The Essential Role of Photosynthesis in Defining Net Zero Carbon Dioxide Emissions for Equilibrium Calculations

Dave White, Chemical Engineer. Climate Change Truth Inc.
Henele E’ale, Ph. D. Climate Change Truth Inc.
Dave White is corresponding author.

Keywords: Photosynthesis, carbon dioxide increase, carbon dioxide scavenging, climate change, Amazon Rainforest

ABSTRACT

In this research paper we, the authors, seek to answer four essential questions relative to the current Climate Change conversation now underway globally: (1) What is the numerically defined goal for annual Net Zero Carbon Dioxide Emissions in gigatonnes essential for global atmospheric homeostasis? (2) Why is atmospheric CO₂ rising even though recent data supports that CO₂ emissions have virtually leveled off globally? (3) Are CO₂ Cap & Trade Policies the best immediate intervention or does globally increasing photosynthesis offer a more rapid (and better long-term) solution to Climate Change? (4) What strategies can be employed to have the greatest positive impact over the upcoming crucial twelve-year period? Nothing absorbs carbon dioxide out of our atmosphere like photosynthesis, and therein lies the most under-discussed solution to the greatest problem of our time. A single hectare of healthy Amazon Rainforest can sequester up to 100 tons of CO₂ annually due to photosynthesis. And the fast-growing deciduous Empress Tree (Paulownia tomentosa), not only grows 10 to 20 feet tall in its first year, but a single hectare of these trees can sequester up to 103 tons of CO₂ annually due to photosynthesis (Emily Chasan, 2019).

Prior to the dawn of the Industrial Revolution (circa 1760) and long before global deforestation devastated Earth’s delicate atmospheric ecosystem, forests around the world have been estimated to consume 400 billion tons of carbon dioxide per annum with photosynthesis. As of 2019, that has been reduced dramatically as global forests are only 3.2 billion tons of carbon dioxide per annum with photosynthesis (Max Roser, 2014).

As a result of the global reduction in forest size, there has been a corresponding loss in photosynthesis and the natural carbon dioxide sequestration it creates. Estimates for global carbon dioxide sequestration have fallen from a minimum of 400 gigatonnes circa 1700 to as little as 10-12 gigatonnes annually, far below what is required to maintain global atmospheric homeostasis (CHRISTINE L. GOODALE, 2002). The minimum 400 gigatonnes is from healthy rain and other forests.

Currently, all organisms on Earth combined (including the burning of fossil fuels) releases approximately 37.1 gigatonnes of carbon dioxide each year. In order for humanity to restore the global atmospheric homeostasis essential for life, we must aggressively plant trees and regrow our beleaguered forests as the foundation of any comprehensive strategy for reversing Climate Change. Our forests are the lungs of our planet. Without them, we simply cannot breathe.
What Is the Numerical Goal for Annual Net Zero Carbon Emissions? (Net Zero CO$_2$e)

The logic of the current climate science theory is based on the hypothesis that we can stop the dramatic shifts in weather patterns that threaten all life by achieving global atmospheric equilibrium as we remove excess carbon dioxide from the atmosphere. However, a major problem in this discussion of atmospheric equilibrium is that the phrase Net Zero Carbon Emissions (Net Zero CO$_2$e) has not been defined. What number, in gigatonnes, is the target goal that would give us atmospheric equilibrium? How much carbon dioxide do we need to be consumed annually to get to the Net Zero CO$_2$e target goal?

Productive scientific communication for the development of a unified global solution with respect to the greatest challenge in human history is dependent upon scientific data that has been reviewed and scrutinized for accuracy before being agreed upon. In today’s climate change conversations, some climate change scientists have suggested that the Net Zero CO$_2$e target goal is 0, meaning every year we would need to absorb 37.1 gigatonnes of CO$_2$. Others simply use the term Net Zero CO$_2$e without having any numerical idea of what the target goal is and thus how much carbon dioxide will need to be removed from the atmosphere each year in order to get equilibrium. Defining Net Zero CO$_2$e is thus crucial in order to establish a foundation for the entire climate change scientific community before we can develop practical strategies designed to stalemate the progression of the rise of atmospheric carbon dioxide and ultimately reverse its threatening course.

The lead author has calculated the Net Zero CO$_2$e to be 9.2 gigatonnes per year, and this research article will demonstrate in detail how that number was arrived at with data sets being available for your review in the references. As of 2019, the estimated global emission of carbon dioxide stands at 37.1 gigatonnes. Therefore, a Net Zero CO$_2$e of 9.2 gigatonnes means that, in order for us to achieve atmospheric equilibrium and global environmental homeostasis, we must re-establish our ability to sequester 27.9 gigatonnes (27.9 billion tons) of CO$_2$ directly from the atmosphere each year.

Global reforestation is much more cost effective, time effective and rapidly attainable than relying on industry and individual governments to curtail their pursuit of control and market share. After all, what is easier to do? (A) Plant trees, as Ethiopia has done with 350 million new saplings in twelve hours or (B) Deliberate endlessly and without action over international policy and legislation that global industry will ultimately challenge before a neutered version becomes a law that must then be enforced through costly regulatory investigation and subsequent legal action. Logic dictates, that with a global catastrophe facing all humanity, now is the time for action with proven, natural, and trusted mechanisms for restoring global atmospheric equilibrium.
The logical reason that atmospheric CO\textsubscript{2} continues to rise in spite of CO\textsubscript{2} emissions leveling off globally (See Figure 7), is that we do not have enough trees, primarily due to deforestation, to photosynthetically reabsorb carbon dioxide from the atmosphere. Additionally the minimum residence time of atmospheric carbon dioxide is increasing (IPCC, 2003). As a result, the carbon that is still being emitted from all sources remains in the atmosphere and accumulates as a result of the 27.9 gigatonnes sequestering deficit gap. As countries like China, India, Pakistan, and Ethiopia have learned, our future is dependent upon trees and our ability to redevelop nature’s carbon dioxide sinks. Reforesting our planet can substantially increase global photosynthesis to first meet, and then exceed, the 27.9 gigatonnes that must be absorbed annually and in doing so buys us the time we need to address the myriad of additional companion issues like ocean clean up, animal agriculture and need for biodegradable plastic solutions.

Planting trees will act as the single greatest weapon we have in the fight against Climate Change. We plant trees en masse to regrow our forests and within twelve years, we position ourselves to end Climate Change. Our survival and the promise of life for future generations are dependent not upon on cap and trade policies or mitigation strategies, but rather upon trees.

### The Photosynthesis Equation

Photosynthesis is the biological process by which the plant cell organelle, known as a chloroplast, is able to “change” carbon dioxide into glucose to support its production of energy (ATP) for cellular function, including the \textit{replicated} biotransformation of CO\textsubscript{2} into glucose. Carbon dioxide is literally the preferred fuel source for all plant life; and with an abundance of it stranded in our atmosphere, there is more than enough fuel to support mass global reforestation. Here is the biochemical equation for photosynthetic sequestration of carbon dioxide from the atmosphere for your reference:

$$6 \text{CO}_2 + 6 \text{H}_2\text{O} \lambda \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2$$

### How Is Annual CO\textsubscript{2} Consumption Lost Due to Lost Photosynthesis?

1. Globally, we lose at least 1 gigatonne of CO\textsubscript{2} consumption annually due to city expansion into previously undeveloped lands.

2. The IPPC Forestry Group estimates we lose 2-3 gigatonnes of CO\textsubscript{2} consumption annually from bio-mass burning due to forest fires which excludes forest clearing for animal agriculture and wood commodity production.

3. Deforestation for animal agriculture and wood commodities in the Amazon Rain Forest alone accounts for a minimal loss of 30 million acres and 0.9 to 1.8 gigatonnes of CO\textsubscript{2} consumption annually.
4. Since 1950, Brazilian government policies and worldwide demand for inexpensive beef and wood have resulted in a loss of more than 60 gigatonnes of carbon dioxide consumption.

According to the IPCC SR1.5, the minimum carbon dioxide sequestration required is 45% of human carbon dioxide emissions by 2030. This reduces our CO\(_2\) emissions to 30 GtCO\(_2\) yr\(^{-1}\) -- in agreement with the statement of 25–30 GtCO\(_2\) e yr\(^{-1}\) in chapter 2 of SR 1.5. However, planting one tree every year for every man, woman, and child on Earth for ten years will increase carbon sequestration from Earth’s atmosphere by 0.7 gigatons each year and by 7 gigatons by the end of the first decade. This equals the 45% reduction in human emissions stated by IPCC SR1.5 2019 (IPCC, 2018). However, there exists no reference to where the 25-30 GT CO\(_2\) e yr\(^{-1}\) data came from. We calculated the current worldwide photosynthesis from land and ocean surface, and it is 9.2 GtCO\(_2\) e yr\(^{-1}\). Additionally, the total oxygen produced is 17.74 Gt yr\(^{-1}\) (E. Kintisch, 2017). Oxygen levels are declining. We need 39 GTO\(_2\) yr\(^{-1}\). The “natural” carbon dioxide emissions are calculated by 280 (baseline)/415 (current)*37.1 gt=20.2Gt yr\(^{-1}\). A 45% cut in human emissions will bring us to 30 Gt yr\(^{-1}\) and not to equilibrium. The emissions level we need to get to is below the natural emissions. Following are the calculations for the Northern and Southern Hemispheres.

### Northern Hemisphere

**Forest Photosynthesis**

Total forest hectares in the Northern Hemisphere is about 2050 million (CHRISTINE L. GOODALE 2002). There are no rainforests in the NH like the Amazon Rainforest. The coastal forests with more rain will consume 5 tons per hectare per year. The forests like the Cascade and Rocky Mountains in the US consume 1.5 tons per HA. Other forests like those in eastern Oregon and more arid locations consume 0.25 tons per HA. So the most that photosynthesis from vegetation in the NH could be is 1050(50% of 2050HA)*0.25 + 615(30%)*1.5+410(20%)*5= 3.2 gigatonnes of carbon dioxide consumption per year. Increased biomass from the Earth warming and higher troposphere carbon dioxide concentrations do not produce enough photosynthesis to offset the massive deforestation around the globe (Zaichun Zhu, 2016). Dave has studied photosynthesis for three years now. This is not what brings lowers the oscillation at Mauna Loa.

### Southern Hemisphere

**Forest Photosynthesis**

The Southern Hemisphere has much less land than the NH; however, it has rainforests. The Amazon Rainforest has switched to become a massive CO\(_2\) producer and oxygen sink (D. White, 2019) (Max Roser, 2014), (Robert Scribbler, 2016). Decay ingests oxygen and emits carbon dioxide. However, the decay contribution from the Amazon
Rainforest is ten to fifteen billion more tons of CO₂ annually with a corresponding loss of oxygen. This is from five tons per acre per year of decay. Anthropogenic forest degradation and biomass burning (forest fires and agricultural burning) also represent relevant contributions. The decay from the over two billion acres remaining of the Amazon Rainforest cancel out any other land and ocean-based photosynthesis in the SH. This is because of its switching to an oxygen sink and carbon dioxide emitter. See figure 1 below and the massive carbon dioxide release from the Amazon (the green arrow points to this area). Certainly, if the Amazon had not switched, then the carbon dioxide around it would have a much lower concentration. Up to 120 gigatonnes (120 billion tons) CO₂ consumption is lost annually from Amazon Rainforest switching, 2.5x our carbon dioxide emissions at 37.1 GT CO₂ yr⁻¹. The worldwide massive deforestation is why the minimum residence time of atmospheric carbon dioxide is increasing.

Since the oxygen levels are decreasing, the photosynthesis must be less than that decrease. See graph 1. The total worldwide oxygen needed is 39 Gt yr⁻¹. See Figure 2. The natural emissions are 20 Gt yr⁻¹. The oxygen from declining photosynthesis and ocean outgassing produced is 17.74 GTO₂ yr⁻¹

Atmospheric Carbon Dioxide Rise

Atmospheric carbon dioxide concentration is still increasing even though the emissions slope has decreased 60%. See Figure 3. Additionally, the rate of rise is still increasing. See Figure 6. This confirms no effect on atmospheric CO₂ rise by slowing emissions.
Atmospheric CO₂ is a binary system statistically [6,18]. Two causes are CO₂ emissions and loss of photosynthesis. We have had mostly flat human emissions (0.2 GT/yr vs. 0.5 GT/yr) since 2014.

However, atmospheric CO₂ is still going up and the rate of rise is increasing. In 2018, the Rxy correlation coefficient was 0.73 and not cause and effect. In 2019 it is now 0.63.

Carbon dioxide emissions correlate to 363 ppm and is a contributor but not the cause of the rise of atmospheric carbon dioxide since 1957.

**Effective CO₂ Emissions**

Effective CO₂ emissions are emissions per year after subtracting the total photosynthesis consumption for the year. For example, the worldwide emissions for 2018 are 37.1 GT. The worldwide photosynthesis is 9.2 GT. Thus, the effective emissions would be 27.9 GT. Calculating it this way tells the actual effect. Instead of our emissions effect being at 135 ppm of atmospheric CO₂, it would be 81 ppm from Effective CO₂ Emissions (ECE). This correlates well with total emissions effect at 363 ppm. 280 ppm are natural CO₂ emissions. 83 ppm actual effect. This confirms the correlation of total emissions at 83 ppm by statistics.

The oscillation at Mauna Loa starts as a very strong signal in South America and then fans out larger and larger until Barrow’s Alaska. The countries in South America burn the Amazon Rainforest, the densest forest
in the world, from October-November through May of the next year. Since 1950, an average of 30 million acres per year have been deforested and burned. So much CO\textsubscript{2} has been released that the trees and plants have grown too fast and died. This massive decay is what caused the Amazon Rainforest to switch to an oxygen sink and carbon dioxide producer. Hundreds of papers have been published on this.

Currently, the Amazon output is 15 GTyr\textsuperscript{-1} of CO\textsubscript{2}, more than twice as much as fossil fuel emissions of CO\textsubscript{2}. The switching of the Amazon Rainforest is a 0.99 cause and effect correlation to the rise in atmospheric carbon dioxide and loss of oxygen since 1957. The oscillation at Mauna Loa increases during the seven months of the deforestation and burning in South America’s spring and summer. See figure 7. Then at the end of May, the deforestation stops, and the Mauna Loa carbon dioxide data recede.

![Figure 7. Amazon Rainforest burning](image)

The rate of rise of atmospheric CO\textsubscript{2} is still increasing even though the global emissions have leveled off. See Figure 9. All countries have lowered their carbon dioxide emissions except China and India. All pollutants are measured by mass and should be reported as such, not reported per capita. China is the worst polluter of carbon dioxide and has not reduced any emissions. The USA has been decreasing its CO\textsubscript{2} emissions since 2006, and Europe has been decreasing since 1990. USA 2006: 6131 MtCO\textsubscript{2} and in 2018: 5270 MtCO\textsubscript{2} -- a 15% decrease of carbon dioxide. Europe 1990: 4479 MtCO\textsubscript{2} and in 2018: 3544 MtCO\textsubscript{2} -- a 21% decrease of carbon dioxide.
Ocean Photosynthesis

The oceans in the NH are currently producing six billion tons of photosynthesis consumption of carbon dioxide. This decline is for many reasons. However, if the oceans are a pump, the area without CO₂ is similar to the area with CO₂. See figure 5. Therefore, the output and the input cancel each other. Ocean photosynthesis is declining because of a lowering of pH (WWW, 1984), (Natalya Gallo, 2014). Excess carbon dioxide in the oceans disassociate to carbonate ions. This causes less carbon dioxide available for photosynthesis.

Cruise Ship Effect

In 2017, 25 million passengers traveled on cruise ships. The ships with on-board sewage treatment plants are so few that their effect is negligible. Thus, with the average cruise lasting seven days, the total passenger days are 175 million. Because people on cruise ships tend to eat more than usual, the wet weight of feces per person is maximum, at 1.5 kg (C. Rose, 2015). The excrement is 30% dry weight. Therefore, the mass is .3*1.5=0.45 kg. Each passenger contributes a little over 0.45 kg of solid waste per day. Therefore, we have 79 thousand tons of solid waste. Most of this is long-chained hydrocarbons with 50 - 125 carbons each. These will be converted to CO₂ by the decay process. For CO₂ the molecular weight is 36 and carbon is 4. Thus, the weight increases by nine for each carbon converted. Consequently, 73 million tons of CO₂ were added from cruise ships in 2017. Since 1990, the decay of human waste dumped into the oceans from cruise ships, based on the reported number of passengers each year, has resulted in a total of 1.1 billion metric tons of carbon dioxide in the oceans. This decay over forty years has removed oxygen and produced carbon dioxide in the oceans.

If all the cruise ships were made to offload their passengers’ waste products at ports and the rivers were cleaned of their pollution (e.g. the Petite Nèthe River near Antwerpen, polluted with horse manure), the ocean CO₂ would decrease. Only one port on the west coast of the USA has a facility to treat passengers’ waste products, but no one is utilizing it.

Diatoms effect

By assimilating the last 15 years of satellite ocean chlorophyll in an established biogeochemical model, we find that there are some significant changes in physical conditions, nutrients and phytoplankton communities in the high latitudes. In the Northern hemisphere, there is a shallowing of the mixed layer depth and a decline in nutrients that affects differently the phytoplankton community depending on the regions (Cecile S. Rousseaux, 2015).
Diffusion of CO$_2$ in the Troposphere

Greenhouse gases, like all gases, diffuse until they are equidistant to each other at any given pressure and temperature combination. At STP (Standard Temperature and Pressure, 25°C, 1 Atmosphere), CO$_2$ has the following diffusion coefficients:

In air: 16 mm$^2$/s

In water: 0.0016 mm$^2$/s

CO$_2$ is more likely to diffuse in the air than in the ocean (WWW, 1984). The diffusion length in air (bulk troposphere) is 2 cm per month toward the exosphere (Figure 10)[24]. The ocean-air interface diffusion is 14.8 cm per day in the direction of the atmosphere. The driving force for diffusion is much greater in the direction of the exosphere, where the concentration was 25 ppm in 2017. One year later, in 2018, the concentration had increased to 40 ppm. Flux = 2 cm per month towards the exosphere. The flux direction is correct. The flux number may or may not be correct. This is because of varying pressures and temperatures from the troposphere to the exosphere. A rigorous calculation is needed to determine the accurate flux number. CO$_2$ that goes into the ocean is from any disturbance of ocean surface (e.g. hurricanes) that allows CO$_2$ to enter the ocean. Most of the ocean’s surface is at standard temperature and pressure at any time. Furthermore, the atmospheric winds distribute carbon dioxide evenly by latitude. Except for temperature effect, every latitude has an equal chance to diffuse into the ocean. However, the concentrations in the flux graph are not even close to what diffusion principles would indicate.

$$J = -D \frac{dc(x)}{dx}$$

(Unit: D: cm$^2$/sec; J: number/cm$^2$/sec)

Figure 11. Ficks First Law

Figure 12. CO$_2$ mixed by atmospheric winds.

Worldwide

The total worldwide consumption of carbon dioxide is 3.2 (NH) +6(NH ocean) = 9.2 gigatonnes per year. Therefore, we cannot lower atmospheric carbon dioxide by working on emissions. It is a waste of resources because emissions are not the primary cause. Logically, 90% of human carbon dioxide emissions are from the NH. See Figure 13. The Mauna Loa carbon dioxide data peaks in May each year, and then declines until rising again in November. See Figure 14. The greater economic activity during the summertime in the NH produces greater amounts of carbon dioxide emissions. Then, in the fall each year, when there is less activity and it is not cold yet, emissions decrease. In November, the temperature drops in the NH, and more fossil fuel for heating is consumed. This increases the carbon dioxide emissions. In
April, it starts warming and carbon dioxide emission decline. See figure 14. However, the Mauna Loa carbon dioxide data show that concentration decreases during the same time that human emissions increase in the summer. Furthermore, the total photosynthesis in the NH forests is 3.2 gigatonnes per year.

Figure 13 SEDAC Population

Figure 14 Mauna Loa oscillation.

Atmospheric CO$_2$ Minimum Residence Time

A 2003 IPCC report states that atmospheric carbon dioxide minimum residence time was between 5 to 200 years, (IPCC, 2003). However, since 2003, the minimum residence time has been increasing. This means we have to wait more than 200 years for a change in our carbon dioxide emissions to take effect. This is also why atmospheric CO$_2$ is increasing even though the worldwide emissions of CO$_2$ have leveled off. Residence time of a system increases in either of two cases: 1. Input is greater than the drain can handle; 2. The drain is restricted. For atmospheric carbon dioxide, the drain restriction is the issue. This is why minimum residence time is increasing.

Solution for CO$_2$ Rise

Planting trees and shrubs is the only way to reduce atmospheric carbon dioxide (Robert Scribbler, 2016). This increases the equilibrium from 9.2 GT to over 100 GTyr$^{-1}$ within 12 years.

Acknowledgments

This research article has received no funding from any outside sources. All work performed by
the authors has been done without any compensation. The goal of Climate Change Truth, Inc. is to follow the data. The goal of The Energetic Health Institute is to share Information from the heart for the betterment of all. We have no conflict of interest that we are aware of.

Appendix 1.

Ideas on How to Plant Trees and Shrubs

Following is a government policy guide to lower atmospheric carbon dioxide quickly. When these actions are taken, atmospheric carbon dioxide consumption will increase by 7 billion tons worldwide annually. We can keep emissions at 37 Gt yr\(^{-1}\) without any new reduction plans. A refocus on planting trees and shrubs is what is required. Native plants that produce oxygen year-round are preferred.

1. Put pressure on Brazil and other Amazon Rainforest countries to stop deforestation as soon as possible. Stop the biomass burning that puts 300 million tons of carbon dioxide into the atmosphere each year, which causes the switching of the rainforest to an oxygen sink and \(\text{CO}_2\) producer. This caused the recent rise in atmospheric carbon dioxide concentration of 53 ppm (D. White, 2019). Then, after ten years, finish burning what is needed at 10% per year for ten years.

2. Provide space where the public can come and plant trees and shrubs on government-owned lands. The cost would be minimal. A website could be created to document each planting area.

3. Plant shrubs in all freeway medians and sides. This would pay for itself within two years because of lower maintenance costs. Plant native shrubs at a minimal spacing so all light is used in photosynthesis. This will take in 1 ton of \(\text{CO}_2\) emissions per acre per year right at the source of auto emissions. The space would not need to be mowed every week in the summer.

4. Get schools involved to plant massive numbers of trees and shrubs on their property and on government property as in 1 above.

5. Add trees and shrubs to parks.

6. Give tax incentives for businesses to plant trees and shrubs. People can plant shrubs on roofs which can structurally handle dirt with minimal spacing and drip irrigation, creating “green roofs.”

7. Attend to wildfires quickly. Get a retainer for a jet plane to use from the start of any wildfire.

When we do these things worldwide, we will increase carbon dioxide consumption by 2-3 billion tons per year (not including the effects of rainforest renewal, which eventually will consume 60-100 Gt yr\(^{-1}\)).
All embassy environmental scientists have concurred with this science and have encouraged their countries to plant trees. China is planting millions of trees. India stopped deforestation of its rainforest and is planting trees. Pakistan has already planted one billion trees and will plant nine billion more in the next four years. Since May 2018, these countries have planted more than 3 billion trees.

Appendix 2.

Simulation Scenarios

I received this response from an IPCC research scholar and chapter scientist of Special Report 1.5, Chapter 2: "Mitigation . . . " from which the statement of 25-30 GtCO₂e yr⁻¹ comes.

“Dear Dave,

Thank you very much for your question on the assessment of quantitative pathways in the SR15. The assessment is based on the ensemble of quantitative pathways compiled by the IAMC and IIASA for the IPCC SR15 process (https://doi.org/10.22022/SR15/08-2018.15429).

The Python script for preparing this table is available under an open-source license at https://data.ene.iiasa.ac.at/sr15_scenario_analysis/assessment/sr15_2.3.3_global_emissions_statistics.html (see https://doi.org/10.22022/SR15/08-2018.15428 for the scientific reference of the assessment notebooks).

Neither the statement nor the table does make any assertion about an equilibrium; it is merely an assessment of the pathways at a specific point in time. I do hope that this clarifies your request.”

The International Institute for Applied Systems Analysis (IIASA) Schlossplatz 1, A-2361 Laxenburg, Austria

A scenario is only as good as its inputs and constraints. This is especially true for predicting future values. The constraints for emissions must be natural emissions and zero emissions. These were not used; thus, wrong conclusions were obtained. It appears that IPCC is using only past data to predict future events. This explains why none of the previous IPCC predictions, including the so-called “Climate Emergency”, worked or will ever yield the desired result. Looking at Figure 16 below, I see two issues. There exists no boundary condition at 20 Gt. This is well known to be “natural” emissions level, which would be when all humans are removed from the earth. The other issue is that the simulation drops below that and below zero. It is impossible to have negative emissions.

Figure 16. IPCC Simulation.

Except for lagging temperature, not one of the IPCC projections is accurate.
Figure 17. IPCC Temperature Lagging

Also in chapter, two of SR 1.5 Mitigation is the table below. The 5 probabilities show only a 50-66% Probability of their emissions of carbon dioxide reduction working to lower atmospheric CO2. Planting A native tree is 100% probability of lowering carbon dioxide

Table 21 Classification of pathways that this chapter deals with, along with the number of available pathways in each class. The definitions of each class is based on probabilities drawn from the IAMC model. For more detail on IAMC model, please refer to https://data.ene.iiasa.ac.at/SR15/08-2018.15429/

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<th>Pathway group</th>
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</tbody>
</table>

Figure 18. IPCC probability 50-66%

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