Reality-Based Warming Potential of Anthropogenic Greenhouse Gas Emissions

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A Report of The Right Climate Stuff Research Team

www.therightclimatestuff.com

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This report is based on the research of Dr. Harold H. Doiron, Chairman, The Right Climate Stuff Research Team

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Bounding Greenhouse Gas Warming: Policy based on Reality

Will increased levels of atmospheric carbon dioxide emitted from human activity reach a level that endangers human welfare and the health of the biosphere? The answer to this question has been the focus of The Right Climate Stuff research team. Our conclusion? Not likely. The rationale for this conclusion is the subject of this paper where we find that it is highly unlikely that added carbon dioxide and other greenhouse gases will add more than 1.8 ^{o}C of warmth by the middle of the next century. This bounding of potential warming means that we do not have a rapidly developing climate problem requiring swift corrective action and transformation of economies.

> The Right Climate Stuff (TRCS) Research Team is an all-volunteer research group comprised primarily of NASA retiree veterans of Apollo, Skylab, Space Shuttle and International Space Station manned space programs. We have been joined by other experienced research leaders from US industry and universities in our goal to determine to what extent unrestricted emissions GHG from man's activities can warm the Earth's surface.
>
> Although we are not climate scientists per se, our research team has internationally recognized experts in chemistry, physics, geology, geo-physics, engineering, applied mathematics and computer simulation of complex phenomena. This in-depth experience enabled us to solve the challenges of safely sending and returning men and women to the moon and the space station. In this endeavor, models were extensively used, but only after they were validated with actual data. This process reflects the NASA moto "In God We Trust; All Others Bring Data".

Governments in industrialized countries are mandating hugely expensive anti-fossil fuel policies in their belief that these policies will keep the global surface temperature under a dangerous tipping point level. This action accepts the widely touted hypothesis that carbon dioxide emissions from the burning of coal, natural gas, and petroleum are the main drivers of the recent trend in warming around the globe, and that predicted increases in CO2, if not abated, will lead to unacceptably harmful effects on humanity and the biosphere. This phenomenon is called the Climate Crisis.

The foundation for the hypothesis, and thus the policies, is computer models based on climate physics and socio-economic assumptions that project a range of warming from less than 2 ^{o}C to 10 ^{o}C by the end of this century. The output from these Integrated Assessment Models (IAM) are based on somewhat arbitrary GHG forcing scenarios called Representative Concentration Pathways (RCP). But the RCPs were never intended by their creators nor required to reflect reality. And they do not. RCP8.5 is especially implausible; erroneously described as "Business as Usual", yet it is misused by the U.S. government to justify the expense that penalizes CO2 emissions (based on the inappropriately named Social Cost of Carbon calculus) and thus justify diminished living standards for its citizens.

The ultimate misuse of the RCP scenarios for policy justification results in the degradation of the economic vitality of a nation or state. It is especially damaging to the poor who will bear most of the burden of higher energy costs.

The Right Climate Stuff research team was formed to investigate the impact of rising atmospheric CO2 levels on temperature. Our requirement was that this impact assessment must be based on actual data that would validate the results; in other words, our product must reflect reality. The result is a metric called Transient Climate Sensitivity (TCS) that projects an upper bound of 1.0 C warming by 2100 from rising CO2, other greenhouse gases and aerosols. Such modest warming would be beneficial, not detrimental, to mankind and the biosphere. We thus suggest that only reality-based projections such as our TCS metric be used in policy development of CO2 emission regulations.

We acknowledge that fossil fuel resources are finite and thus that other sources of dependable, abundant, and affordable energy will need to be developed to take their place. Free markets will, by their nature, insure such a timely transition to these other sources. Mandated solutions, like the current highly-subsidized intermittent wind and solar generation of electricity, will cause much economic harm before their burden is reversed.

The modest warming impact of rising atmospheric CO2 levels over the next 80 years, to the year 2100, makes rash reactionary edicts to limit CO2 emissions unwarranted. Such policies would result in all pain with no gain. Rather, we would instead let the innovation of free markets yield beneficial solutions.

Penalizing CO2, a Gas of Life:

Carbon dioxide is a gas of life, a building block of all plants. Absorbed from the air, CO2 is converted by plants through photosynthesis to form sugars and other hydrocarbons, and in the process oxygen, the other gas of life, is emitted. CO2 is plant food, and like other fertilizers, within reasonable limits the more there is, the more productive and robust plants will be. The response to rising atmospheric CO2 levels is the well-documented greening of the globe (figure 1).[i] CO2 fertilization is exploited by agriculture. It is quite common for commercial growers to inject up to five times the ambient level of CO2 into their hothouses to enhance plant productivity.

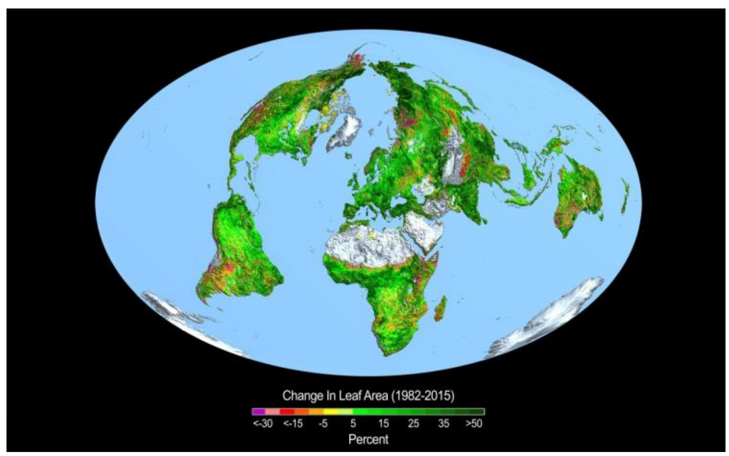

Figure 1. The greening of the earth. Nasa.gov/feature/goddard/2016

Quantitively, the sequestration of CO2 by the biosphere is substantial. Terrestrial biosphere models suggest that global terrestrial gross primary production (GPP) of plants is enhanced by 17 +/-4%, but more recent studies, not yet considered in the models, peg the rise of GPP at +31 +/-5% since 1900[ii], with rising CO2 levels being the dominant driver. Haverd (2020) estimate that a doubling of CO2 from the preindustrial level will result in a 47% increase in GPP, which translates into an additional 638 billion tons of CO2 being sequestered by plants this century.[iii]

Houghton (2007) estimated the mass balance of the carbon cycle. Each year, photosynthesis captures ~440 billion tons of CO2, and the oceans absorb another ~337.3 billion tones. This is balanced by yearly CO2 emissions from biomass decay (~214.5 billion tons), plant respiration (~216.3 billion tons) and ocean outgassing (~330 billion tons). Added to this are ~ 30.4 billion tons of CO_2 emissions from man's activities, mostly from the burning of fossil fuels.[iv] Through this natural carbon cycle, the earth absorbs a little over half of the annual increase in carbon dioxide emissions. The net is an annual accumulation of about 14 billion tons in the atmosphere, which translates to an increase of 2.5 parts per million (ppm) per year at today's emission rate. This trend has been tracked at the Mauna Loa observatory since 1958 (figure 2). CO_2 makes up about 0.04 percent of our atmosphere. Yet CO_2, the gas of life, is classified as a pollutant.[1]

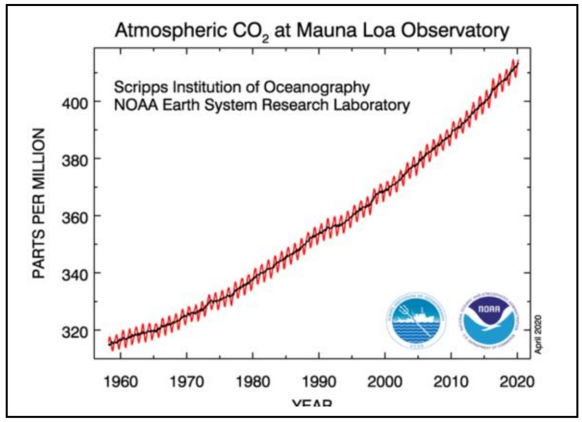

Figure 2. Growth in atmospheric carbon dioxide.

In 2007, the Supreme Court held in *Massachusetts v. EPA* that greenhouse gases unambiguously may be regulated as an air pollutant under the Clean Air Act (CAA). This squarely rejected the contention, then advanced by EPA, that "greenhouse gases cannot be 'air pollutants' within the meaning of the Act." The Court held that the CAA's definition of "air pollutant" "embraces *all* airborne compounds of whatever stripe." This action by the court required the EPA to determine if CO_2 was indeed a pollutant.

On December 7, 2009, the EPA issued its Endangerment Finding that defined as a single air pollutant an aggregate group of six long-lived and directly-emitted greenhouse gases (GHG) that are "well mixed"[2] together in the atmosphere and cause global climate change that endangers public health and welfare. These GHG are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The EPA's attribution of warming to human greenhouse gasses relied on three lines of evidence, none of which has since held up to scrutiny.

Lines of Evidence for Endangerment Finding

(1) indirect, historical estimates of past climate that suggest recent temperature changes are unusual;

(2) basic physical understanding of effects of changing concentrations of greenhouse gases;

(3) computer-based climate models which project dangerous future climate changes.

Nevertheless, the Endangerment Finding has spawned many Federal and state regulations in the United States, which have been mimicked in other developed countries and form the basis of the Paris Climate Accord. These regulations include the Clean Power Plan, the trading of carbon offsets, and higher taxes on gasoline and diesel fuels. They serve as justification for large subsidies and favoritism of wind, solar, and biomass to power the electrical grid. International organizations like the World Bank divert resources to fund these "sustainable" power sources and reject support to fossil fuel-based projects, thus denying the third world access to affordable and reliable energy.

[1] Apparently per the EPA just that anthropogenic 3.4% of total CO_2 emissions is a pollutant.
[2] Water is by far the most abundant greenhouse gas, but it is not evenly dispersed around the globe. "Well mixed" avoids the inconvenient inclusion of water in the EPA definition of harmful GHG.

The Endangerment Finding has also served to support a rapidly expanding climate research community, environmental-focused NGO, and green virtue signaling by industry. All have a high vested interest in supporting the concept of CO2 being the knob controlling climate and form a formidable barrier to objectivity. They feed off of the largesse of government funding.

Recent Temperature Changes are not unusual.

The earth has warmed about 1 ^{o}C since 1850, the beginning of the industrial age, with about half of this additional warmth occurring before 1950 when the increase in atmospheric CO2 began to be significant (figure 3). Going back further in time, indirect indicators of past temperature can be gleaned from proxies, such as analyzing the gas trapped in ice cores (figure 4). J. Storrs Hall observes "In fact for the entire Holocene — the period over which, by some odd coincidence, humanity developed agriculture and civilization — the temperature has been higher than now, and the trend over the past 4000 years is a marked decline. From this perspective, it's the [Little Ice Age] that was unusual, and the current warming trend simply represents a return to the mean."[v] Recent temperature changes are not unusual, in contrast to the contention of the Endangerment Finding.

We show later in this paper that additional warming from future anthropogenic CO2 emissions will be modest. Together, with increases of other GHG, we project an upper bound of +1 ^{o}C by 2100. Such modest warming does not endanger the public.

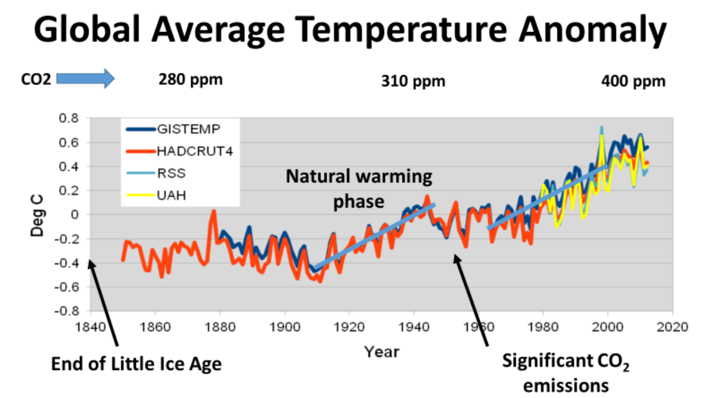

Figure 3 illustrates global surface temperature trends as varied from the average of temperature from 1979 to 1984. Data from the blue line (NASA's Goddard Institute of Space Technology) and the red line (the Hadley Climate Research Unit of the University of East Anglia) are from near ground-level measurements. Satellite analysis of temperature are shown by the turquoise line (Remote Sensing System) and the yellow line (University of Alabama-Huntsville).

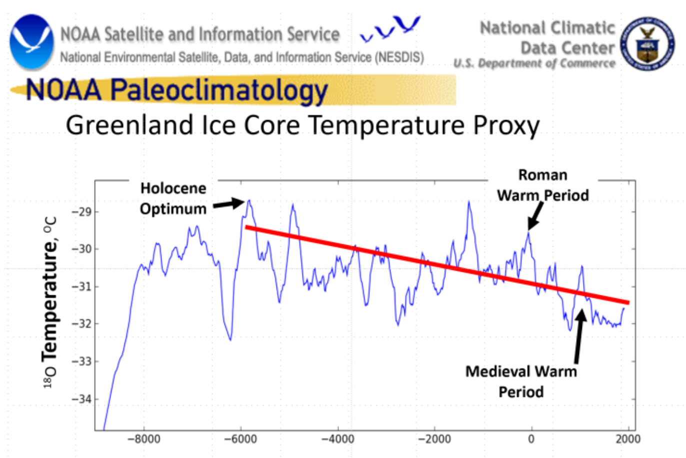

Figure 4. Proxy temperatures of the Holocene period gleaned from the ratio of $^{18}O/^{16}O$ isotopes. Chart notations and the red line trend have been added to the original graphic from NOAA

Effects of Greenhouse Gases:

The warming effect of a greenhouse gas follows a well-established logarithmic curve. Doubling the concentration of CO2, e.g. from 280 ppm to 560 ppm, will add a radiative forcing of ~3.7 W/m2 of warmth, or about 1.1 ^{o}C. This additional warmth will induce feedbacks that can enhance or diminish temperature. Increased atmospheric moisture is an example of the former and increased lower-level cloud cover is an example of the latter.

The net magnitude of the direct forcing from CO2 and feedbacks is described by a metric, Equilibrium Climate Sensitivity (ECS), derived from inputs of assumptions about feedbacks and other parameters into models. ECS is defined by the United Nations Intergovernmental Panel on Climate Change (IPCC) as the Global Mean Surface Temperature (GMST) increase that would eventually occur when a new climate equilibrium is achieved after a sudden doubling of atmospheric CO2 concentration. Not widely advertised to policy decision makers is that the idealized equilibrium state would not be achieved until the response by the oceans is stabilized, i.e. in more than 1000 years after CO2 is doubled. Through many iterations of IPCC technical assessment reports, the reported ECS has remained within a range of 1.5 to 4.5 ^{o}C, with the AR5 report issued in 2013 noting that information from multiple lines of evidence prevented it from reaching any conclusions regarding the mean value of this range. Yet ECS is the basis for the Endangerment Finding and the point of departure for calculating the Social Cost of Carbon, which in turn are used to justify economically harmful policy regulating GHG emissions.

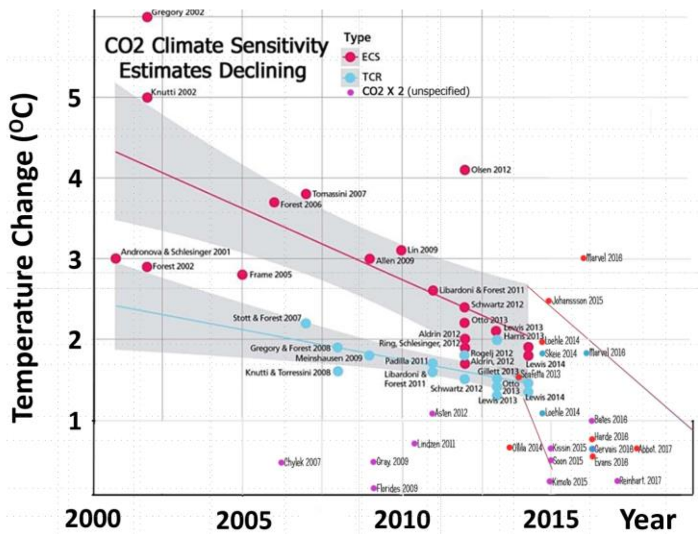

Figure 5. Scafetta, 2017 illustrates the diminished impact projection of the ECS and TCR metrics from calculated from studies between 2000 and 2017.

Multiple studies since 2013 suggest that the ECS is significantly lower than that suggested in the AR5 (figure 5), however neither the SCC assessments nor regulations have been updated to reflect this trend.

Another metric designed to reflect the impact of increasing atmospheric CO2 is the Transient Climate Response (TCR), defined as the GMST temperature change caused by a hypothetical atmospheric CO2 concentration rise rate of 1 percent per year (a 70-year time span). The TCR metric is much more reflective of reality vs. ECS, with a range of 1.0 to 2.5 ^{o}C reported in the AR5. Estimating TCR suffers from fewer difficulties in terms of state- or time-dependent feedbacks, and is less affected by uncertainty as to how much energy is taken up by the ocean.

Yet both ECS and TCR are based on models, which yield hypothetical projections that are not fully constrained by observation. These models are not validated by actual data, and therefore their use as the basis for policy is suspect. Studies that do heavily weigh actual data produce a much lower sensitivity to a doubling of CO2. Such studies are reflected in by the cluster of references in the lower right on figure 5.

Models Diverge from Reality

Models are useful tools to explore "what if" scenarios. In the case of climate, the impact of a doubling of CO2 in the atmosphere over time is explored in General Circulation Climate models. GCM input variations of the complex physics and chemistry processes of land masses, the oceans and atmosphere and the coupled, chaotic reaction of these features of the earth to radiation forcing from added GHG.

Figure 6 shows the results of 102 model runs of the Coupled Model Intercomparison Project, phase 5 (CMIP5). Their growing divergence from each other with time reflects the propagation of different assumptions of each model. This divergence from real-world data is also increasing, as shown in figure 6 by comparison with trends of weather balloon (reanalysis) and satellite temperature data that show only moderate warming during the 40-year satellite era.

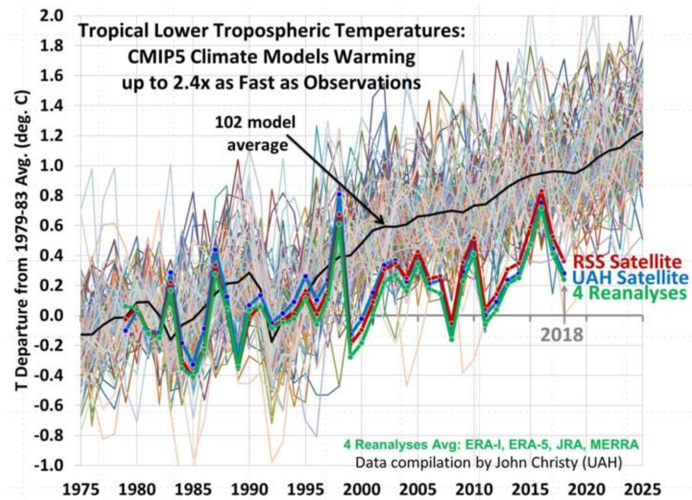

Figure 6

It has been noted that "These models completely lack some critically important climate processes and feedbacks, and represent some other critically important climate processes and feedbacks in grossly distorted manners to the extent that makes these models totally useless for any meaningful climate prediction."[vi] One example of this defect is their treatment of clouds.

Frank, 2019 concludes that "The resulting long-wave cloud forcing (LWCF) error introduces an annual average ±4 W/m2 uncertainty into the simulated tropospheric thermal energy flux. This annual ±4 W/m2 simulation uncertainty is ±114 × larger than the annual average ∼0.035 W/m2 change in tropospheric thermal energy flux produced by increasing GHG forcing since 1979.

Propagation of LWCF thermal energy flux error through the historically relevant [projections from 1988] to the RCP scenarios of the 2013 IPCC Fifth Assessment Report uncovers a ±15 C uncertainty in air temperature at the end of a centennial-scale projection.

The unavoidable conclusion is that an anthropogenic air temperature signal cannot have been, nor presently can be, evidenced in climate observables."[vii]

These data suggest that the climate crisis exists only in models, not in the real world. Yet the 102-model average is the initiation base for forming much of the regulations and policy concerning the use of fossil fuels and renewable energy. This despite the note in the IPCC third assessment report that "In climate research and modeling, we should recognize that we are dealing with a coupled non-linear chaotic system, and therefore that the long-term prediction of future climate states is not possible."[viii] Per Judith Curry, "GCMs have not been subject to the rigorous verification and validation that is the norm for engineering and regulatory science."[ix] Since none of these models have been validated, and their results are in wide disagreement, the IPCC has chosen to use the 102 model average to represent the future. This "averaging" is statistically meaningless since each model is based on different assumptions.

Misuse of Representative Concentration Pathways for Policy Decisions.

The uncertainty of climate models is propagated into Integrated Assessment Models that combine the temperature output of GCM from greenhouse gas forcing with a suite of future socio-economic assumptions including energy use, sea level rise, urban sprawl, agriculture patterns, and population growth.

The IPCC AR5 has selected four combinations of these factors to express Representative Concentration Pathways, each projecting a different radiative forcing by the year 2100. They are designated as RCP2.6 (2.6 W/m2), RCP4.5 (4.5 W/m2), RCP6.0 (6.0 W/m2), and RCP8.5 (8.5 W/m2). Weyant (2017) notes "The objective of these models is to project alternative future climates with and without various types of climate change policies in place in order to give policymakers at all levels of government and industry an idea of the stakes involved in deciding whether or not to implement various policies."[x] RCP2.6 represents significant mitigation of fossil fuel use, whereas the other pathways represent progressively less mitigation and more adaption to a warmer world.

Critically, the RCP were not intended to, nor do they in fact represent the real world. Pielke, 2020 points out "The RCPs were not intended to represent real-world plausibilities or the consistency of socio-economic and radiative forcing pathways…", and that "…subsequent research revealed some surprises indicating that the RCPs were not in fact representative of a literature or the real world."[xi]

Deviation from reality is particularly egregious for RCP8.5. It is based on a future that has high population, little technical advancement, and the combustion of quantities of fossil fuels that vastly exceed known reserves. RCP8.5 thus promotes apocalyptic levels of climate change. Despite these caveat's, RCP8.5 has inappropriately been designated as the Business as Usual scenario, and extensively misused "…as a baseline for projecting future climate impacts and evaluating policy options. The misuse of this particular scenario has been consequential, as it has been emphasized by the IPCC, the U.S. National Climate Assessment, and is pervasive in the underlying literature that these assessments rely upon. A Google Scholar search indicates almost 4,500 articles referring to RCP8.5 and "business as usual." (Pielke 2020)

Other examples of this misuse include the IPCC AR5, the IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, use as a basis for the Social Cost of Carbon calculus, and the U.S. National Climate Assessment (2018) that used the implausible warming projected by RCP8.5 to suggest unrealistic sea level rise.

Per Pielke, 2020, "The consequences of RCP scenario misuse include a myopic perspective on alternative futures and a correspondingly limited view on policy alternatives, the creation of a vast academic literature with little to no connection to the real world, and an unwarranted emphasis on apocalyptic climate futures that influences public and policy maker perspectives and the climate policy discourse in broader society.", and "The scientific literature has become imbalanced in an apocalyptic direction."

Unfortunately, this distortion will be extended in the forthcoming IPCC Sixth Assessment Report, where the RCP8.5 will be reincarnated as SSP5-8.5.

Policy based on reality: The Right Climate Stuff Transient Climate Sensitivity

Clearly, a better metric, reflecting actual data, is needed to guide decisions on policy and regulation. The Right Climate Stuff study group determined that such a metric could, in fact, be derived based on empirical evidence. The result is the Transient Climate Sensitivity, (TCS) metric, which we define as the GMST increase that will occur due to the doubling of atmospheric CO2 concentration from the level in

1850 (284.7 ppm) based on the actual concentration rise history from 1850. We estimate that it will take about 230 years, i.e. until about 2080, for this to occur.

While the theorized effects of atmospheric GHG concentration are relatively simple to model, the natural processes and feedbacks affecting climate change are not well-understood and are questionably accounted for in current General Circulation Models (GCM). The aforementioned problem with clouds is one prime example, as are the effects of solar variation and natural cycles reflected in coupled ocean-atmospheric "oscillations". Examples of the latter phenomena are the Atlantic Multi-decadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO), and the Indian Ocean Dipole (IOD). The signals from large volcano eruptions and the El Nino Southern Oscillation, although strong, are easily recognized and can be segregated from temperature trend data to discern the impact of rising GHG on temperature.

The historic temperature data results from the influence of both natural processes and human activity. As shown in figure 3, these natural processes dominated the temperature signal until global industrialization began in earnest around 1950. These data can be used as the basis for establishing an upper bound of future warming from anthropogenic GHG emissions using the projected growth in CO2 and a factor "β" of constant proportion that would encompass the effect of other elements in the signal. β = 0.5 was estimated from analysis of IPCC AR5 Report data on radiative forcing of atmospheric aerosols and GHG other than CO2 during the 1750 to 2010 time period. By using β, determining the exact attribution of each of forcing and feedback elements other than CO2 would not be needed to determine the upper bound of the likely temperature rise to 2100.

A simple model using this baseline and the algebraic equation below projects the Global Mean Surface Temperature (GMST) shown in figure 7:

$$GMST(year) = GMST(1850) + TCS(1+\beta)LOG[CO2(year)/CO2(1850)]/LOG[2] + 0.021(year-1850)/155$$

The equation was rigorously derived from first principles and agrees with the available 165 years of data on atmospheric CO2 concentrations and earth surface temperature. Therefore, we claim this is a validated climate model suitable for forecasting GMST change as a function of atmospheric CO2 concentration.

The derivation of this equation is presented in Doiron (2016)[xii]. The last term accounts for the warming due to Total Solar Insolation (TSI) increase from 1850 to 2005 and becomes a constant 0.021 ^{o}C for years after 2005. This provides some conservatism in the equation for projections after 2005, as TSI rise ended in about 2005 and is forecast to decrease for the next 200 years or more. For an even simpler equation, this last term can be ignored as it accounts for only 0.021 ^{o}C of the GMST rise since 1850.

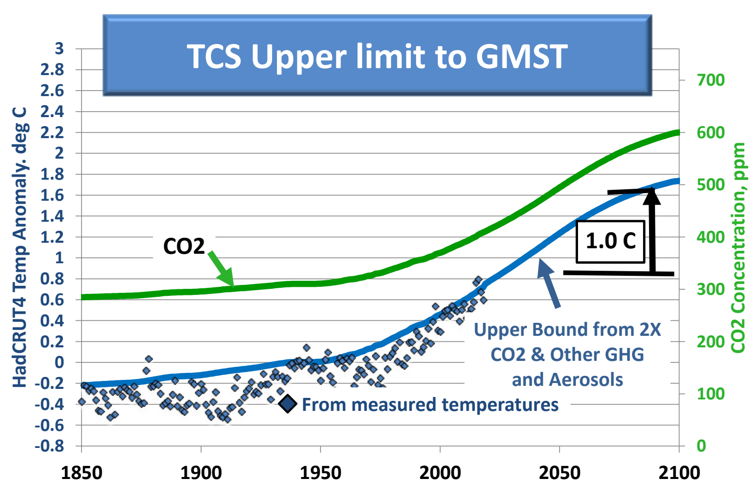

Figure 7. The blue line is the TCS due to a doubling of atmospheric CO2 from the preindustrial level of 284.7 ppm in 1850. HadCRUT4 temperatures above the blue line reflect years having super El Niños.

The model was validated by determining the constant TCS(1+β) = 1.8 ºC, which provided a best fit of the equation to the HadCRUT4 temperature anomaly data set. The changes in this global earth surface temperature anomaly provides an approximation to the actual GMST change over time.

β includes the influence of other greenhouse gases and aerosols, and presumes the influence of natural processes will continue with the same pattern as they have since 1850. This assumption is likely not to be correct as "All three modes of natural climate variability – volcanoes, solar, and internal variability – are expected to act in the direction of cooling during the 30-year period from 2020 to 2050."[xiii] The uncertainty in β does not affect the uncertainty in the constant TCS(1+β) determined from historical GMST data since it reflects a conservative upper bound.

The baseline for the TCS metric requires temperature data that precedes satellite measurements. Of the available temperature datasets, we chose that from the Hadley Climate Research Unit, HadCRUT4, as it extends the furthest back in time in the historical record, to 1850.

Historical values for annual atmospheric CO_2 concentrations come from actual measurements starting in 1958 from the Mauna Loa Observatory in Hawaii.[xiv] CO_2 levels from 1850 through 1957 are derived from the Law Dome ice cores samples.[xv]

The foundation for projected CO_2 emissions is the US Energy Information Administration (EIA) data on current world-wide reserves of coal, oil and natural gas,[xvi] with extraction constrained by the economics of recovery. Since 1980, when accurate data on world-wide fossil fuel production became available, the annual rise in atmospheric CO_2 concentration has been a consistent and constant 48 percent of CO_2 emitted from burning the annual fossil fuel production, with the balance being absorbed by the oceans and biosphere. We assumed all this production was burned in the year produced and used the 48 percent factor to compute future atmospheric CO_2 levels.

Analysis by Stegemeier suggest that, when recovered and burned, these reserves will result in a maximum atmospheric CO_2 concentration of 600 ppm in about 2100.[xvii] Our assumptions about fossil fuel use are resource constrained; details can be found in Doiron (2014).[xviii] This conclusion is supported by others, as reported by Wang (2016)[xix]; figure 8 is from this paper. This level contrasts with the totally unrealistic level of 889 ppm of CO_2 embedded in the IPCC RCP8.5 scenario; fossil fuel reserves to reach this level do not exist. The RCP are based on assumptions of fossil fuel demand and are not constrained by the reality of economically extractable reserves.

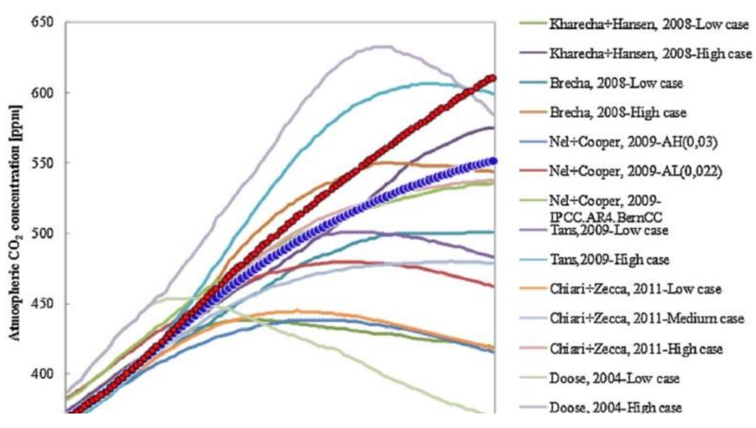

Figure 8 from Wang (2016). Original caption: Fig. 5. Comparison of atmospheric CO_2 concentration under SD [supply-driven] scenarios with those from a range of current literature that examines 'supply-driven' fossil fuel emission scenarios.

Our assumptions on CO2 emissions and atmospheric accumulation presume no effective world-wide CO2 emission controls are enforced, and that a gradual market-driven transition to non-CO2 emitting energy sources will be occur beginning about 2050 to supply growing world-wide energy demand for affordable, reliable, and abundant electricity. In 2100, the net forcing from 600 ppm of atmospheric CO2 would be 6.0 W/m2, which would be equivalent to the IPCC RCP6.0, but without the social-economic constraints and economic penalties embedded in this IPCC pathway. This radiative forcing translates to a maximum temperature rise of 1.0 ^{o}C from the present to 2100.

Conclusions:

Significant, economically-damaging policy decisions are being made based on alarming projections of future warming from anthropogenic emissions of GHG. These projections are based on GCM and scenarios such as Representative Climate Pathways that do not reflect reality yet are misrepresented as "business as usual."

Projections based on actual data, such as TRCS Transient Climate Sensitivity metric, indicate that the additional warming to 2100 will be a modest 1 ^{o}C, and will be peak under 2 ^{o}C during the next century.

There remains a high degree of uncertainty in climate science. Since the warming before 2050 will be modest or even exhibit a slight cooling in the next 30 years, there is ample time for research to resolve uncertainties of both climate science and mitigation and adaptation proposals. Rash forcing of societies into unreliable and expensive "sustainable" energy sources are thus not warranted.

The benefits from such modest warming are many, including increased plant productivity fertilized by atmospheric CO2. Projected increases of severe weather events due to a warming world have not materialized.

We recommend that climate policy be required to be based only on validated data that is available for public examination. It appears that the Social Cost of Carbon calculus should be reexamined factoring in modest warming and its benefits; it should likely be renamed the Social Benefits of Carbon.

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[i] https://www.nasa.gov/feature/goddard/2016/carbon-dioxide-fertilization-greening-earth

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[iv] Houghton, 2007

[v] J. Storrs Hall, on December 5th, 2009 http://www.foresight.org/nanodot/?p=3553

[vi] Tony Thomas quoting from the English translation of Mototaka Nakamura's book, "Confessions of a Climate Scientist: the Global Warming Hypothesis is an Unproven Hypothesis" https://quadrant.org.au/opinion/doomed-planet/2019/09/a-climate-modeller-spills-the-beans/

[vii] Patrick Frank, *Propagation of Error and the Reliability of Global Air Temperature Projections,* Front. Earth Sci., 06 September 2019 | https://doi.org/10.3389/feart.2019.00223

[viii] IPCC third assessment report (2001), Chapter 14, Section 14.2.2.2.

[ix] Judith Curry, Climate Models for the Layman, Copyright 2017 The Global Warming Policy Foundation

[x] Weyant, J. (2017). Some contributions of integrated assessment models of global climate change. Review of Environmental Economics and Policy, 11(1), 115-137.

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[xii]Doiron, Harold, *Recommendations to the Trump Transition Team Investigating Actions to Take at the Environmental Protection Agency* (November 30, 2016) https://www.therightclimatestuff.com/trcs-reports.html

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[xvi] EIA/DOE Energy Information Administration, (2009) BP Statistical Review , BP p.l.c., BP Statistical Review of World Energy June 2008.

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