

Predictive Connection for 2100 between Atmospheric Carbon, Global Warming and Ocean Height Based on Climate History

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Many recent climate panels and committees have predicted a one and a half (1.5°C) to two degrees (2°C) Celsius as an achievable global limit to climate change [1]. Instead, this review has found that observationally informed projections of climate science underlying climate change offer a different outlook for the most likely outcome for 2100 of five to six-degree (5-6°C) increase as "most accurate" with regard to present trends, climate history and models [2]. The most significant result from the review is a quantitative, linear global temperature link to carbon dioxide levels, which has a short temporal feedback loop. The Vostok ice core temperature and CO₂ values for the past 420,000 years, with sea level estimates have produced "Hansen's Graph" [3]. Analysis results in an equation for global average temperature change and an indebted sea level rise, from any CO₂ change. The best-performing climate change models and observational analysis project more warming than the average model often relied upon [4]. World atmosphere, temperature, and sea level trends for 2100 and beyond are examined. A CO₂ experimental analysis proves its dramatic heat-entrapment versus air which relates to the global atmospheric system. Policy-relevant climate adaptation, including carbon capture, positive individual action, zero and negative emissions are reviewed, including Hansen (1988) projected temperature increase for 2019.

Keywords: *Climate change; temperature; thermal forcing; carbon dioxide; PETM; carbon emission; carbon capture.*

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1. INTRODUCTION

Fossil fuel carbon emissions and emission rates are now both increasing annually in several major countries in the world.

The unmitigated growth of carbon emissions worldwide reached a record 37 billion tons of CO₂ (in one year) at the end of 2018, with the U.S, India and China leading the increase [5]. The total carbon emission growth in 2017 was only 1.7 percent while carbon growth rate for 2018 shown in Fig. 1 increased 2.7 percent. As for China, coal accounts for about 60 percent of China's total energy consumption [6].

Fig. 2 is a closeup of the world's steadily increasing, heat-trapping, atmospheric CO₂,

recorded through NOAA's Earth System Research Laboratory at the Hawaiian Mauna Loa Observatory since 1959. The monthly values are seen in Fig. 2 as seasonally oscillating red dots with dashes in between. The black dotted line with the square symbols represents the *averaging correction* for the seasonal cycle. The latter is determined as a moving average of seven adjacent seasonal cycles centered on the month to be corrected, except for the first and last three and one-half years of the record, where the seasonal cycle has been averaged over the first and last seven years, respectively. The amount of CO₂ emissions from fossil fuel burning comes from the Open-source Data Inventory for Anthropogenic CO₂ (ODIAC) and is based on economic data. Most of the emissions are in the Northern Hemisphere [8].

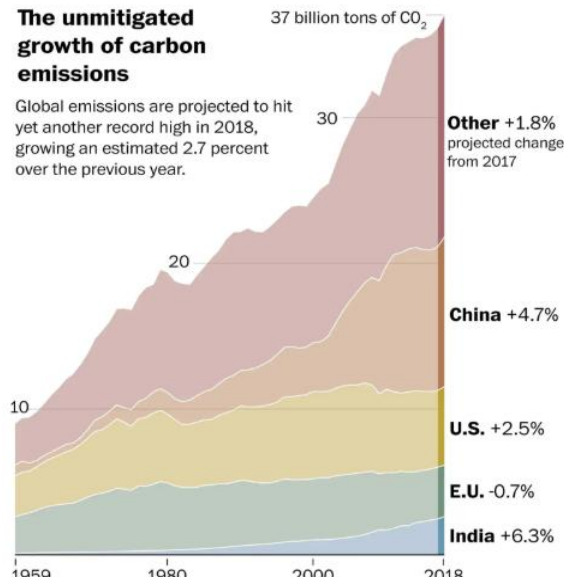


Fig. 1. Annual carbon dioxide emissions 1959-2018 [5]

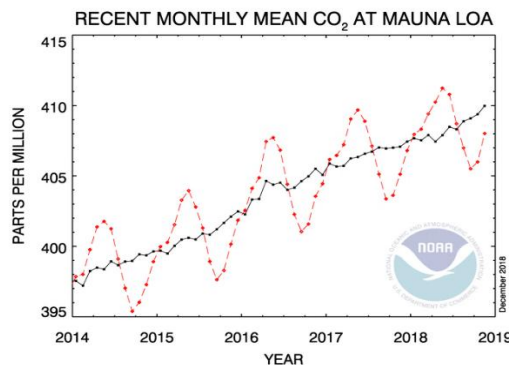


Fig. 2. NOAA global CO₂ records from Hawaii [7]

2. HISTORIC CO₂ AND TEMPERATURE CORRELATION

Not only does such increasing carbon pollution stay in the atmosphere about 100 years (CO₂ from early Model T Fords still lingers in the air today) but as a major greenhouse gas, there is overwhelming evidence that it directly relates to the documented global temperature increase [9]. This can be further corroborated with the historical records of carbon dioxide from Antarctic ice core analysis of air bubbles, going back, as far as 800,000 years (800 ky) [10].

In Fig. 3, the cumulative gigatons (10⁹ tons) of carbon from fuels already burned, known reserves, and additional future emissions of oil, gas, and coal. The equivalent relationship of 1 ppm of CO₂ added to the atmosphere is equal to an additional 2.12 billion tons of carbon, or times 3.67 to equal about 7.77 billion tons of CO₂ [12].

Though CO₂ is well-known to be a long wavelength-trapping hothouse gas that absorbs heat, [13] some skeptics argue that CO₂ data

from ice cores seem to trail temperature increases in the distant past, which has since been physically explained by the way air is trapped in layers of ice cores. “Scientists use air trapped in the ice to determine the CO₂ levels of past climates, whereas they use the ice itself to determine temperature. But because air diffuses rapidly through the ice pack, those air bubbles are younger than the ice surrounding them” and therefore, can affect the *perceived* time correlation [14].

Fig. 4 is a plot of the very similar temperature and CO₂ data from air bubble analysis of the Vostok Station Antarctica ice core. In 1999, the Vostok ice core 420,000-year record of carbon dioxide was published by Petit, et al. [16]. Besides matching the temperature changes closely, one major fact in Fig. 4 is the maximum atmospheric concentration of carbon dioxide over the past 420,000 years. *The CO₂ levels clearly have never exceeded 300 ppm worldwide even through four ice ages.* However now, late in the Holocene, global CO₂ level has done so, even surpassing 410 ppm (Fig. 5) [17].

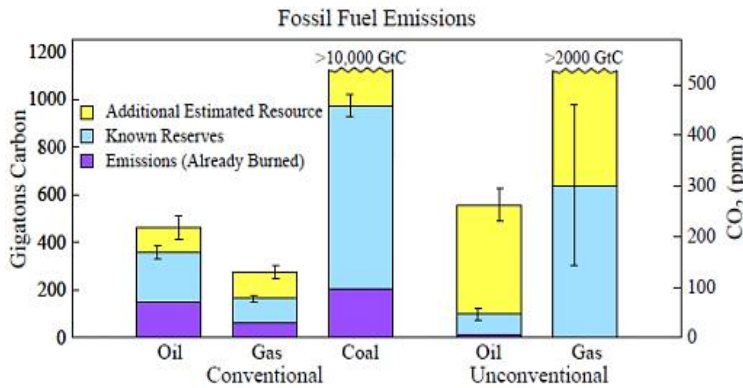


Fig. 3. World cumulative fossil fuel emissions [11]

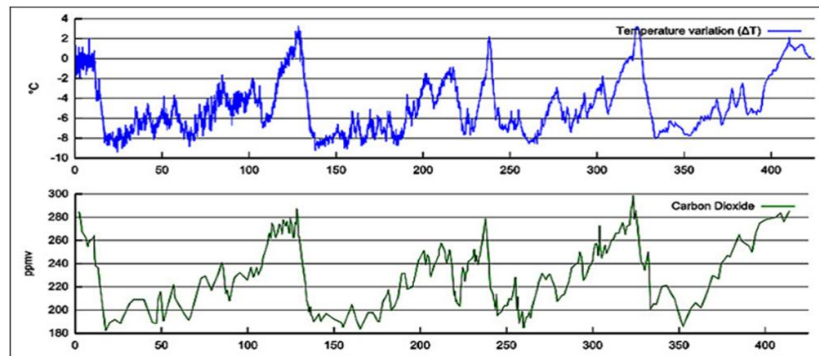


Fig. 4. Global temperature and CO₂ levels for the past 420,000 years [15]

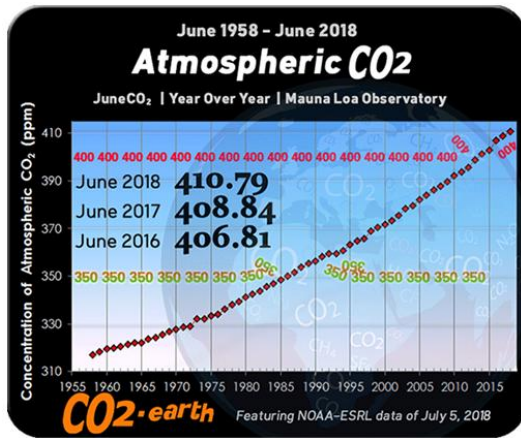


Fig. 5. Global CO₂ levels, 1958 to 2018 [17]

To give us a broader picture of the temperature variations over the past 500 million years, Fig. 6 also illustrates the present (human-dominated) Holocene epoch previously mentioned and Pleistocene epoch [18]. Moving to the present, Fig. 6 is a plot on a logarithmic scale with the most recent data points in the Holocene epoch on the right, showing the remarkably fortuitous temperature stability of the past 10,000 years

and a projection of +5°C (9°F) for 2100 (red dot).

Fig. 7 is the graph of atmospheric carbon dioxide and global temperature (Celsius = Centigrade) based on deuterium concentration in the ice core in the vicinity of air bubbles that are sampled for CO₂ levels. Furthermore, it can be examined closely for the previously noted leading temperature which is followed by a remarkably close, matching trend in CO₂ at a later date in time. However, *the opposite is true*: red-lined CO₂ also occurs prior to the blue temperature trend line *implying causality as it entrains temperature levels*. Therefore, a significant *forward and reverse* temporal correlation between atmospheric temperature and CO₂ levels is apparent. In other words, whichever variable changes first, historically the other will invariably follow in the *same direction* in a proportional manner [20]. With that understanding, the red line on the far right of Fig. 7, shooting up at the “0” Years Before Present is projecting a corresponding +6°C temperature for the future earth’s atmosphere, which will inevitably be realized by the turn of the century or very early in the 22nd century, as a consequence of the “business as usual” scenario.

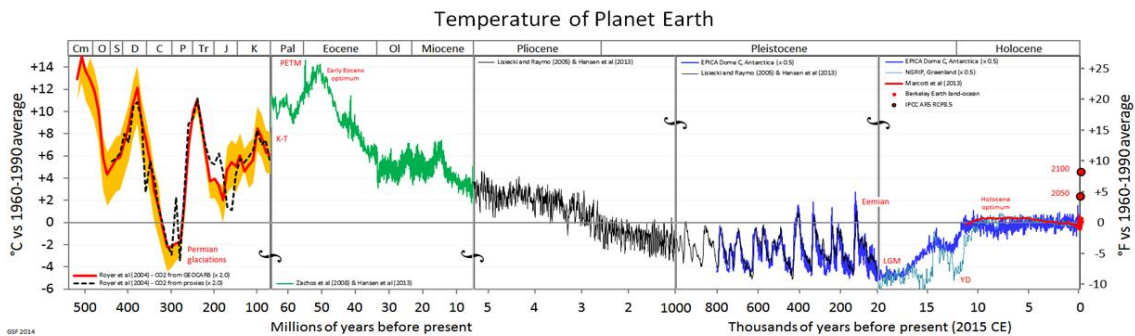


Fig. 6. Geological epochs and earth atmospheric temperature (°C, °F vs. 1960-1990 avg.) [18]

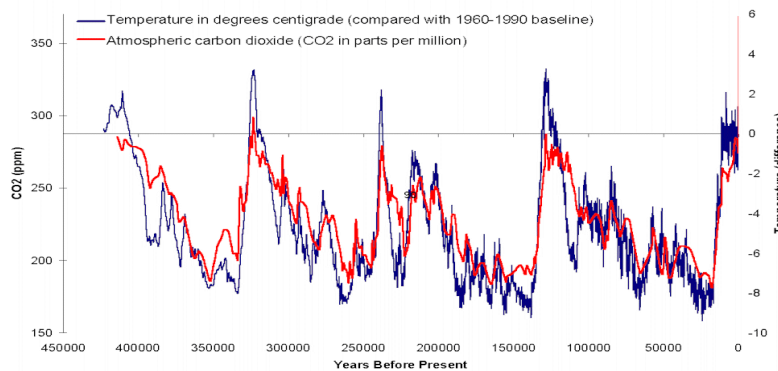


Fig. 7. CO₂ and temperature over past 420,000 years [19]

Such a tight correlation can be understood scientifically in terms of climate forcing or thermal forcing which generates a real force, the same way a mechanical force causes an object to move.

This positive climate or radiative forcing involves shifting the balance, due to an increase in heat-trapping gasses (often labeled “GHG” for “Green House Gasses”), such that the world gains heat and the climate warms (Fig. 8). As the climate warms, the earth will emit more infrared (IR) radiation to space, as a response to the radiative forcing. This extra energy is quantified in watts per meter squared (W/m^2) entering the globe near the top of the atmosphere.

Warming will continue, along with more intense and energetic weather oscillations, *until a new equilibrium level is achieved* between energy gained and lost at the top of the atmosphere. In the meantime, the earth is now experiencing wider swings of hot and cold weather than ever before. As early as 1967, climate models were linking increases in atmospheric CO_2 to global temperature [21].

Comparing Fig. 8 to Fig. 7 is an important exercise for climate denialists since it is from a *separate ice core* of Antarctica, the Dome C, that stretches back to 800 ky from the present. The Fig. 8 graph includes all three major GHG (CH_4 , NO_2 , CO_2) forcing agents. Here again is the remarkably close correlation that is undeniable between the GHG energy density (green) in watts per square meter (W/m^2) and the global temperature (red). It can be reasonably expected that as the green line (right side) launches into the $4 W/m^2$ region far above previous levels for the 2000 Date in Fig. 8, the global temperature (left side) will follow the same pattern to an equivalent level *in a short amount of time*. Here the ratio of temperature and forcing is about $1.5^\circ C$ to each W/m^2 reaching the top of the atmosphere. According to the ordinate axis in Fig. 8, this GHG climate forcing level on the far-right side of the graph independently corresponds to a global temperature of $6^\circ C$ on the far-left side of the graph [23].

How scientists and the public could have overlooked this 800 ky correlation and therefore, a priceless, quantitative prediction of future global warming is perplexing and unexplainable.

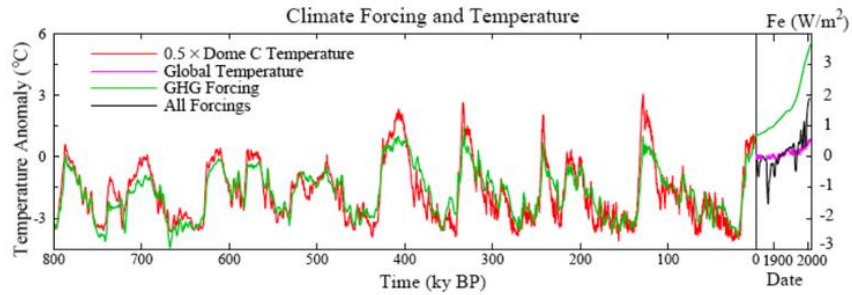


Fig. 8. Climate forcing (W/m^2) of CH_4 , N_2O , CO_2 and Global temperature (from Dome C ice core data) for the past 800,000 years [22]

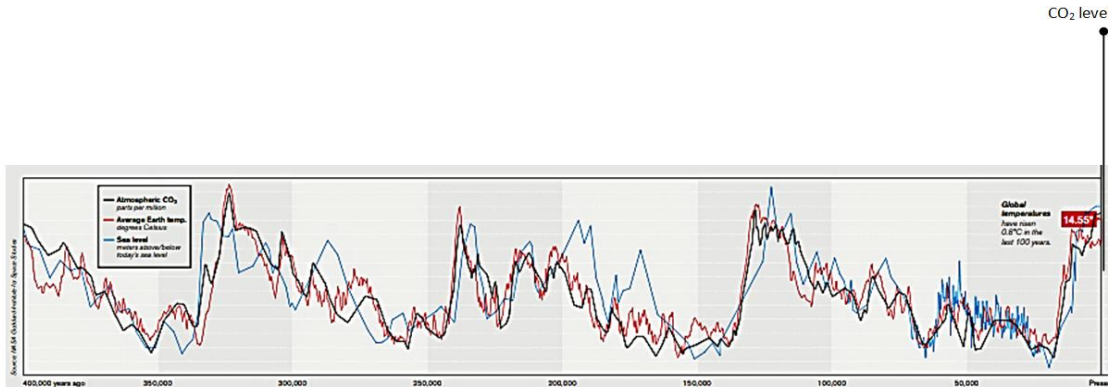


Fig. 9. “Hansen Graph” — Average global CO_2 , temperature and sea level data compared to year 1900 baseline ($14.55^\circ C$) [24]

3. HOW SEA LEVEL VARIES WITH CO₂, TEMPERATURE

Fig. 9 is the best compilation, provided by James Hansen in 2006, including the off-the-chart famous “hockey stick” data point of 377 ppm (labeled “CO₂ level”) in 2006, up to past 410 ppm in 2019. The CO₂ data point in question is significantly far above the highest point in Fig. 9 and also above the graph in Fig. 7, equaling a huge 45% increase in worldwide carbon dioxide levels since 1850 [24]. All three Figs. 7, 8 and 9 are in agreement with the same temperature projections of a corresponding 6°C temperature increase for 2100 seen in Figs. 11, 15 and 16. Hansen at the Goddard Institute of Space Studies used the 1999 Vostok data, to add temperature data with calculated historic sea levels, along with concurrent carbon dioxide levels for the same period, matching maximum and minimum level perhaps in order to provide a similar visible range of the three variables on the same graph.

Thus, Fig. 9 is a further development of an entrainment correlation between temperature and GHG forcing, since sea level also shows a tight correlation to both variables. Massachusetts Institute of Technology (MIT) is credited with the editorial choice of the Technology Review journal to include the Fig. 10 Table of data points for the three variables (CO₂, temperature, sea level) from Fig. 9. It is quite rare that such a Table of data points is included in journal articles anymore but here it was essential for conveying the exacting relationship between the three variables. Fig. 10 offers such an unexpectedly linear, proportional relationship of the three variables (carbon dioxide, temperature, sea level) with whole numbers, in black, red, and blue, that the Table data can be converted into an equation and thereby create a “Key” to Fig. 9.

Thus, a compact form of Figs. 9 and 10 can be expressed, after due examination of the three columns, in a convenient three-variable equation, using real values for the *magnitude* of the variables,

$$\Delta C / 20 = \Delta T = \Delta S / 20 \tag{1}$$

where ΔC is the +/- change in CO₂ in ppm, with a corresponding ΔT in degrees Celsius, and ΔS being sea level in meters. This becomes very analytical with the (before 1950) historically stable, assumed “zero values” of S₀ = 0 m, C₀ of

290 ppm, and T₀ = 15°C from Fig. 10, we find that putting those Δ values in Equation (1), the next scaling point for the Y-axis can be found only for a *limited extrapolated range*. Equation (2) represents a more convenient form of Equation (1), also expressed as a “Key” with conversion terms equaling each other as Hansen found in Fig. 10. Therefore, a composite graph and composite equation resulting from Fig. 9 and 10 can be drawn to compress the data into a compact form, for a corresponding variable change:

$$\pm (20 \text{ ppm CO}_2 \equiv 1^\circ \text{C} \equiv 20 \text{ m sea level}) \tag{2}$$

Such a composite form of Figs. 9 and 10 is presented in Fig. 11, which was initially created in 2006, faithfully representing the information conveyed by Hansen and the Vostok record. Note that global sea level rise has a maximum value based on the total amount of land-locked glacial ice. Temperature rise is also expected to become less linearly dependent on CO₂ as the rise surpasses +10°C perhaps but *may not have a maximum*. This graphic of the “Great Acceleration” of climate change has been updated since then on the Integrity Research Institute’s homepage, which also has a high-resolution version of Fig. 9 [25].

Carbon dioxide p.p.m.	Average Earth temp. °C	Sea level meters
300	15.5	10
290	15.0	0
280	14.5	-10
270	14.0	-20
260	13.5	-30
250	13.0	-40
240	12.5	-50
230	12.0	-60
220	11.5	-70
210	11.0	-80
200	10.5	-90
190	10.0	-100
180	9.5	-110
170	9.0	-120

Fig. 10. Hansen’s data table accompanying Fig. 9 [24]

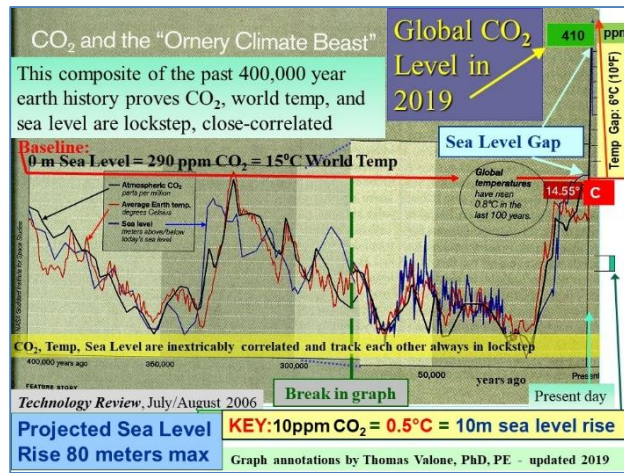


Fig. 11. Annotated update of Hansen graph for 2019 [25]

4. HANSEN'S PROVOCATIVE 1988 NASA Paper

Recently called the most accurate 30-year climate projection that any climatologist has achieved, James Hansen's famous paper of 1988, was *the first* to contain predictions of a global "greenhouse effect" from a 3-D model developed at the NASA Goddard Institute for Space Studies but using the onerous phrase "climate forcing." [26] Since such a concept was not yet accepted by the public, the paper was shunned by academic critics and Hansen was declared to be "wrong" by most of the media at the time.

However, analyzing Hansen's projection reproduced in its original form in Fig. 12 from that 1988 paper (Fig. 3 (a), p. 9247), we easily

discover a high degree of accuracy for temperature prediction, with the benefit of present-day global temperature reports. The three lines for Hansen's data projections are Scenario A with an upper -o- line, B being the middle line -Δ-, and C with -Y- in the lower line of Fig. 12, with Scenario B found to be right on target for 2019.

In Fig. 13, a 2018 evaluation of Hansen's '88 paper offered some averaging information and comparative climate modeling. This 2018 report, thirty years after Hansen's original projections, show that his orange, middle line of Scenario B to be the most accurate prediction of the rise in global temperature in 2018. [27] We find that most sources agree that the earth has reached a 1°C increase in worldwide average temperature from the 1950-1960 baseline.

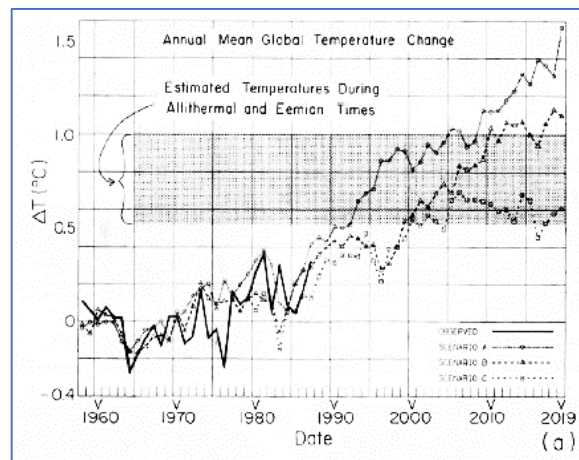


Fig. 12. Original Hansen temperature projection to 2019 [26]

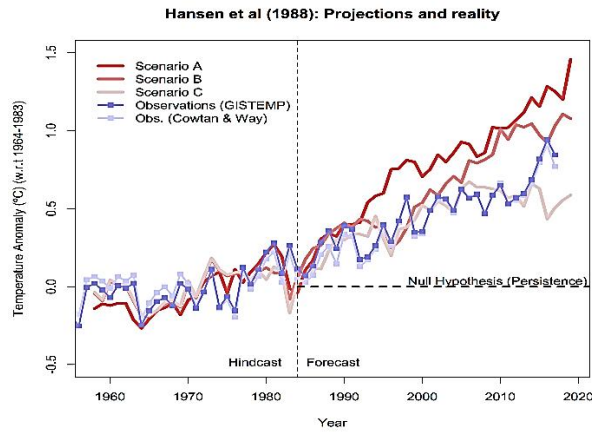


Fig. 13. 2018 evaluation of Hansen’s projection [27]

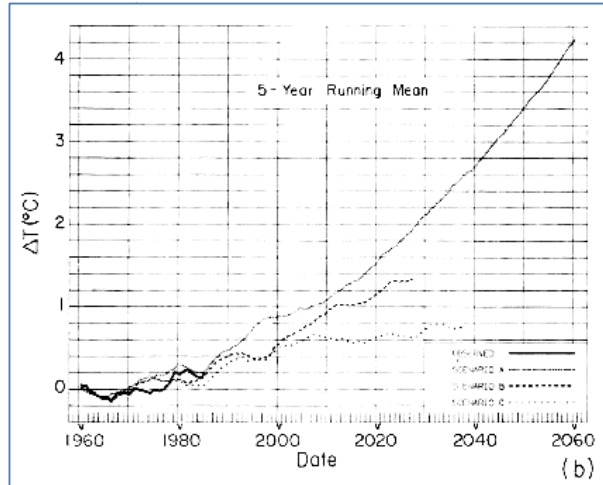


Fig. 14. Original Hansen temperature projection to 2060 [27]

Therefore, an updated assessment actually vindicates Hansen’s Scenario B projection to 2019 in Fig. 12, which provided ample motivation for this present author’s review. Hansen’s courageous 1988 paper is the major reason for publication of this review paper in 2019, in honor of Hansen’s pioneering accuracy in the highly controversial science of climatology and temperature projection three decades ago.

Even more impressive is Fig. 14, an astonishing projection to 2060 by Hansen, from the 1988 article (Fig. 3 (b), p. 9247), though it was more speculative during that era, by calculating such large future temperature change for way in the future, based on Scenario A. However, Hansen’s graph in Fig. 14 is *presently more likely with today’s climate predictions than any other previously cited climate reports*, matching

business-as-usual climate projections, with no reductions, e.g., IPCC RCP8.5. [28] The most realistic climate models today agree with Hansen’s 1988 projection to 2060.

5. RECENT CLIMATE MODEL PROJECTIONS

Global temperature also is a fundamental climate metric highly correlated with sea level, which implies that keeping shorelines near their present location requires keeping global temperature within or close to its preindustrial Holocene range. However, global temperature excluding short-term variability now exceeds +1°C relative to the 1880–1920 mean and annual 2018 global temperature was almost +1.3°C, which is right on the mark with Hansen’s Scenario A or B in Fig. 12 for 2019.

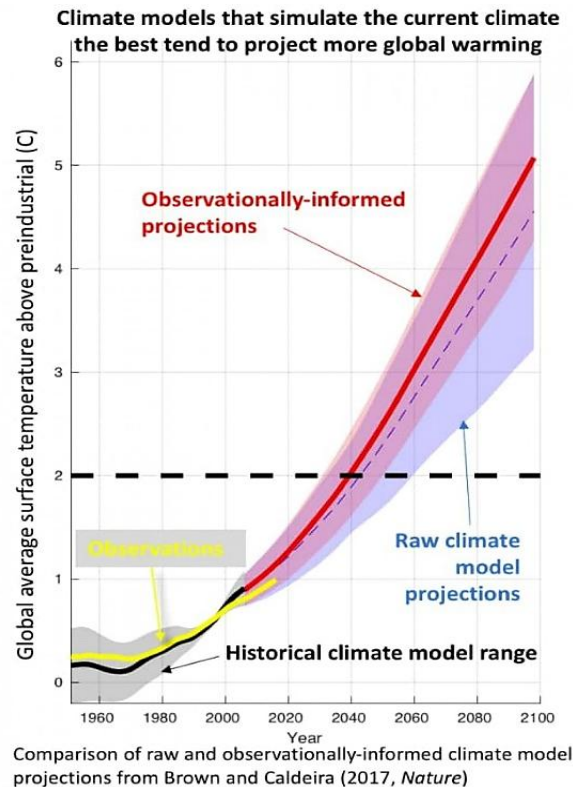


Fig. 15. Stanford University Global temperature to 2100 [31]

It has been shown, as Hansen point out, “that global temperature has risen well out of the Holocene range and Earth is now as warm as it was during the prior (Eemian) interglacial period, when sea level reached 6 to 9 meters higher than today. Further, earth is out of energy balance with present atmospheric composition, implying that more warming is in the pipeline ... [and] the growth rate of greenhouse gas climate forcing has accelerated markedly in the past decade” [29].

Probably the most provocative and disturbing for any audience is a composite temperature trend graph which “reduces uncertainty” (says *Nature*’s editorial introduction) in Fig. 15. The best performing models are shown in dark red, projecting above 5°C. Climate models generally agree that greenhouse-gas emissions will continue to raise global temperatures, but the amount of warming predicted varies considerably. To narrow the field of probability, Patrick Brown and Ken Caldeira at the Carnegie Institution for Science in Stanford, California, assessed a plethora of current climate models. They found that some models more accurately simulate the amount of radiation entering and

leaving the atmosphere, a flow known as Earth’s energy budget, than others [30].

The team combined a number of models but reduced the influence of those that less realistically represent the energy budget. It predicts at least a *five degree* (5°C) *increase* by 2100 (red line) with an uncertainty range that reaches 6°C. Much is known about the present exponential trend in temperature up to 2020 but with Brown and Caldeira’s integrated approach, the climate models are merged to include “observationally-informed projections” up to 2100. Thus, an averaging or median is achieved that statistically ensures high reliability and assurance of accuracy [31]. Though it has been subject to a few online climate denials, the majority of reviewers have embraced Brown and Caldeira’s conclusions, which, as seen from ice core data, is more consistent with the integrated relationship between CO₂ and global temperature in the earth’s past. A summary (2017) YouTube video by coauthor Patrick Brown, and <https://patrickbrown.org/>, provide additional support for their *Nature* article. These findings are a rude awakening. The extreme conditions which we know are inherent in such a

five to six degrees (5-6°C) increase have been well documented over ten (10) years ago. A National Geographic 90-minute online video is one of the best, starting with the usual 15°C baseline which was the stable global average up until around 1980 [32].

6. RECENT TRENDS OF THE EARTH'S LARGEST ICE SHEETS

A 2019 report has found that at least one-third of the Himalayan glaciers, among the world's most vital water resources, are projected to melt by the end of this century even if the most ambitious steps to halt global warming are achieved. Furthermore, as we now understand, nothing major can apparently be done to impact global greenhouse gas emissions reduction in just a few decades. Therefore, glacier melting is projected to continue at the present pace which will cause the loss to rise to two-thirds of all Himalayan glaciers by 2100, says "The Hindu Kush Himalaya Assessment." [33] Mass emigration from India as a result of such an environmental stress from the Himalayan region cannot be underestimated [34].

Arctic sea ice (Fig. 16) has also been undergoing a steady decline (12.8%/decade) since the middle of the last century and monitored by satellite starting in 1979 [35]. Based on an assessment of the subset of models that most closely reproduce the climatological mean state and 1979 to 2012 trend of Arctic sea ice extent, a *nearly ice-free* Arctic Ocean in September before mid-century is likely with high GHG emission scenarios. The total volume of ice in September, the lowest ice month, declined by 78 percent between 1979 and 2012, the record low year, according to an analysis by the University of

Washington in Seattle, Pan-Arctic Ice Ocean Modeling and Assimilation System, a top source for tracking ice volume. Furthermore, Veerabhadran Ramanathan, at the Scripps Institution of Oceanography, states that entirely ice-free summers, could add another half-degree Celsius (0.9 degrees Fahrenheit) of warming on top of whatever else the planet has experienced by that time. This is a well-known phenomenon that a dark, blue ocean will *absorb twice as much sunlight* as a white, ice-covered Arctic ocean [36].

Arctic land-based permafrost also holds more than twice as much carbon in its frozen soil as earth's atmosphere and is already melting as temperature rises, releasing its trapped carbon. In one 2015 summer, over nine (9) million hectares of forest in Alaska's and Canada's Arctic region burned, which set a record. Studied by the Woods Hole Research Center in Falmouth, Massachusetts, destabilizing the soil with such fires and creating microponds, the fires thawed permafrost in a wild zigzag pattern to over a meter deep, releasing locked methane [37]. In 2018, sixty wildfires raged in the Swedish Arctic Circle after a hot, dry summer. This appears to be a trend as more and bigger blazes are reported in other far northern regions like Greenland, Alaska, Siberia, Ukraine, and Canada. Furthermore, 2017 was the worst fire year in Europe's history, causing destruction to thousands of hectares of forest and cropland in Portugal, Spain and Italy, as late as November [38]. In 2019, New Zealand reported record wildfires burning for over a month, covering more than 2,300 hectares (5,700 acres) with a 25-kilometer perimeter, with the evacuation of thousands of residents [39].

Average Monthly Arctic Sea-Ice Extent (September 1979–2016)*

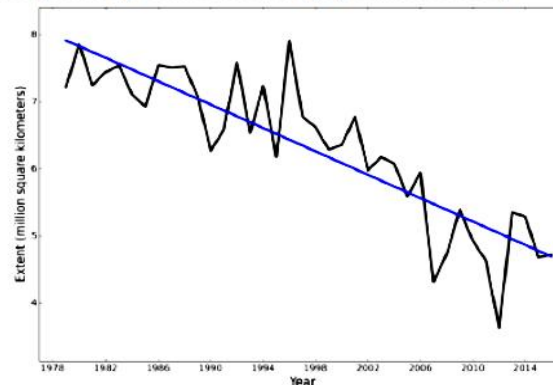


Fig. 16. Arctic Sea ice loss in million square kilometers [35]

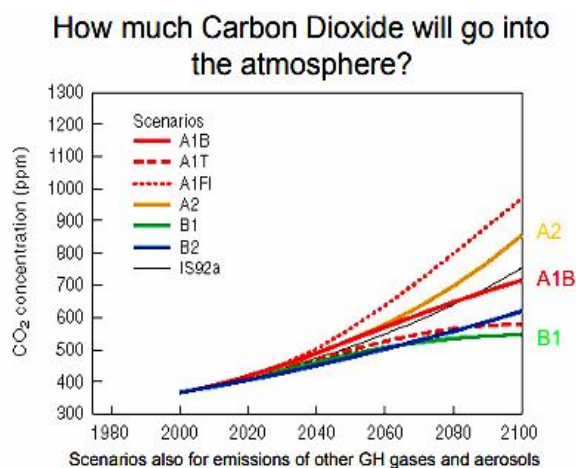


Fig. 19. Carbon dioxide projection models to 2100 [47] (ppm)

The ice mass variation since 2002 for Greenland is seen in Fig. 18, which holds the second largest store of land-locked ice in the world. The seasonal variations are clearly seen, similar to the seasonal variations in carbon dioxide recordings of Fig. 2, yielding one more connection between CO₂ and temperature. A major reason for including Greenland's ice loss is that upon comparison to Fig. 17, it becomes abundantly clear that Greenland is losing twice as much ice mass as Antarctica, *in the same time frame*. [43] Such a major influx of fresh water from Greenland into the Atlantic ocean, with less density than salt water, has also been connected to the decrease in flow of the North Atlantic Conveyor System (NACS) by about 20% in the past few decades. This has major implications for Scandinavia which, along with the UK, receives returning NACS warm sea water current northward from the Mediterranean. Ironically, if the NACS slows down much more, which in all probability it will with present GHG emission trends, the Scandinavian countries may experience a short term cooling trend as the rest of the world continues to rise in average temperature, since there will be a deprivation of the warm northward NACS current to Scandinavia, until global temperature rise dominates. Greenland has also made the news recently because rain-associated melting became twice as frequent in summer and three times as frequent in winter, for the past several years. "Rain now seems to account for 28 per cent of the [Greenland's] ice sheet melt [44]."

All of the ice sheet data above brings home the extreme heat increase which the three major glacial ice masses are experiencing presently.

This scientific information should serve to counter much of the public disbelief that exists today in regards to the effect of a single 1°C average increase in temperature globally, since the rapid increase in ice loss has accelerated in the past few decades at the same time this thermal forcing has occurred. Confronting the climate denialist problem and a general lack of comprehension of the impact of several degrees Celsius of temperature increase is a serious problem [45]. In 1967, Manabe and Wetherald published the first accurate climate model ever. Analyzing absorptivity and albedo, they predicted a 2°C increase as CO₂ levels double but regretted that ice sheet modeling was uncertain [46]. Today, the ice sheet modeling has improved but apparently requires continual updating by close monitoring of the actual amount of accelerated melting such as in Greenland, and calving of ice shelves such as in West Antarctica.

It is an honor to cite the pioneering work of James Hansen, who in 1988 stated that human-made climate change was real and who was the first climate scientist to publicly state, "the greenhouse effect is here," besides "climate forcing" and then several years later, publishing the "Hansen Graph" in 2006 with a surprisingly linear table of historic global temperature, CO₂, and sea level values (Fig. 10), so future trends of all three can easily be extrapolated and calculated, based on the past correlations between these climate variables.

7. PROJECTION OF ATMOSPHERIC CO₂ LEVELS TO 2100

The question is often asked by the public if CO₂ is going to level out or 'peak' soon? The 9th UN

Emissions Gap Report [1] states there is “no sign of peaking” and emphatically issues a warning that carbon emissions are actually increasing. In Fig. 19, the A2 line for CO₂ levels is “business as usual” and most likely by economists and policy makers, according to the University of Washington [47]. It is estimated that humans have emitted about 550 gigatonnes of carbon (multiply by 3.67 for CO₂ gas amount) from 1870 – 2013 [48]. In addition to this global atmospheric volume of human-created CO₂, the world adds about 40 gigatons of CO₂ emissions each year to the atmosphere, which stays there [49]. All three recent climate reports cited earlier [1] acknowledge the Paris limits *are not happening*. No major country seems willing to reverse its long-standing use of fossil fuels with a carbon tax, even if the entire tax goes to funding more renewable energy.

As global energy demand from a growing world economy and related carbon emissions keep increasing (2.3% last year), as they are projected to do, a compounding factor is the need for extra heating and cooling in regions hit by the predicted oscillations in the earth’s climate as it seeks a new equilibrium level [50]. The residential cooling problem is also a contributor to global warming with window AC units set to more than triple by 2050. “RMI.org estimates that the amount of energy that will be required to power the new 4.5 billion window air conditioners expected by 2050 is equivalent to the current electricity demand of the United States, Germany and Japan combined. Growth in the demand for air conditioning is already outpacing growth in solar power, with new residential air conditioning units worldwide consuming approximately 100

GW of energy in 2017, compared to 94 GW of new solar energy generation [51].”

Besides HFCs from leaking AC units and methane from various sources, the single most important and most potent driver of global warming is still the increasing CO₂ level worldwide. The proof of it is the intrinsic nature of the infrared absorption bands of carbon dioxide gas. However, a simple demonstration of its heat absorption capacity is warranted and quite convincing.

8. EXPERIMENTAL PROOF OF CO₂ HEAT ENTRAPMENT

To explain and understand the infrared absorption bands of CO₂ in one case, researchers used an infrared (IR) camera attached to glass chamber slowly filled with CO₂ gas.

With a candle flame used to trigger an image on the infrared camera, sufficient CO₂ gas in the glass chamber between the gas and the camera will literally absorb all of the IR emission from the candle, making the burning candle “disappear from view” as the CO₂ absorbs all of the IR heat.

Similarly, in another case, a more simplified demonstration of CO₂ gas heat absorption capacity has been done with two soda bottles, as in Fig. 20. One bottle (#1 on right) is half filled in equal volumes with air and water while the other (#2 on left) is the same but two Alka Selzer tablets are dropped in it to produce some CO₂ gas.



Fig. 20. Carbon dioxide experiment proves excess heat trapping – nine degrees C hotter [52]

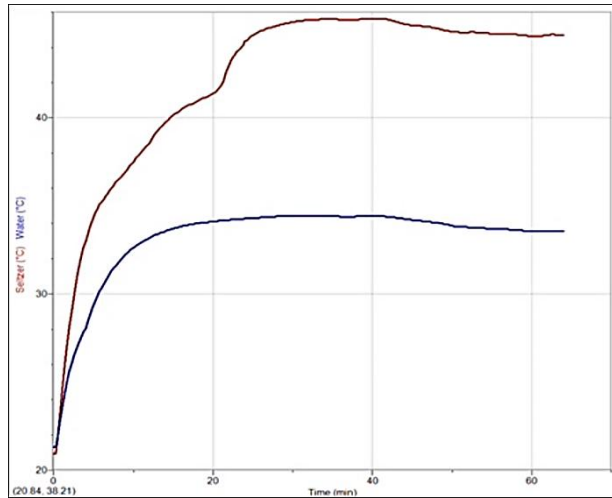


Fig. 21. CO₂ temperature (top curve °C) vs. time (minutes) [52]

A 1 kW spotlight is shown on both bottles equally and the Bottle #2 heats up faster and maintains a higher temperature than the air-filled Bottle #1 [52]. In Figs. 20 and 21, it can be seen the air bottle reaches 35.1°C after an hour but the CO₂ gas bottle more slowly reaches a hotter, stable level of 44.0°C, which is about nine degrees C higher than the irradiated air bottle, proving the heat-trapping property of a significant amount of CO₂ mixed with air. The spectral absorption lines of CO₂ gas cause this dramatic result.

the dramatic heat absorption property of CO₂ gas where the air bottle levels out quickly to 35.1°C but the CO₂ gas bottle reaches a steady 44.0°C at least 20 minutes later. Fig. 21 therefore demonstrates the same delay in the earth's atmosphere which thermodynamically reacts to an increase in CO₂ as the temperature attempts to reach a new equilibrium point. Our earth's previous stable average temperature of 14.5°C (Fig. 9) was the equilibrium leveling point for 290 ppm of CO₂ and the steady solar influx, for thousands of years. However, in the 20th century, the Industrial Age carbon emissions became an increasing, upward slope burden for the earth's atmosphere to find an equilibrium temperature level as in Fig. 21, which takes more time.

Fig. 21 shows the results of 60 minutes exposure to a steady 1 kW spotlight input to two 20°C ambient bottles of air (bottom curve) and CO₂ gas (top curve). This simple experiment proves

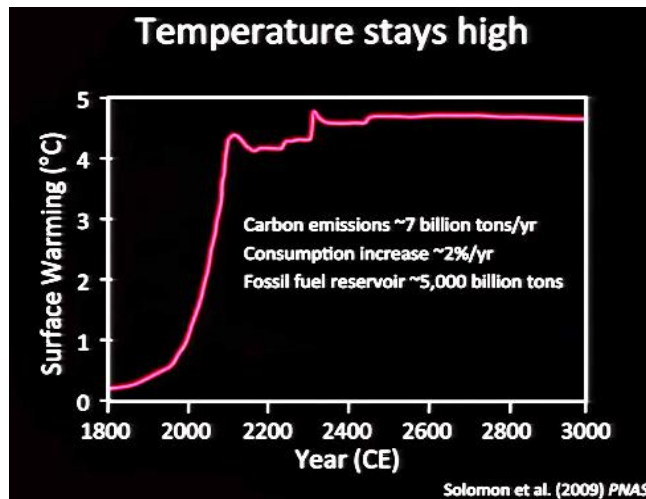


Fig. 22. Solomon projection of temperature based on 2009 CO₂ 25 gigatons/year (Gt/yr) emissions but going into 2020, they are reaching 40 Gt/yr [53]

Fig. 22 is the geologists' view of the finite amount of time for the global system to balance the input solar absorption (radiative forcing) with output heat radiation. Since the earth's atmospheric system is so large (estimated at 4 billion cubic kilometers by a difference in two spheres), there is a significant delay of several decades in the earth's comparable upward slope of the heat absorption curve to reach a comparable leveling off which would signify an equilibrium level of a system-wide temperature. However, humans worldwide now seem more determined than ever to dramatically increasing global CO₂ levels rather than stopping at a certain CO₂ partial pressure to allow the earth's temperature to level off and thereby exhibit a corresponding equilibrium level of input and output heat. Regarding Fig. 22, Solomon explains, "After emissions cease, the temperature change approaches equilibrium with respect to the slowly decreasing carbon dioxide concentrations" which she calls "irreversible climate change [53]." This is based on a 7 billion ton carbon (25 gigatons of CO₂) annual emissions in 2009 which has increased to a 40 gigaton CO₂ level annually a decade later, so the leveling off of a long term temperature is more realistically projected to be around 6°C, as seen elsewhere in this review, and expected to last thousands of years before decreasing to present day levels.

9. PRECEDENT FOR 2100 PROJECTED GLOBAL CO₂ LEVELS

To review, the inhabitants of the earth are now pumping up the CO₂ level worldwide at a rate that averages about 100 ppm increase every twenty (20) years for the foreseeable future. If we allow business as usual (A2 line in Fig. 19) to continue for decades to come, the earth easily surpasses 800 ppm around 2100 (A2 yellow star in Fig. 23) and even 1000 ppm of CO₂ soon after into the 22nd century, with worldwide *cognitive impairment* of human abilities to be expected, as shown in office and classroom studies published on the National Institutes of Health sites [54].

The increasing rate of CO₂ buildup can be compared to world population growth. As the world population will quadruple by 2100 from its previous mid-century level of 2.5 billion to more than 11 billion [55], so the CO₂ level worldwide seems to be headed for a tripling amount from the 290 ppm by 2100, as its energy consumption quintuples from its mid-century level. The notable difference being the rate of growth. While the world population rate of growth reached a peak

of 2.1% around 1970 and has decreased ever since, the world's population has continued to rise, albeit more slowly, with a projected leveling out by 2100 around 11 billion people (Fig. 24). In comparison, the carbon emission rate of growth continues to increase (Figs. 1 and 25), which is even more disconcerting since statistically, such a trend will force a continued CO₂ level increase for at least another hundred years, similar to the disconnect between growth rate and quantity of the world population.

The earliest father of climate change, Nobel Prize winner Svante Arrhenius, published a paper in 1896 after studying the earth's ice age history and the effect of accumulated CO₂ level to temperature. His conclusion was that if the CO₂ level doubled, the global temperature would go up by about 5 to 6°C [56]. Today, his prediction is heralded as matching the business as usual projections but as we have seen from the Hansen analysis, this temperature projection has been linked to a 410 ppm concentration which is quite short of doubling the CO₂ level back in 1896.

The carbon emission growth rate seen in Fig. 25 needs to stabilize by leveling out and decreasing, as the population growth rate did fifty years ago, for there to be any realistic projection for the world's atmospheric CO₂ leveling out into the next century where it may finally reach a peak. The question can be asked, "Has the earth ever experienced similar carbon dioxide levels as we expect by 2100 from Fig. 19?" As a matter of fact, as seen in the composite Fig. 23 from the University of Washington, a complete study of the Paleocene-Eocene Thermal Maximum (PETM) historic precedent has been published, among other recent confirmations [58].

Not only does Fig. 23 show the approximate magnitude of the carbon dioxide increase expected by 2100 for the A2 "business as usual" scenario, which is most likely, but the left side of Fig. 23 extrapolates to several million years ago: "Eocene Period 50 million years ago - palm trees flourished in Wyoming and Antarctica was a pine forest - crocodiles lived in the Arctic - deep ocean temperature was 55°F (today it is ~35°F) - sea level was at least 300 feet higher than today and the difference in global temperature from our baseline of 15°C is an additional 15°C yielding a new average of around 30°C (86°F)." Note: this is ten degrees (10°C) higher than the 5°C increase (yielding 20°C) predicted from Brown and Caldeira (Fig. 15) and Hansen (Fig. 14).

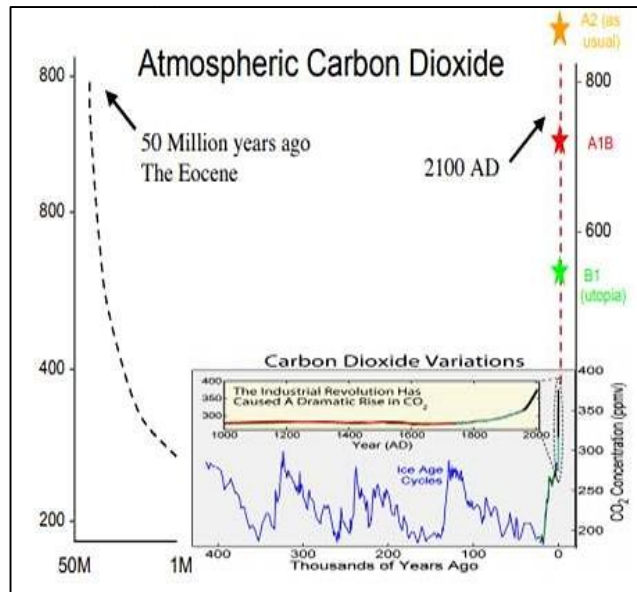


Fig. 23. University of Washington composite CO₂ computer models extrapolating to 2100, where A2 is the top yellow star “business as usual” reaching 800 ppm by 2100, surpassing B1 “utopia” and even A1B (red star) to match the PETM level over 50 million years ago [57]

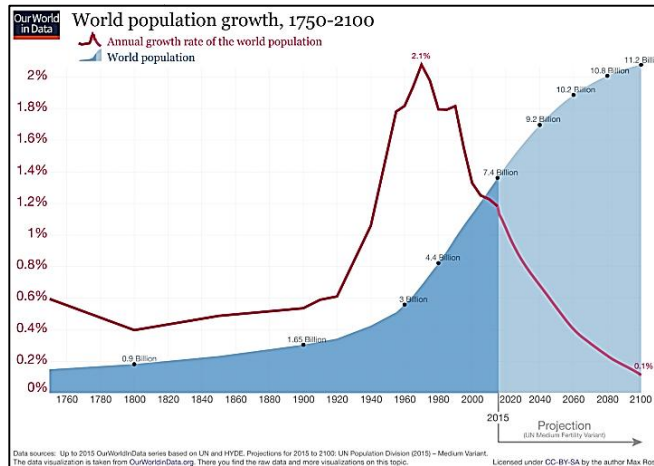


Fig. 24. World population growth rate (Red line) and total population (Blue shaded area) [55]

There are numerous educational videos with detailed reviews of the PETM on YouTube, such as from BBC Radio [59] and a very popular, ten-minute PBS-TV summary (with 2.5 million views) [60]. Referring back to Fig. 6, one can see the PETM peak between the “Pal” and Eocene epochs on the graph. It is important to note that during the geologically short PETM period of about 200 ky, the earth’s atmosphere was gaining CO₂ at a rate of about 1.7 billion tons per year by the best estimates, compared to about 40 billion tons worldwide per year at our present rate.

The upshot of the PETM period was a 5,000 billion ton (5 trillion ton or 5 teraton) increase in carbon dioxide worldwide in a few millennia, which is comparable to the present accumulation rate of excess global atmospheric CO₂ just by 2100 (40/yr x 80 yrs = 3 teraton) with a rough estimate of the annual increase we are pumping into the earth’s atmosphere presently on top of the amount already added to the atmosphere from the start of the Industrial Age. In Fig. 26, Dr. Scott Wing from the Smithsonian Museum of Natural History explains the PETM in comparison to present day carbon emissions and

temperature rise [61]. Presently, we are pumping CO₂ into the atmosphere at an unprecedented rate that is about 20 times the rate of increase during the PETM period. We also can compare the PETM period to the present in another context, the volume in parts per million (ppm) that such an increase of CO₂ will create worldwide. That has already been calculated by several sources cited above, including Fig. 23, where the left-hand vertical axis for the Eocene epoch (PETM in particular) matches the projected 2100 AD level projected, under "business as usual" conditions of 800 ppm of atmospheric CO₂.

To determine if the previous quotation for expected temperature rise from the University of Washington is reasonable for the projected 800 ppm of CO₂, Equations 1 and 2 are used. Taking ΔC to be 800 – 290 = 510 ppm, that ΔC variable goes into Equation 1, so ΔT = 25°C

approximately, to be added to the baseline value of 14.5 or 15°C, yielding 40°C on the average. This value is an overshoot of about 10°C higher than the historically agreed upon value of 30°C found from numerous sources for the PETM period. Figs. 7-11 as well as Equations 1 and 2 all rely upon a 420 ky history of earth atmosphere performance with the interaction of a temperature, sea level, and carbon dioxide system within the range seen in Fig. 9. As the future and the 50 million year past now are on a collision course, while almost tripling the CO₂ levels worldwide, it becomes apparent that the earth relaxes the stringent, linear relationship seen in Equations (1) and (2). For future research, the 30°C historical temperature level corresponding to 800 ppm of CO₂ needs to be put into another, broader equation that becomes more nonlinear as the levels increase to such large amounts, to accommodate a leveling off of the equivalent temperature change.

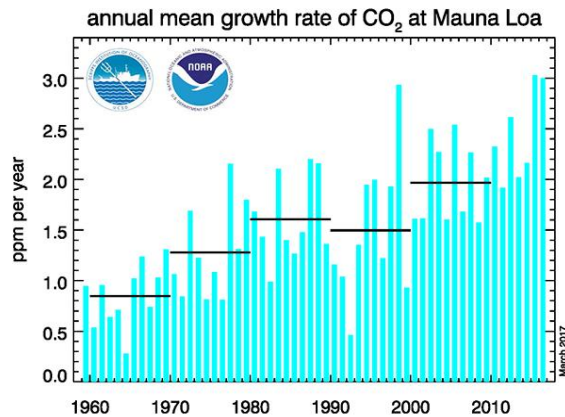


Fig. 25. Rate of growth of worldwide atmospheric carbon dioxide at 3.0 ppm/year in 2017 and continuing to increase its average (mean) CO₂ emission rate, statistically indicating no immanent peaking in the global carbon dioxide levels are expected this century [57]

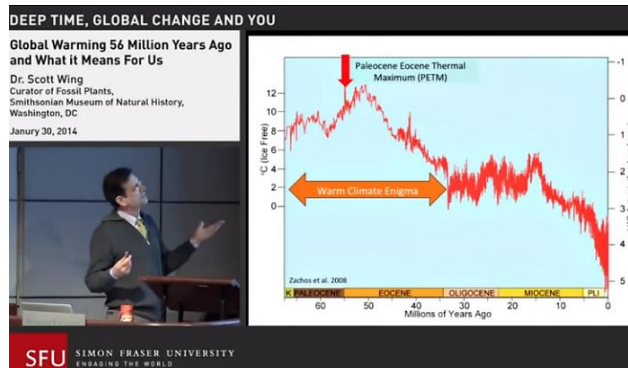


Fig. 26. Dr. Scott Wing explaining the PETM temperature enigma and the relevance for today's global warming climate [61]

It is worth mentioning that, with this perspective, such a CO₂-sensitive earth-atmosphere system has also been regarded as a superorganism, in the “Gaia Theory” which teaches that it will inevitably seek equilibrium and balance, as it naturally recycles *everything* [62]. “Studying Earth’s global biosphere together, Margulis and Lovelock realized that it has some of the properties of a life form. It seems to display ‘homeostasis,’ or self-regulation. Many of Earth’s life-sustaining qualities exhibit remarkable stability. The temperature range of the climate; the oxygen content of the atmosphere; the pH, chemistry, and salinity of the ocean—all these are biologically mediated. All have, for hundreds of millions of years, stayed within a range where life can thrive. Lovelock and Margulis surmised that the totality of life is interacting with its environments in ways that regulate these global qualities. They recognized that Earth is, in a sense, a living organism. [James] Lovelock named this creature Gaia [63]”.

10. PROJECTION OF SEA LEVELS PAST 2100 C.E.

As Antarctica continues to accelerate its ice loss and melting, it is important to realize the full potential of its ability to create sea level rise by 2100. The projections keep increasing as the IPCC continues to reevaluate the climate models with unexpected temperature rate increases but the range of sea level rise just from the melting Antarctic glaciers is at *minimum*, three feet (about 1 meter) by 2100. However, as the ice

sheets are studied more closely with imminent collapse of one of Thwaites, Dibble, Frost, Holmes, or Denman being inevitable, an upward estimate of 2 to 3 meters or 6 to 9 feet of sea level rise by 2100 looks to be more realistic, from a sudden “rapid ice disintegration” that will result in an additional sea level rise [40]. Solomon [53] also cites thermal expansion of the world’s oceans to add 1 meter of sea level rise if we pass 600 ppm and a few more if we pass 1000 ppm of CO₂.

About 125,000 years ago, during the last brief warm period between ice ages (Eemian), earth’s temperatures were barely higher than in today’s greenhouse-warmed world. Yet records show sea levels were 6 to 9 meters higher than they are today, drowning huge swaths of what is now dry land. Scientists have now identified the source of all that water, after analyzing marine sediment cores: a collapse of the West Antarctic Ice Sheet. Glaciologists worry about the present-day stability of this formidable ice mass, which is showing a 30 km crack recently. In fact, some records show that once that ice sheet started to disappear during the Eemian, ocean waters rose as fast as 2.5 meters per century [64].

Another comparable period in the earth’s history is the last time the atmospheric CO₂ amounts were around 400 ppm. This was more than 3 million years ago, when temperature was 2°–3°C (3.6°–5.4°F) higher than during the pre-industrial era, and sea level was 15–25 meters (50–80 feet) higher than today [66].

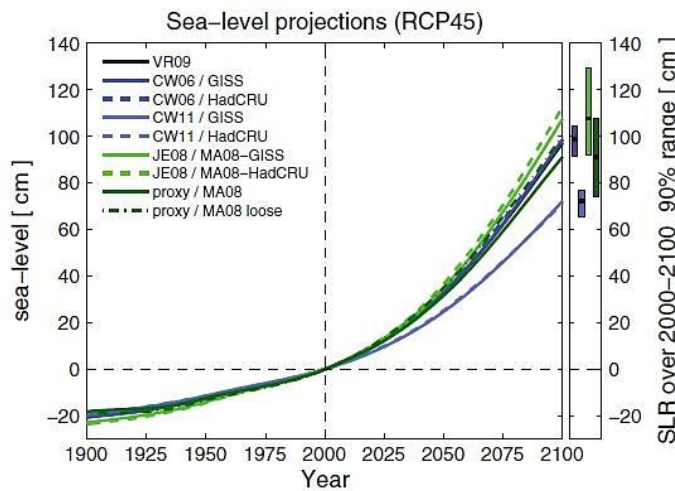


Fig. 27. Composite graph showing at least a one-meter sea level rise by 2100 under present trends from computer models [65]

More recently, a team led by Rob DeConto at the University of Massachusetts Amherst suggested that the unstable Antarctic ice sheet alone can contribute more than a meter to sea level rise as in Fig. 27, leading to a total rise of about three (3) meters by 2100. He is quoted in Forbes as stating, "If the pace of calving we observe in Greenland today someday becomes widespread around the edges of the vastly bigger Antarctic ice sheet, it could cause very fast sea level rise [67]." This Forbes article also recites the common assessment agreed upon by the experts that if the entire Greenland ice sheet melts, the sea level will rise by about 8 meters (26 feet), submerging huge amounts of coastal and low-lying areas around the world, including the majority of the state of Florida.

This brings us to the estimate of the sea level rise stored in the land-locked ice mass of Antarctica. Antarctica's annual ice losses have accelerated six-fold in the past 40 years in a trend that will push sea levels meters higher in coming centuries just from the present 410 ppm of CO₂ level. The East Antarctic ice sheet is thawing at the fringes and adding to rising seas, unlike many past reports which have concluded that the eastern sheet has so far resisted a melt seen on the western side [68]. If the entire Antarctica ice sheet were to melt, sea levels would rise approximately 60 meters, mainly from the East Antarctica ice sheet, with about 3 meters from the West Antarctica ice sheet [69].

Together the Greenland and the Antarctic ice sheets together make up the majority of land-locked glacial ice worldwide, with an equivalent of almost 70 meters of sea level rise contained in their ice mass. Taking Equation (2) and Fig. 11 into account, the Greenland and Antarctica total sea rise is on the same order of magnitude as the Hansen graph sea level projection of 80 meters. The difference is clearly due to the fact that Equation (2) is a linear relationship which begins to become nonlinear as the CO₂ levels surpass the uncharted territory above 400 ppm.

Where the range of 200 ppm to 300 ppm of global CO₂ is very linearly correlated to a corresponding value of temperature and sea level, from historical data, the argument put forward by this author and implied by Hansen's Graph (Fig. 9) is that some limited extrapolation may also be quite accurate. This has now been proven to work up to about 400 ppm, only confined by the fact that the earth holds a maximum of 70 meters of sea level rise known to

be locked in glacial ice. Therefore, it is found that Hansen's Graph of Figs. 9, 10 and as summarized in Fig. 11, presently predicts the same order of magnitude of sea level rise sometime in the future, within a 10% error. This stark realization forces us to the glaring discovery and inescapable prediction that ALL of the land-locked ice on earth will inevitably melt in the coming centuries, just from the force of 410 ppm of CO₂ heat-entrapment of the solar flux as seen in the ironclad Equation (1) and the simple CO₂ experiment of Figs. 20, 21. Hansen's Graph is a remarkably correlated, very tight triad of variables which is *proven* to have a lockstep relation by 420 ky of ice core records. Therefore, simply from historical records, it has to be concluded that Greenland and Antarctica are already gone, like "dead men walking" as they are rigidly compelled to meet the Hansen Table of the forced linear correlation of sea level, CO₂ level, and global temperature! It has taken over thirteen years of analysis since the publication of Hansen's Graph, with careful comparison to all major climate predictions for the disturbing, inconvenient confirmations to finally be widely published here. It therefore can be seen that Equation (1) has remarkable value and a predictive quality (at least in the range of Fig. 10), which could have been put to use worldwide over ten years ago to mobilize public awareness and environmental concern, if only scientists like James Hansen were honored and more highly respected.

David Fenton, chairman of Fenton Communications, recently was on National Public Radio recently, speaking about "Selling the Science of Climate Change" and his conclusion was that "Facts don't work by themselves. Facts only really work when one, they are embedded in moral narratives. Secondly, facts don't work unless they're embedded in stories. And third, the brain only absorbs messages that are simple and are repeated [70]".

11. REMEDIATION METHODS NEEDED BEFORE 2100 C.E.

Targets for limiting global warming thus, at minimum, should aim to avoid leaving global temperature at Eemian or higher levels for centuries. Such targets now require "negative emissions," i.e., extraction of CO₂ from the air, also called "carbon capture" or "carbon sequestration." If phasedown of fossil fuel emissions begins soon by declaring CO₂ a

pollutant, improved agricultural and forestry practices, including reforestation and steps to improve soil fertility and increase its carbon content, may provide much of the necessary CO₂ absorption. In that case, the magnitude and duration of global temperature excursion above the natural range of the current interglacial (Holocene) could be limited and irreversible climate impacts will possibly be minimized.

In contrast, continued high fossil fuel emissions today place a burden on young people to undertake massive (tens of billions of tons per year) technological CO₂ capture, sequestration, and extraction if they are to limit climate change and its consequences [9], even if radical schemes to reduce global inbound solar flux are implemented. This concern has been emphasized even more urgently as continued warming into the next century will push the CO₂ levels past 1200 ppm, as present rates (see Figs. 19, 22). At that level, new findings modeling the effect of high CO₂ levels suggest that *cloud cover will become increasingly scarce* and we could trigger a cloud feedback effect with the loss of stratocumulus clouds which will add 8°C on top of all the warming up to that point. That means the world could warm by more than 14°C above the pre-industrial level according to Tapio Schneider at the California Institute of Technology, Pasadena, who led the research. Schneider's team modelled stratocumulus clouds over subtropical oceans, which cover around 7 per cent of Earth's surface and cool the planet by reflecting the sun's heat back into space. They found there was a sudden transition when CO₂ levels reached around 1200 parts per million (ppm) — the stratocumulus clouds broke up and disappeared. The reason why this finding applies only to subtropical stratocumulus is that these clouds are unusual. The cloud layer is maintained by the cloud tops cooling as they emit infrared radiation — and very high CO₂ levels block this process [71].

11.1 Stratospheric Welsbach Seeding

Many extreme ideas for reducing global warming have been proposed and some actually have been implemented in the past several decades. The first to be reviewed, which may be revisited by desperate scientists in the near future, is the US Patent #5,003,186 “Stratospheric Welsbach seeding for reduction of global warming” method of putting aluminum, barium, and cadmium flakes into the atmosphere, ostensibly to reflect sunlight and reduce the absorbed heat rays. Conceived

by Ken Caldeira, climate expert who ran computer simulations, he also warned that stratospheric spraying of sunlight-reflecting chemicals could destroy the ozone layer and pose human health risks, which didn't stop the infamous Dr. Edward Teller, “Father of the H-Bomb”, from calling for a billion-dollar per year sky shield program [72]. The patent was licensed to Hughes Aircraft which then became a secret activity of the U.S. military as the patent rights changed hands from one aerospace corporation to Raytheon. The result of the ill-gotten pursuit was the precipitation of poisonous “chemtrails” visible in the sky, that rained down on Canadian and American farmlands, among other rural and urban areas, affecting the food crop quality. Raytheon called it the “Deep Sky Program” and discontinued it after numerous public complaints, including from air traffic controllers (reflective particles confused radar), a detailed letter from this author, as well as a House bill HR-2977 that banned chemtrails, back in 2002. There are still solar-shading concepts on the drawing boards of military offices, including the International Military Council on Climate and Security [73].

11.2 Million Tree Planting Initiatives

Other less radical concepts for carbon capture include the ‘million trees’ concept: “Tree offset calculation is based on a tree planted in the humid tropics absorbing on average 50 pounds (22 kg) of carbon dioxide annually over 40 years: *each tree will absorb 1 ton of CO₂ over its lifetime*” (<http://www.carbonify.com/carbon-calculator.htm>). Therefore, it has been a popular initiative from several groups to start many more “million tree” initiatives, with many posting results online. My inspiration for this is from Hunter Lovins who told me that she planted a million trees! I took that to mean she caused a group of people to effectively act on her behalf to accomplish the task. Of course, the easy calculation from the above is that a million tons of CO₂ is removed from the atmosphere for such a feat. However, the challenge to the environmentally aware community is the same one that Richard Branson issued over ten years ago for a \$25 million prize (Washington Post, Feb. 10, 2007): How can we remove a billion tons of CO₂ from the atmosphere each year? Some like the “Trillion Trees” concept with a few billion hectares of forests planted (Crowther Lab Study, Science News, 2019).

Hansen recently published a critical warning article for the next generation: “Young people's

burden: requirement of negative CO₂ emissions” <https://www.earth-syst-dynam.net/8/577/2017/>. Once again being very erudite, he explains, the “Earth is out of energy balance with present atmospheric composition” in regards to the previous Eemian interglacial period. Since Hansen does state in the Abstract that temperature is “highly correlated with sea level,” the implication is that the CO₂ level is also critically driving the system and requires extraction by the next generation to limit and minimize the “irreversible climate impacts.” However, what is needed is the motivation for a much less expensive scenario of carbon sequestration at the gigaton (billion ton) level. It is also worth noting that South Koreans planted an estimated billion trees after the close of the Korean War in the 1950s as revealed while this author was attending the International Conference on the Unity of Sciences (ICUS XXIV) in Seoul, Korea in 2018.

11.3 Green New Deal

The Green New Deal summarized in Fig. 28 is a congressional resolution proposed in 2018 that lays out a grand plan for tackling climate change. Introduced by Thomas Friedman in 2007 and endorsed by President Obama in 2008, it was revived by Representative Alexandria Ocasio-Cortez of New York and Senator Edward J. Markey of Massachusetts. The proposal calls on the federal government to wean the United States from fossil fuels and curb planet-warming greenhouse gas emissions across the economy. It also aims to guarantee new high-paying jobs in clean energy industries. Parts of the Green New Deal have already been implemented over the course of the last several years, with government support for programs like making buildings more energy-efficient and training workers with green skills. And of course, the terminology used for the proposal is even older, harking back to President Franklin D. Roosevelt’s New Deal, which put unemployed Americans to work (including with environmental jobs) during the Great Depression [74].

However, from what has been presented in this review so far, it appears that the Green New Deal offers a long-term renewable energy path but without even remediating the past “short term” carbon dioxide buildup in the atmosphere. This is the major problem contributing to temperature and sea rise as in the PETM and needs carbon capture on a grand scale. Furthermore, it has been noted that the Green

New Deal parameters as seen in Fig. 28 do not include nuclear energy, which supplies about 58% of carbon-free electrical power in the U.S. and simply requires an environmentally safe waste disposal [75].

Safe nuclear waste disposal is not an unrealistic prerequisite for Green New Deal admittance. Since Yucca Mountain, the options for remediation of radioactive waste have multiplied. Remediation that reduces mass or radioactive lifespan are the most desirable with various scientific methods being proposed and tested. Plasma filtering techniques for nuclear waste remediation is available for vastly reducing the volume by separating out the radioactive portions for burial [76]. Perhaps the cleanest and most exciting is the photo-transmutation of nuclear waste, driven by lasers. This recently revived process uses low-energy, 7 - 10 MeV X-rays (close to gamma) to break up long-lived isotopes into very short half-life waste products that decay quickly and can be included in non-radioactive landfills afterwards [77].

There also are new nuclear reactor designs, such as thorium molten salt reactors which cannot be weaponized [78], or fast neutron reactors that can also burn the long-lived actinide nuclear waste from other reactors [79]. Adding safe nuclear power, such as cited above, to the Green New Deal would make it more effective for powering the United States, bring in more supporters and increase its wide-range appeal. Adding new emerging energy discoveries for a fast-track, such as “salinity gradient energy converters” from mixing fresh water with saltwater and special electrodes, could generate up to 2 terawatts (2 TW) of electricity from existing estuaries [80]. The US Department of Energy, along with MIT, supports expanded geothermal energy generation for up to 60 gigawatts (60 GW) of untapped electrical power [81].

11.4 Carbon Capture and Storage (CCS)

Motivated by multiple reports about the increasing trajectory of global carbon emissions, more and more businesses, policymakers and researchers are coming to the same conclusion: The world must improve and commercialize methods to capture carbon dioxide from the air and store it (sequestration) or find practical uses for it (e.g., making calcium carbonate). The Petra Nova Carbon Capture Project at the NRG Energy W.A. Parish generating station in Thompsons,

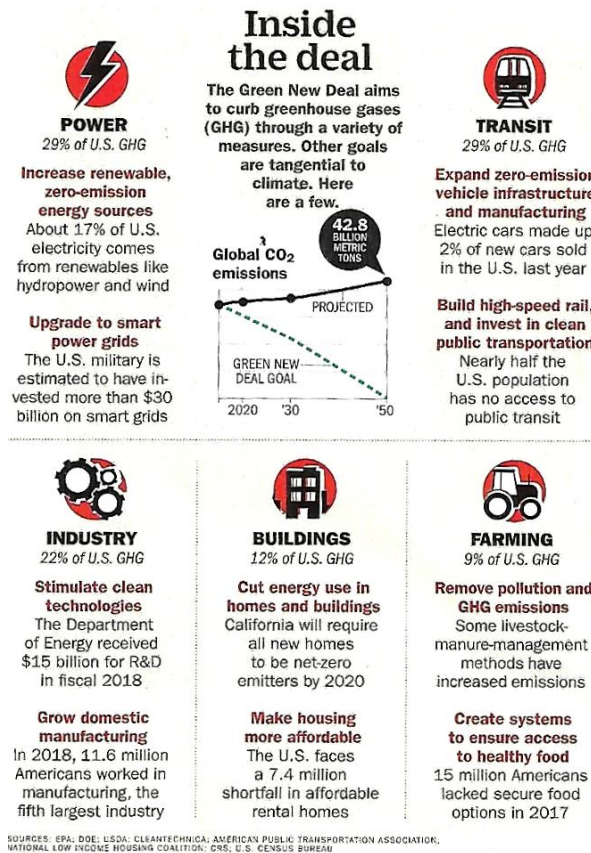


Fig. 28. The proposed green new deal summary of benefits [72]

Texas is a good example of a solution to present carbon emissions. The project reportedly captures and repurposes more than 90 percent of the plant's carbon dioxide emissions. "As we look out to the middle of the century, one thing is very clear: Going to net zero [emissions] will require carbon capture and storage on a substantial scale," said Nicholas Stern, a climate economist and chair of the London-based Grantham Research Institute. "And we're going to need it quite soon [82]."

FutureGen Industrial Alliance, Inc. has conducted a five year CCS project of injecting 1.1 million metric tons (tonnes) of carbon dioxide into stratigraphic boreholes each year from coal burning power plants. The boreholes are deep saline formations suitable for carbon sequestration [83].

One method of iron seeding of plankton reaches a CCS billion-ton range. It is sponsored by Planktos.com in Foster City, California. The level of planktons all over the globe have reduced by 10% since the 1970s. To replenish the ten

percent reduction will require between three and five billion tons of the atmospheric carbon dioxide, says David Kubiak, Director of Planktos. This news has created a stir among the environmentalists who have high uncertainty on the probable problems that may arise due to the huge geo-engineering proposal [84]. There are also questions as to whether the iron fertilization will significantly reduce the carbon dioxide or if the technique can qualify as the viable carbon offsets. Tests to settle the environmental debate are ongoing [85]. The technique is not only beneficial to address the problems arising due to climatic changes but also useful to refill the declining stock of planktons.

Another method gaining popularity for carbon sequestration is the possibility of carbon-negative cement used for making concrete. Research shows that depending on the extent thermal fuel supply is decarbonized, a CO₂ capture rate between 53 percent and 80 percent will make cement carbon-neutral, and higher CCS capture rates achieve net carbon-negative cement [86]. This offers the prospect of a world where simply

constructing buildings and infrastructure reduce atmospheric CO₂ concentrations and contribute to the fight against climate change [87].

Of interest to local communities are the examples of CCS applied to coal-fired power plants like New Mexico's San Juan Generating Station (SJGS), targeted for closure by state lawmakers. Acme Equities LLC wants to refit the 46-year-old, coal-fired plant to use carbon capture and sequestration (CCS) technology. Retrofitting the 847-MW plant with CCS technology would cut carbon emissions by 90% and offer the plant another revenue stream—selling the captured CO₂ to help produce oil. Acme is negotiating with local Farmington, N.M., officials to take over the San Juan plant, a major employer in the area, and keep it operating [88].

One of the world's largest CCS systems is Petra Nova (mentioned above) which "captures 1.6 megatons of CO₂ each year, equivalent to taking 350,000 cars off the road." CO₂ is pressure-pumped into depleted oil fields to free up more oil. Petra Nova uses CO₂-binding amines which is sprayed through fossil fuel exhaust (coal or gas) so it latches onto 90% of the CO₂. The solution is then collected and heated so the CO₂ bubbles out so it can be captured, pressurized, and removed. The amine solution can then be reused [89]. Another example is Xcel Energy in Minneapolis who promise to deliver 80% carbon-free energy by 2030 and zero-carbon electricity by 2050 with CCS [90]. The best may be the world's peatlands (moors, bogs, or mires) that remove an estimated 370 megatonnes of CO₂ each year from the air if left untouched (*Time*, 9/23/19, p. 54).

A \$20 million international competition to make profitable products from a gas that otherwise would contribute to global warming has also been conducted. The finalists in the contest sponsored by a U.S. energy company and a group of Canadian oil sands producers first showed in a lab they could use carbon dioxide from power plants to potentially turn a profit making everything from concrete to methanol, an alcohol used in a range of products. The teams had to use 1 metric ton of CO₂ daily in the actual competition using flue gas emission from a coal-fired or gas-fired plant. The finalists include C2CNT, a team from Ashburn, Virginia, making carbon nanotubes, and CarbonCure, of Dartmouth, Nova Scotia, Canada, which already has been using carbon dioxide on a commercial scale to chemically create limestone in concrete.

CarbonCure works with almost 100 concrete plants in the U.S. and Canada. The competition was organized by the XPRIZE Foundation [91].

11.5 Solar Geoengineering

Solar geoengineering and carbon removal technologies often overlap. However, like Welsbach Seeding, solar geoengineering has the same concept in mind – reducing the solar influx by shading for the short term, until enough reduction in carbon emissions has taken place with a well-managed global energy awareness program. Sulfates that produce sulfuric acid in the atmosphere are a proposed scenario, made into tiny droplets on the micron level and put into the stratosphere about 20 km above the earth's surface. Sulfuric acid droplets, rather than water droplets, will survive in the stratosphere for about a year without evaporating, according to the experts, as they reduce incoming sunlight. About 25 thousand tons of sulfur per year would be needed, which keeps increasing as more carbon emissions occur [92]. This proposed short-term plan fails to include a method for carbon capture of the billions of tons of carbon emissions that will be continually added to the earth's atmosphere however but it gives humanity some borrowed time, at a cost of at least a billion dollars per year. It has been pitched as a "cheap alternative to cutting emissions [93]."

11.6 Radical Geotechnology to Modify the World

Many other reports and books offer a wide range of geoengineering concepts, many of which have not been tested, like solar sails in orbit around the earth for example innocently called a "veil" [94]. The promise is to remake the planet on a global scale but political and scientific opinions often are lacking in the most radical and untested approaches. However, Clive Hamilton is a well-qualified professor of public ethics who has several books on subjects such as climate engineering – exercising technological mastery over nature [95], requiem for a species – why we resist the truth about climate change [96], defiant earth – the fate of humans in the Anthropocene [97] and the global environmental crisis [98].

Saving a total of 12.1 billion tonnes of annual global carbon emissions in 2030 is also a radical idea, which amounts to about 43 tonnes of CO₂ (since the CO₂ to carbon ratio is 3.67). The radical idea would eliminate ALL of the anticipated global carbon dioxide emissions in

2030 (Fig. 25) and probably well worth implementing globally. The details of the radical idea were formulated in 2015 by Finland's national innovation fund SITRA, with twelve leading environmental institutions around the world. They require a total of eighteen (18) implementable and existing success stories be expanded worldwide [99]:

- 1) Off-Grid Solar, 2) Better Buses, 3) Home Insulation, 4) Improved Electric Motors, 5) Green Mortgages, 6) Rooftop Water Heaters, 7) Responsible Farming, 8) Wood Burning, 9) Reduce Food Waste, 10) Stop Methane Leaks, 11) More Efficient Air Conditioners, 12) Improve Gas Mileage on New Cars, 13) Industrial Efficiency, 14) Reforestation, 15) No More Coal or Wood Stoves, 16) More Wind Turbines, 17) Reduce Deforestation, 18) On-Grid Solar.

Another radical and controversial concept is a diversified portfolio of renewable energy sources, tailored individually for 139 countries, so they can reach 100% renewable by 2050. A wonderful summary by Prof. Jacobson is also on YouTube,[100] explaining with video and charts, the feasibility of his team's proposal.

Though several countries have objected to the perceived cost of Fig. 29 to make the necessary infrastructure and jobs available, most of the public has embraced his 2050 plan for implementation of an ambitious renewable energy portfolio worldwide [101]. However, it is extremely naïve to think that just implementing such a reduction in emissions by the 2030 to

2050 time frame will magically avoid even a 2 degree C global warming. The world's 139 countries also need to address the sequestration or carbon capture of billions of tons of atmospheric CO₂ to bring the global level back down to the historical maximum of 300 ppm or lower, in order to avoid the inevitable torture of a 5 to 6 degree C temperature increase by 2100, since CO₂ is the driver and the effect is reversible, as proven in the Vostok ice core records. Though the oceans absorb a large portion of atmospheric CO₂ as they are becoming three times more acidic by 2100, forming carbonic acid, the carbon content of the air is the critical factor when considering the greenhouse effect, whether methane or CO₂ is the greenhouse contributor.

Some physicists such as this author have also considered breaking carbon bonds, with the help of a laser, heat, or microwaves to break apart CO₂ directly. The analysis from photochemistry, using ultraviolet lasers, is that the yield, even for high CO₂ concentrations, is on the order of 5% which makes the process less attractive [102]. However, Sandia National Labs has been developing its "Sunshine to Petrol" project for a decade to convert CO₂ and water into hydrocarbon fuels and oxygen, using concentrated sunlight up to 1500°C in a reverse combustion process with a thermochemical heat engine [103]. A recent CO₂ Summit II conference focused on this thermochemistry for solar fuels [104]. A carbon dioxide microwave plasma torch has also been developed with a 2kW microwave source at 2.45 GHz by at least two countries [105].

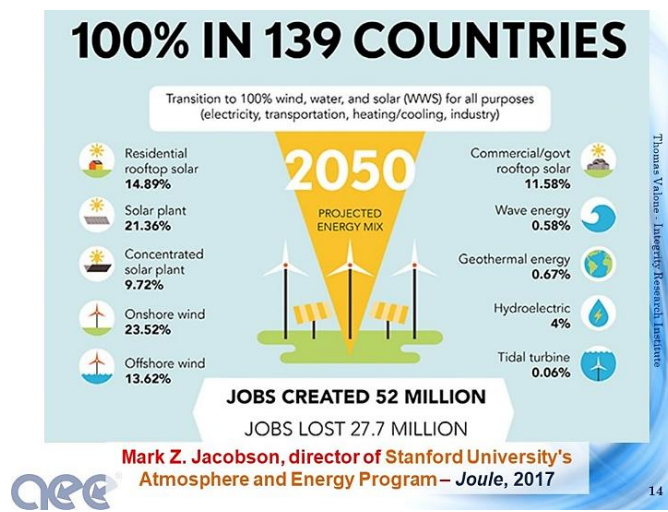


Fig. 29. Proposed 100% renewable energy for 139 countries [97]

A 67-page “Comprehensive National Energy Initiative” report by this author, published by Integrity Research Institute in 2009 also includes many radical, far-reaching suggested innovations, such as government-endorsement of private renewable energy generation sales to local utilities (as successfully implemented in Germany), a long-overdue, declassification of some of the \$32 billion Black Budget energy inventions which are unaccounted for, and zero bias diode array rectification of electrothermal fluctuations for electricity generation [106].

11.7 Time for Adaptation to a Warming World

As we approach mid-century and beyond, some experts state even today that it is not enough to try to limit further global warming – we must also do far more just to ensure that we survive it. That is the message of the Global Commission on Adaptation, a coalition of 28 global commissioners including Bill Gates, a former UN head and the CEO of the World Bank, Kristalina Georgieva. Overseas, urgency is the word from the newly formed Global Centre on Adaption, says its CEO, Patrick Verkooijen. Today, half of the money lent by the World Bank is for climate-related projects or \$20.5 billion in the past year for adaptation [107]. With the coming shock to the global atmosphere being a call for alarm, as many nations, scientists, and politicians agree, as CO₂, already 38% higher than the 290 ppm historic maximum, aiming to triple by 2100, with temperatures projected to be surpassing six (6°C) degrees hotter by 2100, adaptation should be a high priority for everyone.

Now that more and more young people are motivated, such as the U.K. Student Climate Network, old and young alike may want to know some of the best methods for adapting to hotter environments. For homeowners, one of the most important is *cool roof coatings* that work to keep your home cool in two distinct ways. It’s a potent combination of high solar reflectance and thermal emittance that make these roof coatings so effective at keeping your home cool and your energy costs and usage down [108].

Another option that is similar is simply to install white roof shingles. The White Roof Project is a nonprofit movement which seeks to educate the public about such a simple, long-term solution to increased environmental heating of dark-roof home and business buildings. A white roof is constructed with solar reflective white coating

and reflects up to 90% of sunlight (as opposed to traditional black roofs which reflect only 20%). White roofs' benefits are measured partly according to the solar reflectance index, or SRI. A roof's SRI is a measure of a surface's ability to reflect solar heat. SRI measures reflectance (reflecting the sun's rays) and thermal emittance (the roof's ability to radiate absorbed heat). If you've ever worn a black T-shirt in the sun than you already understand that black's reflectance is negligible and its emittance is zero. A white roof's reflectance is as high as 90% and its emittance is 100% [109].

In the construction of new homes, many states like California are designing more efficient insulation so that the structure requires very little heating or more importantly, expensive air conditioning. The best and most advanced building insulation consists of phase change materials (PCM). Phase-change materials (PCMs) use a quirk of physics to aid in thermal storage. When you warm up a solid material (like ice), its temperature rises steadily until it nears the melting point. At that point, the temperature remains roughly the same as the material continues to absorb heat; the process of changing phase from solid to liquid absorbs a lot of energy, called latent heat. Once the material is entirely melted, its temperature resumes rising. When you cool down and freeze a liquid, the same process happens in reverse, releasing stored energy [110]. A one centimeter of the best, BioPCM brand of soy-based gel, from Phase Change Energy Solutions, in wall cavities has low flammability and equals about 25 cm of concrete! Other companies such as DuPont “Energain” and BASF “Miconal” sell similar PCM products for insulation as well, which are highly recommended for those middle-income individuals who want to keep their costs minimized as each decade becomes hotter with continued global warming.

GlassX Crystal is another PCM product designed as quadruple-glazing windows. The four panes of tempered safety glass form three separate insulating glazing units great for southern facing windows to allow low-angle winter sun to aid in heating but to also keep out high summer sun to minimize cooling costs [111].

To complete this section, the ultimate adaptation is a zero energy home. Fortunately, another nonprofit organization called the “Zero Energy Project” has pioneered such information for us. Recent counts done by a coalition of net zero

advocates shows the number of zero and near-zero energy home projects in the U.S.A. and Canada at over 6,177 residential units in 3,330 buildings [112]. With \$23,500 in upgrades, it costs less than \$10.00 per square foot more to build a home that uses no energy: \$0.0 energy cost every month for a net zero home; \$125-\$200 energy cost per month for standard homes versus 10 to 16 years to recoup the additional cost of building a net zero home [113].

12. CONCLUSION

This approach to the climate outlook has been a systematic review and examination of global carbon dioxide emissions over past millennia, along with concurrent temperature records, to quantitatively evaluate the effects on the earth's atmosphere. These historical records offer more agreement and insight into future temperature and sea level rise than previously anticipated. Contrasting the past, ancient history of CO₂ with the present exponential increase in carbon emissions makes the case for what James Hansen and others have seen, e.g., an extremely rapid pumping rate (3 ppm/year) of carbon into the earth's atmosphere, which has no precedent in any past known age or epoch on earth. We found that the closest similar event to the modern anticipated carbon levels is the 56 million year old Eocene epoch (PETM), which required thousands of years to build up 800 ppm of CO₂ and a 15°C increase in global temperature. Looking into the 22nd century, the business as usual increasing levels of CO₂ will, according to the best climatologists, start to recreate and repeat the PETM event again, with a ten (10) to fifteen (15) degree Celsius temperature increase, as briefly shown in Patrick Brown's short video from Stanford University [114].

With the grand perspective of geological time and the lithosphere interacting with the hydrosphere, humans are only a large portion of the many different species that inhabit the planet. Any changes such as the influx of billions of tons of carbon into the biosphere normally lasts for thousands of years, as Solomon and Wing have indicated, which is a short time geologically. Some scientists take the perspective that it is prudent to adapt to a warming world and to prepare just to survive the future extreme heat and droughts that Solomon outlines in her worldwide map [53] for Mexico, eastern South America, and southern Africa. Such extremes are already being experienced in Turbat, Pakistan

with a 54°C (129°F) record temperature (*Time*, 9/23/19, p. 34).

The invaluable, predictive value of the Hansen approach has been proven in this review, with evidence from the past to the present. It has been shown to be superior to many other climate probability models, mainly due the discovery that the correlated global temperature increase and long term sea level rise can now be accurately predicted with ease by anyone, using Equations (1) or (2), simply based on CO₂ concentration amounts in parts per million, up to 500 or 600 ppm where a divergence begins in the correlation, with increasing nonlinearity.

Comparing the growth rate of change of the global CO₂ emissions to the global human population growth rate, it was hypothesized that the CO₂ emission growth rate will first peak and then show a decline as renewable energy begins to be universally adopted, about a century before the actual global CO₂ level begins to level out. Various remediation methods were also discussed to help speed up this recovery process.

13. RECOMMENDATIONS

It is recommended that many or all of suggested remediations of Section 11 should be implemented in the next few decades, before the deleterious effects of each degree of temperature increase for every twenty (20) years starts occurring on a regular and totally predictable basis well into the 22nd century. Furthermore, specific actions must be taken to reverse this catastrophic, runaway train which threatens the survival of a huge portion of humanity. As Fig. 9 proves historically, the driving effect of CO₂ on the global temperature response is reversible. It also has been proven by humans to have a relatively short time delay of only a few decades and can go in either direction as indicated by Equations (1) and (2).

Therefore, it is recommended that, at the same time as adopting carbon-free, renewable energy sources worldwide, the real heavy lifting will be designing herculean carbon capture and carbon sequestration on a global scale to start bringing the global concentration of the heat-trapping CO₂ downward instead of upwards. Furthermore, judging from the ineffectual and minimal impact of previous national commitments, it is recommended that at least one and perhaps several specific multinational agencies are vital,

along with the United Nations endorsement, to implement a scaled up massive, hundreds of billions of tons of CO₂ injection into a distributed array of carbon capture technologies outlined in Section 11.4. The goal needs to be a sequestration, capture, and conversion of 4,000 to 5000 billion (4-5 trillion) tons of CO₂ in relatively few decades, even as other nations keep adding more and more CO₂ to the limited, transparent, overhead storage bin otherwise called our earth's atmosphere. Integrating Fig. 1 under the curve (using calculus) and reviewing Section 9 PETM discussion adequately provide the corroborating facts for these CO₂ tonnage numbers.

Though it may seem like an impossible task at this time, the requisite trillion-ton carbon capture technology recommended here will only become more and more difficult with each passing year from now, similar to the US national debt, both of which keep growing. Justification for this "Saving the Earth for Humanity" project can simply be the realizable vision of a forlorn 300 ppm CO₂ environment or below, seen in Fig. 10, where only a 1°C increase from 14.5°C is maintained to stabilize global average temperature at 15.5°C and the global heat sinks called glaciers start to see the right, compatible environment to begin refreezing.

It is hoped that the simple, inextricably tight connection between global CO₂ values and global temperature, delineated and publicized by James Hansen and others, will finally create an urgency in the minds and hearts of all people, so that global atmospheric carbon capture by the gigaton can begin in earnest and *in parallel* with carbon-free fuels, zero carbon emissions, renewable energy, and even *negative carbon emissions*, implemented worldwide. That is our only hope to avoid Drs. Wing's and Solomon's assessment of "irreversible climate change."

COMPETING INTERESTS

Author has declared that no competing interests exist.

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