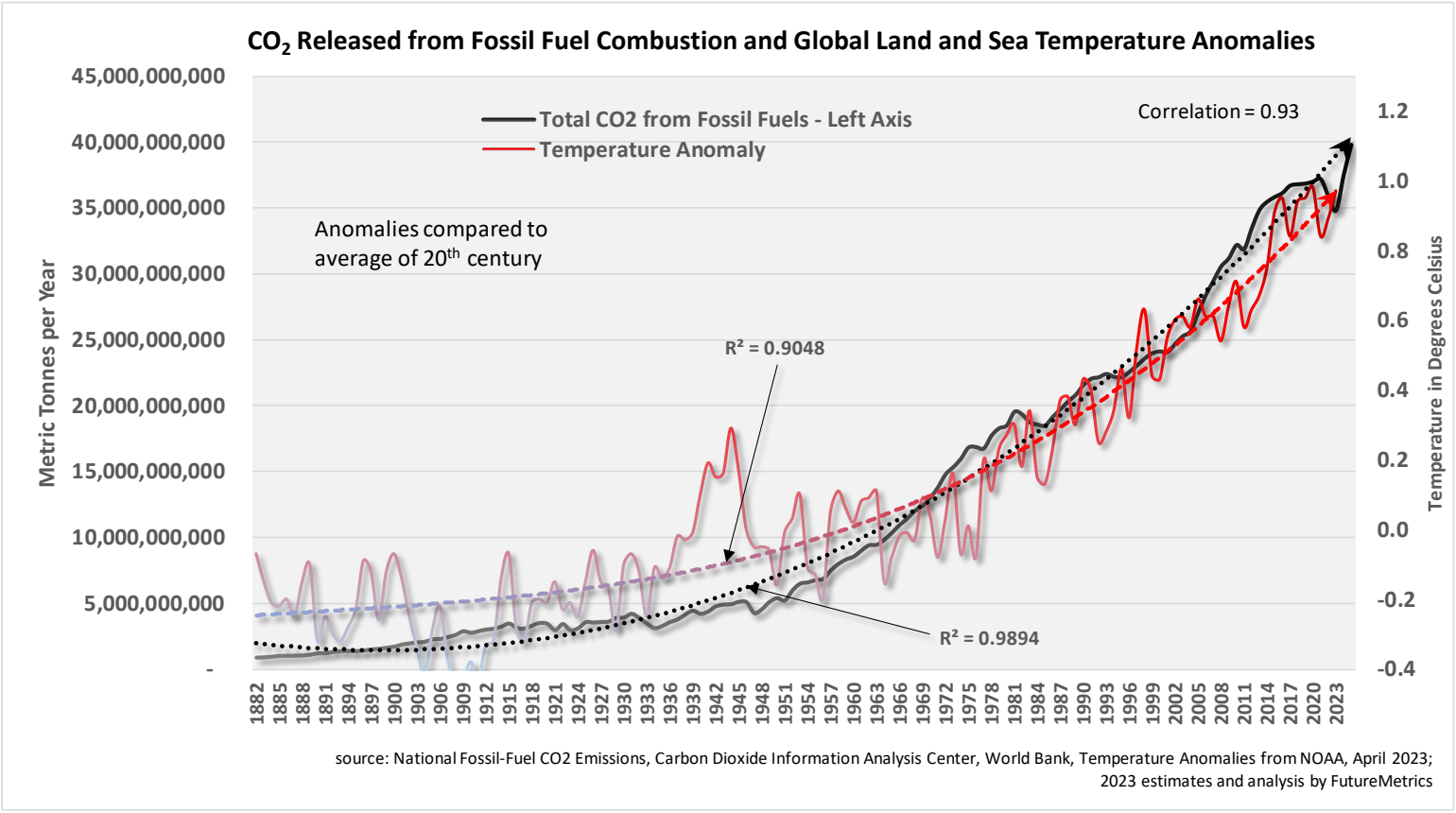

Figure 5 - CO_2 from Fossil Fuel Combustion and Land and Sea Temperature Anomalies

The only significant dip in CO_2 emissions (the black line) was from the economic shock induced by the Covid-19 pandemic. The increasing amounts of CO_2 pollution have a high correlation with the increases in land and sea temperatures.

It is not just weather and the increasing frequency of so-called black swan weather related events[4]. The oceans are changing rapidly and with very dire consequences. Figure 6 below shows the average of three time series that are measuring the total energy content of the oceans[5].

[4] See Wikipedia discussion HERE.

[5] IAP (Institute of Atmospheric Physics) 2021 update to data originally published in: Cheng, L., K.E. Trenberth, J. Fasullo, T. Boyer, J. Abraham, and J. Zhu. 2017. Improved estimates of ocean heat content from 1960 to 2015. Science Advances 3(3):e1601545; NOAA (National Oceanic and Atmospheric Administration). Global ocean heat and salt content; MRI/JMA (Meteorological Research Institute/Japan Meteorological Agency). Global ocean heat content.

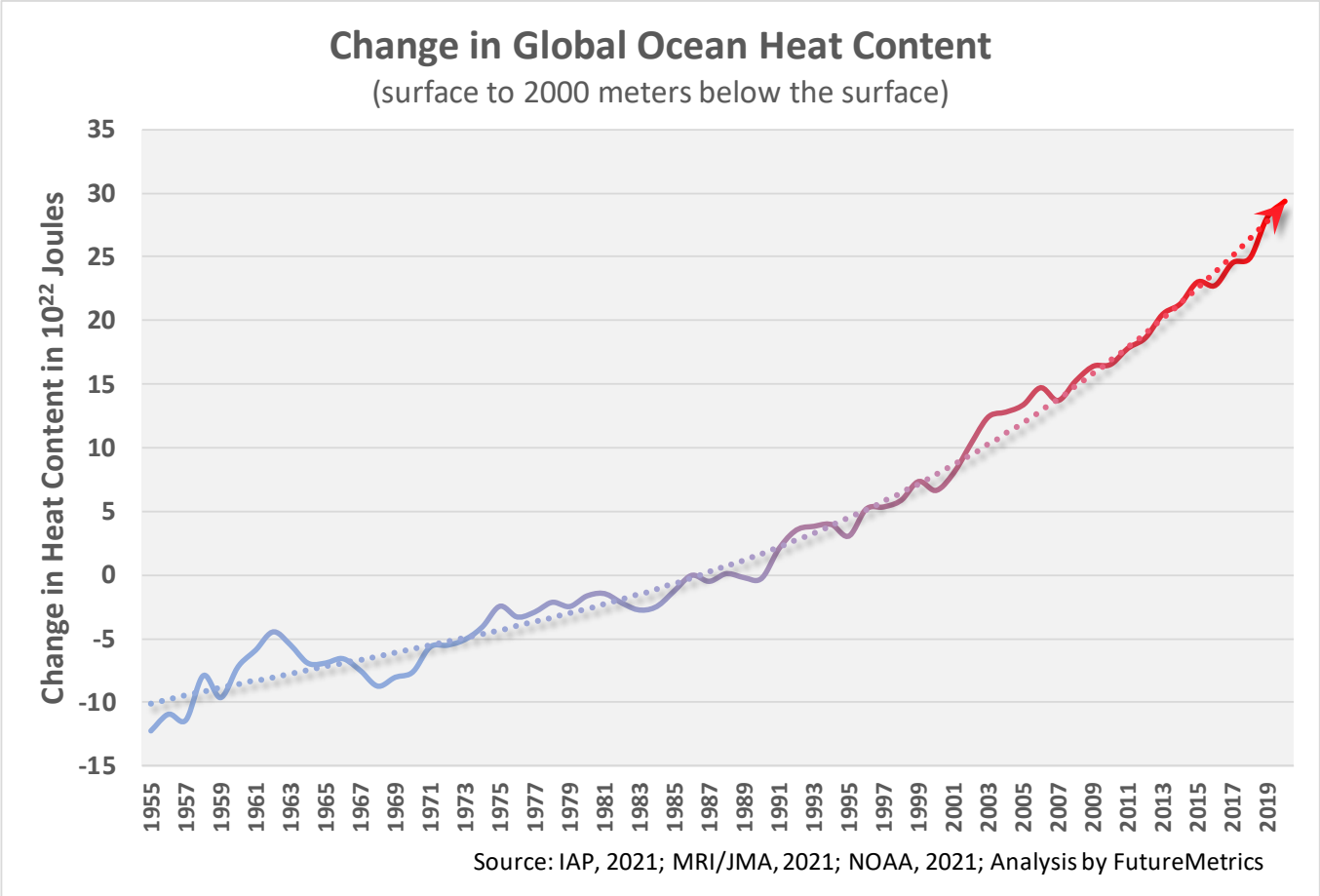

Figure 6 - Change in Global Ocean Heat Content

For context, the increase in heat stored in the oceans in 2020 of about 29.3 x 10^{22} joules equals the energy in 69,878,928 one megaton hydrogen bombs[6].

Warmer temperatures and higher atmospheric CO_2 are changing the ocean's acidity. Figure 7 below shows how pH has steadily decreased (increasing acidity) while the concentration of free CO_2 in the seawater has increased.

[6] One megaton = 4.2 x 10^{15} joules. https://www.atomicarchive.com/science/effects/energy.html

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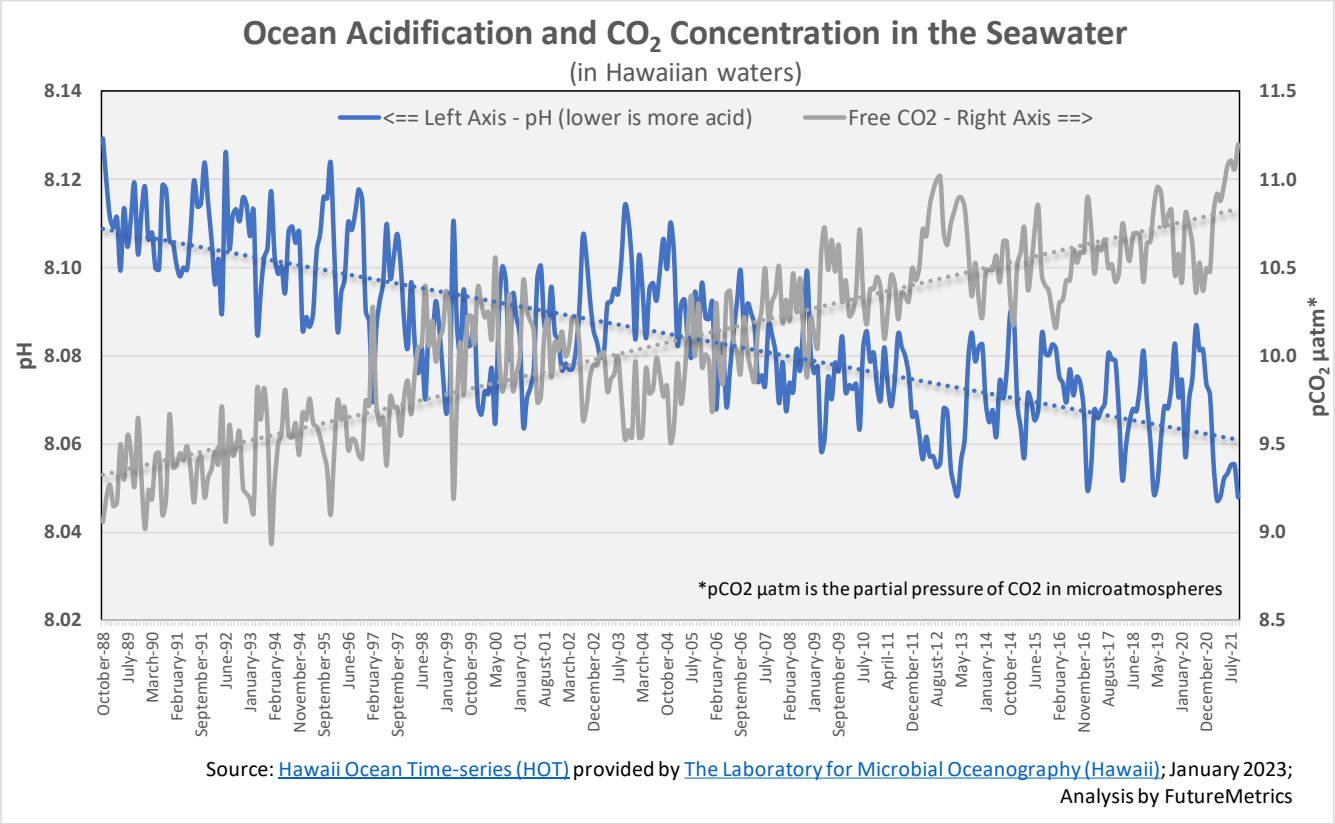

Figure 7 - Ocean Acidification and CO2 Concentrations in Ocean Water

The impacts are as follows:

> "When CO_2 is absorbed by seawater, a series of chemical reactions occur resulting in the increased concentration of hydrogen ions. This increase causes the seawater to become more acidic and causes carbonate ions to be relatively less abundant.
>
> Carbonate ions are an important building block of structures such as seashells and coral skeletons. Decreases in carbonate ions can make building and maintaining shells and other calcium carbonate structures difficult for calcifying organisms such as oysters, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton.
>
> These changes in ocean chemistry can affect the behavior of non-calcifying organisms as well. Certain fish's ability to detect predators is decreased in more acidic waters. When these organisms are at risk, the entire food web may also be at risk.
>
> Ocean acidification is affecting the entire world's oceans, including coastal estuaries and waterways. Many economies are dependent on fish and shellfish and people worldwide rely on food from the ocean as their primary source of protein."[7]

[7] From NOAA https://oceanservice.noaa.gov/facts/acidification.html

Finally, a critical question: What could be the consequences of a failure to curtail the combustion of hydrocarbons and to take action to remove CO_2 from the atmosphere?[8]

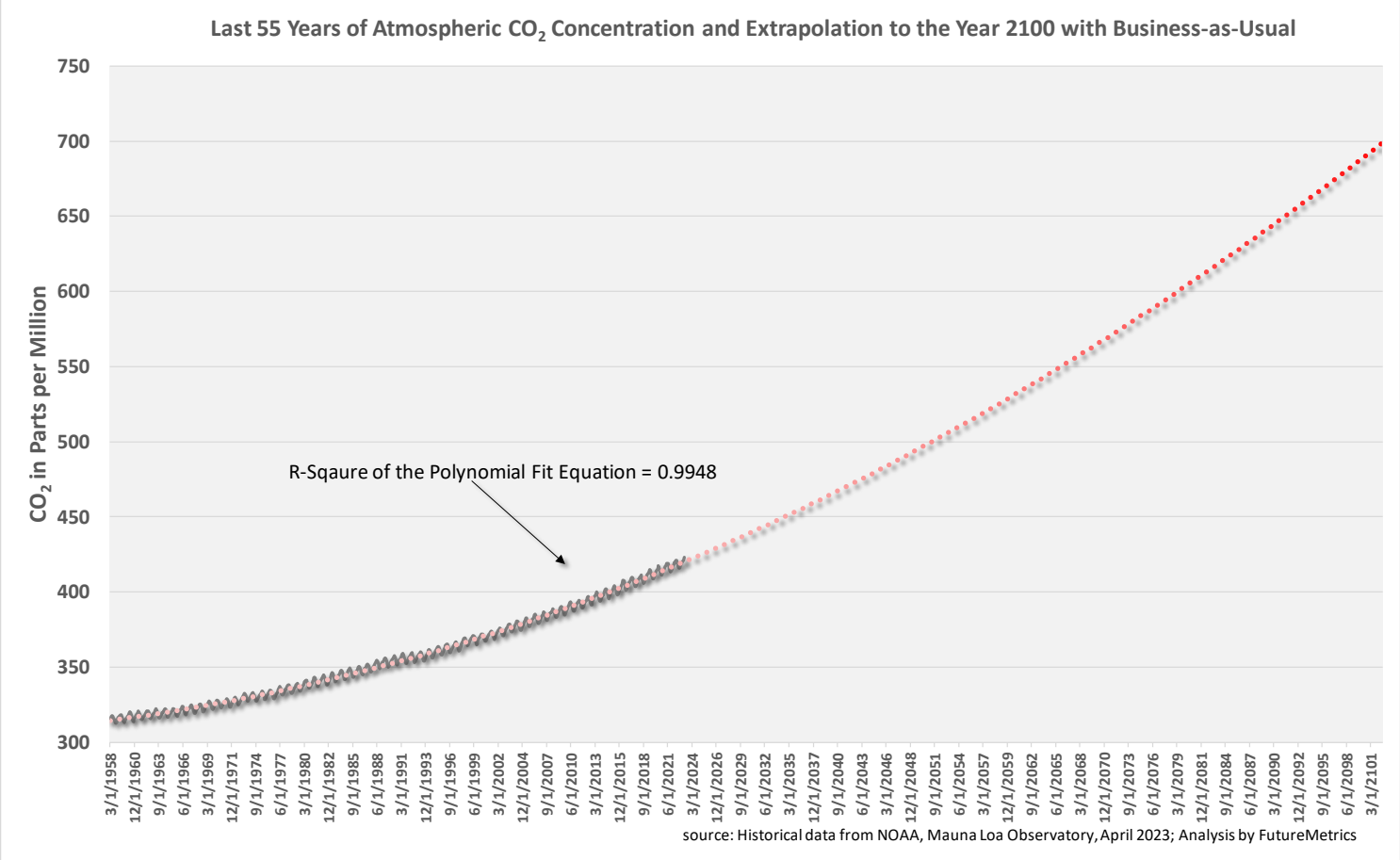

Figure 8 - Last 55 Year of CO_2 Concentration and Time Series Forecast to the Year 2100

Figure 8 above is a simple time series best fit equation[9] that is allowed to generate values to about the year 2100. The complexity of the earth systems and the fact that fossil fuels are a depleting resource that probably will not be mined in sufficient quantities to match the quantity needed to get us to over 700 ppm means that the future shown in the chart

[8] See FutureMetrics' white papers on bioenergy carbon capture and sequestration (BECCS) for a rational and pragmatic pathway to negative emissions while generating baseload and load following electricity. https://www.FutureMetrics.com

[9] Very cool undocumented Excel tip for spreadsheet geeks: The documentation for "LINEST" in Excel does not tell you about the function's ability to take array inputs inside the function to allow estimates of polynomial equations. To estimate the equation $y=ax^2+bx+c$ (which is the underlying form of the fitted line in the chart), highlight three cells in a row and then type in {=LINEST(Yvalues,Xvalues^{1,2})} but without the outside squiggly brackets. The undocumented bit is to put the function on notice that there are two "Xvalues" with exponents of 1 and 2. Those are encased in the squiggly brackets that define array functions. Enter the function using Crtl-Shft-Enter to create an array function which gets the function encased in the squiggly brackets,{ }. The parameters for X^2, X, and the intercept will be in the three highlighted cells. You can then easily forecast a simple extrapolation of the best fit from the past.

seems unlikely. However, the trajectory we are currently on would get us there if there were no limits to the growth of fossil fuel use and policy totally fails.

Imagine our climate under those conditions. Imagine sterile oceans. Imagine the chaos that sits between now and that dismal future.

So far, the aggregate global response to this clear and present crisis has been poor. Perhaps there is too much inertia:

> *"And it ought to be remembered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new. This coolness arises partly from fear of the opponents, who have the laws on their side, and partly from the incredulity of men, who not readily believe in new things until have had a long experience of them. Thus it happens that whenever those who are hostile have the opportunity to attack, they do it like a partisan, whist the others defend lukewarmly" (Machiavelli, 1515, p. 27).*

But perhaps the increasing cost signals from the markets will turn the tide.

Perhaps leaders in business and those in political power will value critical thinking skills, fact-based decision making, and put pragmatism over opportunism.

Darwin's simple message holds the key:

> *"It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change"*[10]

Maybe those leaders resisting change will realize that they are on the wrong side of history.

> *"Heavier than air flying machines are impossible." (Lord Kelvin, Royal Society, 1895)*

> *"There is no likelihood that man can ever tap the power of the atom. The glib supposition of utilizing atomic energy when our coal has run out is a completely unscientific Utopian dream, a childish bug-a-boo." (Robert Millikan, Nobile Laureate, Physics, 1923)*

> *"There is not the slightest indication that nuclear energy will be obtainable." (Albert Einstein, 1932)*

[10] This quote has become attributed to Darwin and is cited frequently; but it does not appear in his published works.