CLIMATE EMERGENCY RESPONSE

Independent Stakeholder Group
Austin, Texas
September 2021

Re: Introduction and Report

This report is being submitted to Austin City Council to complement the *Climate Equity Plan*, a five-year revision to the *2015 Austin Community Climate Plan*. What we hope to accomplish with this report is two-fold: to introduce the most recent and advanced climate science, and to create discussion about leadership actions with climate change mitigation policy, that ensures activated climate tipping stabilizes, and unprecedented extreme weather events return to their normal rare occurrence rates, by restoring Earth's temperature to within the boundaries of Earth systems' evolution at less than 1.0 degree C above the normal pre-industrial temperature.

This deeply referenced report is divided into three sections: why a lower than 1.5 degrees C temperature target is now mandatory, solutions that seek to ensure we can restore our climate in time frames that matter to climate tipping, and issues that warrant further discussion in the *Climate Equity Plan*.

Why Less Than 1.0 Degrees C Is Mandatory

Our climate has now changed beyond the evolution of our Earth systems. This has resulted in the repeatedly unprecedented extreme weather events that have now become so blatantly obvious. The fires, floods, droughts and even the 2021 Texas ice bomb, are all associated with ongoing collapses of our Earth systems. These increasingly extreme events are definitively representative of climate tipping.

More than half of known climate tipping points are now active 100 years ahead of long-held consensus projections they would not become active until after 5 degrees C warming. They include the recently announced collapse of The Amazon, Canada's forest, and permafrost, totaling at least 3.5 gigatons of climate pollution emissions (not sequestration) every year. This is more than half of total US emissions. Nearly half of activated tipping systems have dynamic relationships with other tipping systems that increase the speed and extremeness of those systems irreversible collapses.

The ever-increasing extremeness and frequency of unprecedented weather events has been understated in science findings and our current 1.5 degree C climate policy. The reasons for understatement include scientific reticence, compromising consensus reporting, scientific communication that poorly addresses non-scientists' understanding of principles, and the slow nature of science in relation to the increasing rate of climate change. Climate modeling also does not yet robustly project rapid or abrupt climate changes. More deeply embedded in climate science, because our climate has just recently changed beyond its former stable state, a situation of non-stationarity in scientific data exists that in itself is one of the most important understatement factors in climate change.

These things, in addition to 30 years of delay in meaningful action to limit climate pollution emissions, have resulted in a climate system that is passing through irreversible thresholds generations ahead of when we have previously understood these things would happen. They have already resulted in critical environmental services from our Earth's systems being degraded, eliminated or reversed, and they are capable of initiating unrecoverable scenarios that result in large areas of Earth becoming uninhabitable.

Climate tipping is like an avalanche. Once it starts, it will not stop until collapse is complete, even if we were to halt all warming today. Also with no further warming, extreme events will become much more extreme as time passes because not enough time has elapsed since our climate has warmed above its natural evolutionary boundaries for rare events like the 20- or 100-year storm to occur. Warming to 1.5 degrees C additionally compounds these systems collapses multifold. This is the nature of these nonlinear threshold crossings of our Earth's systems. The concept of "what we do now influences the future" cannot be more existential.

A Local Solution Scenario

Austin cannot do it alone, but Austin has a proven record of environmental leadership and leaders are what are now needed, literally, existentially. There are about 2,500 climate plans globally with a significant proportion of 1.5 C plans. All of these plans allow already active irreversible tipping systems to complete, as they all allow further warming. Fundamentally, time is up and past goals for climate stability have changed. We do not know exactly when and how the point of no return will be crossed, but we do know it will result in large parts of Earth becoming uninhabitable much sooner than previously expected.

Because the fundamentals of climate safety have now changed, and because national, international and most state efforts to limit climate change have failed, we must take matters into our own hands to advance a new goal of removal of climate pollution from our atmosphere, by simply doing what we have been doing for well over a century with so many different local and regional infrastructures we have developed for the common good. The specifics of exactly how we do this may or may not resemble the specifics we suggest in this report. But the concept remains. We cannot risk further delay. And after all, the climate pollution remaining in our sky that has caused Earth systems to begin collapsing was emitted by us. It is our responsibility to clean up our own pollution –*and in addition and simultaneously*--achieve net zero emissions as soon as humanly possible.

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CLIMATE EMERGENCY RESPONSE

The Urgent and Immediate Response Needed to Reverse Activated Climate Tipping With a Safe, Sustainable and Equitable Target of Less Than 1.0˚C Warming Above Normal

offered as an enhancement to

Austin Climate Equity Plan

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https://climatediscovery.org/Climate_Emergency_Response_Austin.pdf

Prologue

A bomb cyclone in the North Pacific teleconnected into the Arctic about the first of 2021 with sudden stratospheric polar warming of 73 degrees Fahrenheit in five days. The sudden stratospheric warming caused a polar vortex collapse that sent a pulse of bitterly cold arctic air to Texas for Valentine's Day, riding a Rossby wave on an arctic amplification-caused jet stream stall that penetrated south to the Yucatan Peninsula. These things have all occurred before, but are likely happening much more frequently and extremely on our warmed planet, and will likely increase in frequency and extremeness even without more warming, creating far more cascading catastrophes like Arctic Storm Uri in Austin during February 2021.

Eleven days before the Texas ice disaster it was 85 degrees. Eleven days after, it was 86. At the coldest, it was 2 in the hills southwest of Austin. A total of 69 percent of Texans (20 million people) were without power for an average of 42 hours. All across Texas, the temperature plummeted inside homes without power, some to below freezing. Austin- Bergstrom Airport shattered their previous hours below freezing record of 121 from 1951, when they experienced 154 consecutive hours below freezing. Then, the cascading feedbacks and simultaneous catastrophes vastly complicated the disaster. Up to 978 people died because of this storm and the inadequacies of our current culture to address extremes worse than the worst-case scenario. The disaster cost $200 to $295 billion, more than the cost of Hurricanes Harvey and Katrina combined. Eleven feet suffering from frostbite were amputated at just one of Austin's three hospital systems. One of my senior engineering colleagues died of hypothermia; a senior engineer like me. We came four minutes from the Texas grid collapsing, an event that would have left most of the state without power for months. It wasn't a blizzard by the standard meteorological definition; but to most Texans, this epic event was most certainly a blizzard. A blizzard so extreme, that to us, it was unfathomable that conditions like these could ever occur in Texas.

Our climate has changed beyond its evolutionary boundaries. Climate catastrophes today, right now, are likely common in our *currently* warmed climate because, not enough time has elapsed since our climate has warmed above its evolutionary boundaries for rare and overly extreme events to have already occurred.

Bruce Melton PE, Principal Author
(References in Appendix 2)

What is a climate emergency response?

A climate emergency is upon us. For 30 years we have been warned of irreversible dystopian climate tipping impacts if we did not act to responsibly manage our climate pollution. Because of delay in action, more than half of climate tipping systems are now active. These impacts were only supposed to happen in the distant future, but like most climate change–caused impacts, they have now been activated 100 years ahead of widespread projections. The emergency has been caused by warming already experienced and by climate pollution already in our sky. Because climate tipping has now been activated, it will become irreversible with no further warming leading to unrecoverable human consequences.

Our response must definitively not be just more aggressive decarbonization, or broader and faster implementation of net-zero emissions. These actions only affect future warming. Likewise, our response must not be a target of 1.5 degrees C above normal as this allows tipping to become irreversible, causing the repeatedly unprecedented weather mayhem to increase nonlinearly in extremeness and frequency. To secure a safe future for humanity, we must now remove climate pollution from our atmosphere to reverse warming already experienced. Decarbonization and net-zero are still important for many reasons, but fundamentally we must reduce current warming to less than 1.0 degrees C above normal, back to within the evolutionary boundaries of our Earth systems, to stop the mayhem and reverse irreversible tipping.

A climate emergency response is the same as any emergency response. It is about acting immediately, using the tools at hand to save countless lives, by dramatically and rapidly lowering Earth's current temperature to prevent large parts of Earth from becoming uninhabitable in our lifetimes.

This report is being submitted to Austin City Council as a complement and enhancement to the Austin Climate Equity Plan update of the Austin Community Climate Plan 2015. It has been written by a range of Austin stakeholders, some of whom were not involved in the City's formal climate plan revision process.

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Cover Image: Wind turbines photographed across the Laguna Madre from South Padre Island during King Tide, October 2013. Normal, non-storm high tides exceeded dune erosion levels on South Padre Island 53 times June 2018 to May 2019 according to the tide gauge at Brazos Santiago Pass. The foreground of this image should be dry sand flats on the lee side of South Padre Island. The appearance of wind turbine flooding is caused by mirage. The dark blobs are tree motts or groups of trees growing closely together.

CLIMATE EMERGENCY RESPONSE

The Urgent Response Needed to Reverse Currently Initiated Climate Tipping: a Safe, Sustainable and Equitable Goal of Less Than 1.0°C Warming with Local and Regional Action

Delay in climate change action has now been so prolonged that impacts are happening 100 years ahead of schedule and climate tipping has already been activated. Climate tipping is far more rapid and extreme than the climate changes we have endured to date and causes Earth systems to collapse and change to states incompatible with the evolution of our advanced civilization. If the currently activated climate tipping systems are allowed to proceed, many will become irreversible and result in unrecoverable scenarios.

Once activated, tipping will complete with no further warming from today's global temperature of about 1.0°C degrees above normal. Therefore, a new and non-negotiable mission of climate restoration is required to cool Earth well below the 1.5°C goal of most climate plans (including the *Austin Climate Equity Plan)*, to less than today's temperature, in order to avoid unrecoverable scenarios.

This new mission of "less than 1.0°C warming above normal" requires we achieve net-zero as fast as possible, and simultaneously remove historic (already emitted) climate pollution accumulated in our sky. For 30 years climate scientists have warned us that delay would cause our climate to deteriorate more rapidly and mitigation would become more complicated. This warning is now being realized as a climate emergency. This report presents concepts and details of a new climate change mission, which describes our climate emergency and how appropriate response relates to known emergency behaviors in our society.

We will describe why recent climate impacts are now increasing more rapidly and how they could continue to increase more rapidly in the future even with net-zero emissions because of "warming in the pipeline". And we will discuss why extreme weather events today are likely common in our currently warmed climate, simply because not enough time has occurred since our climate has warmed beyond its former evolutionary boundaries for overly extreme and rare events to have occurred. We report why compulsory climate pollution management today must be much more aggressive than proposed in the past, when emissions reductions alone were thought sufficient to prevent dangerous climate change. We explain why further warming to 1.5°C dramatically increases inequities beyond what have already occurred and allows already activated climate tipping to become locked in.

Our interpretation of scientific findings defines the urgent time frames of this emergency, and how 30 years delay in climate reform by international, national, and most state entities has created a reality where local and regional leaders must accomplish what others have been unable to achieve.

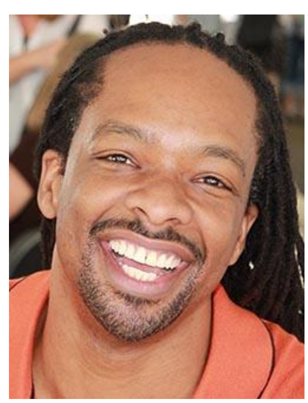
This report is the first of its kind to describe a local and regional climate emergency response plan based on a goal of less than 1.0°C. It consists of a sampling of last resort solutions by local and regional entities, so that we can responsibly deal with both future and historic climate pollution emissions, ending outsized risks from climate tipping and weather mayhem, and reversing already endured inequities through a safe level of warming of less than 1.0°C above normal.

Bastrop Complex Fire, September 4, 2011, 34,356 acres, 1,673 homes, $325 million of insured losses. This most destructive wildfire in Texas' history burned during the new drought of record. It was ignited by southerly winds above 25 mph from tropical storm Lee making landfall over Louisiana and fueled by record dry fuels.

“Hope is the opposite of desperation—it’s not as comfortable as certainty, and it’s much more certain than longing. It is always accompanied by the imagination, the will to see what our physical environment seems to deem impossible. Only the creative mind can make use of hope. Only a creative people can wield it.”

...with permission, Dr. Jericho Brown, 2020 Pulitzer Prize Winner

Jericho Brown a Winship Distinguished Research Professor in Creative Writing at Emory University, where he also directs the university’s creative writing program. His books of poetry are The New Testament, Please, and The Tradition, for which he won the 2020 Pulitzer Prize.



Lakeway City Park, Lake Travis, Central Texas, Drought of Record 2013.

TABLE OF CONTENTS

VISION STATEMENT
ADVANCING THE MISSION OF A CLIMATE EMERGENCY

Our new mission, according to the latest science, must be to cool Earth to less than 1.0°C warming above normal if we are to restore our climate in time frames that matter to climate tipping. We must act with the same urgency as any emergency demands by using the tools at hand to save lives.

Net-zero and 1.5°C climate plans, like the *Austin Climate Equity Plan*, represent the state of the art in how we as a society have been attempting to manage climate pollution. One hundred twenty countries, 823 cities, and over 1,541 companies have net-zero plans in 2020. (1) However, globally we are 57 percent behind emissions reductions required in 1992 to meet a 2.0°C warming target. (2) Austin is 10 percent behind the 1992 path. (3) With 30 years of delay in meaningful action, our current global warming of 1.0°C above normal has activated more than half of known climate tipping points 100 years ahead of schedule. This was not supposed to happen until after 5.0°C warming. (4)

The delay in action has simply been too long. Without a new climate emergency mission, many of these tipping points will become irreversible with societally unrecoverable scenarios “potentially making large areas of Earth uninhabitable," according to 14,000 scientists in a "Climate Emergency Warning" in the journal *Bioscience*. (5) Of critical importance, no further warming is required for these already activated climate tipping points or collapsing Earth systems to complete. Existing warming has pushed these Earth systems across collapse thresholds, and these threshold crossings are irreversible unless the global temperature is lowered below the tipping threshold temperature of less than 1.0°C warming above normal.

California fires burned an all-time record of over 4 million acres in 2020, rivaling annual totals from a century ago. CalFire alone spent $1.3 billion on firefighting in 2020 compared to almost zero a hundred years ago. (6) Colorado experienced their three largest wildfires ever recorded in 2020. Five hurricanes struck Louisiana in 2020 tying the record from 2005 set in Florida. (7) Permafrost collapse is plausibly releasing as much carbon dioxide every year as all transportation across the globe, and methane work has yet to be completed. (8) The Antarctic Ice Sheet has initiated collapse. (9) All of the National Oceanic and Atmospheric Administration’s (NOAA) tide gauges in the lower 48 reported an average of 1.5 inches (38 mm) of sea level rise in 2019 which is triple the previous record and ten times greater than the global average long term sea level rise of 3.5 mm per year. Sea level rise is on track to rise 14 inches by 2030 according to NOAA because of ice sheet collapse. (10, 11) The latest sea level rise cost evaluations are $14.2 trillion at risk with 10 to 20 inches of rise by 2030. (12)

Our former climate reform mission of greenhouse gas pollution emissions cessation can no longer create a safe and equitable climate. Warming has now driven the climate pollution reform mission into the realm of emergency. What we do today to treat the climate pollution already in our sky defines our climate in the long term. Our historic target of 1.5°C warming above normal is too warm. If we do not cool Earth to below 1.0°C above normal and reverse tipping activation, the scenarios will become unrecoverable.

To prevent unrecoverable scenarios we must restore our climate to a state where tipping stabilizes. Climate restoration requires we add a new focus to our climate pollution mission. Atmospheric climate pollution treatment needs to become central to our

Meaningful Action

The concept of "Meaningful Action" is pivotal in understanding the general failure of climate reform actions for the last 30 years. There are a few shining lights that have not failed: Austin is one example, California is an even greater example, and there are now thousands of excellent net-zero plans across planet Earth. However, results are what matter to our advanced civilization. Not only do we continue to warm, but very few of us are anywhere close to our emissions reductions paths allowing our climate to continue to warm at an ever alarming rate. Over the last several years the concept of "meaningful" action has taken on an even more urgent nature in that:

> *The great delay in meaningful action has caused repeatedly unprecedented weather mayhem, and activated ecological collapse and irreversible climate tipping points 100 years ahead of projections.* (13)

These extreme impacts ongoing today, especially climate tipping, have the capacity (if not reversed) to end civilization as we know it or as Ripple and 14,000 scientists state in their "Climate Emergency Warning" in the journal *Bioscience*s in November 2019, (14) "potentially making large areas of Earth uninhabitable." No amount of action even remotely similar to what we have been proposing for the last 30 years can reverse the climate change we are already experiencing, and restore our Earth systems to a non-collapsing state. Net-zero and emission reductions are still a part of the plan, but a small part. The critical challenge of climate reform is now addressing the last 200 years of emissions that have accumulated in our sky. If we would have started action 30 years ago as scientists advised, we would not now be in this position, but now we have no choice. "Meaningful action" is now defined as restoring our climate, not just following the legacy strategies of the past where we simply tried to avoid the worst of climate change by attempting to limit or eliminate emissions.

efforts. Net-zero is still important, but the amount of climate pollution we must deal with to prevent runaway mayhem globally is 8 to 12 times the amount of climate pollution we must address to achieve net-zero. ([15](#))

Our new mission demands infrastructure is in place in a decade that can not only achieve net-zero as fast as possible, but can remove excess climate pollution from the sky by 2040 to prevent unrecoverable scenarios.

Climate science has systematically overstated the amount of warming needed to create an emergency. This systemic lack of ability to accurately model future climate change–related impacts is why repeatedly unprecedented weather mayhem and the collapse of Earth systems are generations to a century or more ahead of projections. If we do not put into place mechanisms that not only achieve net-zero ASAP, but cool Earth to below the threshold of irreversible Earth systems collapse in time frames that matter, the result is a cascade of unrecoverable scenarios.

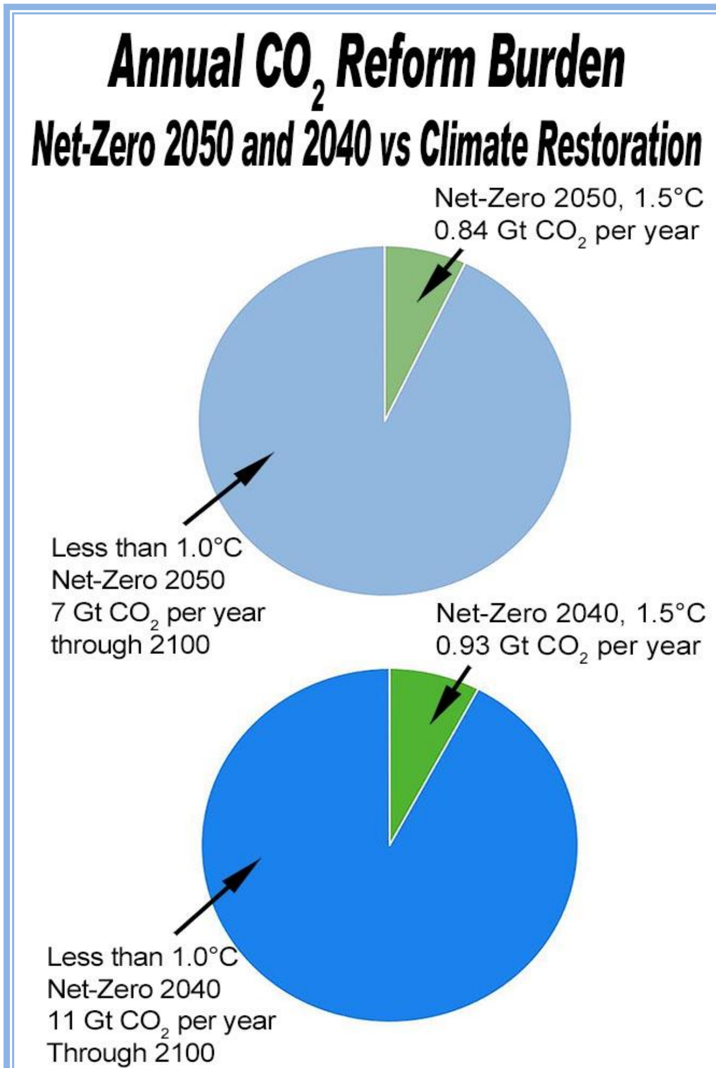
A climate emergency is no different than any other emergency. Emergency response means we must do what is necessary immediately with the tools at hand in order to save lives. Once the mission is adopted, actions implied by the new mission will allow us to move forward to create a safe world free from risks of societally unrecoverable tipping scenarios "potentially making large areas of Earth uninhabitable."

International, national, and most state leaders have failed to create climate safety for 30 years and they can no longer be relied upon. Further delay does not just mean more devastating impacts, it means unrecoverable scenarios. We must not only redouble all our past efforts, but we must create new action at the local and regional level capable of restoring our climate alone. Time is up. Tipping is active. We can restore our climate with local action, but first a new mission is required.

An NPR/PBS poll on September 19, 2020 reveals a new public sentiment that will spur leadership to act. Among Democrats likely to vote in 2020, climate change is now the number one priority--an even higher priority than Covid-19. [(16)](#) The priority of climate change in the history of our climate culture has been near or at the bottom of the list up until now.

The science is now clear that our new mission must address many times more historic climate pollution accumulated in our atmosphere than we will have to address with net-zero. Locally we must assume responsibility for about 288 million tons of historic climate pollution to limit warming to less than 1.0°C above normal. To create net-zero emissions by 2040, Austin must eliminate about 13 million tons. ([See Reference 30, Section 1.3.3](#)) The question is, "How will we address this new mission at the local level to both achieve net-zero, and take responsibility for our historic climate pollution?"

First adoption of a new mission has already occurred with two noted examples: in March 2020 Sierra Club adopted a new limit to warming of less than 1.0°C above normal [(17)](#) and in January of 2020 Microsoft, with 12 million tons emissions per year (Austin has 13 million), adopted a new mission of 0.0°C warming above normal with their commitment to assume responsibility for all climate pollution they have ever emitted. [(18](#), [19)](#) Leaders on the forefront can commit, and Austin is a leader at the forefront. It is time for Austin to commit.



These two graphics show that 8 and 12 times more CO_2 must be addressed to achieve climate restoration of less than 1.0°C warming vs a net-zero emissions and 1.5 C warming target, with negative emissions extending through 2100. Climate restoration includes net-zero emissions. Gt is gigatons, or billions of tons.

Ref: Hansen et al., Young people's burden-requirement of negative CO2 emissions, Earth Syst. Dynam., July 18, 2017.

For Austin to remove 288 million tons CO_2 from our atmosphere, we can create local infrastructures not only for things like carbon free energy and electric vehicle charging stations, but systems that advance building efficiency, increase public awareness, and create carbon dioxide removal (CDR) from the atmosphere with natural systems and traditional pollution treatment strategies. The infrastructures for CDR can use the captured CO_2 as an industrial feedstock to generate revenues both with traditional uses of carbon dioxide and for new uses like carbon negative concrete, myriad durable goods, and even low and negative carbon fuels.

We have been creating similar infrastructures for well over a century to benefit the commons that include our transportation systems, health systems, social support, societal governance, environmental safety, policing, public education, and critically, our water and wastewater and other utility infrastructures. We treat 116 gigatons (116,000 million tons) of potable water and human sewage every year in the United States alone. (20) Particularly important here is the concept of pollution treatment. When we discovered human sewage was killing millions in the 19th century, we did not stop making human sewage; we simply learned how to treat it just like we need to do with climate pollution.

We can remove some of the climate pollution with natural systems but they are limited. The key to our new mission is pollution treatment technology that in many ways is even simpler than the biologic reactor used to treat most human sewage. The recyclable lime and potash technology to treat climate pollution in our atmosphere was developed in the early 20th century and is noted for use in submarines in World War II to keep our sailors safe from carbon dioxide poisoning. This mature technology is now being scaled to remove millions of tons of CO_2 from our atmosphere every year. The next step is gigascaling, as we have already done so successfully with wind and solar energy, transistors and computing, as well as the 74 million automobiles we build every year, and recently with battery gigafactories.

The cost discussion is also fundamental to the things we do for the commons every day. The cost to remove CO_2 from the sky today is $100 a ton using the simple recyclable lime and potash process from submarines in WWII. (21) To remove Austin's entire historic climate pollution of about 288 million tons would cost $29 billion at $100 ton. Giga-scaling like with giga-battery factories would reduce costs per unit by at least 90 percent, (22) and when industrialization and disposal costs are included, total costs will be similar to the proposal to fix IH-35 in downtown Austin.

Carbon dioxide is a commodity that can be sold like electricity sold by Austin Energy. There are numerous markets that could be developed at the gigascale which include carbon negative enhanced oil recovery, low carbon or carbon negative concrete, and myriad industrial feed stock uses. Revenues generated from these uses can defray costs of capture and plausibly create positive revenue streams. What we have to do to realize this potential is first create the mission. The mission then drives an understanding of implementation. The final aspect of the new mission is the meaning of leadership.

We have a responsibility to deal with all of our pollution so that we can be safe regardless of whether it is climate pollution or human sewage pollution. First, adopting leaders have a great burden in imposing costs of new measures to ensure the viability of the common good: to be successful, the people they lead must agree. With "Democrats likely to vote" perceiving climate change as the number one issue, the Austin Region's chance of success is higher than most. With a change of national leadership, shovel-ready infrastructure projects could become reality, and climate reform infrastructure will be high on the list.

IT'S NOT THAT REMOVING CLIMATE POLLUTION FROM OUR SKY COSTS SO MUCH, IT'S THAT IT COSTS SO LITTLE.

This mission change is new. It is demanded by science. Leadership must declare the mission. Further warming, whether it is caused by delay in action or by the adoption of an outdated scientific target of 1.5°C warming, will result in nonlinearly increasing costs to our society with outsized risks "potentially making large areas of Earth uninhabitable."

Pinnacle Fire 2011, Oak Hill, Southwest Austin, Drought of Record. Live fuel moisture was similar to dead fuel moisture.

Beyond Evolution

It's the extremes that matter. The flood debris in this image is from the 2013 Halloween Flood on Onion Creek in Austin that city staff estimated was a very rare 1,900 to 2,300-year rainfall in our old climate. We have warmed Earth beyond the boundaries of the evolution of our advanced civilization and it is quite probably that extremes will increase nonlinearly with further warming above 1.0˚C.

It takes generations of data to understand how frequently these rare floods happen and we have only observed these extreme events in just a relatively few years where warming has been above the 0.5˚C warming above normal threshold that defines the natural variability of our old climate. In 2015 we saw a nearly identical flood on the Blanco River just ten minutes south of Onion Creek. Then, Harvey created over 20 inches of rain in less than 24 hours about 20 minutes east of Onion Creek on Cedar Creek which was significantly more rain than either the 2013 or 2015 events mentioned here.

The 100-year storm only happens on average every 100 years in long time frames. We have just begun to collect data on these epic storms in our new climate and it is very unlikely that in our warmed climate these storms are rare.

EXECUTIVE SUMMARY

Thirty years of delay in meaningful climate pollution reform action has allowed warming impacts to advance to such a degree that a climate emergency is now underway. We are 57 percent behind on emissions reductions that should have taken place based on 1992 projections for 2.0°C warming above normal and current impacts now demand much more comprehensive solutions than the past 30 years of policy.

Over the last decade, climate scientists have come to accept that 2.0°C is too warm, and have adopted a target of 1.5°C. The most recent science on climate tipping however suggests less than 1.0°C is the safe target and because most climate scientists agree that 1.5°C is now not achievable with historic climate reform strategies, a mission change is now required.

The *Austin Climate Equity Plan* is a leading policy document which we fully support, but our climate has now warmed so much that traditional solutions can no longer create safety. We have now entered into a phase of climate change that is so damaging to society that emergency response is mandatory. The amount of climate pollution already in our atmosphere will lock in currently initiated Earth systems collapses creating unrecoverable scenarios. This report is about the great urgency and scope of additional emergency actions required to realign the climate reform mission, to create emergency response to save lives, and to create policy that will help lead the world beyond failed historic climate reform actions. This is a science-guided document, based on academic references with detailed summaries following in the Reference Section.

Top Three Focus Areas of This Report

#1 Less Than 1.0°C Warming Target

Irreversible climate tipping is active 100 years or more ahead of schedule. We must immediately reduce Earth's temperature below our current 1.0°C warming above normal or climate tipping completes with grave risks to our civilization.

#2 A 1.5°C Target Dramatically Increases Injustice

Our most vulnerable citizens are already impacted by climate change more than others. Additional warming to a 1.5°C target creates greater inequality than already exists. To reduce inequality we must restore Earth's temperature to normal.

#3 Implement Immediate Emergency Response

Emergency response must be implemented now to save lives. Warming of more than 1.0°C above normal completes tipping which will trigger catastrophic unrecoverable scenarios risking hundreds of millions to billions of lives as large parts of Earth become uninhabitable.

SUMMARY OF KEY FINDINGS

Section 1 - A Safe and Equitable Target of Less Than 1.0°C Above Normal

1.1 - Why 1.5°C Is Not Safe: Climate science is understated which is evident by repeatedly unprecedented weather impacts and activated climate tipping, or Earth systems collapses, happening generations to a century or more ahead of projections. These impacts continue to increase nonlinearly (exponentially) with further warming to 1.5°C at a rate that is much faster than increases we have endured recently. More than half of known tipping points are now active and include: Arctic sea ice, Greenland ice sheet, boreal forests, permafrost, the Gulf Stream, the Amazon, coral, and the Antarctic Ice Sheet. Individual climate tipping systems feed back into other systems creating a cascade of uncontrollable impacts.

1.2 The Inequity and Injustice of 1.5°C: A warming target of 1.5°C above normal creates vastly more inequities and injustices than does warming of less than 1.0°C, because climate change impacts increase nonlinearly with further warming due to nonlinear systems responses. These extremes translate directly into nonlinearly increasing inequities with the greatest effect on economically and systemically prejudiced populations and are disproportionately felt by low income communities, Indigenous people, people of color, the elderly and children, those with illnesses and disabilities, and other marginalized peoples.

1.3 A Safe and Equitable "Less Than 1.0°C Warming Target": Prehistoric evidence shows elevated concentrations of greenhouse gases in our atmosphere cannot ensure a safe and stable climate like that in which our advanced civilization has evolved.

1.3.1 Target Atmospheric CO_2 - 350 ppm: The 2019 CO_2 concentration in our atmosphere was 411 ppm. With an atmospheric concentration above 350 ppm CO_2, prehistoric evidence shows collapse of ice sheets, 70 feet sea level rise, ocean acidification, and reduced sunlight reflectivity with diminished snow and polar ice (Earth's largest self-warming feedback). Earth systems' stability with less than 1.0°C warming is critical to the evolution of humanity and Earth's ecologies.

1.3.2 "Young People's Burden: Requirement of Negative CO2 Emissions:" A CO_2 concentration held stable at today's 411 ppm CO_2 results in a global temperature of at least 2.0°C at 2100 and 3.0°C at 2200. An atmospheric concentration of 350 ppm CO_2 is approximately 0.85°C at 2100. Globally, to achieve a target of 1.5°C at 2100, we need to achieve net-zero by 2040 or 2050 and remove at least 7 or 11 gigatons CO_2 from the atmosphere every year until 2100.

1.3.3 Austin's Historic Climate Pollution Burden (Legacy Emissions): Austin has emitted about 693 million tons of CO_2eq since 1900 of which about 576 million tons is CO_2. Because our climate is a net total system where all CO_2 behaves similarly, and half of CO_2 is absorbed by the Earth's biosphere, our historic climate pollution burden is about 288 million tons CO_2.

1.3.4 The Gap and Net-zero Cannot Achieve 1.5°C Anywhere, at Any Time: There is a 31 million ton CO_2eq (26 mt CO_2) gap of emission reductions in the *Climate Equity Plan's* emissions reductions strategies by 2040. Using natural systems atmospheric carbon dioxide removal, the *Climate Equity Plan* can remove an additional 13.7 million tons by 2040. If the entire gap could be filled so that the *Climate Equity Plan* could achieve net-zero, if transferred to the rest of the world, the equivalent net-zero world temperature would be greater than 2.2°C warming above normal at 2100. For Austin to achieve a warming target of less than 1.0°C or 350 ppm CO_2 by 2100, an additional 14.4 million tons CO_2 removal per year is required through 2040. If the amount of natural systems carbon dioxide removal proposed in the *Climate Equity Plan* was increased by ten times, 3.4 million tons of CO_2 could be removed per year leaving a balance of 11 million tons per year needing to be removed by atmospheric climate pollution treatment also known as industrial or technological carbon dioxide removal (CDR).

1.4 Local and Global Responsibility, Leadership, and Equity: Leadership at the international, national and state levels has failed to lower CO_2 emissions for 30 years. Because our climate has now rapidly entered the tipping phase, a state of emergency exists that requires local and regional entities to ensure climate safety leadership in a much abbreviated time frame. Historic leaders in environmental issues have a responsibility to accept this new leadership challenge.

(Summary of Key Findings continued)

1.5 The Climate Emergency, Climate Ethics, Moral Hazard and Precautionary Principle: Dystopian climate tipping points are now active and will complete, leading to unrecoverable scenarios, if we do not lower Earth's temperature to below the tipping point activation threshold of less than 1.0°C above normal.

1.5.1 Climate Emergency: The climate emergency is no different from any other; immediate action must be taken now to save lives. This action must be significantly more aggressive than those required to achieve a target of 1.5°C. Austin's 2019 *Climate Emergency Declaration* directs the City Manager to, "identify innovative policy approaches to address the climate crisis's causes as well as mitigation strategies, including the promotion of natural systems, green infrastructure, and carbon sequestration." The *Climate Equity Plan* addresses some of these but not enough to achieve 1.5°C. Additional "natural systems" and "carbon sequestration" are required to meet not only a target of 1.5°C, but a safe and equitable target free of irreversible tipping at less than 1.0°C warming above normal.

1.5.2 Climate Change Ethics, the Moral Hazard and Precautionary Principle: Historic interpretation of the moral hazard comes from the Precautionary Principle that states if there is substantial scientific uncertainty about the risks and benefits of a proposed activity, policy decisions should be made in a way that errs on the side of caution with respect to the environment and the health of the public. Because the risks of outsized impacts of irreversible climate tipping potentially include "large areas of Earth becoming uninhabitable," it is a moral imperative to accept a warming target of less than the climate tipping threshold of less than 1.0°C above normal.

Section 2 - Restoring a Safe and Healthy Climate to End the Climate Emergency

2.1 What is CDR? Carbon dioxide removal or CDR, is any strategy, practice or technology that removes carbon dioxide from the sky. CDR can be achieved with natural systems like forests, soils, agricultural practices and oceans, or it can be removed from the sky with traditional pollution treatment strategies.

2.2 CDR Strategies, Quantities, Cost/Benefit for Less Than 1.0°C Warming: Austin's climate pollution treatment burden is 11 million tons CO_2 removal per year that can only be filled with CDR pollution treatment technology. The simplest mature process for CDR is the recyclable lime-potash process, developed in 1904 and popularized in submarines in World War II to keep our sailors safe from carbon dioxide poisoning. This technology is being industrialized at the rate of a million tons per year today at a cost of less than $100 per ton CO_2 removed. With gigascaling, as with transistors, solar cells and batteries, costs will very likely fall by 90 percent. The total cost of CDR to address Austin's entire historic climate pollution burden would then be similar to what is being projected today to fix IH-35 downtown.

2.3 Funding and Revenue Generation for Less Than 1.0°C Warming: Austin's share of global World War II spending adjusted for 2020 global GDP is $40 billion per year. As a society we have demonstrated that we can pay what it takes to prevent unrecoverable global catastrophe if we find enough motivation. CDR has the great benefit of revenue generation through the sale of CO_2captured from the atmosphere. Local and regional entities can sell CO_2 like they sell electricity, or they can sell climate pollution treatment like they sell human sewage pollution treatment. There is a large menu of markets for air captured CO_2 that can be used to generate revenues that are enhanced by the California Low Carbon Fuels Sequestration Incentive and the IRS 45Q sequestration tax incentive. Very important -- CO_2 capture can occur wherever the demand for CO_2 exists, so climate restoration from far afield actions transfer to both Austin and the entire world.

2.4 Implementing a Climate Emergency Response to Limit Warming to Less Than 1.0°C: Incentives are the precursor to widespread technology adoption where adopting that technology has benefits to society. Incentives work with both nature-based and pollution treatment CDR. Because these CDR strategies are typically large scale, partnerships are advantageous. These partnerships can be with other governmental organizations, NGOs, private individuals, industry and mechanized agriculture. Funding for CDR infrastructure and partnerships to develop CDR strategies is the same as or similar to funding mechanisms and strategies local and regional entities have developed for infrastructure for transportation, water and wastewater treatment, social welfare, health care and police services.

(Summary of Key Findings continued)

2.4.1 Climate Emergency Response Actions, Ranked

1. **Adopt the Mission of Less Than 1.0°C Warming:** Once the mission is adopted, the path becomes clear.
2. **Assume a Global Leadership Position:** Austin cannot do it alone. First adopters have the responsibility of assuming a national and international leadership position to transfer policy for a climate emergency response.
3. **Implement Three Major Tasks Simultaneously:** These are: *Austin Climate Equity Plan* 2020, and Phase 1 and Phase 2 of the *Climate Change Emergency Response Plan*.
4. **Phase 1 - Immediate Climate Emergency Response:** Phase 1 implements emergency response to save lives with the tools immediately at hand. This response should be determined through executive decision based on emergency evaluation by staff, consultants, and partners, and be implemented before 2022.
5. **Phase 2 - Emergency Scaling:** Strategies, incentives, governance, and infrastructure should be in place by 2030, to not only meet our net-zero goals, but to become responsible for our total historic climate pollution burden by 2040. Results of this strategic planning should be included in budget year 2023.
6. **Stay On Target:** Dynamic strategic planning should be a 24/7 task appropriate to an emergency. It should also be based on the new nonlinear trajectory of climate change as well as addressing worse than worst-case scenarios.

Section 3 - *Austin Climate Equity Plan* 2020: Topics That Merit Additional Attention

3.1 Emissions Pricing: REACH (Reduce Emissions Affordably for Climate Health), is the largest and lowest cost one-year emission reduction achieved by a city program. Further exploration and implementation of REACH strategies should be carried out to enhance net-zero emissions reductions efforts.

3.2 Natural Gas: Emissions from natural gas should be treated no differently than emissions from Austin Energy. Power to Fuels (PtF) and Air to Fuels (A2F) should be explored and implemented to aid in net-zero emissions strategies.

3.3 Decarbonization of City Investment Portfolios: City of Austin can further its goals to reduce risks due to climate change and to its own investment holdings by assuring that those holdings are central to a portfolio of decarbonization.

3.4 Smart Building Technologies: Further strategies to advance the potential of Smart Building digital technologies should be explored and implemented including: Digital Twins, Internet of Things, AI (artificial intelligence), and Analytics, for automated and optimized control of HVAC and lighting.

3.5 Scope and Magnitude of Net-Zero (Carbon Neutrality) Costs: It is recommended the City couple the urgency of action with strategic vetting of the costs, equity, and barriers to carbon reduction methods to prioritize highest ranking strategies.

That Austin alone cannot create a safe climate is clear, but time is critical to prevent future unrecoverable scenarios. Leaders with Austin's reputation are needed to hasten action by others. Only if the world becomes responsible for its historic as well as future climate pollution will our civilization remain viable.

Our legacy climate reform strategies, or those strategies we have attempted to implement for 30 years, are no longer capable of saving our climate because of delay in their implementation. We were warned the solutions would become much more complicated with delay. Further complicating our current scenario, legacy strategies assumed our Earth systems could sustain substantial warming and remain intact. More than half of known climate tipping points or Earth systems collapses are now activated up to a hundred years ahead of projections.

The collapses began in the 2000s with between 0.5°C and 1.0°C warming. For most of the last 30 years, widespread consensus on when tipping was supposed to become active has been only after 5.0°C warming. These Earth systems: Arctic sea ice, Greenland ice sheet, boreal forests, permafrost, the Gulf Stream, the Amazon, coral, the

West Antarctic Ice Sheet, and parts of the East Antarctic Ice Sheet, are all fundamental to the evolution of our advanced civilization. Without their services, our human evolution is at risk of collapse. It is now clear that only the restoration of our old climate can preserve the evolution of our Earth systems and prevent unrecoverable scenarios.

The emergency responses we must now implement are crucial to the survival of humankind. For 30 years we have assumed simple reduction or elimination of climate pollution emissions could prevent climate change that exceeded what was assumed to be the dangerous threshold of 2.0°C. We now know this thinking was inaccurate at best with the consensus lowering the warming target to 1.5°C. But this new target was set before it was known that tipping has now activated. This is why a new mission with a warming target of less than 1.0°C is so crucial. The reason it is "less" than 1.0°C is our natural climate variability, or the range of temperature where our Earth systems evolved.

This range of temperature was about 0.5°C warmer than the average temperature from about 200 years ago, or what is referred to as the pre-industrial era. Like almost any system and especially living systems, when baseline conditions change beyond the evolution of that system, the system collapses, then re-evolves into a system that can exist within the new range of baseline conditions. We are seeing this happen now with activated climate tipping a hundred years ahead of schedule and only cooling Earth below today's temperature can prevent unrecoverable scenarios.

The concepts in this report rely upon leadership, and are based on the future instead of the past. When President John F. Kennedy said we would go to the moon in 1963, Americans had spent a total of 15 minutes in suborbital space. The naysayers of the day were adamant that man would never walk on the moon, in large part because we had yet to actually visit deep space. President Kennedy understood the capacity of our advanced civilization to overcome challenges if -- there is appropriate leadership to spur motivation. We the people of this same world can indeed be responsible for all of the climate pollution we have ever emitted that remains in our sky if -- leadership creates appropriate motivation.

This report presents the strategies that can finally address the climate emergency and enhance the *Austin Climate Equity Plan* so that it speeds emergency response, develops local and regional governance and funding mechanisms that must occur to be successful, creates revenues that can be generated with climate pollution treatment to reduce direct costs, and furthers the concepts of responsible climate reform leadership to restore a safe climate and eliminate climate change-caused inequity worldwide.

Inset, next page - Dune erosion from sea level rise on Padre Island: These two images are both from Texas' Padre Island, the longest barrier island in the world at 113 miles. They are both representative of the condition of the island in 2003 (top) and 2018 (bottom.) None of Padre Island is significantly impacted by human–caused subsidence and only very marginally affected by natural subsidence. Both were relatively stable at the end of the 20th century considering sand starvation from inland reservoirs. About the year 2013, the beach on Padre Island began to be completely submerged during King Tide periods because of sea level rise beyond the barrier island disintegration threshold. About 53 times between June 2018 and May 2019 the tide gauge at South Padre recorded a maximum daily tide that was high enough to create dune erosion. NOAA's 2019 high tide flooding report says that the year 2019 saw a substantial one-year sea level rise record set at 1.5 inches, triple the previous record. This record is ten times greater than the global long-term average sea level rise. (1)


2003


2018

CORE CONCEPTS CENTRAL TO THIS REPORT

This report is largely about the future, in that if we do not invest heavily in what could be, but rely upon guidance from the past, it is quite likely we will continue to fail at climate reform, with the inevitable untenable societal scenarios that we have been warned would occur if we delayed. It is understood that some of the technologies or points of science discussed in this report may be represented in popular media to be nascent, controversial, or too expensive, and many scientific summaries also may make similar representations. The reality is that almost all of the climate science consumed by the media and policy makers comes from consensus works that by nature are reticent and therefore understated. When this understated reporting is viewed with the knowledge that the individual science findings themselves are reticent as well, understatements are even greater. For more on the magnitude of understatements in climate science, please see Section 1.1, "Why 1.5°C Is Not Safe," and importantly, see the bulleted list on page 24. Also please remember, without leadership --without leaders willing to take risks-- advancements come slowly; too slowly to meet time frames that matter with a collapsing climate.

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Climate policy today is based on consensus reporting of academic literature and has created a situation where classic academic understatement and the accompanying debate have delayed action on the most important issue of our time. This delay has allowed impacts to rapidly intensify into an emergency situation. As a result, traditional solutions can no longer create safety; we have been warned this would happen. Traditional solutions still help, but they are only a small fraction of the effort now needed to restore safety and end the emergency.

This document draws upon individual findings and expert knowledge from around the world to move climate policy forward at a rate appropriate to emergency response. We do not dwell on the academic debate on the issues -- this debate delays action and is why dystopian scenarios are now active. What we do is present the solutions in the academic literature appropriate for an emergency, to move forward with immediate response to save lives.

Content in this document is not intended for debate; it is intended to prescribe action that must occur immediately to prevent already activated climate tipping from creating societally untenable scenarios. We present the leading edge: a place where emergency action begins immediately. These actions can certainly be refined, changed, or modified as new knowledge dictates, but in an emergency, debate and refinement occurs after immediate action to save lives with the tools at hand.

GLOSSARY OF TERMS, CONCEPTS AND DEFINITIONS – Appendix 1

Some of the terms, concepts, and definitions we use are common in science but poorly understood by some so we have included a glossary of terms to enhance understanding. A sample of glossary topics is below:

- 0.5°C Maximum Normal Temperature Variation in Our Old Climate
- 1.0°C, 1.5°C, 2.0°C, Degrees Above Normal, etc.
- Degrees C (Centigrade or Celsius) of Warming - Conversion to Fahrenheit
- Benchmark Plans for 1.5°C and 2.0°C
- Carbon Dioxide, CO2, CO2eq and Emissions
- CO2 ppm, the Concentration of CO2 in Our Atmosphere
- Carbon Dioxide Removal (CDR) and Negative Emissions Technologies (NETs)
- Climate Modeling Projections
- Climate Restoration
- Committed Warming or Warming in the Pipeline
- The Consensus
- etc.

Lake Buchanan, Greenwood Acres Pier, Central Texas, Drought of Record 2011-2013

Section 1
A Safe and Equitable Climate

For nearly 30 years we have all supported a goal of limiting warming to the dangerous threshold of 2.0°C warming above normal. The 2.0°C target, however, was created with imperfect knowledge in 1989. The IPCC 1.5°C Report in 2018 basically reduced the dangerous warming limit to 1.5°C above normal. Now, we find that our modeling of future climate extremes has been greatly underestimated by generations to a century or more. Unprecedented weather extremes are happening repeatedly in recent years, and activation of climate tipping is now evident 100 years or more ahead of projections. In addition, globally we are 57 percent behind on emissions reductions that should have taken place based on 1992 projections for 2.0°C warming above normal. (1)

Science and the consensus are slow. The recent weather extremes and climate tipping have not yet been baked into consensus reporting of climate science upon which policy is based. This is why we need leaders to adopt new missions with our rapidly changing climate emergency. Our policy world is trapped in a dangerous 1.5°C box. It takes vision and a keen knowledge of the latest science to ensure our safety.

Austin is a leader in environmental issues with a proven track record and now is the time to advance that record again. By adopting an even more forward-leaning climate policy of less than 1.0°C warming above normal, Austin can do its part in helping the world restore increasingly unprecedented and more frequently occurring weather catastrophes to normal rare levels; reverse activated climate tipping to prevent irreversible scenarios, reverse current inequities caused by our already dangerous climate, and prevent further inequities caused by additional warming on our way to a 1.5°C target.

South Padre Island wilderness beach erosion from non-storm high tides. (Drone shot) The black sand is iron-based magnetite, heavier than normal sand and a common though very small component of almost all sands. Erosion has pulled the lighter sand off the beach out into deeper water and the heavier magnetite remains on the beach.

Pinnacle Fire losses, Austin, Oak Hill, Texas, May 2011.

1.1 Why 1.5°C Is Not Safe

In this section we describe the basis for a climate emergency with well over a dozen relatively new things in climate science to illustrate how vastly understated climate science has been for the last 30 years. These demonstrate how dangerous our world is today and suggest how astonishingly more extreme our world can become with just a small amount of additional warming to 1.5°C.

Today's warming is 1.0°C above normal, or above the average temperature from the time when we began to burn fossil fuels and emit the climate pollution that largely remains in our sky today. This 1.0°C above normal is 0.5°C warming above the maximum natural variation in our old climate, or 0.5°C above the boundaries of the evolution of our world's ecological systems that we depend upon for the existence of our advanced civilization. Because 0.5°C warming above our old climate's natural variation has created such unprecedented understatements in climate science projections with repeatedly unprecedented weather events, and additional warming creates impacts that are nonlinearly more extreme than previous impacts, the importance of not allowing additional warming above 1.0°C cannot be understated.

The definition of climate safety is not what it was in 2015. The shift started around the year 2000 when our climate warmed above the evolutionary range of our advanced civilization. (1) This range is also known as natural variability, or the meaningful natural range of our normal climate's temperature. At first, it was difficult to identify those impacts and extremes that were caused or enhanced by climate change. Then the science of *event attribution* was developed to help us understand impacts of warming. (2) As we warm further, impacts increase more rapidly, much faster than the rate of warming and the rate of increase follows the nonlinear physics related to temperature, and can be compared to a flash flood, an out of control wildfire or an avalanche. More heat in the environment creates nonlinearly more energy. In other words, a little more warming does not create a little more extreme weather; it creates a lot more because of the basic laws of thermodynamic physics. (3)

Since about 2015, the ever-increasing extreme nature of impacts has begun to be quite obvious – so obvious that a National Public Radio poll found the climate change issue has suddenly leapt to first priority among Democrats that are likely to vote, ranking even above Covid-19. (4)

Climate change-enhanced and -caused weather extremes and Earth systems collapses are now happening far ahead of schedule. Antarctic Ice Sheet collapse is 100 years ahead of schedule. (5) Permafrost collapse is 70 years ahead and plausibly emitting as much CO_2 as all transportation globally every year, and the collapse is so new that its methane emissions have not been determined.

(6) The Amazon has already flipped from carbon sink to carbon source three times since 2005, with a permanent flip now projected by 2035. (7, 8) Canada's forests have also flipped. (9) Globally, major hurricanes have increased in intensity on average 32 percent and up to 60 percent. (10) Intense rainfall today is already triple the IPCC 2100 projection in Houston and double in Austin.

Southwestern North America is 20 years into a megadrought that rivals the worst megadrought in the last 1200 years. Naturally, these droughts can last for hundreds of years and are ten to a hundred times worse than the Dust Bowl, but this one is principally driven by human climate warming, resulting in much more extreme conditions than would occur naturally. (11)

The largest California fires ever have tripled in size in the last four years regardless of fire suppression and excess fuels. In our old climate, these were main contributing factors, but the latest science suggests that warming has caused dryer fuels, bigger winds, and easier ignition with warmer temperatures, creating wildfires that are now 400 degrees hotter than before climate change. (12) Forest area failing to regenerate after fire in the American West has doubled since 2000 and overall regeneration density has been reduced by half. (13) Drought is now so widespread, persistent, and so severe that a new type has been defined, "ecological drought," where existing ecosystems are being replaced through ecological evolution by more tolerant species. (14)

Sea level rise is currently following the Intergovernmental Panel on Climate Change's (IPCC) worst-case scenario (15) and NOAA has now stated that the US average sea level rise not including Alaska, from 2018 to 2019, is an astonishing 1.5 inches, or 38 mm – ten times the global average. (16) Impacts from sea level rise are projected to put $14.2 trillion in assets at risk across the globe when the rise reaches 10 to 20 inches. (17) NOAA's 2017 sea level rise report matches this 10 to 20 inch rise projecting the worst-case to be up to 14 inches by 2030 (18) and NOAA's 1.5 inches sea level rise record in 2019 is on track to linearly achieve 14 inches by 2030. With 20 inches of sea level rise, impacts are expected to be $10.2 trillion –*per year,* with 34 inches, $14 trillion per year and with 70 inches, $27 trillion per year and the IPCC maximum adaptable sea level rise is three feet per century, with economic collapse the result of exceedance. (19)

Climate Tipping, or Earth Systems Collapse

Climate tipping, or abrupt collapses of Earth systems, are fundamental systems changes that radically alter our climate in extremely rapid time frames. These time frames are 10 to 100 times faster than climate changes we have been expecting. They were not supposed to happen until greater than 5.0°C warming, but have now been activated up to a hundred years ahead of schedule. They have initiation periods that once exceeded, can create scenarios that are irreversible in meaningful time frames. These are likely by mid-century, and can only be reversed if we cool Earth to below today's 1.0°C above normal. More than half of known Earth systems tipping points are now active.

> *Over 14,000 scientists have declared a climate emergency warning in the journal Biosciences because of the outsized threat of irreversible climate change that has the capacity of "potentially making large areas of Earth uninhabitable." (Ripple 2019)*

More than half of known climate tipping points are now active or in other words, they have been initiated. They represent the collapse of Earth systems. No further warming is needed to complete their initiations, and many are likely irreversible. Forty-five percent create positive feedbacks that enhance and hasten tipping collapses through cascading chain reactions. There was widespread agreement for most of the last 30 years that tipping points were not supposed to become active until after 5°C warming (9°F average globally over land and water, 18°F over land). These tipping systems are now active 100 years ahead of schedule with our current 1.0°C warming (1.8°F average globally over land and water, 3.6°F average over land) and they include: Arctic sea ice, Greenland ice sheet, boreal forests, permafrost, the Gulf Stream, the Amazon, coral, the West Antarctic Ice Sheet, and parts of the East Antarctic Ice Sheet. (20)

There are many reasons why climate change is happening so far ahead of projections that are fundamental to understanding the urgency of the climate emergency. We will not go into the details here, but a simple list is meaningful:

Climate Change Understatement Factors

- Consensus reports upon which climate policy is based compromise individual findings to reach a consensus.
- Individual science findings themselves are reticent.
- The climate change countermovement has sown doubt that has infiltrated climate science outreach. (21)
- False balance in the media gives equal weight to the factual and nonfactual nature of the perceived climate change "debate", furthering doubt. (22)
- Climate policy is politically influenced.
- There are fundamental statistical challenges of robustly revealing recent trends in long time frame dependent climate change data evaluation.
- Modeling cannot robustly project weather extremes and abrupt Earth systems tipping, and
- There are only very poor safety factors in climate science.

Given the understatements in climate science, and the policy and awareness that have resulted; given the dangerous impacts of ever-increasing extremeness of unprecedented weather, and given that further warming above today's 1.0°C above normal likely allows near future irreversible Earth systems collapse tipping – a 1.5°C world is decisively unsafe.

To achieve a healthy climate equitable to all, we can no longer rely upon the 1.5°C target. The science on exactly where this new limit should be set below our current 1.0°C of warming is not yet clear, but it is clear that current warming is decisively unsafe. Time frames to achieve climate safety are also not clear because it is only in the last few years we have come to understand that climate tipping has caused a true climate emergency to be under way.

What we do understand is risk. We know that all the mayhem began sometime in the decade of the 2000s when our temperature rose above the natural variability of our old climate at about 0.5°C of warming. We also know that risks from climate impacts increase even more rapidly than the temperature with further warming (nonlinearly), and that some tipping systems active today could take control of our climate, if (when) they cross the irreversible thresholds, "potentially making large areas of Earth uninhabitable." (23)

To ensure a safe world free from risks of climate tipping, emergency risk avoidance processes should be followed. Traditionally, the insurance industry has set the standard in risk avoidance. The general insurance standard for weather catastrophes is to protect against a rare occurrence, "the 100-year event" or that event that has a one percent chance or a 1 in 100 chance of occurrence or failure. Net-zero 1.5°C 2040 and 2050 scenarios however have a much greater chance of failure of 1 in 3 or 1 in 2 (a 33 or 50 percent chance of failure). (See more at the Safety Factor discussion in Appendix 1) Because climate change impact projections can largely be associated with the worst-case modeling scenarios, and scenarios are significantly understated, worse than worst-case scenarios should be used for both emergency, and normal climate change planning purposes.

Climate Science Safety Factors are 30 Times Less Than Insurance Standards

Traditional insurance standards protect to the 100-year event, or an event with a one-percent chance of occurrence or failure. Climate policy only protects to "most likely" scenarios. With 1.5 °C scenarios, there is at best a 33 percent chance of failure; in other words, 33 times more likely than the 100-year event. (See more at the Safety Factor discussion in Appendix 1)

Bastrop Complex Fire, Labor Day 2011, just east of Bastrop on US 71

Normally, the forests in our region do not burn. They have not evolved with fire. Epic drought, like in 2011 to 2013, produced drying that is foreign to the evolution of our regional forests creating condition where these epic fires can not only exist, but become common, especially if we allow further warming to 1.5°C. This image was one of eleven homes destroyed by the Pinnacle Fire in May 2011.

1.2 The Inequity of 1.5°C

Very simply put, a warming target of 1.5°C above normal creates more inequities and injustices than does a warming target of less than 1.0°C. The reason is that impacts and inequities increase with warming and additionally, they increase nonlinearly with further warming.

Systemic racial and economic inequities are hard-wired into our society. The reasons are many, the reality undeniable, and the *Austin Climate Equity Plan* is doing its part to reduce inequities on a warmer planet. But what we want to emphasize in this section is that further warming from our current 1.0°C above normal creates markedly more inequities from climate change than what we have already endured both globally and in the United States.

Research in 2019 from Stanford tells us that, "The gap between the economic output of the world's richest and poorest countries is 25 percent larger today than it would have been without global warming." (1) Inequities from climate change are already significantly impacting the poorest, and we are still far below the accepted warming target of 1.5°C above normal.

Research from University of California Berkeley, Cambridge, University of Chicago, Rutgers, Princeton and others tells us, "In the United States, the effects of climate change are disproportionately felt by the least privileged, and so climate becomes another conduit for reinforcing existing inequalities." (2)

The *Austin Climate Equity Plan* addresses inequities with a 1.5°C target, and lessens future inequities as we warm to this 1.5°C target. However, large challenges remain that include: current inequity caused by current warming, that portion of inequity not addressed in the Equity Plan by further warming to 1.5°C, and the reality that net-zero alone and the "The Gap" in the *Climate Equity Plan* cannot achieve 1.5°C. IPCC is clear that a temperature of less than 1.5°C requires up to 1,000 gigatons CO_2 removal, plus net-zero new emissions. (3) This amount of removal is roughly the same as all the CO_2 ever emitted that remains in our sky. As the *Austin Climate Equity Plan* says, "if all the strategies in the *Climate Equity Plan* are adopted, greenhouse gas emissions will still remain above the 2040 net-zero target line." The Plan goes further to say offsets or negative emissions are required to meet Austin's warming goals. Negative emissions and offsets are carbon dioxide removal or CDR that are used to achieve warming goals where emissions reductions or elimination is limited. (See CDR and NETs)

Creating and purchasing offsets requires a global scale and takes time we do not have. It is up to leaders to shorten the emergency response time frame so that we can reduce Earth's temperature below the tipping threshold before tipping becomes irreversible.

There are also sustainable and equitable offset quantity limits from natural systems of about 10 percent of future annual emissions. Less privileged peoples should have first and equitable access to these "easy" offsets and limiting warming to a safe level of less than 1.0°C requires more offsets (or CDR /NETs) than a 1.5°C target. The remaining offsets to achieve a target of less than 1.0°C must be created by CDR strategies. Though this technology has been in existence for 100 years, it has yet to be scaled to meaningful capacities. This is the responsibility of climate emergency leaders – to scale or incentivize scaling of needed CDR so that less privileged cultures do not have to. (See Sections 1.3.2 through 1.4 for more on quantities.)

It is very important to understand that net-zero alone allows 2.0°C warming by 2100 and 3.0°C by 2200 according to the former director of NASA's climate modeling agency as well as the majority of academic literature summarized by IPCC and other consensus climate science organizations. (See Section 1.3.2)

The prolific net-zero plans today vastly increase inequity because they allow further warming. It is the responsibility of leaders to advance policy to lessen inequity. These inequities cannot be cured by Austin alone, but Austin can advance leadership by progressing their own policy.

There are further inequities from afar if Austin chooses a warming limit of 1.5°C. The City of Austin and its citizens depend on manufactured goods that come from places far away. Manufacturing of these goods in faraway places creates pollution. That pollution creates inequities for those in the vicinity, and we in the Austin Region use those goods and services. Therefore, we are liable for the inequities embodied in goods and services that originate outside our region.

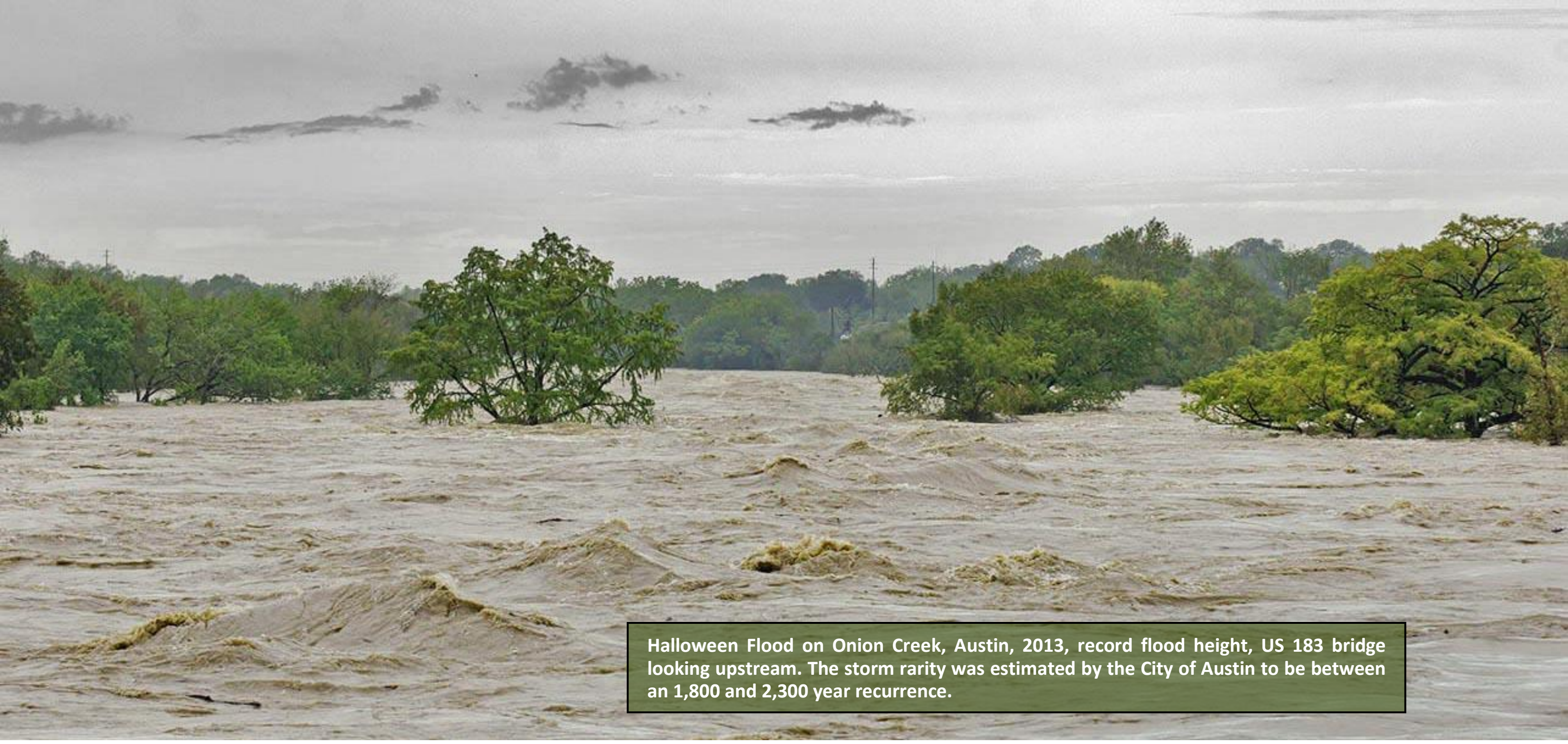
"IN THE UNITED STATES, THE EFFECTS OF CLIMATE CHANGE ARE DISPROPORTIONATELY FELT BY THE LEAST PRIVILEGED, AND SO CLIMATE BECOMES ANOTHER CONDUIT FOR REINFORCING EXISTING INEQUALITIES." (REFERENCE 2, SECTION 1.2)

A lower warming target of less than 1.0°C above normal, one that returns weather extremes to their normal rare occurrence rates and reverses climate tipping, can eliminate ever increasing inequities that would otherwise occur with warming to a 1.5°C target, and reduce harmful inequities already being endured today.

There is a remarkable equity component that can come from leadership adopting a lower warming limit. If enough leaders adopt a lower limit, the lower limit will likely be transferred to global policy. This eliminates warming-caused inequity world-wide.

Further Warming From Today Increases Inequity Nonlinearly

Inequity from climate warming is directly linked to warming-caused or –enhanced climate change impacts. Because climate change-caused or -enhanced impacts are already unprecedented today, and because impacts increase nonlinearly with further warming due to the basics of thermodynamics physics, inequities will increase dramatically with warming from today's 1.0°C to a warming target of 1.5°C.



Halloween Flood on Onion Creek, Austin, 2013, record flood height, US 183 bridge looking upstream. The storm rarity was estimated by the City of Austin to be between an 1,800 and 2,300 year recurrence.

1.3 A Safe and Equitable "Less Than 1.0°C Warming Target"

The "less than 1.0°C warming target" is not new. It was developed by Dr. James Hansen, known for his 1988 Congressional testimony on climate change that was one of the first national calls to address climate pollution. (1) He was the director of the NASA Goddard Institute for Space Studies for 32 years, which is also the de facto US climate change modeling agency. He is likely the world's premiere climate modeler that in 2008 with a team of nine others published in *Open Atmospheric Science Journal*, "Target Atmospheric CO_2: Where Should Humanity Aim?" This work was the principle origin of the 350 ppm target. (2)

1.3.1 Target Atmospheric CO_2 - 350 ppm

When Bill McKibben founded his climate change advocacy organization 350.org, he literally waited on James Hansen to publish his "Target Atmospheric CO_2" paper as the basis for labeling his organization "350.org."

James Hansen's "Target Atmospheric CO_2: Where should humanity aim?" established the only climate change scenario to date that addresses warming of less than 1.5°C, and a safe climate with an atmospheric CO_2 concentration of 350 ppm.

In "Target Atmospheric CO_2," Hansen looked at prehistory to evaluate the amount of CO_2 we could depend on to provide us with a safe climate like that in which our advanced civilization has evolved. His evaluation was based on ice sheet melt and sea level rise, ocean acidification, Earth's reflectivity with diminished snow and polar ice (Earth's largest self-warming feedback beyond water vapor), and the importance of climatic stability to the evolution of humanity and Earth's ecologies.

What Hansen found in "Target Atmospheric CO_2" was that Earth has a sweet spot of stability that can be sustained with only less than 350 ppm CO_2, where ice sheets, sea level rise and Earth's ecologies can sustain humanity's evolution. (1) In 2019, the average atmospheric concentration of CO_2 was 411 ppm at Mauna Loa Observatory. (2) Our "normal climate" CO_2 concentration, referred to as pre-industrial CO_2 from before the fossil fuel era prior to the middle 1800s was about 280 ppm. (3)

The classic 2.0°C limit to warming in the Paris Agreement, that was created for the first IPCC report in 1990 by the Stockholm Institute's "Targets and Indicators of Climate Change," (4) and modified in 2018 by our contemporary climate culture to 1.5°C, (5) is not the definition of a safe climate target, but a target that was meant to avoid dangerous climate change; these are really quite different things altogether. The original definitions of dangerous climate change avoidance warming targets from the Stockholm Institute are below:

Stockholm Institute, Dangerous Climate Change

- "Beyond 1.0°C may elicit rapid, unpredictable, and non-linear responses that could lead to extensive ecosystem damage."
- "An absolute temperature limit of 2.0°C can be viewed as an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly."

These rapid, unpredictable, and non-linear responses are what we are seeing today as active climate tipping or abrupt Earth systems collapses. They are 10 to 100 times more likely than what we see in climate modeling upon which our current climate policies are based. (6) These climate tipping responses were not projected to happen until after 5.0°C of warming, but in the 2018 IPCC 1.5°C report, a grave acknowledgement was made that tipping could occur between 1–2°C warming. (See Reference 4, Vision Statement) Because 5.0°C warming is something that most worst-case scenarios for the last 30 years have placed at some time in the 22nd century, tipping is now happening at least 100 years sooner than the worst-case scenarios.

Hansen's work on 350 ppm CO_2 tells us, "Although a case already could be made that the eventual target probably needs to be lower, the 350 ppm target is sufficient to qualitatively change the discussion and drive fundamental changes in energy policy." Hansen continues, "Limited opportunities for reduction of non-CO_2 human-caused forcings are important to pursue but do not alter the initial 350 ppm CO_2 target. This target must be pursued on a timescale of decades, as paleoclimate and ongoing changes, and the ocean response time, suggest that it would be foolhardy to allow CO2 to stay in the dangerous zone for centuries."

This work was also done in 2008, before tipping activated and it was well understood how much carbon must be removed from our atmosphere to achieve 350 ppm CO_2. The next chapter discusses the advances in modeling that now show how much CO_2 must be removed from our atmosphere to achieve 350 ppm CO_2.

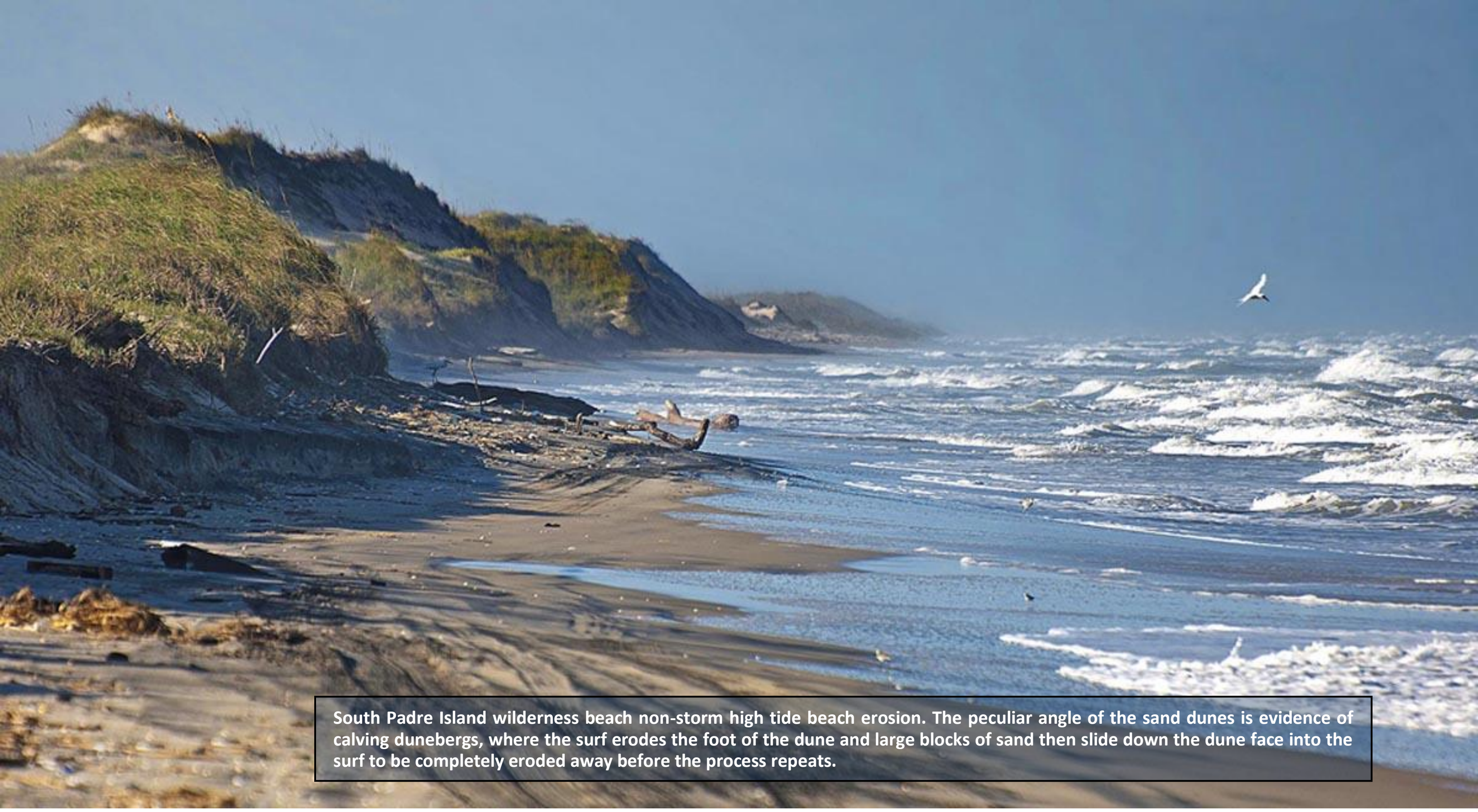
Target Atmospheric CO_2: Where Should Humanity Aim? James Hansen, 2008

The following is excerpted from James Hansen's "Target Atmospheric CO_2: Where Should Humanity Aim?" published in the *Open Atmospheric Science Journal* in 2008 (See Section 1.3, Reference 2):

"Paleoclimate evidence and ongoing global changes imply that today's CO_2, about 385 ppm, is already too high to maintain the climate to which humanity, wildlife, and the rest of the biosphere are adapted. Realization that we must reduce the current CO_2 amount has a bright side: effects that had begun to seem inevitable, including impacts of ocean acidification, loss of fresh water supplies, and shifting of climatic zones, may be averted by the necessity of finding an energy course beyond fossil fuels sooner than would otherwise have occurred."

"We suggest an initial objective of reducing atmospheric CO_2 to 350 ppm, with the target to be adjusted as scientific understanding and empirical evidence of climate effects accumulate. Although a case could already be made that the eventual target probably needs to be lower, the 350 ppm target is sufficient to qualitatively change the discussion and drive fundamental changes in energy policy. Limited opportunities for reduction of non-CO_2 human-caused forcings are important to pursue but do not alter the initial 350 ppm CO_2 target. This target must be pursued on a timescale of decades, as paleoclimate and ongoing changes, and the ocean response time, suggest that it would be foolhardy to allow CO_2 to stay in the dangerous zone for centuries."

Interpretation: "Paleo climate evidence" is scientific data gathered from evidence of Earth's climate history before humankind began keeping records. "[W]ith the target to be adjusted as scientific understanding and empirical evidence of climate effects accumulate" refers to gathering of new scientific evidence that supports changing Hansen's 350 ppm CO_2 limit, as in the new evidence on rapid, unpredictable, and non-linear responses in our climate systems that we have now identified in 2019 as active climate tipping. See Stockholm Institute's "Targets and Indicators of Climate Change" on this page. "Non-CO_2 human-caused forcing" are other greenhouse gases (forcing agents) like methane and refrigerants. The "ocean response time" is how long it takes sea level to rise.



South Padre Island wilderness beach non-storm high tide beach erosion. The peculiar angle of the sand dunes is evidence of calving dunebergs, where the surf erodes the foot of the dune and large blocks of sand then slide down the dune face into the surf to be completely eroded away before the process repeats.

1.3.2 "Young People's Burden: Requirements of Negative CO_2 Emissions"

This section discusses the academic backup for the amount of negative emissions (carbon dioxide removal or CDR) required to achieve 350 ppm CO_2, and the first modeling of the temperature of 0.85°C that corresponds to 350 ppm CO_2 in the year 2100. We take the title of this section from James Hansen's 2017 paper of the same name in the journal *Earth Systems Dynamics*. (1)

For the first time, James Hansen and a team of 15 published a paper on the modeling of a concentration of 350 ppm CO_2 in our atmosphere, suggesting this work represented a "safe climate" based on the discussion in the section 1.3.1 and Hansen's “Target Atmospheric CO_2…” paper. Hansen et al. (2017) modelled four scenarios: A burn-all-the-fossil-fuel-business-as-usual scenario of 2% annual CO_2 atmospheric increase, a constant CO_2 concentration scenario to represent theoretical, immediate net-zero, and -3% and -6% per year emissions scenarios where we reduce emissions every year correspondingly to represent net-zero 2040 and 2050 (approximately). This work went much further though, as the title of the paper indicates with "Requirements of Negative Emissions." Hansen modeled all scenarios twice, once with only net-zero actions, and once with negative emissions and net-zero, to evaluate the amount of negative emissions needed to achieve a climate safe 350 ppm CO_2.

A TARGET OF "LESS THAN 1.0°C WARMING ABOVE NORMAL BY 2100 REQUIRES NET-ZERO BY 2040 TO 2050 AND SIMULTANEOUSLY THE REMOVAL OF 7 TO 11 GIGATONS CO_2 FROM THE ATMOSPHERE EVERY YEAR UNTIL 2100.

What he found was that in addition to net-zero CO_2 emissions by 2040 and 2050, we need to remove between 7 and 11 gigatons of historically emitted CO_2 from the sky every year until 2100 to achieve a target of 350 ppm CO_2, and that the resulting temperature in 2100 would be about 0.85°C degrees above normal. (See figure 1.3.2) Hansen's work with this paper is the basis for a "less than 1.0°C warming above normal target" for a safe climate.

There are two very important bits of information in Hansen 2017 that must be taken into consideration. Hansen and his team did not have the knowledge that more than half of known tipping points were active when they published "Young People's Burden." Their time frame of 2100 is likely far too long to prevent completion of tipping initiation and irreversible outcomes.

The other *very* significant issue is that Hansen 2017 includes "overshoot" like all other scenarios. Overshoot is additional warming above the warming target that occurs as we are implementing net-zero actions and industrialize the CO_2 removal infrastructure needed to achieve the scenario warming target. Therefore, Hansen's 0.85°C scenario includes a couple of human generations where the temperature is warmer than it is today, while we are getting our act together and implementing net-zero plus simultaneously removing the excess CO_2 pollution in our atmosphere. In other words, even with the best we can do with net-zero and CO_2 removal, we still endure additional warming with increasingly extreme events. This is why a much abbreviated time frame to restore our climate is needed rather than a 2100 goal – because the risk of climate tipping becoming irreversible increases nonlinearly with further warming.

So Hansen's work must now be abbreviated because the science has changed. We have a new scenario happening far ahead of previous assumptions, which is capable of becoming unrecoverable.

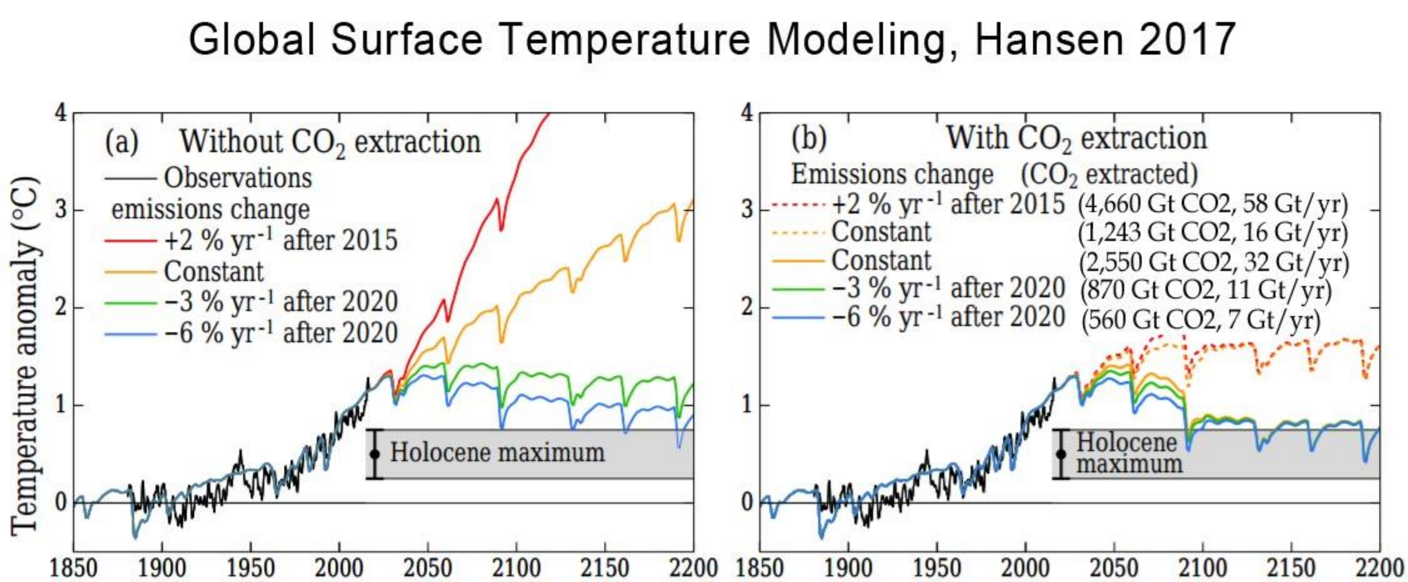
We have every reason to believe that the time to the point of no return, or the time when tipping becomes irreversible with untenable scenarios resulting, is by mid-century, far ahead of previous projections; in line with the timeline change for tipping activation that was supposed to only happen with 5.0°C warming in the 22nd century.

What this all means is that we have just a few decades, not only to bring our atmospheric temperature back to within its normal range of less than 1.0°C, but also to cool the upper oceans back to their stable state to prevent ice sheet collapse from going irreversible from ocean warming. Therefore, in addition to restoring our atmosphere back to normal by mid-century, we must restore ocean temperature or at least upper and surface ocean temperature back to normal too, by mid-century.

To do this we have to go further than Hansen 2017 and remove CO_2 from our sky faster and in greater quantity. How much more extensive this removal must be is not yet known as it has yet to be modeled, but we do have a good idea of 7 to 11 Gt CO_2 removal per year from Hansen, and 1,000 Gt removal from IPCC. This will get us in the ballpark. One last thing that is made very clear in Hansen 2017 is that in the year 2100, Hansen found the difference between net-zero 2040 and net-zero 2050 to be less than 0.2°C. Earlier net-zero would provide less benefit. The challenge is the load in the sky.

Because time is of the essence, we must act with the urgency appropriate to any emergency, where the first thing we do is save lives with the tools at hand. Though we do not know exact timelines, we do know further delay nonlinearly increases risks of passing through the point of no return.

Figure 1.3.2 – Global Surface Temperature Modeling, Hansen 2017



On the left is without negative emisions or carbon dioxide removal (extraction) on the right includes both net-zero and carbon dioxide removal. The red scenario is business as usual, orange is constant emissions, green and blue are approximate net-zero paths of 3% and 6% annual emisisosn reductions to achieve net-zero in 2050 and 2040. The gray shaded area of "Holocene Maximum" represents the maximum natural variability temperature or our old climate, with a centerpoint of about 0.5 C warmer than normal. Reference: Hansen et al., Young people's burden--requirement of negative CO2 emissions, Earth Syst. Dynam., 8, 577–616, 2017, Figure 12.

Drought kill live oaks, Doublehorn parcel, Lower Colorado River Authority, Lake Travis 2013

Galveston Island after Hurricane Ike, 2008: A Cat 2 storm with a Cat 4 storm surge

1.3.3 Austin's Historic Climate Pollution Burden (Legacy Emissions)

Austin's historic climate pollution legacy is 693 million tons CO_2eq. Of this amount we must remove 288 million tons CO_2 from our sky, or otherwise treat it, mitigate for it, or permanently offset it, to achieve total climate pollution responsibility and promote policy that ensures a safe, non-emergency Earth temperature of less than 1.0°C above normal. (See Figure 1.3.3a)

Determining our emissions is challenging. Many different factors contribute to the varying amounts of CO_2 and non-CO_2 greenhouses and cooling aerosols that are emitted from a given activity or economic sector. The *Climate Equity Plan* has created a robust accounting of much of Austin's emissions and how these will be reduced on our path to net-zero. However, future emissions are but a small part of the big picture as we must address the 288 million tons CO_2 that remain accumulated in our sky since 1900 or the time when we began to meaningfully emit climate pollution.

THE AUSTIN REGION HAS RESPONSIBILITY FOR ITS HISTORIC CLIMATE POLLUTION OF ABOUT 700 MILLION TONS CO_2EQ EMITTED SINCE 1900, OF WHICH 288 MILLION TONS CO_2 MUST BE REMOVED FROM OUR SKY TO ENSURE LIFE AS WE KNOW IT CONTINUES ON EARTH.

Current warming is what has created all the mayhem and is caused by climate pollution already resident in our sky, emitted in the past and accumulated to levels toxic to Earth systems' evolution. Even if we stopped emitting all greenhouse gases today, the repeatedly unprecedented weather catastrophes and climate tipping would continue to reach new extremes because of warming in the pipeline.

Additional warming of at least 0.5°C to 1.2°C is baked in, even if we halted all greenhouse gas emissions yesterday morning. (1) This warming in the pipeline, or committed warming, is caused by our cool oceans and ice sheets masking warming that would have otherwise already have taken place. It takes 30 to 50 years for the oceans to come into equilibrium or balance out warming in the pipeline, much like it takes a while for the air conditioner to cool down a hot car in summertime. (2)

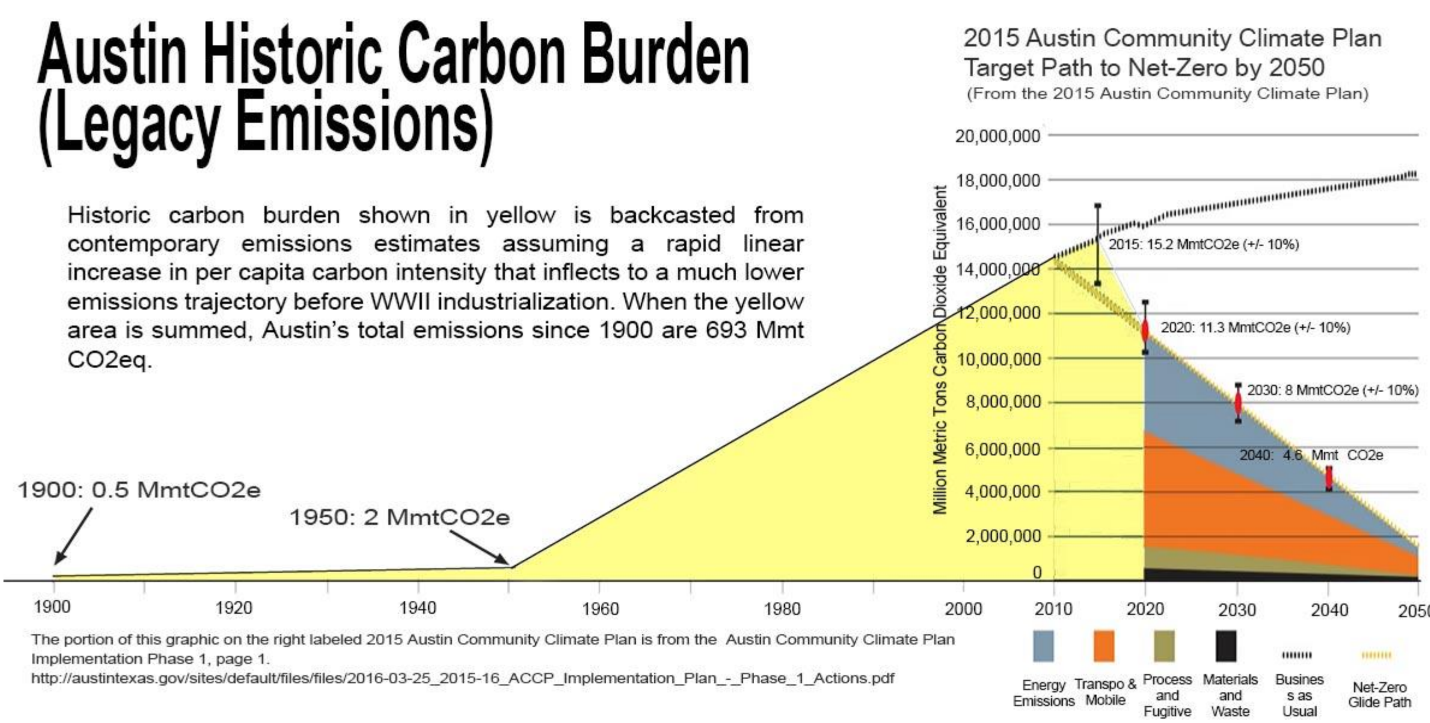
Our climate pollution burden comes in two parts: future and historic. To create a safe climate, we must deal with both, but it is extremely important to understand that future reduction in emissions of climate pollution does not reduce unprecedented extreme weather or reverse activated climate tipping. Even a complete cessation of all climate pollution immediately would still result in warming in the pipeline increasing, not decreasing our global temperature.

The amount of historic climate pollution emitted by the Austin Region that we are responsible for removing so as to stop tipping from becoming irreversible, is up to 27 times the amount of climate pollution we must deal with in Austin to achieve net-zero. (See Figure 1.3.3a and Reference 6 this section.)

It is these already emitted greenhouse gases that we focus on in this section and that define the actions we must take in addition to net-zero 2040, that will provide a safe climate for us, our children, and those who follow us.

To define the burden of historic emissions (legacy emissions or pollution burden) we must deal with in order to restore a safe climate, we backcast Austin's recent emissions history from the 2015 *Community Climate Plan*. Note: this cursory backcast evaluation should be confirmed by a more detailed work.

Figure 1.3.3a Austin's Historic Climate Pollution Burden (*Austin Community Climate Plan 2015*)



The Austin Region's total historic emissions are about 693 MmtCO_2eq (million metric tons) and as CO_2 about 576 million tons. (3) Because of the long life of CO_2 in the atmosphere, where most of it stays for 300 years while 25 percent lasts forever, it is critical that we deal with our historic emissions that remain in our sky because this warming will not go away in time frames that matter. (4)

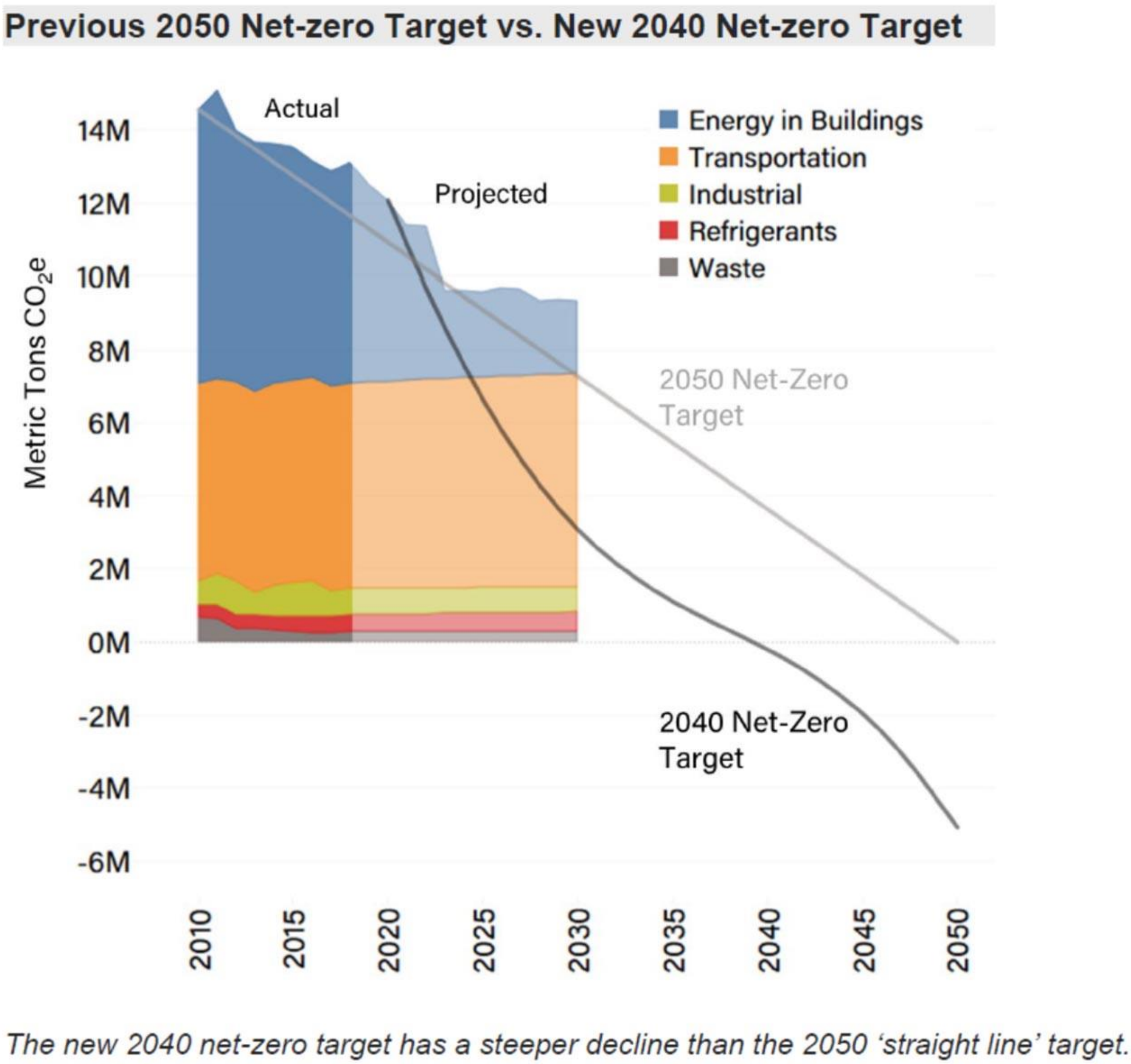
Importantly, only half of greenhouse gases emitted, or 288 million tons of Austin's CO_2 emissions, remain in our sky. The reason only half remain is about half of all CO_2 ever emitted is absorbed by plants, soil, rock, and our oceans and water bodies. The annual emissions of CO_2 globally are 1.3 percent of the total 3206 Gt CO_2 in our sky.

The half of CO_2 that is instantaneously absorbed after it is emitted will eventually return to our sky, once atmospheric CO_2 falls below our current equilibrium at about 325 ppm CO_2, but only very slowly as the paths to re-emission are as long if not longer than the paths to absorption.

Think of it this way; if all of us removed all of the CO_2 we ever emitted from our sky, or 2404 Gt CO_2 equal to 308 ppm CO_2, our atmospheric CO_2 concentration would be 103 ppm considering it was 411 ppm in 2019. This would be less than half the 280 ppm CO_2 concentration of pre-industrial times, far less than the minimum ice age concentration of 175 ppm, and far less than any CO2 concentration on Earth in the last 300 million years. (5)

In summary, to be responsible for all of the CO_2 we have ever emitted, the Austin Region must remove half of what we emitted or 288 Mt CO_2, or 14.4 Mt per year 2020 to 2040. (See Figure 1.3.3b)

Figure 1.3.3b Austin's 2040 Net-Zero Climate Pollution Burden (*Climate Equity Plan,* page 32)



The graphic above from page 32 of the *Austin Climate Equity Plan 2020* shows the steeper trajectory to the 2040 net-zero target in comparison to the 2050 net-zero target. The total and average annual emissions reductions for 2040 it is 94.3 MmtCO_2eq, or 78.1 Mt CO_2, and the average annual emissions reductions 2020 to 2040 for a total volume is 3.90 Mt CO2 and an annual increment of 0.54 Mt CO_2.

Austin's burden to achieve net-zero by 2040 from the *Climate Equity Plan* can be interpreted from Figure 1.3.3b with a total of 78.1 Mt CO_2 emissions reductions, or 3.9 Mt CO_2 per year 2020 through. This is 10.4 Mt per year short of the 14.4 Mt CO_2 needed to achieve less than 1.0 C warming by 2040.

These two greenhouse gas emissions burden calculations, of historic CO_2 emissions removal at 14.4 million tons CO_2 per year, and future emissions reductions at 3.9 Mt CO_2 per year, are not directly comparable, but they are quite meaningful in the order of magnitude of effort that is required. We don't remove CO2 from our atmosphere with emissions reductions of course. But once we remove CO_2 from our sky, it is gone; we do not have to maintain behaviors and mechanisms that continue to result in emissions reductions. The relative emission reduction effort is up to about 27 times more effort for historic vs. future emissions reductions. (6)

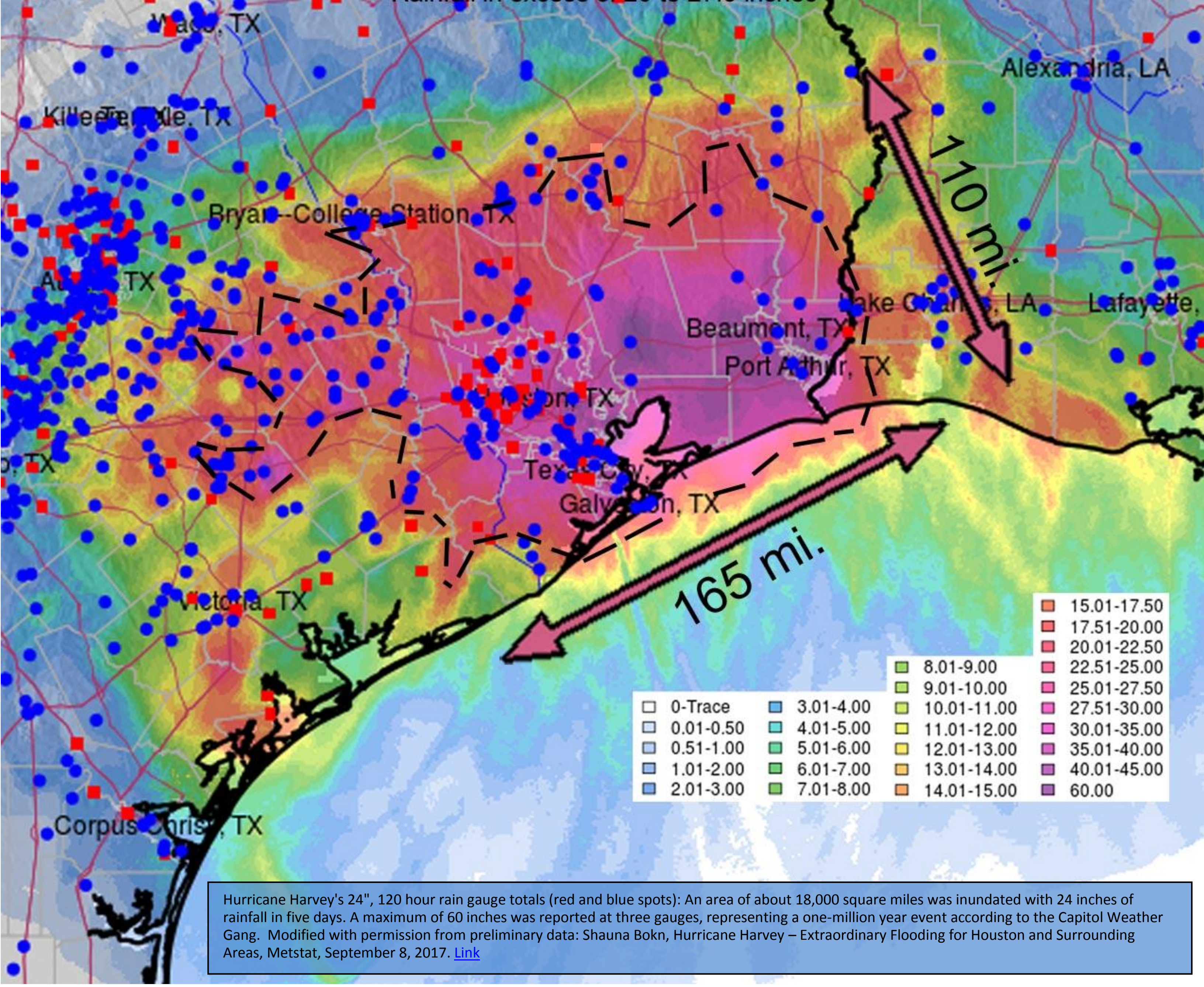
Fundamentally then, to remove the climate pollution we have historically emitted that remains in our environment is the responsibility we must bear, as we bear that responsibility with any other pollution.

Because the time frames are short and risks are so high, and because there are no safety factors with these calculations, our historic climate pollution cleanup responsibility should be at least 27 times more urgent of an action than is commonly understood as the urgency of creating zero net future climate pollution.

Historic vs. Future Emissions Burden
The Relative Weight of Dealing With the Past

The amount of historic climate pollution we must deal with to restore a safe climate is 4 to 27 times the amount of climate pollution we must deal with to achieve net-zero on a volumetric and incremental basis. (See Reference 6, Section 1.3.3)

Remains of a melted canoe, Pinnacle Fire, Oak Hill, Southwest Austin, May 2011



Hurricane Harvey's 24", 120 hour rain gauge totals (red and blue spots): An area of about 18,000 square miles was inundated with 24 inches of rainfall in five days. A maximum of 60 inches was reported at three gauges, representing a one-million year event according to the Capitol Weather Gang. Modified with permission from preliminary data: Shauna Bokn, Hurricane Harvey – Extraordinary Flooding for Houston and Surrounding Areas, Metstat, September 8, 2017. Link

1.3.4 The Gap and Worst-Case Scenario Planning

There is about a 31 million ton CO2eq emissions reductions gap (26 million tons CO2) between what the Climate Equity Plan describes as achievable, and what is needed to reach net-zero. Natural systems carbon dioxide removal (CDR) identified in the Plan can achieve about 13.7 million tons of the gap, but the gap is for an overly dangerous 1.5°C target. To ensure safety, 288 Mt CO_2 *must be removed from our sky by 2040, in addition to net-zero by 2040. New policy is needed that significantly enhances the scope and extent of natural systems CDR, and adds a platform of atmospheric CDR to fill the remainder of the gap with traditional pollution treatment. Because climate projections are understated by up to 100 years or more in many instances, worse than worst-case scenarios should be used for emergency planning.*

Current climate policy goals globally, not just in Austin, cannot reduce and remove enough climate pollution to achieve net-zero or to create a safe and equitable climate for humanity. This is why we are writing the bulk of this report. A new kind of policy is needed that advocates for total carbon responsibility, both into the future and for our already-emitted historic climate pollution that lasts for hundreds to thousands of years in our atmosphere. New policy is needed because we have delayed action and impacts are now happening far ahead of projections. The gap in emissions reductions is directly related to this delay. We have seen nearly as many greenhouse gases emitted in the last 30 years as were emitted in the previous 250 years. (1)

What the *Austin Climate Equity Plan* Can and Cannot Do

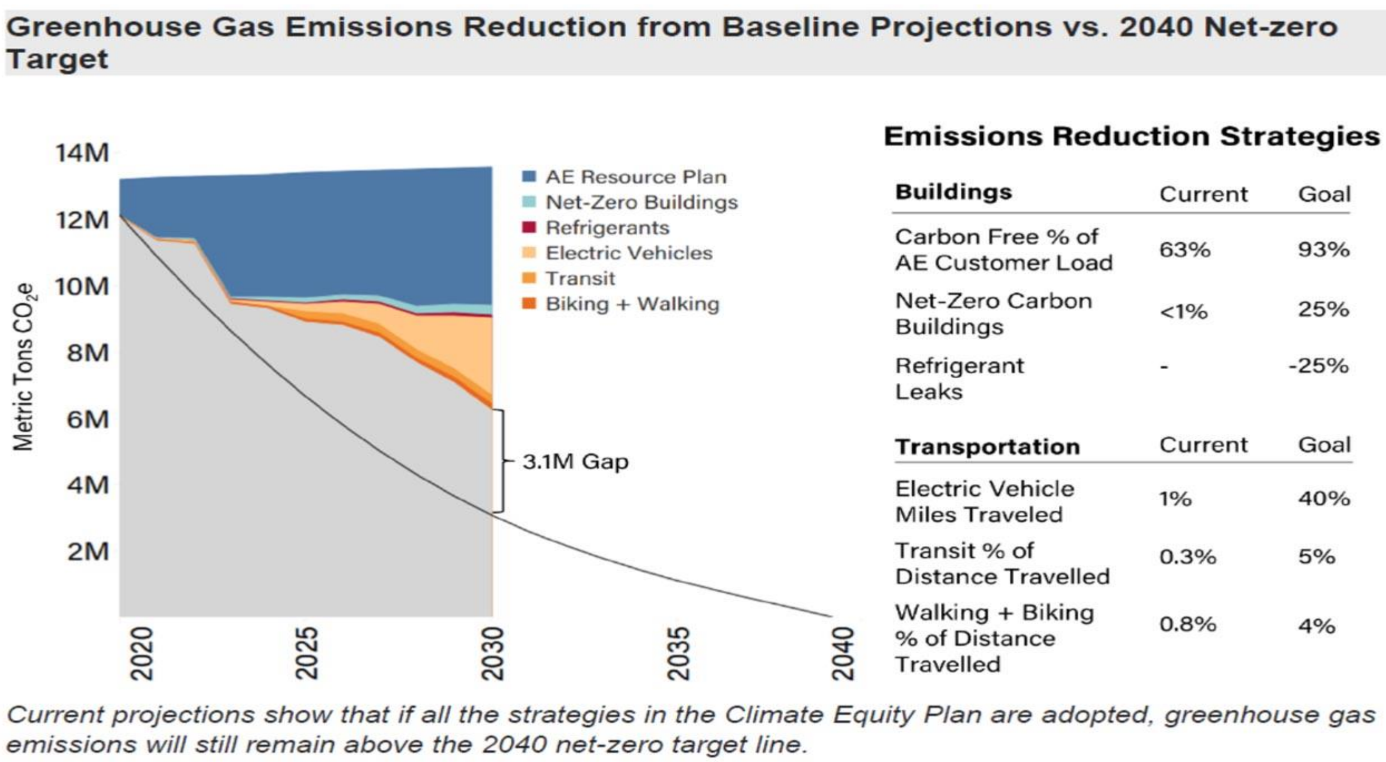
The "gap" is that amount of net-zero actions that are beyond the *Climate Equity Plan's* emissions reductions and natural systems carbon dioxide removal (CDR) or permanent offsets. (See Figure 1.3.4a)

The *Climate Equity Plan* states on page 35, "Even if we reach all the goals in our individual strategies, we don't project that we will meet our 2030 emissions target. Additional solutions to reduce and offset emissions will be needed."

Figure 1.3.4a shows the *Austin Climate Equity Plan's* graphic, "Greenhouse Gas Emissions Reductions From Baseline Projections vs. 2040 Net-zero Target." The "gap" of 3.1 million metric tons CO_2eq ($MMtCO_2$ eq) in 2030, and about 31 $MMtCO_2$ eq total 2020 through 2040 or about a third of total net-zero emissions reductions, remains after the *Equity Plan's* net-zero emissions goals have been met, and as the plan says in the quote above, "additional solutions to reduce and offset emissions will be needed." The *Climate Equity Plan* suggests we can plausibly achieve 0.6 million tons (Mt) CO_2 capture annually with natural systems, of the 3.1 $MMtCO_2$ eq gap needed annually to achieve a 1.5°C warming goal as shown in Figure 1.3.4b. The 0.6 Mt quantity, or 0.5 Mt CO_2 is however, only five percent of the removal needed to achieve a less than 1.0°C target at a rate of 14.4 Mt per year CO_2 removal. (See Section 1.3.3)

Globally, if natural systems were fully restored, forests completely reforested and agriculture adopted regenerative practices to the fullest extent feasible, the National Academy of Sciences (NAS) says that we are limited to about 2.75 Gt CO_2 removal annually with sustainability and equity considered. As per NAS, this amount does not include Bio Energy with Carbon Capture and Sequestration (BECCS) as repeated studies show a very low viability of this strategy with very high risks of inequity. (2) Net-zero 2050 globally requires we address our current annual 49 gigatons CO_2eq, or a total from 2020 to 2050 of 760 Gt. Austin's share considering 94.3 Mt total net-zero CO_2eq emissions reductions by 2040 is 0.012 percent of NAS' 2.75 Gt, meaning our maximum share of natural systems emissions reductions according to NAS is 0.33 Mt annually or 330,000 tons. (3)

Figure 1.3.4a The Gap in Needed Emissions Reductions to Achieve 1.5°C and Net-Zero (*Climate Equity Plan*, page 32)



The graphic above is from page 34 of the *Climate Equity Plan* and shows the gap in remaining emissions reductions required to meet net-zero that are beyond the plan's emissions reductions and CDR capacity. When added up through 2040 the gap equals approximately 31 $MmtCO_2$eq. Total emissions reductions are about 94.3 $MmtCO_2$eq so the gap is about a third of plausible emissions reductions in the plan.

The Challenge of Climate Tipping, Evolutionary Collapse and Natural Systems Carbon Dioxide Removal

Fundamentally, climate tipping results from Earth systems collapse and climate tipping is now underway. (4) Earth systems collapse when their baseline evolutionary boundaries are exceeded in some way. With ecological systems, this collapse results in failure of the ecology as it attempts to reevolve to new climate conditions.

We passed the outer limits of our climate's natural variation at about 0.5°C warming, at some point between the years 2000 and 2010. (5) Collapse means services provided by the failing ecological system (trees sequestering CO_2 *for example) are lost, and generally reverse, where the systems flip from storing carbon to emitting it. Because climate tipping is now considered to be active in more than half of known tipping systems, this means those systems are collapsing and their services are either degraded or have already flipped to emitting carbon instead of capturing and storing it.*

Permafrost, The Amazon and Canadian forests are three identified systems or parts of systems that have flipped from sequestration to emissions with a total reported annual emissions of about 3.5 Gt CO_2 *per year. Considering the rest of our world's similar ecologies are behaving likewise, the annual emissions from these natural systems are at least 5.5 Gt, net. (6)*

Further warming to a 1.5°C target exasperates the ecological failures that are ongoing and increases the speed and extremeness of climate tipping. The failures themselves create a cascade of feedbacks where other systems fail too, or fail faster, because of the initial system failure. Up to 45 percent of known tipping systems create these cascading feedbacks. (7)

Impacts to ecosystems between our current 1.0°C warming and a 1.5°C target will also be more extreme than the impacts we have seen since we departed the natural variation of our old climate at about 0.5°C warming. This is because of the nonlinear effects of thermodynamics physics where increased heat causes nonlinearly increased reactivity.

Re-evolution will only succeed when boundary conditions stabilize, but this will take generations once stabilized and we will not have the benefit of ecological services until ecologies begin to approach maturity. Restoring our old climate only requires that existing ecologies self-heal so that we can regain full benefit from the ecological services they provide. If our climate continues to warm to a target of 1.5°C, evolutionary chaos will continue. It is only when climate conditions are stable that ecological systems evolution can succeed.

These challenges mean that natural systems sequestration capacity is suspect at best. The latest science shows broad signs of evolutionary failure. To rely upon natural systems sequestration in any meaningful way is likely very risky until we restore our climate back to the natural variation boundaries where Earth systems evolved.

The *Equity Plan* suggests we can address 600,000 tons annually in the Austin Region with natural systems, plausibly more than our equitable share considering our emissions share is more than the global average. On top of this, net-zero comes nowhere close to achieving 1.5°C. IPCC tells us that net-zero alone results in 2.2°C warming by 2100 and they also tell us that to achieve 1.5°C, 100 to 1,000 Gigatons CO_2 removal are required globally (best and worst-case) in addition to net-zero. (See Section 1.2, Reference 3) If the above-mentioned gap is not filled, if the rest of the world followed the same path as the *Equity Plan*, warming with will result in significantly more than 2.2°C.

The additional solutions needed to remove enough CO_2 from our atmosphere to fill the gap, just to achieve an overly dangerous 1.5°C target, could only plausibly be entirely nature-based if we had the time available and if nature-based resources were not already compromised with current warming beyond the evolution of our ecologies. (See Box 1.3.4 and Reference 6)

There are likely nature-based solutions that could be utilized where current warming has not already degraded them, or where future warming to 1.5°C will not degrade or flip them to greenhouse gas sources. In order to prevent unintended consequences, the current and future viability of nature-based solutions must be studied very carefully. Historical science on natural climate solutions is dated and not enough time has elapsed for the current impacts of warming to nature-based solutions to be known. Any proposals for using nature-based solutions should be backed up by validation and confirmed with strict monitoring. Bonding should be deeply considered.

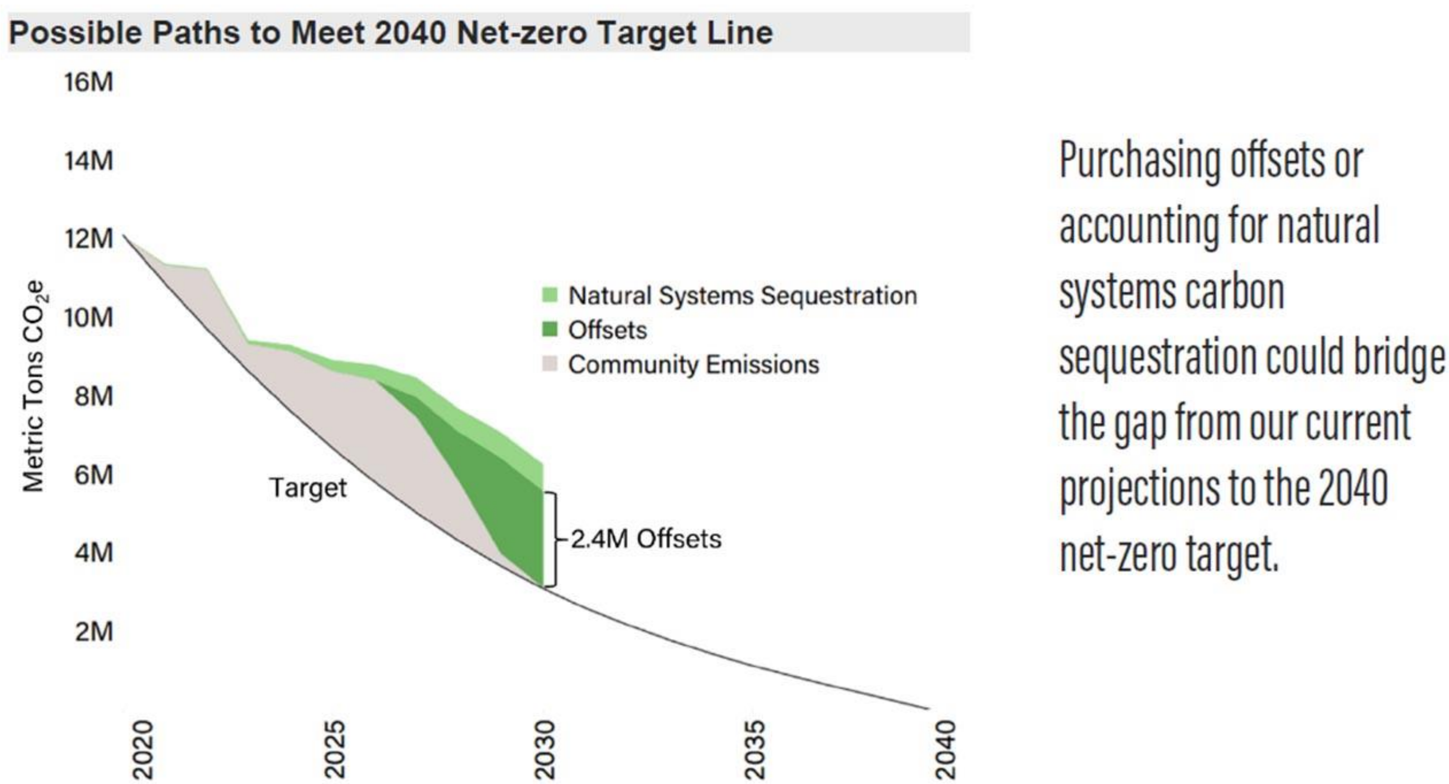
Evolutionary collapse also holds the additional challenge of permanence of stored CO_2. If an ecology is viable as a carbon storage source today, but warming to 1.5°C flips that resource to a source of greenhouse gas emissions, the carbon stored is not permanent and the carbon returns to the sky to continue warming. Even with current warming levels an ecology's viability for carbon storage may simply be a reflection of its buffering capacity to endure impacts beyond its evolution. At some point even without further warming, the buffering capacity will be used up and a tipping point reached where the resource flips to a carbon emissions source. For any natural system or any form of sequestration to be a valid carbon sink, it must have a permanence of more than 100 years. Again, bonding should be deeply considered.

This 100-year permanence metric comes from the California Low Carbon Fuels Sequestration Standard (8) and as governance is beginning to be developed across the world, it is likely that this 100-year standard will be the chosen metric. A hundred years of course is not permanent, but it does give our civilization ample time to get its climate pollution act under control and restore our climate to within its evolutionary boundaries.

To get to a target of less than 1.0°C where our climate and our future are stable, we need to not only stop creating climate pollution, we need to remove the climate pollution we have already emitted from our sky.

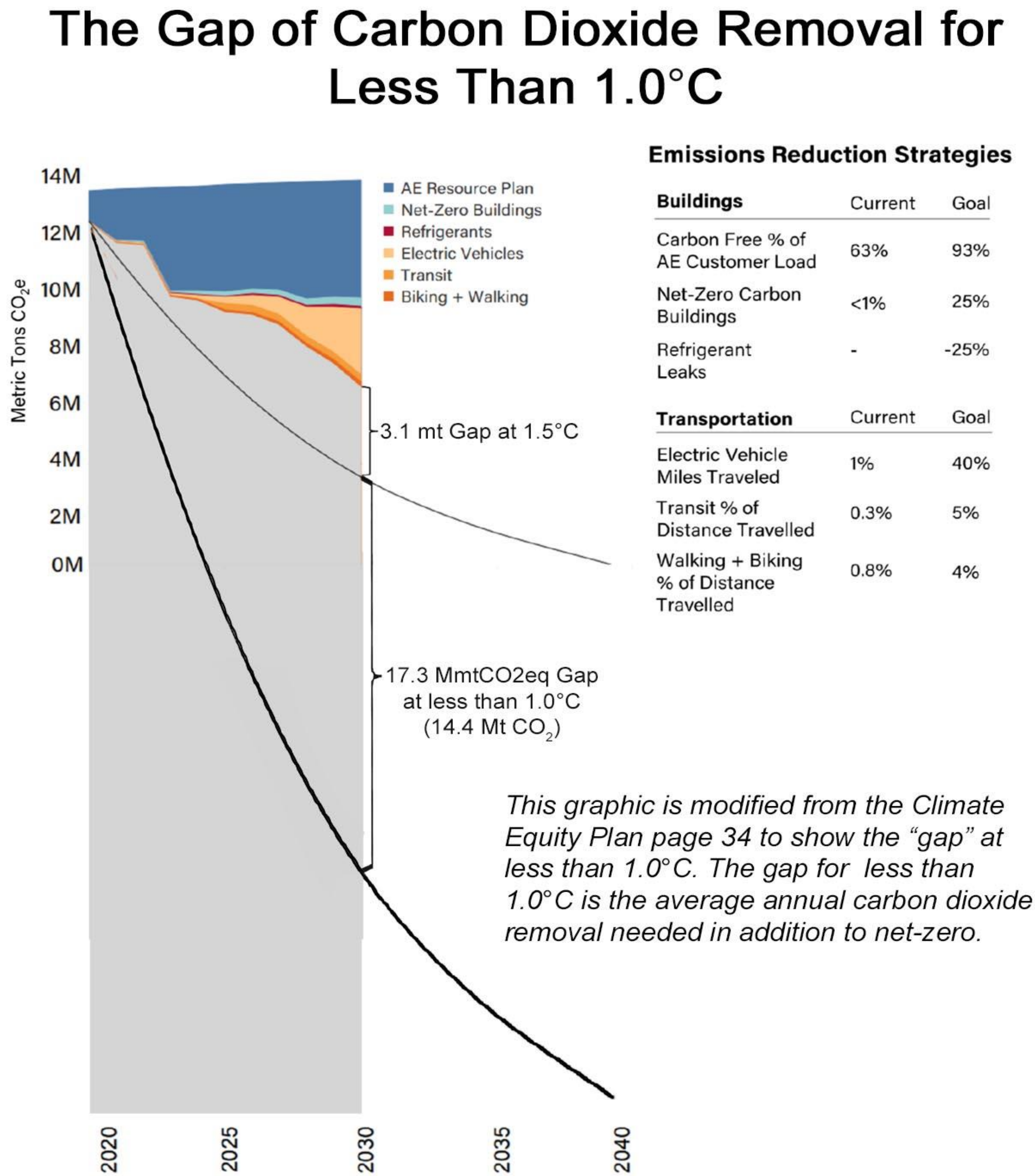
In Figure 1.3.4c we extend the gap to a 1.0°C target which is the minimum needed to stop the climate emergency. This does not include a safety factor and does not include non-CO_2 greenhouse gases. To meet a less than 1.0°C target, about 14.4 million tons of CDR per year is needed by 2040 in the Austin Region. The numbers here are based on simple visual extension the *Climate Equity Plan* emissions reduction curve and should be confirmed with detailed analysis.

Figure 1.3.4b - Natural Systems Carbon Dioxide Removal (CDR) and Permanent Offsets Needed to Fill the Gap



The graphic above is from page 35 of the *Austin Climate Equity Plan* and shows the natural systems CDR and permanent offsets needed to fill the gap. The total plausible natural systems CDR given in the Plan is about 611,000 tons per year or 12.2 $MmtCO_2eq$ by 2040, leaving offsets of 18.8 $MmtCO_2eq$ per year average through 2040 or an average of 940,000 tons CO_2eq per year. Converted to CO_2, totals are: 10.1 $MtCO_2$ total through 2040 and 778,000 tons CO_2 per year.

Figure 1.3.4c - The Gap of CDR for Less Than 1.0°C

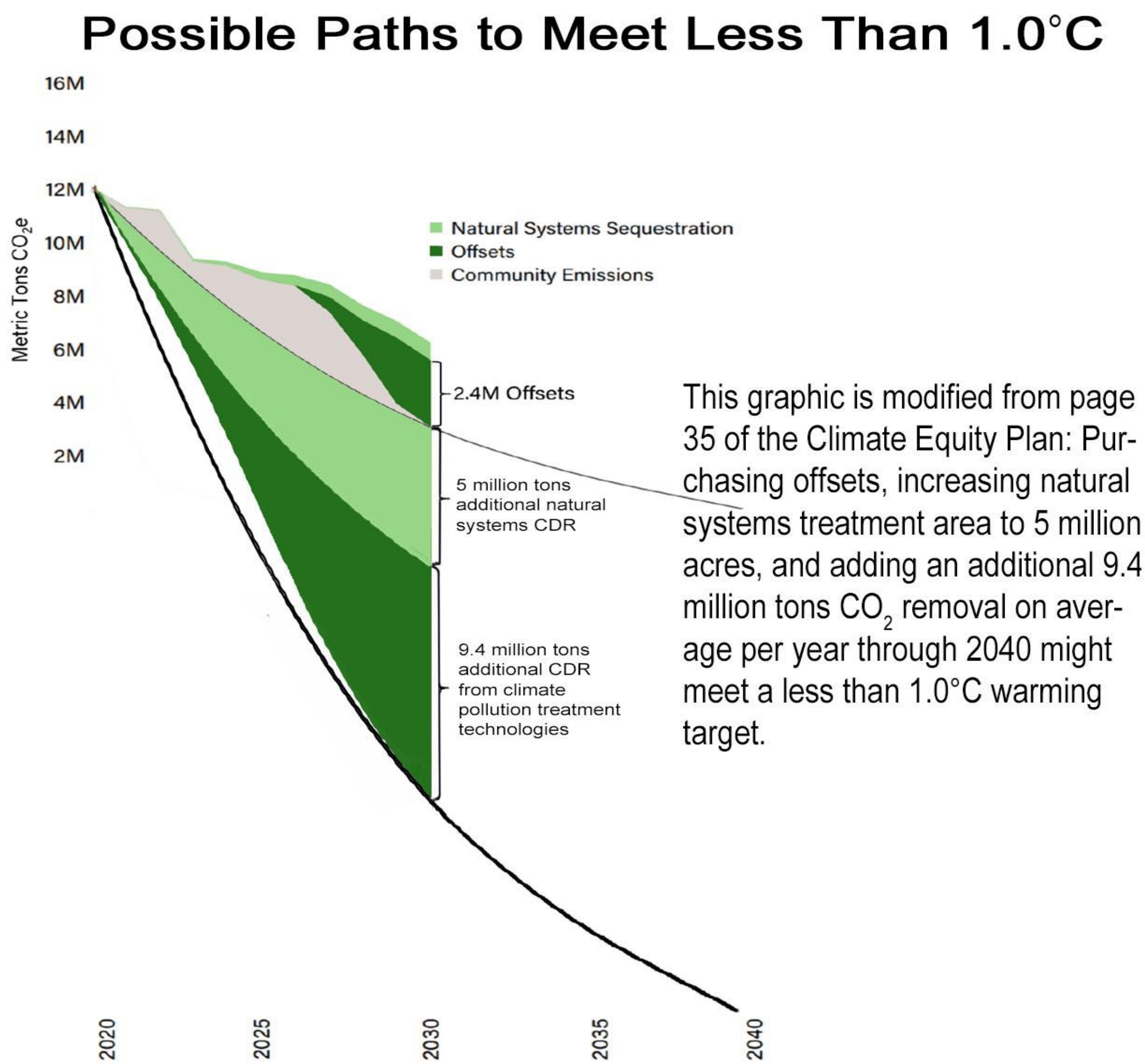


The graphic above is modified from page 35 of the *Austin Climate Equity Plan* and shows the CDR and permanent offsets needed to achieve a less than 1.0°C target. On average every year until 2040, to achieve less than 1.0°C and halt the climate emergency, we must remove 17.3 MmtCO_2eq from the atmosphere, or 14.4 Mt CO_2.

One partial pathway to achieving less than 1.0°C is to significantly enlarge the area of natural systems CDR by looking to areas further afield than the Austin Region. If we were to increase the prescribed natural systems area in the local region by about ten times to 5 million acres, 6.1 million tons of nature-based CDR could be realized per year which reduces our amount of required climate pollution treatment technology CDR to 8.3 million tons on average per year through 2040. It is important to note that natural systems greenhouse gas removal is already compromised by current warming, and that far-away equity is of concern for offsets as Austin's fair share could be as low 330,000 tons. (See Reference 3 above)

Further warming compromises the ability of these systems to remove CO_2 and other greenhouse gases even more. It will also take decades to generations to fully implement natural systems solutions to the scale needed to achieve meaningful historic climate pollution removal. During this time our climate will continue to warm and the ability of natural systems to remove CO_2 will continue to degrade. Great care must be taken to ensure the total climate restoration platform accurately represents the ability of our ecological resources to remove greenhouse gases from our atmosphere.

Figure 1.3.4d - Possible Paths to Meet Less Than 1.0°C (Modified from the *Climate Equity Plan*, page 35)



The graphic above is modified from page 35 of the *Austin Climate Equity Plan* and shows the CDR and permanent offsets needed to achieve a less than 1.0°C target. To achieve less than 1.0°C and halt the climate emergency we must remove 17.3 $MmtCO_2eq$ from the atmosphere, or 14.4 Mt CO_2. Great care must be taken to ensure far-away equity, natural systems viability, and 100-year permanence of sequestered carbon.

In Section 2 of this report, "Restoring a Safe and Healthy Climate to End the Climate Emergency," we will outline strategies, governance, funding sources, and revenues generated from carbon dioxide removal using natural systems and climate pollution treatment strategies. These strategies are necessary to remove historic climate pollution from our sky so we can achieve net-zero, and drawdown atmospheric CO_2 to restore a safe and equitable climate free from mayhem and climate tipping with a less than a 1.0°C target. Figure 1.3.4d shows a possible path to less than 1.0°C warming.

Worse Than Worst-Case Scenario Planning

Planning is what we do to advance as a society. We look to the past to guide us into the future. Planning for climate change is different. We have never experienced climate change before so we have no past from which to draw knowledge. We do have future projections of climate change, but they have been broadly understated by generations to a century or more.

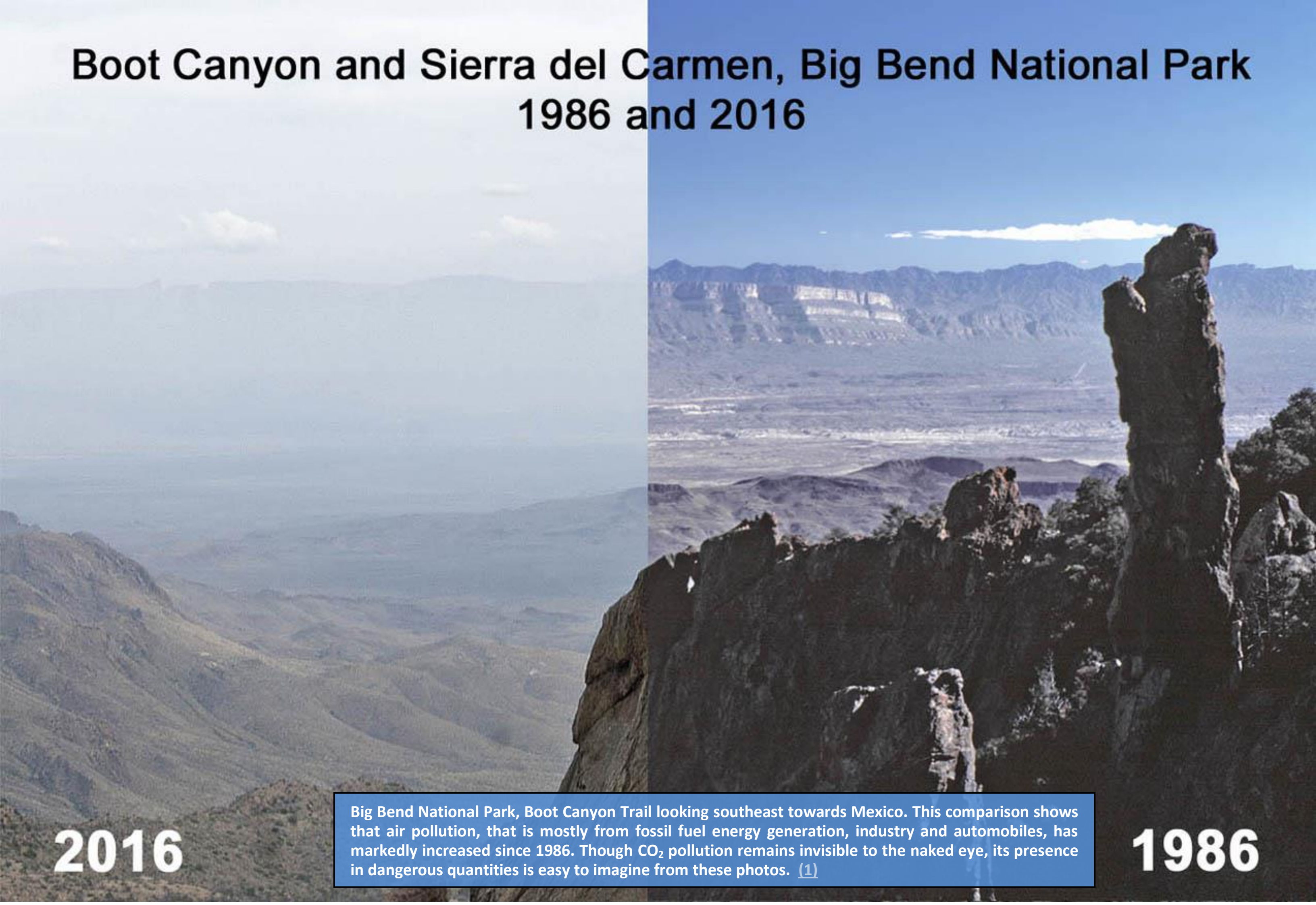
We have safety factors in climate science scenarios that are thirty to fifty times less than traditional safety factors our society has chosen to ensure our safety and the safety of our assets with the insurance industry. (See the Glossary for more on safety factors.)

We have impacts happening now that 30 years of climate change planning has assured us would not happen until well into the twenty-second century with more than 5°C warming. We see that scientists have been moving the safe warming limits to ever-lower levels. We are beginning to see impacts that have the capacity to end civilization as we know it. To avoid the worst impacts, as the "Climate Emergency Warning" in the journal Bioscience states, "potentially making large areas of Earth uninhabitable," we must restore our climate to the boundary conditions where our Earth systems were stable and capable of providing the services with which our civilization evolved.

If we continue on with our climate policies based upon climate science as usual, those really poor safety factors are going to catch up with us. This is bad enough if it were just one pandemic, or one tropical forest that was collapsing, or just one island nation's civilization ending as we know it. What is happening now is planet Earth as we know it is collapsing and it too, like our ecologies around the world, will re-evolve. This in itself may or may not be a bad thing in the very long-term big picture. But in the short term, as it relates to us advanced humans, re-evolution of our Earth systems is an existential event because it means collapse of the boundary conditions of our civilization.

Continuing to follow precedent anywhere close to climate policy of the recent past will allow these dystopic scenarios we have been warned of for generations to occur much sooner than thought will allow. It is thus an imperative that worse than the worst-case scenarios be followed in planning efforts to assure we can avoid untenable scenarios. The responsibility to reduce the risks we face lies with leadership. The faster leadership gets this message across to the rest of the world; the lower will be the risks of creating the dystopic world scientists have been warning us about for 30 years.

The mouth of Barton Creek at Lady Bird Lake, October 2018: Two 50-year storms in quick succession on the Llano River above the Highland Lakes created a sediment runoff event that was extreme enough for Austin to issue an unprecedented boil water notice to their entire water service area of over one million people. Photo: Al Braden, AlBradenphto.com



Big Bend National Park, Boot Canyon Trail looking southeast towards Mexico. This comparison shows that air pollution, that is mostly from fossil fuel energy generation, industry and automobiles, has markedly increased since 1986. Though CO_2 pollution remains invisible to the naked eye, its presence in dangerous quantities is easy to imagine from these photos. (1)

1.4 Local Responsibility, Leadership, and Equity

History has shown that governance on international, national, and state levels has failed to provide meaningful climate pollution management for 30 years. As a result, climate pollution ethics have now advanced from a sustainability ethic to emergency response. Sustainability issues still apply, but emergency response demands are now a higher priority. Without emergency response, climate tipping completes with unrecoverable scenarios and all else is moot. There is a critical path in management of this emergency where the future depends on responsibility for historic greenhouse gas emissions. It is time for local and regional entities to do what international, national and most state leadership has failed to do.

Those other efforts will hopefully still be meaningful. But something has to be done fast and history has shown past efforts have failed. Those with a history of leadership must now honor the responsibility of that legacy and continue to catalyze change. To ensure history is not repeated, management of this emergency falls to those at the local level.

Local and regional entities have been dealing with massive global infrastructure for well over a century. Our roads were the first to be governed by local entities, then gasification and electrification. Massive social, medical, and educational infrastructure soon followed, paired with what is likely even more massive infrastructure ensuring safe drinking water. Our military and police institutions across the world are exceptional examples of massive infrastructure that bears no fruit except protection of the commons. Austin, Houston, Dallas, and San Antonio all spend at least $434 million on their respective police departments annually, more than a third of their city budgets. (2)

We have mature and stable governance, and financing concepts and structures in place from which to model, implement, and operate infrastructure that removes historic greenhouse gas emissions from our sky.

We can transfer this infrastructure knowledge to natural systems restoration and enhancement, and further develop safe and simple pollution treatment strategies that we have been using in other applications for a century to take carbon dioxide out of air. This task may sound daunting, but its scale is little different from things we do in our culture constantly.

INTERNATIONAL, NATIONAL, AND MOST STATE CLIMATE REFORM EFFORTS HAVE FAILED. WE MUST NOW ACT OURSELVES, BY HARNESSING THE POWER OF LOCAL INFRASTRUCTURE AND COMMON SOCIETAL GOVERNANCE THAT HAS CREATED COMMON SERVICES FOR CITIZENS FOR A CENTURY OR MORE, SO THAT WE CAN FINALLY RESPOND TO THE CLIMATE EMERGENCY AND SAVE LIVES.

We treat 116 gigatons of potable water and human sewage in the US every year with an infrastructure that spans the breadth of our cities like a fine mesh screen. (3) The technology to treat human sewage involves a biologic reactor and complex natural bacteria, whereas one of the 100-year old technologies available to remove CO_2 from the sky uses a much simpler chemical potash and recyclable lime process. Enhanced oil recovery (EOR) using air capture CO_2 will likely be a profitable venture in the first potash-lime, million-ton-per-year facility being developed in the Permian Basin by Occidental Chemicals. It will be profitable because of the $200 per ton California Low Carbon Fuel Standard (LCFS) Incentive that California leadership has created. The LCFS incentive requires the fossil fuels recovered be carbon negative before the incentive is paid, and this includes emissions from burning the recovered oil and gas and from the complete EOR supply chain. (4)

This incentive process, regardless of the technology, is far more than a means to encourage CDR. It is a gigascaling catalyst. The scaling that results will increase facility capacity and decrease cost per unit CO_2 removed and sequestered much like incentives for wind, solar and batteries. Catalyzing gigascaling starts with a new mission. As more leadership from others adopts the new mission, like with other technologies, gigascaling will grow. Without gigascaling of carbon dioxide removal, unrecoverable scenarios will result.

As prices fall, implementation of CDR without incentives becomes more feasible. As CDR demand increases, a regional entity must ensure CDR equity by fairly proportioning its share of CDR resources so that they do not store so much carbon underground, or lock up so much agricultural or forest acreage that neighboring entities go wanting for CDR resources or opportunities.

Another critically important equity issue with CDR mirrors equity issues with net-zero. Regional and local entities must be responsible for the historic emissions of those who are unable to fulfill their carbon responsibility, in the US as well as abroad.

To act in time frames that matter to irreversible tipping and eliminate the possibility of international, national and most states failure to act appropriately, responsibility now falls on local and regional leaders to not only address the climate emergency to save lives, but to help those who cannot help themselves.

We Can't Wait Any Longer

When President John F. Kennedy announced that the United States would go to the moon, we had spent only 16 minutes in suborbital space. Yet Kennedy's vision of the future, his understanding of the current state of space technology, and his need to keep America at the forefront, allowed him to see a path few saw. In 1961 he said, "Now it is time to take longer strides--time for a great new American enterprise--time for this nation to take a clearly leading role in space achievement, which in many ways may hold the key to our future on Earth." With climate change, America's government may yet succeed, but 30 years of failure has created not only an emergency, but an emergency like no other, capable of creating large parts of the world that are uninhabitable. Now is the time for environmental and civic leaders like Austin to "take longer strides." Climate pollution is local. It is created locally and like almost all other kinds of pollution it should be cleaned up locally. Like space in 1961, climate is now "the key to our future on Earth."

1.5 The Climate Emergency, Climate Ethics, Moral Hazard and Precautionary Principle

Today's climate change impacts are far advanced from impacts of the past. They are now increasing at a rate that is much faster, and those dystopian scenarios are now creating irreversible climate tipping points that were not supposed to happen for over a hundred years. Millions are dying and hundreds of millions will die if we do not cool Earth to a temperature lower than what allowed Earth systems climate tipping to begin. (See Section 1.1)

1.5.1 Climate Emergency

Delay in action on climate pollution reform has created a new and dangerous climate where we are faced with a climate emergency that like any emergency, requires immediate action to save lives now and hundreds of millions more in the future. In an emergency, it is inappropriate to delay response when solutions are available that save lives. Longer delay in the removal of historic climate pollution already accumulated in our sky means more lives are lost and lives lost increases nonlinearly with time and lack of adequate response.

Millions of lives are being lost today because of climate change weather extremes and warming-related implications of zoonosis with Covid-19; i.e. animal to human disease transmission (zoonosis) is enhanced and plausibly directly caused by habitat loss that is crowding more animals into smaller spaces, thus creating more animal to human contact, and by warming that creates ecological stress beyond the evolution of species, thereby increasing animal disease and transfer to humans. (1) Greater instance of disease on a warmer planet, and specifically disease from warming-caused stress and pathogen reanimation from permafrost collapse, are impacts we have been warned would occur at some distant point in the future when climate tipping began. Climate tipping has begun far ahead of schedule and in order to save lives, we must now treat climate change as if it were any other of the myriad disaster-caused emergencies we now see happening repeatedly as warming impacts grow.

Even though we understand and can respond to almost any emergency, we have never experienced a climate emergency before and we simply do not know how to behave. We have no historic knowledge from which to draw upon to create action.

The *Austin Climate Emergency Declaration* of August 8, 2019 declares: “700 governmental jurisdictions across the world have recently declared or officially acknowledged the existence of a global climate emergency; more than 70 health organizations including the American Medical Association and the American Public Health Association declared climate change to be a health emergency; and the City of Austin has been at the forefront of sustainability and environmental policy and can be a global leader in emergency climate action.” The *Climate Emergency Declaration* resolves, “Austin City

Council declares a climate emergency and calls for an immediate emergency mobilization to restore a safe climate; and that the City Manager is directed to identify innovative policy approaches to address the climate crisis's causes as well as mitigation strategies, including the promotion of natural systems, green infrastructure, and carbon sequestration." (2)

The "innovative actions" the City Manager is directed to identify are here in this document, mostly in Section 2, "Restoring a Safe and Healthy Climate to End the Climate Emergency." Like any emergency, first response means we have to take things into our own hands. We can be responsible for our own pollution and we can help teach the world these behaviors. Hopefully we will get help from our national and state governments; but time is of the essence. After 30 years, emissions are still rising. Our new presidential administration may very well be different, but we cannot afford to wait as tipping is already active and large uninhabitable areas of Earth loom.

Immediate action means stop the bleeding fast! It means we must act now on issues that have previously been reserved for action in the distant future with business-as-usual emissions. With climate pollution, because it is the climate pollution already in our sky that is causing the emergency – not future emissions – and because we must deal with up to 27 times more climate pollution in our sky than we must deal with to achieve net-zero in the Austin Region, we must move with true urgency to address this cascading emergency.

Emergency response means doing many things at once to preserve life and property. Implementing natural systems CDR on a scale 10 to 100 times greater than in the *Climate Equity Plan* is high on the list and must begin with immediate action. Partnering with local and regional entities for CDR and sequestration and utilization leverages immediate action. Piloting CO_2 to synthetic aggregates for revenue generation is another avenue and there are many more. (See Section 2)

Because of the long time frames necessary to reverse current warming, the very short time frame to respond, and the very large scale of innovative actions demanded by the risks of current and future loss of life, emergency response actions must begin now with urgency akin to wartime response.

The actual timeline is short and continues to shorten. Best estimates of the carbon budget remaining before irreversible scenarios are realized are, "by 2030." (3) But timelines for implementing much more complicated and extensive actions to cool Earth to below 1.0°C so as to preserve our Earth systems and reverse irreversible tipping are not yet robust in consensus science. Delay has activated tipping. Further delay allows tipping to become irreversible.

Operating under the worst-case scenario, we know that tipping will likely complete in decades rather than centuries, so prudent worse than worst-case planning tells us the 2040 time frame assigned to the urgency of our previous net-zero, 1.5°C mission, should apply to the new climate emergency mission at the bare minimum.

This means globally, if we complete the infrastructure that will drawdown excess climate pollutants from our atmosphere by 2030, including natural systems that remain viable, we should then be able to create a restored climate by mid-century.

Emergency response should begin by implementing known solutions at emergency scale and in emergency time frames. Every day of delay in implementing emergency actions means the scope and scale of loss of life increases nonlinearly, and the risk of failure and unrecoverable scenarios rapidly become untenable.

Box 1.5.1 – Immediate Responses to the Climate Emergency

Immediate Simultaneous Adaptation and Life Preservation Responses to the Climate Emergency

1. Implement actions with wartime urgency
2. Plan for worse variants in the Covid-19 pandemic
3. Ensure immediate net-zero emissions action
4. Begin installing an infrastructure to remove Austin's share of accumulated climate pollution from the atmosphere
5. Create adaptation measures to reduce risks from unprecedented extremes that include much greater extremes than have already occurred
6. Develop equitable and effective policy that can be transferred to others in leadership across the world
7. Work with the Biden Administration to focus adequate worse than worst-case scenario funding of climate reform strategies for less than 1.0°C warming
8. Do more than a fair share to help those who cannot help themselves locally, nationally, and abroad

Pinnacle Fire, Oak Hill, Southwest Austin, May 2011, Drought of Record. Eleven homes were lost. University of Texas researchers said that live fuel moisture, meaning living trees and plants, had a similar moisture content to dead fuels.

1.5.2 Climate Change Ethics, the Moral Hazard and Precautionary Principle

The "moral hazard" as it has historically been used relative to climate change issues involves a perception that fossil fuels are inherently required to be eliminated because of their damaging direct and indirect effects, and replaced with "clean" renewable energy. Actions that create a moral hazard would be doing anything that does not directly contribute to the elimination of fossil fuels. These actions then would be described as being morally wrong. Because both emissions cessation and carbon dioxide removal are required for a safe climate, this interpretation of the moral hazard argument is unhelpful, misleading, and is very likely to create irreversible scenarios. (1)

One of the direct interpretations of the moral hazard is that, if we as a society allow greenhouse gas polluting from the burning of fossil fuels to be directly treated, or directly removed from our sky, this gives climate polluters "license to pollute." This "license" would allow them to continue burning fossil fuels because they can simply treat or mitigate for the climate pollution they emit. The reason that actions to do something other than cease fossil fuel use would be morally wrong is that all of the other direct and indirect effects of the fossil fuel extraction and utilization industries – not including greenhouse gases, would continue unabated.

Historical interpretation of the moral hazard comes from the Precautionary Principle where: if there is substantial scientific uncertainty about the risks and benefits of a proposed activity, policy decisions should be made in a way that errs on the side of caution with respect to the environment and the health of the public. (See Box 1.5.2) This interpretation is entirely appropriate with an understanding of how climate change would progress before we learned that climate tipping from Earth systems collapses had been activated a century ahead of projections.

These Earth systems collapses are now capable of creating societally disrupting scenarios. These scenarios are most profoundly described by the quote from the "Climate Emergency Declaration" in the journal *Bioscience*, where completion of the activation of climate tipping systems that complete with no further warming and have very significant cascading effects on other tipping systems, are capable of "potentially making large areas of Earth uninhabitable."

Climate ethics now presents a new interpretation of the moral hazard. Unprecedented risks are upon us from current climate warming that include: sub-continental scale ecological collapse, risks of widespread mortality from climate change-caused or -enhanced disease, and irreversible feedbacks from collapse of Earth systems that create runaway scenarios. These risks are far greater than the traditional climate change impact risks of stress, strife and famine from climate change projections of the past. Risks from Earth systems collapse are now much greater than the risks to public health and the environment from production and utilization of fossil fuels, creating a new interpretation of the moral hazard. All of this is new in the last several years. Science has been projecting the occurrence of these events for decades, but their projected occurrence has been in the distant future. These new risks from tipping that have just been realized in the last couple of years have changed the most basic long-held assumptions about our response to climate change.

Climate tipping now gives new meaning to words from the Pope and the United Nations on the moral hazard and the moral imperative of addressing climate change. (2) We must continue on with our long-agreed upon path of cultural change to address climate pollutants, but new knowledge must also be addressed.

The excess climate pollution now in our atmosphere, that we have emitted in the past and has accumulated to an extent great enough to change our climate beyond the evolutionary boundaries of Earth's ecologies, is now the primary issue with climate change.

The extreme and repeatedly unprecedented weather events we are seeing today, the irreversible tipping activation; these things are caused by current warming, and are likely common in our currently warmed climate. The reason they are common is that we simply have not had enough time elapse since our climate warmed above its former natural variability for rare and overly extreme weather events to occur. Much more extremeness will occur, and like almost everything with climate change, these catastrophes will occur much sooner than believable, with much more ferocity than imaginable.

Our legacy of already emitted climate pollutants that remain in our sky for centuries is important to our advanced civilization in way that no other thing in human culture is important; if we halted all future emissions tomorrow morning, and even if we held Earth's temperature to exactly the same temperature it is today (which is impossible because of warming in the pipeline), tipping would still complete with irreversible and unrecoverable scenarios.

Replacing dirty fossil fuels with clean solutions is still imperative and is well described in places like Sierra Club's climate policies (3), but we cannot deny the new science and the existential importance activated tipping has created in our climate change culture relative to the moral hazard. This is why Sierra club has created new climate change policy, the first in the world, to limit warming to less than 1.0°C.

Box 1.5.2 The Precautionary Principle in Environmental Science

The Precautionary Principle in Environmental Science

1. Scientific studies can tell us something about the costs, risks, and benefits of a proposed action, but there will always be value judgments that require political decisions.
2. The scientific data used for making policy will nearly always be limited by uncertainty. Even the best theory and data will leave much that is not known about estimates of risks, benefits, or costs.
3. In conducting their research, scientists must make assumptions, choices, and inferences based on professional judgment and standard practices, that if not known by the public or policy makers, may make scientific results appear to be more certain and less value laden than is warranted.
4. Although there are some situations in which risks clearly exceed benefits no matter whose values are being considered, there is usually a large gray area in which science alone cannot (and should not) be used to decide policy.
5. In these gray areas, status quo activities that potentially threaten human and environmental health are often allowed to continue because the norms of traditional science demand high confidence in order to reject null hypotheses, and so detect harmful effects.
6. This scientific conservatism is often interpreted as favoring the promoters of a potentially harmful technology or activity when the science does not produce overwhelming evidence of harm.
7. The precautionary principle, then, is meant to ensure that the public good is represented in all decisions made under scientific uncertainty. When there is substantial scientific uncertainty about the risks and benefits of a proposed activity, policy decisions should be made in a way that errs on the side of caution with respect to the environment and the health of the public.

Kriebel et al., "The Precautionary Principle in Environmental Science," *Environmental Health Perspectives*, September 2011, National Institute of Environmental Health Sciences (4)

Ethics of the Commons

"Scientists can depict the problems that will affect the environment based on available evidence, but their solution is not the responsibility of scientists, but of society as a whole." Mario José Molina; awarded the 1995 Nobel Prize in Chemistry for his role in noting and resolving the threat to the Earth's ozone layer from chlorofluorocarbon (CFC) gases.

The Valentines Day ice bomb in Texas, Winter Storm Uri, killed up to 978 people including indirect deaths, just counting the seven days of the storm itself. A total of 69 percent of Texans, 20 million people, were without power for an average of 42 hours. Austin-Bergstrom Airport shattered their previous hours below freezing record of 121 from 1951, when they experienced 154 consecutive hours below freezing. Eleven feet were amputated from frostbite at just one of Austin's three major hospital systems. The disaster cost $200 to $295 billion just in Texas, up to more than the cost of Hurricanes Harvey and Katrina combined. (See references in the Prologue Section)

Pinnacle Fire, Oak Hill, Southwest Austin, May 2011, Drought of Record. Coincidentally, this C130 supertanker had laid over at Austin Bergstrom Airfield and was available to fight this fire. If it were not for the air tanker, losses would undoubtedly have been much higher.

South Padre Island, 18 miles beyond the end of pavement on the wilderness beach. This is one of the last remnant beaches on South Padre during a sunny day King Tide erosion event in 2014.

Section 2 Restoring a Safe and Healthy Climate to End the Climate Emergency

The key to our world today is our climate. Everything is connected to our climate. When our climate changes to beyond the evolutionary boundaries that created our world as we know it, our world must re-evolve to the new climate state. This re-evolution generally requires that our Earth systems' ecologies collapse, and then over time they are replaced with new ecologies. When this happens, we lose the environmental services that allowed the evolution of our advanced civilization.

This section discusses implementation strategies for a target of less than 1.0°C warming to end the climate emergency. Because international, national and most state efforts have failed to meaningfully address climate pollution for 30 years, the only thing remaining to do is to do it ourselves at the local and regional level.

Time is up. Globally we are 57 percent behind the 2.0°C path from 1992. Austin is 10 percent behind the 2.0°C path and if it weren't for cheap fracked gas our situation would be worse. (See Ref 2 and 3, Vision Statement) We have been waiting for 30 years. Will the future be different from the past? Will international, national, and state leadership accomplish more extensive climate reform needed today, when they have been unable to accomplish climate yet, especially if Obama couldn't do it when Democrats controlled Congress?

Risk management says it is bad luck to rely on something to change after 30 years of failure. It's now up to us, though it would be nice if other higher authorities were able to finally make a meaningful contribution.

What remains however, is that Austin cannot fix our climate alone. This is why we wrote Section 1.4, "Local Responsibility, Leadership, and Equity." As a leader, Austin has a responsibility to actively lead. Leading is an active task that involves encouraging and influencing others – a task the Austin Region has succeeded with in the past, and that we have the responsibility to fulfill in the future.

Generally, this discussion can enhance the ability of the *Climate Equity Plan* to fill the gap to meet net-zero, and it can provide further carbon dioxide removal (CDR) to meet 1.5°C. But fundamentally, we have to cool Earth to below 1.0°C to reverse the collapses that are now activated, before they complete their initiations and we lose control of warming. To do this we must take full responsibility for the climate pollution we have emitted in the past that has caused climate tipping to activate.

The strategies presented here are not new. Some have been in existence for 100 years. Nature-based strategies are preferred, but can only provide 10 to 20 percent of the needed CDR if they have not already degraded with current warming.

> *"When we try to pick out anything by itself, we find it hitched to everything else in the Universe."*
> *John Muir, founder of Sierra Club*

Climate pollution treatment technologies are simple and quite cost effective. They can also generate revenues to defray costs. The most important thing to remember about climate pollution is that it is only pollution, and we should treat it like any other pollution in our environment by responsibly removing it so we can be safe.


South Padre Island, about 10 miles beyond the end of pavement on the wilderness beach. The dunes here have been completely eroded away. Dunebergs can be seen calving into the surf in the distance. The black sand is iron-based magnetite, first shown in this document on page 20, it is heavier than normal sand and a common though small component of almost all sands. Erosion has pulled the lighter sand off the beach out into deeper water and the heavier magnetite remains.

2.1 What is CDR?

Carbon dioxide removal or CDR, sometimes referred to as NETs, or negative emissions technologies, is anything that takes excess carbon dioxide or other greenhouse gases out of the sky or renders them harmless to global warming. This includes Earth's natural systems like forests, soils and ocean or water processes; natural processes like geologic absorption and atmospheric chemical processes that render greenhouse gases harmless, and pollution treatment processes that remove climate pollutants from the sky. Removing carbon dioxide from exhaust streams of fossil fuel burning industry and energy generation is also carbon dioxide removal, but these processes only reduce the amount of future emissions. CDR is required to address our historic emissions burden that has already been emitted and is now resident in our sky, so as to respond to and reverse the climate emergency in time frames that matter. (1)

The preferred method of CDR is using natural systems. These strategies restore or enhance our natural world to help it do what it does naturally and in many cases economically. These natural systems strategies change CO_2 into living matter through photosynthesis, or react with CO_2 in the environment to store it permanently.

CDR OR CARBON DIOXIDE REMOVAL IS ANYTHING THAT TAKES CARBON DIOXIDE OUT OF THE SKY OR RENDERS IT HARMLESS TO GLOBAL WARMING.

In a perfect world with unlimited time, natural systems would not only create a safe world free from excess greenhouse gases, but they would also provide vast co-benefits to humankind. This amount of time however is not a luxury we possess, as we have exceeded the environment's time-limited ability to absorb carbon so that it can provide meaningful amounts of CDR. We are therefore left with no choice except to remove a significant amount of greenhouse gases from our atmosphere with pollution treatment technologies.

These technologies are not new. The recyclable lime-potash technology was invented shortly after 1900. The other major existing technology uses amines developed in the 1930s. Amines are one of the most important and widely used groups of chemicals in all of industry that were put to widespread use in the 1950s. The recyclable lime-potash process was used in submarines to keep our sailors safe from carbon dioxide poisoning in World War II.

The plausible capacity of air capture CDR technologies has been colored in academic literature by an artifact known as scenario bias. Because academic literature on climate change modeling and projections is based on widely used scenarios, quantities of plausible climate pollution treatment CDR are limited by the scenarios. The common scenarios have widely been created to project market-based forces influencing the rate of penetration of air capture CDR. Because CO_2 markets are currently limited, this limits scenario penetration of CDR.

In reality, in time frames that matter, much of the CDR demand to restore our climate and reverse tipping will be a function of the commons that generates no revenue. These CDR services provided are no different than things like policing, the military, or social services. This means that once we as a society are motivated, the quantity of feasible air capture CDR is only limited by how motivated we are.

CDR has few side effects other than normal industrial processes where already existing environmental regulations keep us safe. CDR is not geoengineering. It does not manipulate our climate, but removes pollution from our environment. Equity issues with climate pollution CDR treatment technologies are low because these strategies have very small footprints compared to nature-based CDR solutions. Facilities siting equity with tech-based CDR should be considered no differently than other industrial or pollution treatment processes.

Claims of exorbitant energy and water use, and significant air pollution, are artifacts of assumed fossil fuel energy usage scenarios to power tech-based CDR facilities. (See the CDR Cost Controversy Summary in the Section 2.2 references, number 6) With the recent plummeting of alternative energy and battery storage costs, site-built utility scale wind and solar will logically be used, eliminating issues with excess fossil fuel energy, and associated water use and air pollution, and significantly reducing excess alternative energy site footprint issues.

Because we are in a climate emergency, emergency response procedures demand that we first deploy immediately available strategies to save lives. These recyclable lime-potash and amine processes are here now and already doing the job of removing CO_2 from the atmosphere. They are currently and rapidly being scaled up in industry. (2) Our emergency response is to scale them to the gigascale like we have done with so many things in our society, so that we can deal with the giga-demand of carbon dioxide removal, just like we scaled solar cells and batteries to address the giga-demand our society created for these things.

Developing novel technologies takes too long for emergency deployment. We have effective technologies right now. They are a century old and use off-the-shelf components. It is a given that new tech could be better, but emergency response demands we act immediately to save lives. Once an emergency response is mounted, we can implement new technologies that will perform even better. But if we wait, millions die, and our environment will be irreversibly harmed to the detriment of our advanced civilization.

Big Bend National Park, near the western entrance and Lajitas. These ocotillo "trees" have been killed by an outbreak of native ocotillo borers in a very similar way to drought stress and how vast outbreaks of bark beetles have killed conifers all over the world. Fundamentally, our climate has warmed beyond the evolution of our planet's ecologies. Whenever biologic systems experience changes in baseline conditions that are beyond their evolution, the systems are degraded or fail completely, and we lose the services those systems provide.

Western Travis County tree kill from the 2011 to 2013 drought. This tree kill actually continues today, due to stress from drought that can last decades with long-lived, slow growing species. Drought stress creates pathways for insect and disease to degrade or create mortality. Regrowth of these forests will not reach maturity until our climate stabilizes. Meanwhile, we lose most if not all their environmental services. Three hundred million mature trees were killed in Texas in 2011. (1)

2.2 CDR Strategies, Quantities, Cost/Benefit for Less than 1.0°C Warming

We should begin our emergency response with nature-based CDR. It can accomplish a lot, but only if we expand our sequestration footprint beyond our local region suggested in the *Equity Plan*, and only if we immediately begin to reduce warming and diligently understand the impacts of warming on natural systems sequestration capacity. The *Equity Plan* prescribes about 100,000 acres of nature-based solutions by 2030 and 500,000 by 2040, to achieve 680,000 tons CDR or about 5 percent of the Austin Regions annual emissions. We can achieve 6.8 million tons sequestration per year with 5 million acres of nature-based strategies. (2) This section discusses how we increase CDR to the needed 14.4 million tons per year to achieve less than 1.0°C warming.

One of the most promising categories of nature-based strategies is labeled regenerative agriculture, and it consists of numerous individual strategies that can either stand alone or complement one another. Regenerating forests is one such strategy, but nature-based solutions simply do not have the capacity to address the amount of CDR needed alone. (3)

The CDR strategies that remain are climate pollution treatment strategies where the quantity of removal is limited only by motivation. The leading climate pollution treatment strategies are 80 and 100 years old, use potash and recyclable lime, and ammonia-derived chemicals that have few drawbacks. Because they are mature and use simple tech, they are economical too. All CDR strategies including regenerative agriculture must be scaled quite significantly to be effective. Scaling will very likely allow costs to drop 90 percent or more, based on the historic cost decreases of things like solar, wind, batteries, transistors, mechanized agriculture, etc. The price of solar cells for example, was 35,000 percent more in 1976 than it is today. (4)

On a global scale, the quantity of sustainable, equity-aware, nature-based strategies is about 5 percent of what is needed to achieve 1.5°C, which aligns well with the *Austin Climate Equity* Plan prescription. (5) This global quantity can be scaled to the Austin Region's burden based on our historic emissions, and the amount of equity-based CDR we choose to do to address the needs of those who do not have the means to do so. (See Section 1.2)

Time frames are critical in that nature-based solutions generally take far too long to address a meaningful quantity of the CDR, whereas the time to implementation of climate pollution treatment-based CDR is determined, again, by motivation to address the challenge. Dealing with our historic climate pollution responsibility may initially be expensive, yet we certainly have the capacity in our world to spend far more when appropriately motivated. Most of the CDR we need to responsibly address climate change pollution we have emitted historically in the Austin Region however, will have to be provided by industrial pollution treatment technologies, like human sewage treatment we do on a local and regional basis without a second thought. The quantity of these technological pollution treatment strategies is only constrained by constrained by motivation, which in turn almost completely dictates the allotted funding.

Costs of nature-based solutions are generally low, and many of the regenerative agriculture strategies also achieve agricultural efficiency gains that return net profits to the land owner. Nature-based solutions also offer many other co-benefits, particularly when they are located on public lands. However, it is critical that the limits of nature-based solutions are fully understood, where current warming has already degraded Earth's ecologies and activated climate tipping, or ecological re-evolution that likely results in not only loss of sequestration capacity but flipping resources from carbon sinks to carbon sources. (See Box 1.3.4)

CDR IS OFTEN PRESENTED AS COMPLEX AND EXPENSIVE. IN REALITY, IT IS LITTLE DIFFERENT THAN THE $500 BILLION WE SPEND ON ENSURING SAFE DRINKING WATER ACROSS THE PLANET EVERY YEAR. (6)

Costs of climate pollution treatment strategies have also been overestimated in academic literature because of early errors in published literature that persist today despite ample academic rebuttals; because of the scenario bias that relies upon market penetration and revenue generation where, in reality most CDR will be a function of the commons because markets for giga quantities of CO_2 will never exist; and because private investors cannot jeopardize trillions of dollars in future revenues by opening their trade secrets to the world. These biases have resulted in an abundance of publishing of hypothetical scenarios that show costs of CDR pollution treatment strategies are five to ten times higher than the small amount of process-based publishing available. This bias is evident in the recyclable lime-potash process first used in a widespread way to keep our sailors safe from carbon dioxide poisoning in submarines during WWII where early hypothetical publishing estimated costs of $600 to $1,000 per ton and recent process-based costs are at $100 per ton. (7)

Air capture CDR using the mature recyclable lime-potash process currently costs $100 per ton based on a one-thousand ton per year pilot facility scaled up to one million tons per year using off the shelf components and known scaling factors. (See information on David Keith and Carbon Engineering, Reference 7 above) This process is currently scheduled to begin construction in 2022 for a million ton per year facility in the Permian Basin and billions are being invested in others across the globe. Costs are actually far less than $100 per ton as follows:

The Carbon Engineering facility in Squamish, British Columbia uses natural gas energy for 87 percent of process costs and a 10 percent carbon penalty. Using carbon-free solar and wind energy, the cost will be 66% less in five years. Further eliminating the carbon penalty for natural gas energy and the 8 percent profit because we need to remove carbon from the air for the commons, not for profit, and costs will fall 80 percent before gigascaling cost reductions. The same can likely be said for the ammonia chemical process (amines developed in the 1930s) and Klaus Lackner's moisture swing process at the University of Arizona that uses room temperature process chemical regeneration instead of 700 °C regeneration. All three of these processes are currently in the megaton industrialization stage. (See Reference 7 "Cost Controversy")

Once captured, the CO_2 disposal cost in outer continental shelf saline aquifers is less than $5 per ton in 2012 with a capacity of over 2,500 gigatons. (8) Some CO_2 disposal will generate revenues like Air to Fuels (A2F) and have no bottom-line costs at all, but will be able to create revenues to defray costs of industrialization and scaling.

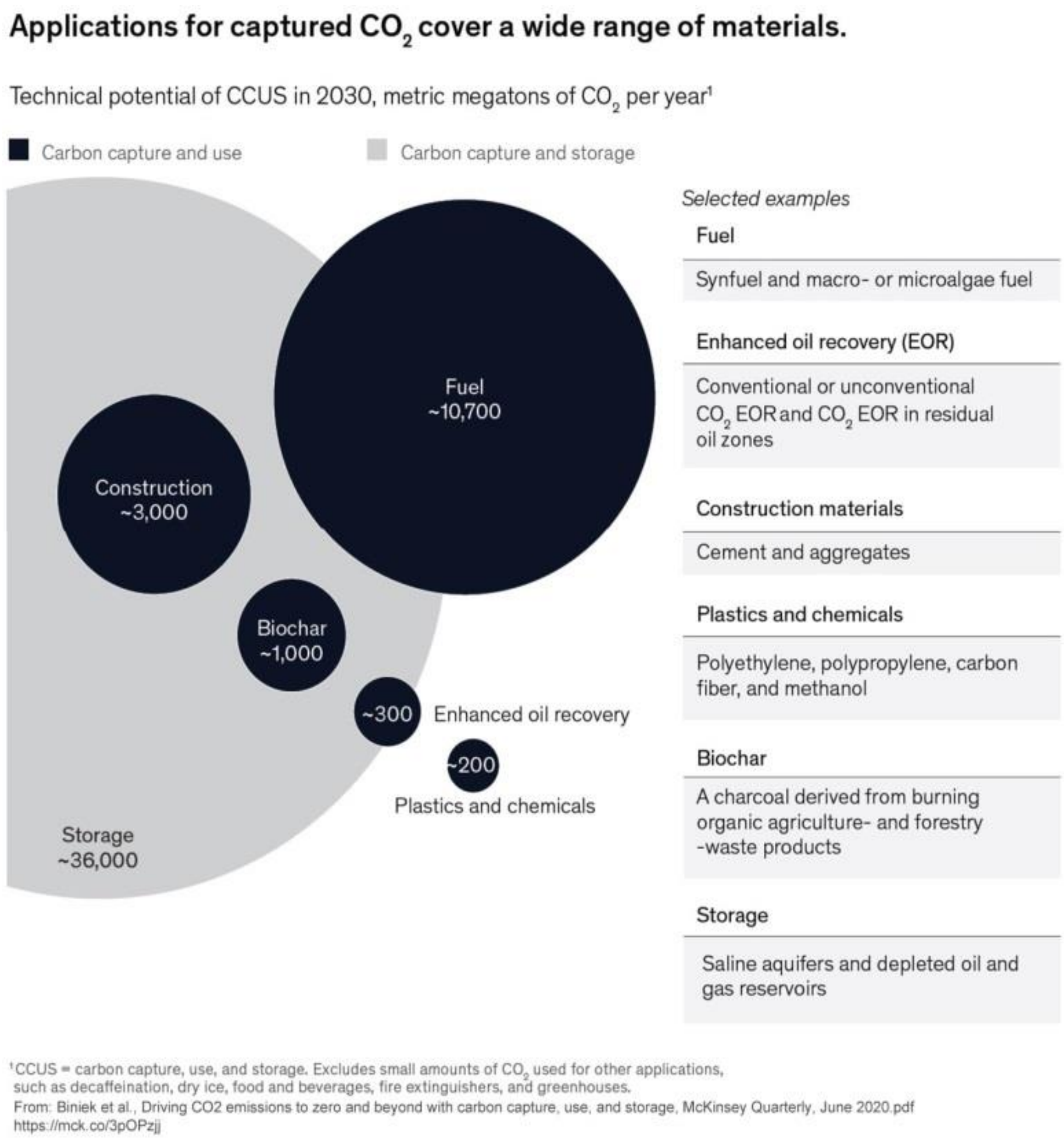
If market forces or motivation to benefit the commons could lower the capture and disposal costs of CO_2 to a feasible scaled price of $10 to $15 per ton, removing 100 percent of Austin's CO_2 climate pollution burden of 288 million tons would be $2.9 to $4.3 billion, or less than the proposed cost of improvements to IH-35 downtown. Phasing up to scale could likely be another several billion, but these are the costs of leadership. The process scaling is just now beginning in industry as they see the future revenue possibilities. Austin can help lead by sharing in these costs and Section 2.3 discusses ways to defray these costs, plausibly to the point of excess revenue generation. One example is that costs could be mitigated by using the output of the carbon capture process to produce the concrete that will be required by the IH-35 project itself. A City department could be created – a Department of Carbon Recovery and Reuse, which would produce carbon-based building materials for use in Austin's growth in a very similar manner to how Austin Water, Austin Energy, and Austin Resource and Recovery sells water, energy, and waste reuse and disposal.

McKinsey and Company is a worldwide management consulting firm, founded in 1926, that advises on strategic management to corporations, governments, and other entities. Their publication, "Driving CO_2 emissions to zero and beyond with carbon capture, use, and storage," McKinsey Quarterly, June

2020, suggest a very bullish carbon capture market in the near future. McKinsey states, "From now to 2030, our research and modeling suggest, carbon capture, utilization and sequestration (CCUS) could expand from 50 million tons of CO_2 abatement per year (Mtpa) today, mostly for enhanced oil recovery and beverage carbonation, to at least 500 Mtpa [0.5 gigatons a year]." (See Figure 2.2)

Austin, and the world, can achieve these things, but first we need to be motivated by the scientific reality of the problem. Understanding climate tipping points and understanding how weather extremes will nonlinearly increase in size and extremeness with further warming to a 1.5°C target are critical to appropriate planning. Changing our philosophy on greenhouse gas pollution to one where we treat greenhouse gas pollution no differently than we treat any other pollution, by removing it from our environment to keep us safe, is a pivotal step in addressing these realities. Adopting a less than 1.0°C warming target will help Austin lead the world into the next phase of climate reform that is now required by our dangerous 30-year delay in climate pollution reform action, and this leadership stance will drive others to adopt similar positions as well.

Figure 2.2 Applications for carbon capture, utilization and sequestration (CCUS) in 2030



The Cost of Air Capture CO_2

The Austin area annual GDP is $150 billion. It is not that air capture of carbon dioxide is so expensive; it is that it is so cheap! For less than $10 billion, Austin could solve its share of the climate puzzle and also the shares of millions of people around the world who cannot afford to solve their own – not counting revenues generated from reuse of captured CO_2, or from services provided by nature-based CDR solutions.

Tree kill from the 2011 drought near Johnson City. The Texas Forest Service says 301 million mature trees were killed in Texas in 2011. (35) About 6 percent of the trees in Central Texas perished. At the time, it was believed that self-restoration would be a given. Since then though, research on regrowth of trees killed in fire across the American West has shown that because of ongoing drought, one-third of burned forests are not regenerating, and of those that are regenerating, densities have decreased by half. (See Section 1.1, Reference 13)

Pinnacle Fire, Oak Hill, Southwest Austin, May 2011

2.3 Funding and Revenue Generation for Less Than 1.0°C Warming

What does leadership cost? Whose responsibility is it to develop the means necessary to address common challenges? What are the benefits of leadership?

In World War II globally, we spent a gross domestic product (GDP) adjusted $37 trillion per year for 7 years, mostly on industrialization for the war machine. (1) Dealing with our historic climate pollution responsibility may be expensive, but we have the capacity in our world to spend far more when appropriately motivated. Austin's share of this WWII GDP adjusted spending is $40 billion per year. (2)

Austin's capital budget for 2020 was $1.2 billion. Responsibly removing Austin's 288 million tons of historic climate pollution burden from the sky at $10 per ton is only $144 million per year for 20 years – a quarter of Austin's annual police budget. (See Section 1.4, Reference 2 and Section 2.2, Reference 7)

These costs also do not include revenues generated from captured CO_2, through plausible CO_2 reuse industries like concrete and road building material using reduced and negative carbon concrete, and numerous markets for CO_2 products from soda water to baking soda.

There are 5.75 million tons of concrete placed in Central Texas annually or about 11.5 million cubic yards. (3) Blue Planet Aggregates carbon negative concrete sequesters about 1320 pounds of CO_2 net per ton of concrete, considering CO_2 emissions in the supply chain including cement manufacturing. If the CO_2 captured to create the aggregate is from flue gas of a cement kiln, 1920 pounds of CO_2 is sequestered per each cubic yard of concrete. If the CO_2 is captured from air, because half of CO_2 emissions are absorbed by Earth systems, 2,220 pounds of CO_2 emissions are sequestered per cubic yard of concrete. (4) Blue Planet Aggregates will design a synthetic aggregate manufacturing facility specific to a region for $250,000. (5)

REMOVING AUSTIN'S 288 MILLION TONS OF HISTORIC CLIMATE POLLUTION FROM THE SKY AT $10 A TON IS ONLY TWO YEARS' WORTH OF AUSTIN'S CAPITAL BUDGET, OR $144 MILLION PER YEAR FOR 20 YEARS – A QUARTER OF AUSTIN'S ANNUAL POLICE BUDGET.

The costs of concrete in Central Texas are not yet high enough to create revenues from negative carbon concrete because we live in an aggregate rich area. However, aggregate poor areas like metros in California have much higher aggregate costs and can realize profits from carbon negative concrete. One solution to generate revenues is for Austin to partner in carbon negative concrete facilities in California. A downtown IH-35 solution in Austin could remove carbon from the air not only with carbon negative concrete, but by capping IH-35 to remove CO2 and other pollutants from ventilation exhaust.

Another solution is carbon negative oil using enhanced oil recovery (EOR) with the California Low Carbon Fuels Standard (LCFS) Carbon Sequestration Incentive of about $200 per ton CO_2 sequestered and the IRS 45Q tax credit of up to $35 per ton CO_2 sequestered for EOR. (Reference 6 and 7, and Section 1.3.4, Reference 8)

Carbon Engineering and Occidental Chemicals are building a one-million ton per day air capture facility for EOR in the Permian Basin (See Section 2.1, Reference 2) that is revenue positive and carbon negative using the LCFS incentive. (8) Further burning of fossil fuels is of course not at all ideal, but scaling of air capture technologies is the critical path to stopping tipping as it is the biggest and most developed tool at hand that could plausibly achieve enough CDR to cool Earth back below the tipping threshold in time frames that matter. If done with carbon negative processes, it helps lower Earth's temperature. We are in an emergency and we must save lives with the tools at hand. Gigascaling of CO_2 air capture technology is the single most important thing we can do right now.

Plausibly the greatest revenues can be generated from synthetic hydrocarbon fuels. We can create these fuels using technology developed in the 1920s and used extensively during World War II to create replacement liquid hydrocarbon fuels in Europe where traditional liquid fuels were no longer available. Replacement of liquid fossil fuels with air captured fuels provides near-100 percent emissions reductions, and a revenue center that will not go away when we transition to electric vehicles.

The REME study in 2014 showed that with $0.02 kWh renewable energy, which is about the price of wind and solar energy today, and $50 dollar per ton air capture CO_2, we can create $3 per gallon liquid hydrocarbon fuel. With lower CO_2 capture costs that are certain in the future, synthetic liquid hydrocarbons can be highly competitive with fossil fuels. (See Box 2.3) This study was produced by the chief engineer at Global Thermostat, who has developed a pilot project for air capture CO_2 using amines. Global Thermostat was collaborating with ExxonMobil until the Covid pandemic delayed the project. (9)

These are just three technological opportunities that did not exist a decade ago. Many, many more exist. One in particular that is still at the early pilot stage is air capture CO_2 to carbon nanotubes that can create carbon nanofiber materials cheaper than aluminum. (10)

These technologies, with the exception of carbon nanotubes, are piloted and ready to scale. What remains is gigascaling – and we know how to gigascale – we simply have to be motivated and have leadership. It is this gigascaling that is so important to humanity. Because we cannot rely upon leadership other than at the local and regional level, it is time for us to create local infrastructure to benefit the commons, paid for by the commons, before it is too late.

Box 2.3 REME – Renewable Energy and Materials Economy

Renewable Energy and Materials Economy (REME)

The REME approach using carbon from the air can make our energy and materials at lower costs than from their fossil energy equivalents and make energy carbon neutral and building materials carbon negative.

1. With renewable energy at less than $0.02 kWh (Current price for wind and solar is $0.02 kWh)
2. Capture of CO_2 from the air at under $50 ton (For comparison a ton of CO_2 at $50 has the equivalent carbon content as $20 dollar/barrel oil and costs of air capture CO_2 will likely be less than $50 ton by 2023)
3. Production of hydrogen at under $1 kilogram with $0.02 kWh renewable energy, allowing us to make:
4. Liquid synthetic fuels from CO_2 and hydrogen for around $3 gallon, also other hydrocarbons at comparable costs to fossil-based hydrocarbons (like ethylene for plastics)
5. Carbon-fiber-based construction materials from atmospheric CO_2 with cost/performance properties competitive and comparable to steel, aluminum, and concrete that sequester more CO_2 than they generate (carbon negative).

REME makes sense even if private cost (cost paid by the consumer, based upon the cost to produce the energy and materials) is greater than the cost for producing energy and materials using fossil fuel or mineral resources. This is because of REME's social benefits compared to the social costs of fossil energy use. The social benefits of REME in providing energy security, removing conflict over resources, preventing environmental damage and addressing the climate threat are very significant. (11)

Global Thermostat pilot facility, Menlo Park, California. Photo, global Thermostat

Carbon Capture News Headlines July 6 through 19, 2021

Carbon Capture Journal is the world's leading magazine for carbon capture storage and utilization, published by Future Energy Publishing in London since 2007. Below are their news headlines from just July 6 to 19, 2021. (Individual references at 12)

Sembcorp collaborates on UK net zero power plant
(Jul 19 2021) The company is exploring a potential 300MW Net Zero emissions NET Power station at Wilton International, Teesside with carbon capture technology.

ExxonMobil to participate in Acorn project
(Jul 16 2021) The project plans to capture and store approximately 5-6 million tons of CO_2 per year by 2030 from gas terminals at the St Fergus complex at Peterhead, Scotland, which includes ExxonMobil's joint venture gas terminal.

Carbon Clean selected for Acorn project carbon capture
(Jul 15 2021) Carbon Clean has been awarded the contract to carry out the Front End Engineering Design (FEED) services for the Acorn carbon capture plant at St Fergus, Scotland.

Shell proposes large-scale CCS project in Alberta
(Jul 14 2021) The proposed Polaris CCS project, the largest in a series of low-carbon opportunities Shell is exploring at Scotford, would capture CO2 from the Shell-owned Scotford refinery and chemicals plant.

Aker Carbon Capture launches Carbon Capture as a Service
(Jul 12 2021) The company has launched an integrated offering that 'covers everything a customer needs to reduce emissions by CCS' called Carbon Capture as a Service; Carbon capture made easy™.

Air Liquide, Borealis, Esso, TotalEnergies and Yara collaborate
(Jul 12 2021) The companies have signed an MoU collaborating on decarbonizing the industrial basin of Normandy in France.

INEOS and Petroineos at Grangemouth join the Scottish Cluster
(Jul 11 2021) The companies are partnering with the Acorn Project to capture and store up to one million tons of CO_2 by 2027.

Gulf Coast ready to develop Carbon Storage Hub
(Jul 11 2021) The stage is set for a new carbon storage economy to emerge along the Gulf Coast, according to a study led by The University of Texas at Austin.

Aker Carbon Capture and Carbfix to explore CCS with Elkem Iceland
(Jul 11 2021) Norway's Aker Carbon Capture has joined forces with Carbfix and Elkem Iceland to reduce CO_2 emissions at Elkem Iceland's ferrosilicon plant through carbon capture and mineral storage in basalt structures.

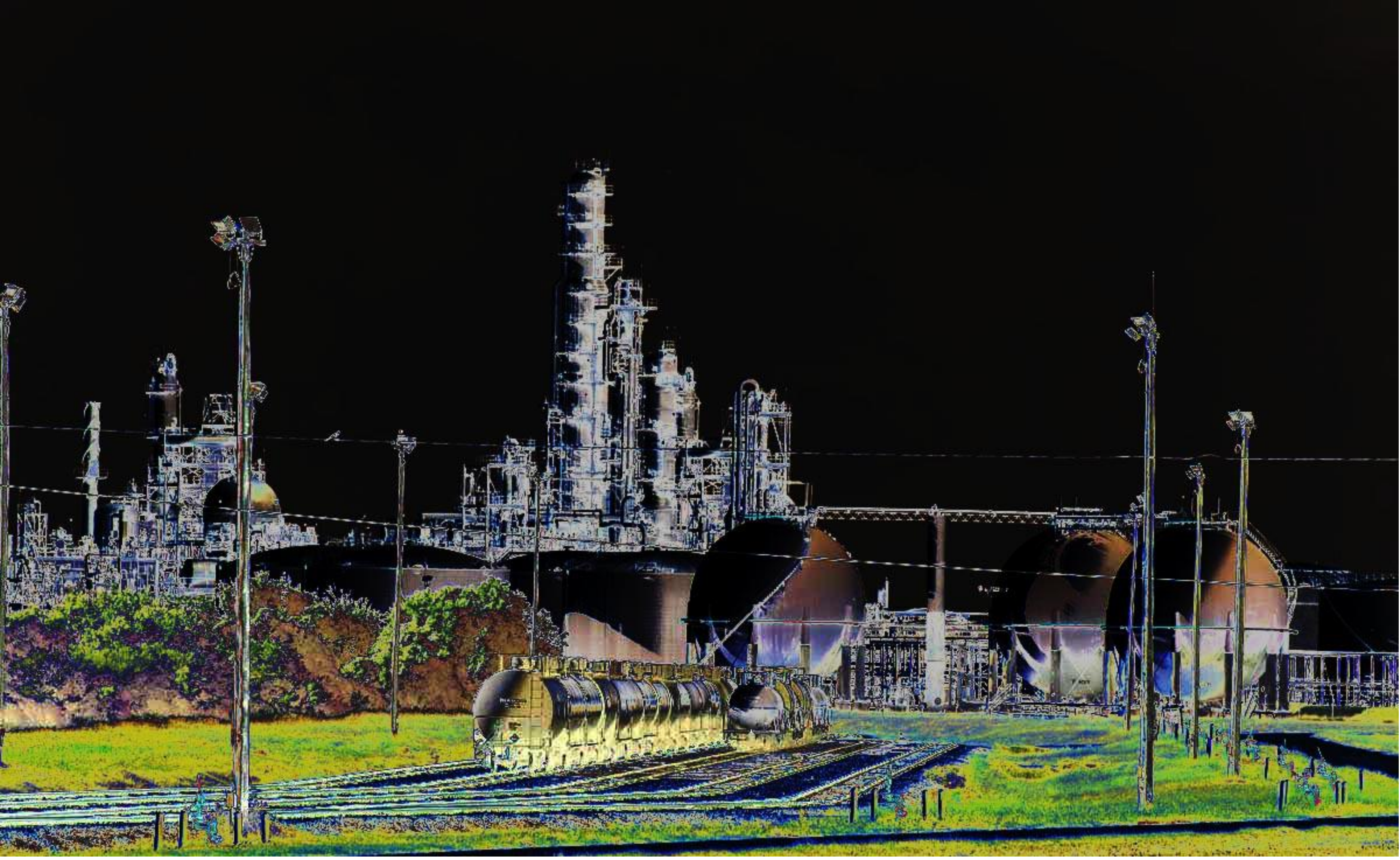
Svante receives $25 million from Government of Canada
(Jul 09 2021) The Government of Canada made a CDN$25 million investment to support the industrialization and commercialization of its novel low-cost carbon capture technology within the North American market.

CCUS scale-up could create 10,000 UK jobs this decade
(Jul 08 2021) If the UK Climate Change Committee's 2030 CO_2 capture target is delivered, 10,000 new green jobs could be created in industrial heartlands by the middle of this decade.

Aker Carbon Capture to explore CCS with BIR
(Jul 07 2021) Waste management company BIR has signed an agreement with Aker Carbon Capture to explore possibilities for a future carbon capture plant at their waste to energy plant in Rådal outside Bergen on Norway's west coast.

Crown Estate launches forum to unlock CCUS
(Jul 07 2021) The Offshore Wind and CCUS Co-location Forum which will identify the key challenges and opportunities associated with the co-location of Offshore Wind and CCUS.

Sinopec launches China's first megaton scale CCS project
(Jul 06 2021) China Petroleum & Chemical Corporation (Sinopec) has begun the Qilu-Shengli Oilfield CCUS project, set to become China's largest whole industrial chain CCUS demonstration.



Gulf Coast Ready to Develop Carbon Storage Hub

First published on July 5, 2021, by University of Texas News (13)

(Editor's Note: The time is here. Leaders are moving. Billions are being invested in carbon capture and storage.)

AUSTIN, Texas — The stage is set for a new carbon storage economy to emerge along the Gulf Coast, according to a study led by The University of Texas at Austin, with the region offering ample opportunities to capture and store carbon, and recent state and federal incentives giving an added push to get started.

Carbon capture and storage, or CCS, is a technology that keeps CO_2 out of the atmosphere by capturing emissions and storing them deep underground. It can help fight climate change by lowering industrial emissions now while renewable energy sources are being developed, said Tip Meckel, a senior research scientist at the Gulf Coast Carbon Center, a research group at the UT Bureau of Economic Geology that has been studying CCS for the past 20 years.

“This is a viable way to reduce emissions in the near term,” Meckel said. “It’s feasible and has a reasonable economic structure that can support, retain and create jobs.”

The study, which was published in Greenhouse Gases: Science and Technology, provides a high-level overview of policy incentives for CCS and how Texas and Louisiana’s high concentration of industry and unique offshore geology make the region a particularly good spot to build up a carbon storage economy.

The topics explored in the paper are especially relevant considering recent moves that Texas has made to bring carbon storage under a similar regulatory framework as oil and gas. In June, Gov. Greg Abbott signed into law HB 1284, granting the Texas Railroad Commission the same regulatory authority over CO_2 injection wells as it has over oil and gas wells.

Carbon Engineering pilot facility, Squamish, British Columbia. Photo, Carbon Engineering

2.4 Implementing a Climate Emergency Response to Limit Warming to Less than 1.0°C

Two areas of implementation are fundamental to fully addressing our historic climate pollution burden: nature-based and climate pollution treatment strategies. Nature-based solutions largely rely on incentives to produce CDR. These solutions are in use today in relatively small quantities and mostly associated with what we know as organic, holistic or sustainable agriculture and forestry practices.

Incentives are needed to further scale nature-based strategies and Austin can provide incentives for producers to apply these strategies that can then create carbon storage as well as profits for incentive recipients and benefits for the Austin Region.

Implementing the other main category of CDR that includes direct treatment of climate pollution through chemical and physical techniques is two-faceted: revenue-generating strategies and strategies for the benefit to the commons.

Revenue-generating strategies will be quite helpful in implementing gigascale CDR infrastructure. Austin can catalyze these strategies through both positive and negative incentives. Positive incentives are things like the Austin Energy programs GreenChoice and Solar Rebates. They can also be in the form of ordinances (often negative incentives) for things like reduced carbon or

Emergency Deployment of CDR as a Response to the Climate Crisis

Hanna 2021 describes several scenarios of emergency deployment of CO_2 air capture for climate reform. The following are excerpts from these findings: ***(1)***

"Our purpose here is to elaborate one component, DAC [direct air capture of carbon dioxide], that might also prove attractive. Though public attitudes vary, from a technological and industrial perspective DAC has attributes of high value to the politics of emergency response: deployments are modular, scalable, and highly controllable by the governments and firms that invest; carbon removals are verifiable; and deployment does not inherently harm existing industrial interests.
(Continued next page)

carbon negative concrete and other building materials as well as incentives for local industry to become responsible for their lifetime emissions, like the commitment [Microsoft has made to clean up all their historic emissions]. If Austin were to implement these strategies, revenues could be generated to help fund the second facet a climate emergency response: CO_2 removal for the benefit of the commons.

To generate revenues however, these technologies need to be scaled so they are profitable. Right now these processes are widely thought to be too expensive, but "expense" is a relative term. Even the most expensive strategies of carbon removal today are incomparable to the costs of unrecoverable Earth systems collapse and creating collapse of our civilization as we know it. The bottom line is that we must remove carbon from the sky or unrecoverable scenarios will result. At any and all costs, we must restore our climate to a point within the evolutionary boundaries from which our global ecologies evolved or tipping will complete.

The investment that must be made to scale these climate pollution removal technologies, and to scale nature-based CDR is something that in the absence of national and state leadership must be made by local and regional entities. We have been investing in these no-profit strategies locally to create benefits to the commons for over a century and they include public health, policing, social services, transportation, our military, and many others. Of particular importance are local and regional infrastructures for the benefit of the commons that we have been building and operating for over a century to sell products or services that include potable water, wastewater treatment and electricity generation.

The infrastructures for these revenue generating strategies can serve as models for CDR services for the commons. Austin or any local or regional entity can build these new infrastructures themselves and reap direct benefits, or they can offer incentives for others to develop these processes to use their CDR for offsetting the net-zero emissions gap, and for removing historical climate pollution from the sky.

LOCATION, LOCATION, LOCATION… ALL CO2 IS CREATED EQUAL IN THE EYES OF CLIMATE WARMING, SO SEQUESTRATION ANYWHERE CAN BE USED AS CDR TO ADDRESS HARD-TO-DECARBONIZE ASPECTS OF NET-ZERO

Because the gigascaling of these strategies is relatively large, partnerships could be created among multiple local and regional entities to defray costs with larger and larger processes. These partners are similar to partners Austin already contracts with, whether they are individuals NGOs, private industry, large scale agriculture, or quasi-public industry like Austin Energy or Texas Gas Service.

Incentives include cash per acre for regenerative agriculture strategies, ordinances requiring carbon reduced or carbon negative building materials, or profit motivation for others to create CDR for our region where others benefit from profits.

It is understood that in some political circles, these things may be more difficult than flying a man to the moon; the point however, is that political atmospheres change. Beyond elections, emergency response motivation is highly related to crisis situations. The extremeness of current catastrophes is very likely common with current warming and these catastrophes will definitively grow much more extreme and frequent even if we were to magically halt all warming at our current 1.0°C. Those who are shovel-ready get the benefit of State or Federal funding when political changes occur. Planning for the impossible today may seem wise tomorrow.

One other point must be made here regarding political issues. Those of us who do not support climate

(Continued rom previous page)

Though energy intensive, DAC appears to have no biophysical limits, unlike bioenergy with carbon capture and sequestration (BECCS). Nor does DAC require large-scale land use changes and hence compete with important sustainability goals such as maintaining biodiversity and food production. Moreover, unlike strategies for controlling emissions from industry and the broader economy, deploying DAC does not intrinsically require intrusive policy interventions, such as requiring existing firms to transform their production methods."

Hanna continues, "For policy makers, one implication of this finding is the high value of near term DAC deployments—even if societies today are not yet treating climate change as a crisis—because near-term deployments enhance future scalability. Rather than avoiding DAC deployments because of high near-term costs, the right policy approach is the opposite."

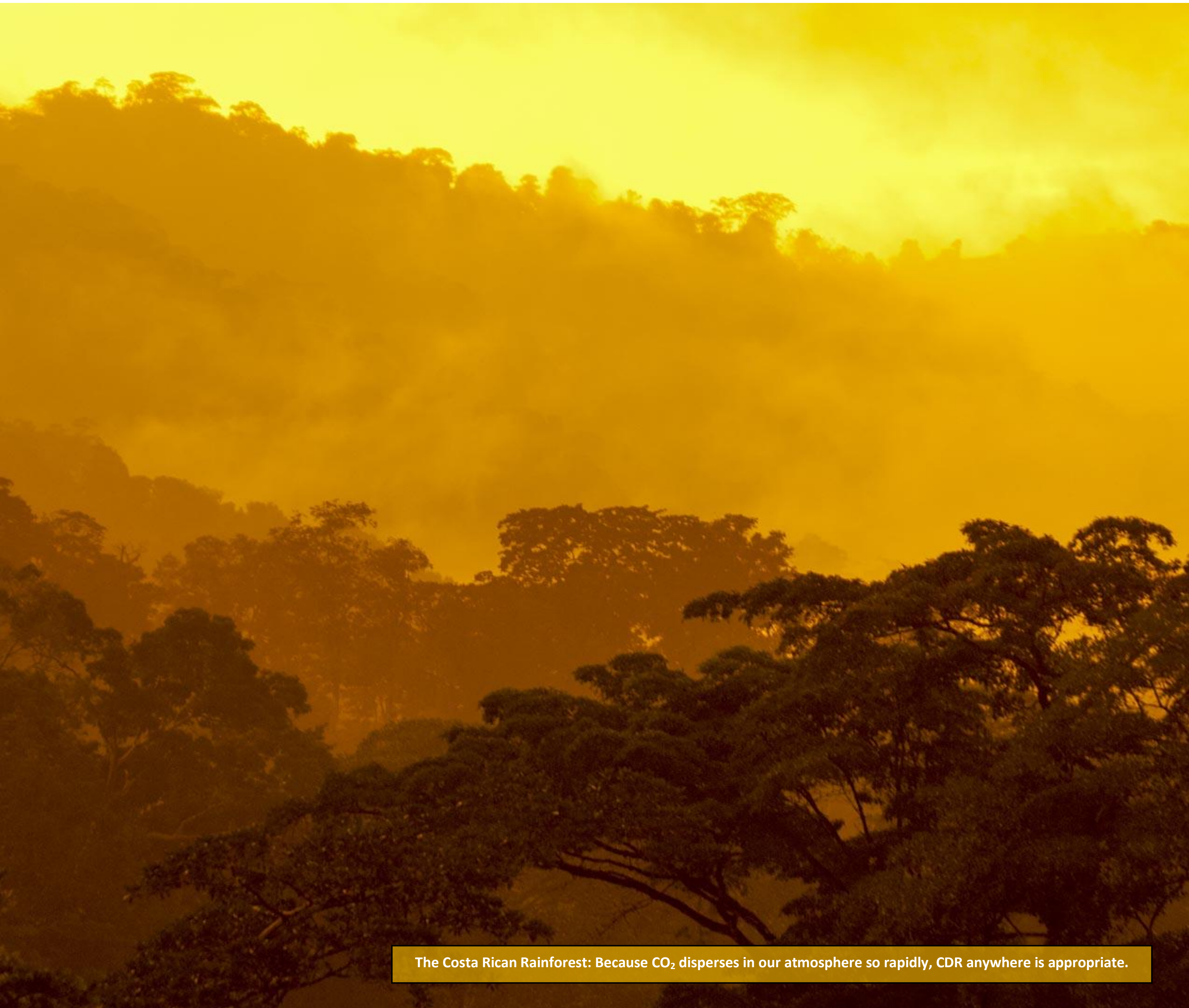
The take away from this study is embodied in this quote, "The near-term political approach to crash deployment should seek not to maximize CO_2 removals but rather to deploy many plants to push the technology down the learning curve."

change actions in general, often do support strategies to create market-based solutions that generate revenues from climate actions, like the IRS 45Q tax incentives for enhanced oil recovery with carbon sequestration, with or without oil recovery.

Expanding our sequestration footprint for nature-based solutions is mandatory, but we must ensure nature-based solutions are viable today with current warming and even more critical, sequestration must be permanent for 100 years with whatever warming happens in the future. The issue with our nature-based solutions being beyond the boundaries of their evolution must be deeply considered. (See Box 1.3.4)

All CO_2 is created equal in the eyes of climate warming and sequestration anywhere can be used to reduce our historic climate pollution burden as well as address those hard to decarbonize aspects of net-zero. Some benefits accrue to others when strategies are not implemented close to home, but this is a part of the climate reform puzzle that cannot be avoided when developing emergency strategies with enough CDR capacity to be meaningful to the commons as a whole. Of course, equity must also be considered, which includes helping those who cannot help themselves; not just in the Austin Region, but across the world.

Fundamentally our world has changed. We have no history from which to base our response decisions. A climate emergency now exists, that we have caused ourselves through inaction. New things are needed, but we do not know which of these new things are best. We must continue research on an emergency basis but foremost, we must take immediate emergency action. These actions are things that we know how to do right now, that we can implement with urgency to save lives.



The Costa Rican Rainforest: Because CO_2 disperses in our atmosphere so rapidly, CDR anywhere is appropriate.

Greyrock's M Class platform enables the conversion of otherwise flared natural gas into liquid transportation fuels that reduces emission of greenhouse gases 92 and 113 percent for gasoline and diesel, with a life cycle analysis comparison to flaring only. Basically, the M Class produces carbon neutral liquid hydrocarbon fuels. Photo, Greyrock (1)

2.4.1 Ranked Actions - Implementing a Climate Emergency Response

The most important part of an emergency response is understanding what to do first. A climate emergency is no different than any other emergency in that respect. In all other respects, our climate emergency is far more urgent than any other disaster because the stakes are far higher than any other disaster save a total global nuclear conflagration.

If we do not act in time – and we do not know how little time we have—all is lost. Irreversible tipping will have begun. If we do not remove the warming that has already occurred that has activated climate tipping systems, we lose and emission reductions alone result in zero reduction of the warming that has already occurred. It's very simple. All urgency must be used in immediately implementing responses that reduce the load of greenhouse gases already in our sky, or the future will deliver unrecoverable scenarios.

A CLIMATE EMERGENCY MEANS ACT NOW, IMMEDIATELY, AT THIS MOMENT, BEFORE ANY FURTHER TIME ELAPSES. IT MEANS DO NOT DO ANYTHING ELSE ACCEPT RESPOND TO THE EMERGENCY. THIS IS NOT A DRILL. LIFE AS WE KNOW IT LITERALLY DEPENDS ON IMMEDIATE EMERGENCY RESPONSE.

We must use the tools at hand to mount our first response. This is Phase 1. Once this first response is underway, then we plan for Phase 2. The decisions we must make are not difficult, as long as we understand that we have no time to waste. *It does not matter* if the actions we begin immediately are not the best actions. It is 30 years of wasted time that has put us literally in a life and death situation.

To begin, we simply start doing. We already know how to take CO_2 out of the air and store it safely. Nature-based systems play an immediate role, but so does moving with great speed into definitive actions to implement CDR technologies and strategies to address current warming that has caused this emergency. There is no difference in the urgency of this climate emergency, and a wildfire emergency, a pandemic emergency, a flood emergency, or an ice bomb that cripples electrical generation. And of course, net-zero action should proceed with all haste.

We can immediately create an office of carbon capture and utilization or dedicate this response to existing departments. We can immediately hire professionals to guide our emergency response, whether they are biologists or engineers or administrative personnel. We can immediately begin writing carbon reuse materials ordinances, and enter into partnerships with other entities, near and far, to urgently address the climate emergency.

Below in Box 2.4.1 are the steps needed to create climate safety, as interpreted from climate science findings on global warming psychology and impacts happening generations to a century or more ahead of schedule. These are solutions to reduce, treat and mitigate for past as well as future emissions of greenhouse gas pollution:

Box 2.4.1 – Implementing a Climate Emergency Response, Ranked Actions

Implementing a Climate Emergency Response
Ranked Actions

1. Adopt the Mission of Less than 1.0°C Warming: Once the mission is adopted, the path becomes clear.

2. Assume a Global Leadership Position: Austin cannot do it alone. Assuming a national and international leadership position is mandatory to transfer policy on implementing a climate emergency response. The entire world does not have to do this, just enough of us in privileged countries must be responsible for enough climate pollution to achieve equity for those who cannot.

3. Implement Three Major Tasks Simultaneously: These tasks are: *Austin Climate Equity Plan*, and Phase 1 and Phase 2 of the Climate Change Emergency Response Plan below.

4. Be Shovel-Ready: New Federal legislation could be implemented to not only put a price on carbon, but to implement New Deal-like infrastructure spending for climate reform.

5. Phase 1 - Immediate Action: Phase 1 implements emergency response to save lives with the tools immediately at hand. This response should be determined through executive decision based on emergency evaluation by staff and partners, and be implemented before 2022. Scores of solutions are available; we have described some of them in this document. The actual solutions that Austin implements will be decided by staff, consultants, partners and leadership in an emergency evaluation, where emergency cost effectiveness, benefit and equity will be taken into consideration.

6. Phase 2 - Emergency Scaling: To ensure we can achieve our total climate pollution responsibility and help others do the same, we must implement a strategic plan to install infrastructure, provide incentives, create action from ordinance making, and transfer governance strategies from existing infrastructure platforms. Infrastructure must be completely installed no later than 2030 so as to enable us to not only fill the net-zero gap, but to take responsibility for our historic climate pollution emissions that have created the climate emergency so we can achieve a temperature (if these strategies were implemented worldwide) of less than 1.0°C above normal by 2040.

7. Stay on Target: Climate change is dynamic, very dangerous, and far out ahead of us. Achieving the mission of less than 1.0°C warming likely will require significant modifications to strategic planning as time progresses. Every budget year we must stay abreast of not only the latest science and implementation successes of climate pollution reform strategies, but we must be limber. The beast we are up against can change faster than has been evident so far. Opportunity to change course mid-budget is mandatory. The importance of planning for far worse than the worst-case scenario cannot be understated.

Overflow parking at Snoopy's Restaurant on Padre Island, Corpus Christi at the JFK Causeway. This is non-storm high tide flooding from King Tides that happened 53 times on Padre Island from June 2018 to May 2019. Normal is zero.

Henry Petroski said it best: "Science is about knowing; engineering is about doing."

“A person with a new idea is a crank until the idea succeeds.” Mark Twain

“Scientists investigate that which already is; Engineers create that which has never been.” — Albert Einstein

“It is no use saying, 'We are doing our best.' You have got to succeed in doing what is necessary.” Winston Churchill

Section 3
Austin Climate Equity Plan 2020
Topics That Merit Additional Attention

This section is meant to capture topics we perceive as meriting greater attention than the *Austin Climate Equity Plan* could provide or that were beyond its scope. All topics are meant to expand the reader's understanding of scale and opportunity in establishing the responsive actions for which the *Equity Plan*, this report, and our circumstances call. It is important to note that while these suggestions can enhance the efficiency of the *Climate Equity Plan*, they only represent strategies to reduce future emissions, whereas our current warming has already created a climate emergency where even net-zero future emissions tomorrow result in continued warming. Section 2 of this report addresses the climate emergency via actions to achieve less than 1.0°C warming via local and regional entities.

3.1 Emissions Pricing

The Austin Energy REACH Program (Reduce Emissions Affordably for Climate Health) has created the largest and lowest cost one-year emission reduction achieved by any city program. From March through July 2020, the REACH program reduced Austin Energy CO_2 emissions by 480,000 tons. (1) Carbon pricing efforts, such as the REACH concept should be a priority method for reducing emissions across all sectors.

In April 2018, Austin City Council recommended a revenue neutral carbon fee and dividend pricing mechanism as an equitable federal policy that would mitigate climate change, support current and planned efforts to reduce carbon emissions, and spur market innovation. (Resolution 20180426-037)

It is an accident of history and tradition that greenhouse gas (GHG) emissions are ignored by our economic markets. That we continue to ignore them in our market designs only assure exacerbation of inequities and burdens the most vulnerable people with the greatest harms, while placing us all at tremendous risk.

Inaction by federal and state level authorities to modify our markets and make them cognizant of the harms of GHG emissions does not obviate the need for forceful climate action at the local and regional level. Emissions pricing at the local and regional level is a powerful policy tool that has been demonstrated by Austin Energy, through REACH.

The strategy of carbon pricing can aid in rapid emission reduction at the local and regional level through sector-specific efforts. By directly pricing emissions or more broadly using an internal carbon pricing and supply chain assessment, emissions pricing concepts can create market pressure to substitute lower carbon goods and services and provide revenue streams to support development of technologies and products supporting emissions reduction.

We may design any of these policies with the hope of encouraging market policy implementation at the state and federal level. We should hope that wider state and federal policy will supersede and better municipal efforts because of their broader scope. Wider level policy might be expected to come with advantages of efficacy and fairness achievable from broader scope, but any local pricing efforts now can prepare our community for their desired implementation. In the meantime, pricing emissions has an advantage in transparency by most directly associating climate change cause and cost. If any resulting revenue is applied to the direct benefit of people or GHG reduction, an immediate and virtuous cycle of improvement can be better assured from an evolving market.

FROM MARCH THROUGH JULY 2020, THE AUSTIN ENERGY "REACH" PROGRAM REDUCED AUSTIN'S CO2 EMISSIONS FROM ELECTRICITY BY 480,000 TONS. WE SHOULD EMBRACE "REACH" CONCEPTS AS A PRIORITY STRATEGY ACROSS ALL SECTORS.

3.2 Natural Gas

Natural gas utilities produce about 20% of greenhouse emissions in Central Texas. These emissions should be treated no differently than emissions from Austin Energy or transportation. Policies required for emissions reductions and equity include:

1) Adoption of a progressive rate structure,
2) Funding of customer assistance to low-income customers in proportion to Austin's electric and water utilities,
3) Full capital recovery fees collected from new customers,
4) Defunding gas energy-conservation programs that cost more than fuel saved from them,
5) Funding industrialization of natural gas substitutes produced with renewable energy using existing technologies, and
6) Funding research of new technologies.

These policies should be a central part of all future rate cases and franchise negotiations for natural gas utilities that serve Austin.

Power to Fuels (PtF) and Air to Fuels (A2F) as Dispatchable Energy Storage: Technology and Deployment Driver – The RFP (Request for Projects)

Over a decade ago, Austin Energy helped usher in dramatic growth in utility scale wind and solar power to the benefit of its ratepayers and as an element enabling current environmental goals. To drive costs down, Austin Energy tested the market through continual Request for Projects (RFPs) which helped raise the quality and lower the price of proposals.

A similar opportunity exists for power to fuels (PtF) air to fuels (A2F) and carbon dioxide removal (CDR) strategies. With PtF and A2F, fuels are created from CDR and renewable energy generated hydrogen and then these fuels are burned to generate electricity during periods when alternative energy is not available. All three strategies: PtF, A2F and CDR can benefit from the RFP process to drive down costs, as was done in Austin's quest to be a leader in wind and solar energy generation.

3.3 Decarbonize City Investment Portfolios

Because financial and investment practices are based on precedent and previous experience defining secure or prudent financial behavior, we can safely say that the unprecedented risks posed by climate change are not well captured by current norms. Major entities and financial institutions are beginning to acknowledge these risks by declaring their intent to alter their investment strategy or make calls for significant federal regulatory action to respond to climate change. For brevity, only two examples are noted here:

1. BlackRock, Inc. is the world's largest asset management firm. It made one of the most substantive announcements in the world of global finance in January 2020 when it announced that environmental sustainability would be core criteria for BlackRock's future investment decisions. In October 2020, BlackRock launched a sovereign bond exchange traded fund (ETF, a collection of securities that trade on an exchange just as a stock) designed to weight countries on their level of risk from climate change. Until now the focus has been on corporate level risk, but this signals that government financing will now be judged on susceptibility to climate change effects and policy shifts that will be required to respond to it. (1)

2. "Managing Climate Risk in the US Financial System", Report of the Climate-Related Market Risk Subcommittee, Market Risk Advisory Committee of the U.S. Commodity Futures Trading Commission was released in September of 2020. (2)

The first key recommendation from *Managing Climate Risk in the Financial System* is notable and quoted here in full: "The United States should establish a price on carbon. It must be fair, economy-wide, and effective in reducing emissions consistent with the Paris Agreement. This is the single most important step to manage climate risk and drive the appropriate allocation of capital." The City of Austin can further its goals to reduce risks due to climate change and to its own investment holdings by assuring that those holdings, carried on behalf of public employees and the citizens of Austin, are aligned to the *Climate Equity Plan* and the community's welfare.

3.4 Smart Building Technologies

We applaud the content and strategies discussed within the *Climate Equity Plan* section on sustainable buildings. Here we only wish to specifically call out the potential of Smart Building digital technologies (Digital Twins, Internet of Things, AI (artificial intelligence) and Analytics, for automated and optimized control of HVAC and lighting).

Powerful and flexible tools for improving energy efficiency have been created using software as the core innovative component. Over the last decade or so, innovative uses of computation as applied to energy efficiency of buildings have evolved in important ways. One umbrella concept is "SmartBuildings", which couples an aggressive use of a variety of sensors (e.g. thermostats) with various forms of computational modeling of energy flows in buildings. This, in effect, provides climate modeling at the resolution of buildings. "Digital Twins" refers to devising a digital model of each physical building. The software then utilizes the model to simulate and control energy flows involving that building.

A new area of focus by DOE, called Grid-Interactive Efficient Buildings, provides simultaneous optimization of HVAC settings over a complex of multiple buildings. The Austin Energy Downtown District Cooling Project provides a testbed for such approaches.

3.5 Scope and Magnitude of Net-Zero (Carbon Neutrality) Costs

Climate pollution responsibility for the City of Austin, may likely represent the greatest cost of any endeavor in Austin's history. Since the costs for large scale carbon emissions reduction methods are highly variable and expected to be equally dynamic in the future, it is recommended the City couple the urgency of action with strategic vetting of the costs, equity, and barriers to these emissions reduction methods.

Rocky Mountain National Park, Westgate entrance monument, 2008. This is one of the earliest climate change impacts to our national treasures. The red and brown conifers are mortality from native bark beetles driven berserk from warming. A hundred million acres of forest have been killed or mostly killed by these beetles across North America since the turn of the century.

Attribution

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All content was prepared on a volunteer basis. Interpretation of the science in this report was enhanced by Sierra Club's new groundbreaking climate policies, March 2020.
https://www.sierraclub.org/sites/www.sierraclub.org/files/2020-Sierra-Club-Climate-Resilience-Policy.pdf

The authors of this report would like to thank Zach Baumer, Climate Program Manager for the City of Austin, for his invitation to prepare this report and his valuable suggestions on content.

Paradise, California, Camp Fire 2018. Over 14,000 homes were destroyed and 85 lives lost per official reports, but 104 fatalities according to locals. Over 19,000 structures were lost, most of them in a four hour period.

About Climate Change Now

The Climate Change Now Initiative is an IRS 501c3 educational charity founded in 2005. It is the oldest *independent* climate science education entity in the world, or at least in English speaking countries. The mission of the Initiative is to report the latest discoveries in climate science in plain English, using global warming psychology to communicate this new science on the right side of the brain with learning techniques that involve plain English narrative and interpretation, images, films, storytelling and music. The Initiative specializes in impacts happening now, generations to a hundred years or more ahead of projections, and implications for policy that seek a safe and restored climate that is not hostile to the ecologies of planet Earth and the species and cultures that depend upon them. We have written reviews of over 500 of the most important climate science findings and our latest film series project, *Climate Change Across America*, has accumulated over 50,000 miles of observation of climate change enhanced or caused ecological collapse across North America. The first film in this series was nominated for award at the Austin Indie Film Festival. Our crowning policy achievement has been with the National Sierra Club where we played the lead role in the Club adopting new climate policy, March 2020, for a "less than 1.0°C above normal, less than 350 ppm CO_2 warming target." Our work can be seen at ClimateDiscovery.org.

About the Photos

All the photos in this document were taken by Bruce Melton except as noted, and almost all of those prior to the end matter were all in Texas. Almost all of them are climate change impacts.

Black Mountain Sequoia Grove, Sequoia National Monument, California, 2018. Sequoias thick bark, their very tall stature and water-based sap has allowed them to be almost impermeable to destruction from wildfire until the 2017 Pier Fire that killed 53 monarch sequoias. Fires burning 400 degrees hotter because of extreme fuel dryness and more extreme Santa Anna wind events have now begun to destroy these thousands of years old giant treasures that for millennia have been almost impermeable to fire.

Appendix 1 - Glossary

0.5°C Maximum Normal Temperature Variation in Our Old Climate – (See also Natural Variation in this glossary) Warming beyond the maximum normal temperature range of our old climate exceeds the boundaries of the evolution of Earth's ecologies that our advanced human civilization depends upon. When this normal range of temperature is exceeded, Earth's ecologies must re-evolve. This re-evolution usually includes collapse of the old ecology with degradation, loss, or reversal of ecological services like carbon sequestration. Recovery, restoration or re-evolution does not occur until boundary conditions stabilize and the ecology matures or approaches maturity. The time that warming rose above the evolutionary boundaries of our planet's ecologies was about the turn of the 21st century. King 2015 tells us most heat and precipitation season normals and extremes have or will soon cross the anthropogenic emergence boundary, with most having beginning about the year 2000 or in the decade of the 2000s. Hansen 2017 shows the upper temperature limit of the Holocene Epoch to be between 0.25°C and 0.75°C. Randers and Goluke 2020 show that the permafrost collapse boundary is 0.5°C.
King et al., The timing of anthropogenic emergence in simulated climate extremes, Environmental Research Letters, September 10, 2015.
https://iopscience.iop.org/article/10.1088/1748-9326/10/9/094015/pdf
Hansen, Young People's Burden: Requirement of Negative CO2 Emissions, Earth Systems Dynamics, July 18, 2017, Fig. 12.
https://www.earth-syst-dynam.net/8/577/2017/esd-8-577-2017.pdf
Randers and Goluke, An earth system model shows self-sustained melting of permafrost even if all man-made GHG emissions stop in 2020, Nature Scientific Reports, November 12, 2020.
https://www.nature.com/articles/s41598-020-75481-z

1.0°C , 1.5°C, 2.0°C, Degrees Above Normal, etc. - These designations represent the safe warming targets that have been set since we began setting these targets in 1990 with the first Intergovernmental Panel on Climate Change Report. They represent a dangerous amount of warming above pre-industrial times that in the past should have been the target for climate pollution reform action. Pre-industrial times refers to the time when we began burning fossil fuels in earnest in the mid-1800s. For clarity, the label we try and stick with in this report of “pre-industrial times” refers to being within the range of temperature of our “normal” climate.

Degrees C (Centigrade or Celsius) of Warming - Conversion to Fahrenheit
1.0°C= 1.8°F
1.5°C = 2.7°F
2.0°C = 3.6°F
Note: These designations used in this report represent global average temperature. Warming over land is twice that of warming over the oceans.

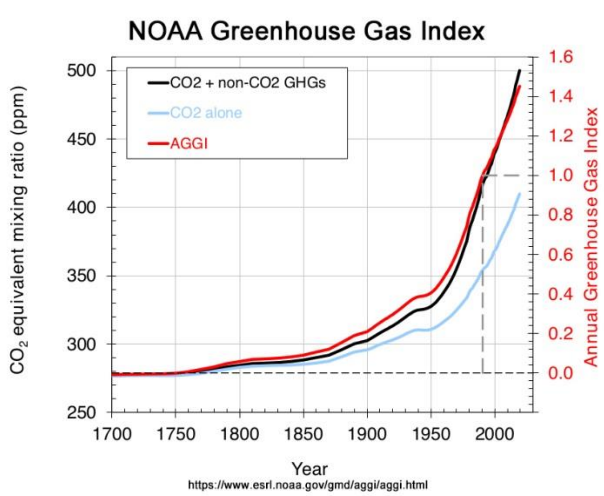
Benchmark Plans for 1.5°C and 1.0°C- Few plans exist that are cooler than 1.5°C, but 1.5°C climate plans are now widespread (https://www.c2es.org/content/state-climate-policy/). Net-zero plans, while not as common as emissions reductions plans, are relatively common nonetheless. (https://www.climatechangenews.com/2020/09/17/countries-net-zero-climate-goal/) China now has a net-zero 2060 plan. The realities of net-zero are that there is little difference between net-zero plans and their resulting temperature. All plans require additional carbon dioxide removal to achieve net-zero. All plans require additional carbon dioxide removal to meet 2.0°C. 1.5°C, and 1.0°C. Sierra Club is now noted for setting a warming target of 1.0°C (https://www.sierraclub.org/sites/www.sierraclub.org/files/2020-Sierra-Club-Climate-Resilience-Policy.pdf), and Microsoft for setting a target of 0.0°C. (https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/) There are 87 companies globally, as of September 2019, with a capitalization of $2.3 trillion, that have declared climate plans with a 1.5°C target and net-zero by 2050. https://www.reutersevents.com/sustainability/15c-pledge-87-global-companies-fuels-hope-bending-emissions-curve-climate-week#:~:text=On%20the%20eve%20of%20Climate,zero%20by%20no%20later%20than One-hundred twenty countries, 823 cities, and over 1,541 companies have net-zero plans in 2020. (see reference 1, Vision Statement)

Carbon Dioxide, CO_2, and CO_2eq, and Metric Tons, US tons, Emissions – In this report we mostly use CO2 and tons. We use CO2 because most science addresses CO2 only with the understanding that most strategies to address CO2 also address non-CO2 greenhouse gases and other physical climate forcing factors. We "tons" like the Intergovernmental Panel on Climate Change (IPCC), to designate metric tonnes or Petagrams CO2. With CO_2eq, the "eq" is the "equivalent" warming of all greenhouse gases calculated as if it were warming created by CO_2 alone. Sometimes the academic literature lumps all greenhouse gases together as CO_2eq emissions, at other times only CO_2 pollution is referred to as "emissions." In this report, we generally use CO_2 (carbon dioxide) to represent all greenhouse gases including but not limited to CO_2, even though a third of warming is caused by non-CO_2 greenhouse gases or other forcing agents. One of the reasons this nomenclature is used here and elsewhere is that much of the non-CO2 emissions are addressed when we address CO2 because reducing or eliminating CO2 also reduces or eliminates non-CO2 forcing from the same sources or with the same strategies. Nature-based sequestration of CO2 also often sequesters non-CO2 forcing agents. We use this simplification to diminish confusion because the policy content and scientific literature generally do not significantly acknowledge non-CO_2 greenhouse gases and other climate forcing agents other than caveats acknowledging their importance, and that they too must be managed appropriately. See "Forcing" in this Glossary for more on non-CO2 greenhouse gases and other warming and cooling agents.)

The Possible Errors and Their Meaning:

- Metric tons are 10% heavier than US tons. The CO2eq to CO2 conversion is 0.828.
- The difference in quantities between tons, tonnes, CO2, and CO2eq is very likely significantly within the error bars. The numbers using either unit classification are then essentially identical, because they all fall within the ranges of the outcome of climate change scenarios used. Concentrating on the difference in quantities between US and metric units then, is not only spurious but quite confusing.
- Everything is less confusing to the public and US policy makers if we say "tons" and CO2 only. Metric tons, or tonnes is simply confusing to US civilians and policymakers and this whole mess is confusing enough without a "units" conundrum. We discuss this in the Glossary, and I will review this discussion right now and see if I need to add anything further from what I say here.
- This is a vision document and as long as the metrics we use are clear and consistent, implementation will better-understand the requirements needed.
- Because we are so far from meaningful implementation, the mandate now is to begin and not worry about quantities with 10 to 20 percent discrepancies.
- Because the quantities we need to address climate pollution removal are so vastly much larger than anything we are doing now, once we get a scaled infrastructure in place, dealing with a 10 to 20 percent discrepancy is not very meaningful. In other words, dealing with the discrepancy of whether or not our historic burden is 288 million tonnes or tons, CO2 or CO2eq, with a variation between the two is +/- 28.8 million tons or tonnes, or +/- 17% CO2 or CO2eq, is just not meaningful at this point where our current capacity is in the thousands of tons. In the future when we have infrastructure capable of dealing with millions of tonnes (or tonnes) so as to be able to achieve climate restoration, it will be no big deal to address a whole lot more climate pollution than we have the capacity to address today.

CO_2eq Conversion to CO_2 – National Oceanic and Atmospheric Administration Annual Greenhouse Gas Index (AGGI.) An example of how to use this graphic is: the average 2020 CO_2 at Mauna Loa of about 414 pm gives CO_2eq of 500 ppm for a ratio of CO_2 to CO_2eq of 0.828.
https://www.esrl.noaa.gov/gmd/aggi/aggi.html



CO_2 ppm, the Concentration of CO_2 in Our Atmosphere - The acronym "ppm" stands for parts per million and the 2019 average concentration of CO_2 in our atmosphere of 411 ppm is 0.04 percent of all the air in our sky. Normal CO_2 concentration from before fossil fuel usage was 280 ppm, or 0.03 percent. Relative concentration is important. A concentration of 135 ppm cyanide is a lethal dose. A CO_2 concentration in our atmosphere of greater than 350 ppm (about 0.85°C degrees warming above normal, Hansen 2017) creates Earth systems collapses that are significantly lethal to parts or all of those Earth systems and in addition, collapses of Earth systems lead to feedbacks that create more warming and further lethal implications.

Carbon Dioxide Removal (CDR), Negative Emissions Technologies (NETs) and Offsets - CDR and NETs are the same labels for strategies that remove CO_2 or greenhouse gases from the atmosphere. They include natural systems restoration and enhancement strategies for land-based plants and soils, as well as water and ocean processes. They also include chemical and physical methods for removing climate pollution from the sky like the recyclable lime-potash process developed in 1904, chlorine chemicals (amines) developed in WWII, and adsorptive processes that use room temperature heat for sorbent regeneration. In Net-zero and 1.5°C climate plans, negative emissions are used to decarbonize hard to decarbonize sectors like agriculture and electrification, and to some extent to reach the 1.5°C and 2.0 °C targets. CDR and NETs are basically offsets when used to prevent further warming.

Climate Modeling Projections - the vast majority of climate science and policy is based on model projections. Here we refer to these mostly with terms related to the schedule of events that are projected, predicted or forecast by the models. As in, climate impacts are happening sooner, and much ahead of schedule or much ahead of modeling projections.

Climate Restoration - The warming targets for net-zero, 2.0 °C and 1.5°C are not restoration targets because they allow further warming from today's 1.0°C warming above normal, where today's 1.0°C is beyond the evolutionary boundaries of the ecologies and systems of our old climate. When an ecology or system moves beyond its evolutionary boundaries, it must re-evolve. During this re-evolution process, ecological or systems collapse and loss of environmental or system services is common if not the rule. Therefore, because our ecologies are dependent upon the boundary conditions from which they evolved, so they can provide services, and our advanced human civilization is dependent upon the services provided by ecologies in our old climate, only a target that seeks to restore our climate to its range of natural variability is climate restoration.

Committed Warming or Warming in the Pipeline - Emissions of climate pollution over the last 200 years at a rate that is up to 100 times faster than natural greenhouse gas emissions has caused our climate to be out of balance. That is, our vast oceans are cooling Earth more than greenhouse gases are warming it, enough so that complete cessation of greenhouse gases results in further warming as our oceans warm. This warming commitment results in total warming by 2100 of 2.0°C in what are now likely unattainable best-case scenarios, to 5°C warming by 2100 in worst-case scenarios.
100 times faster - The annual rate of increase in atmospheric carbon dioxide over the past 60 years is about 100 times faster than previous natural increases, such as those that occurred at the end of the last ice age 11,000-17,000 years ago.
Lindsey, Climate Change: Atmospheric Carbon Dioxide, NOAA Climate.gov, August 14, 2020.
https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide
IPCC 1.5°C Report committed warming of 0.5°C average, up to 1.2°C above 2020 - Beginning in 2020, zero CO2 and aerosol emissions, and constant non-CO2 greenhouse gas (GHG) forcing equals 0.5°C average additional warming by 2100, up to 1.2°C above 2020 max. Worst-case IPCC, Zero CO_2 and aerosol emissions, constant non-CO2 GHG forcing is about 2.2°C above pre-industrial at 2100.
IPCC 1.5 C, Chapter 1, Figure 1.5, page 65.
https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter1_Low_Res.pdf
Committed warming of up to 7.5 degrees F in the pipeline - (no cooling from aerosols) "The observed increase in the concentration of greenhouse gases (GHGs) since the pre-industrial era has most likely committed the world to a warming of 2.4°C (1.4°C to 4.3°C) above the pre-industrial surface temperature. The estimated warming of 2.4°C is the equilibrium warming above pre-industrial temperatures that the world will observe even if GHG concentrations are held fixed at their 2005 concentration levels but without any other anthropogenic forcing such as the cooling effect of aerosols."
Ramanthan and Feng, On avoiding dangerous anthropogenic interference with the climate system-Formidable challenges ahead, PNAS, September 2008, abstract.
http://www.pnas.org/content/early/2008/09/16/0803838105.full.pdf
Hansen 1.4 C committed warming at 385 ppm CO_2 -The remaining gap between equilibrium temperature for current atmospheric composition and actual global temperature is about 1.4°C. This further 1.4°C warming still to come is due to the slow surface albedo feedback, specifically ice sheet disintegration and vegetation change.
Hansen et al., Target Atmospheric CO_2 Where Should Humanity Aim Open Atmospheric Science Journal, November 2008 Highlights.
https://arxiv.org/abs/0804.1126
0.5°C committed warming - Beginning in 2020, zero CO_2 and aerosol emissions, and constant non- CO_2 GHG forcing equals 0.5°C additional warming by 2100, to 1.5°C, 1.4°C by 2050.
Meehl et al., How Much More Global Warming and Sea Level Rise? Science, March 2005.
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.417.8091&rep=rep1&type=pdf

The Consensus – Climate consensus organizations are the large national or multinational organizations that summarize recent climate science findings upon which policy are based. Examples: Intergovernmental Panel on Climate Change (IPCC,) National Academies of Sciences of (many countries), World Meteorological Organization (WMO), World Health Organization (WHO), etc.

Environmental or Ecological Services – These are functions of an ecology or system. A few of these services are: carbon dioxide absorption, rainfall propagation from forests, oxygen creation form photosynthesis systems, the stable climate where our breadbaskets produce food, stable sea level where a majority of Earth's wealth is located, etc. All are not lost with ecologic collapse and re-evolution, but many are and most are likely degraded.

Forcing – Greenhouse gases cause warming, or forcing of our climate to change. some forcing agents emitted by humans cause our climate to cool. The other greenhouse gases or climate forcing agents that contribute about a third of total warming are methane (CH4), nitrous oxide (N2O), black carbon or soot, and refrigerants (fluorocarbons). There are also global cooling agents like aerosols (sulfates) that are a major cooling forcing or warming mask also emitted by burning fossil fuels, and there are also other warming and cooling effects of humankind's emissions like changes to clouds that change as we warm. It is a widespread practice that we generally follow in this document to simplify these complicated concepts by referring to climate warming from CO_2 alone, because CO_2 is by far the largest player and addressing CO_2 results in also addressing much of the non-CO_2 forcing.

Infrastructure - In this document we introduce new infrastructures that are fundamental to restoring a safe climate. Stanford's Social Innovation Review suggests, "To truly address these 21st-century problems, our society needs 21st-century solutions. We need to build a new civic infrastructure—one where fairness, justice, and economic and educational opportunity prevail, and where all people are engaged as stakeholders in civic and community life." From the University of Illinois at Urbana-Champaign, "The term "infrastructure systems" is used in its broadest sense, encompassing both built infrastructure (buildings, roads, bridges, pipe networks, treatment facilities, etc.) and infrastructure services that rely on integrated built and natural systems to provide fundamental needs of society." Our public infrastructure not only includes buildings, roads, bridges, pipe networks, treatment facilities, etc., it includes things like health systems, social support, societal governance, environmental safety, policing, and public education. Expanding our public infrastructures for the 21st-century includes not only things like utility and distributed scale carbon-free energy generation and distribution, electric vehicle charging stations, and expanded public transportation, it includes things like systems and platforms that advance building efficiency, increase public climate change awareness, enhance remote business and social functioning, and that remove carbon from the air with natural systems and traditional pollution treatment strategies. The infrastructures for carbon dioxide removal (CDR) strategies remove climate pollution from the air and even use the removed greenhouse gases as industrial feedstocks to generate revenues both with traditional uses of carbon dioxide and for new uses like carbon negative concrete, myriad durable goods, and even low and negative carbon fuels. We have been creating similar infrastructures to benefit the commons for well over a century that include our transportation systems, health systems, social support, societal governance, environmental safety, and critically our water and wastewater infrastructures. Critical to our world today is this statement from Stanford, "To address 21st-century problems, we need to build a civic infrastructure that serves all members of society, especially those on the margins… one where fairness, justice, and economic and educational opportunity prevail, and where all people are engaged as stakeholders in civic and community life."
Stanford, Building an Intentional and Inclusive Civic Infrastructure, August 7, 2015.
https://ssir.org/articles/entry/building_an_intentional_and_inclusive_civic_infrastructure
University of Illinois at Urbana-Champaign, Sustainable and Resilient Infrastructure Systems Program
https://cee.illinois.edu/areas/sustainable-and-resilient-infrastructure-systems-program#:~:text=The%20term%20%E2%80%9Cinfrastructure%20systems%E2%80%9D%20is,provide%20fundamental%20needs%20of%20society.

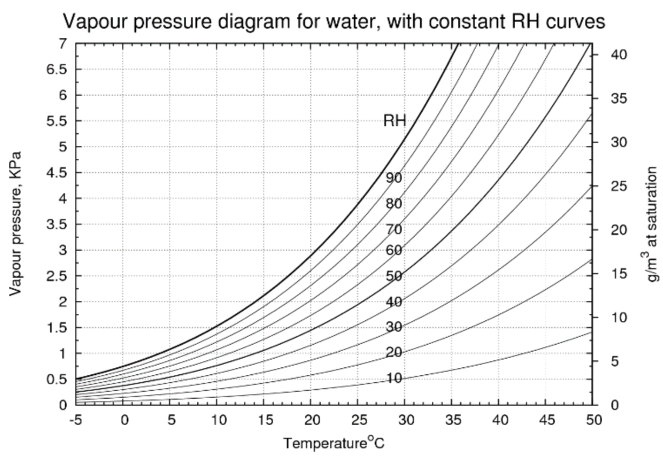
Meaningful Action - The meaning of "meaningful" as we use it in this document relates to the entirety of the last 30 years of delay in action to deal with climate pollution. While there are a relatively few recent actions that are meaningful, on the whole these only relate to achieving net-zero emissions that allow further warming detrimental to Earth's systems and that ensure climate tipping activation completes. Hundreds of excellent net-zero plans now dot planet Earth, but results are what matter to our climate and we continue to warm. According to the 1992 IPCC best-case scenario to meet a 2.0°C warming target, emissions in 2019 should have been 27.5 Gt CO2 total for fossil fuels and land use change. Actual 2019 total emissions were 43.1 Gt CO2 or 57 percent more than projected. Over the last several years the concept of "meaningful" action has taken on an even more critical fundamental, in that it is the great delay that has caused all the weather mayhem and activated ecological collapse and tipping point initiations. No amount of action even remotely similar to what we have been proposing for the last 30 years can reverse the climate change we have already experienced and restore our climate to a non-collapsing state. Net-zero is still a part of the plan, but a small part. If climate change could be compared to Covid, what we have experienced for the last 30 years could be considered as asymptomatic. Tipping is Covid on a ventilator. There is literally a one in three chance of death of our climate, or successfully limiting warming to 1.5°C above normal with net-zero 2040, and a one in two chance with net-zero 2050. Very critically, extreme weather becomes nonlinearly more extreme with further warming of a 1.5°C target and tipping irreversibly locks in much faster. (See the section, "Core Concepts in This Document" for more.) The critical nature of meaningful action is also tied to the lack of appropriate safety factors in our climate culture that is displayed in the one in three and one in two chances of successfully achieving 1.5°C warming above normal with net-zero 2040 and net-zero 2050. See "Safety Factors" below for more.
27.5 Gt CO_2 - Emissions Scenarios for the IPCC, an update, 1992.
https://www.ipcc.ch/site/assets/uploads/2018/05/ipcc_wg_I_1992_suppl_report_section_a3.pdf
43.1 Gt CO_2 - Based on Global Carbon Project Budget 2019
https://www.icos-cp.eu/science-and-impact/global-carbon-budget/2019
One in three and one in two chance… See Safety Factors below in this glossary.

Natural Gas - Natural gas is 60% to 80% methane and our discussions about natural gas generally refer to issues with the global warming potential of methane, and are relevant to natural gas alone. Two important things about the methane in natural gas are that in the short term it has 30 times more warming power than CO_2 in the long term and 105 times more, but in the long term, because methane has a much shorter life than CO_2, its *cumulative* warming is much less than that from long-lived pollutants like CO_2.
Science Direct
https://www.sciencedirect.com/topics/earth-and-planetary-sciences/methane#:~:text=Methane%20is%20a%20colorless%2C%20odorless,of%20vegetation%20and%20organic%20matter.

Natural Variation in Our Climate, Boundary Conditions – (see also 0.5°C in this glossary) The natural variability of our old climate is about 0.5 C degrees warmer than what we call normal, or above the baseline of our pre-industrial climate's average temperature from before we began burning fossil fuels 200 years ago. Changes to the evolutionary boundary condition of ecologies caused them to re-evolve. This re-evolution usually is preceded by collapse of the old ecology and results in the loss of environmental services like CO2 sequestration. These services are not restored until the boundary conditions stabilize and the ecology matures. This ecological collapse and re-evolution is what has been activated now with climate tipping. Our climate warmed 0.5°C above the evolutionary boundary conditions of our ecologies about or soon after the year 2000.
King et al., The timing of anthropogenic emergence in simulated climate extremes, Environmental Research Letters, September 10, 2015.
https://iopscience.iop.org/article/10.1088/1748-9326/10/9/094015/pdf

Nonlinear, Exponential, Asymptotic - As we warm further, impacts increase more rapidly, much faster than in the past, and much faster than the rate of warming. This happens because of the basic physics of thermodynamics (heat,) where the rate of increase follows nonlinear physics relationships with heat, and can be compared to a flash flood, an out of control wildfire, or an avalanche. In other words, a little more warming does not create a

little more extreme weather; it creates a lot more because of the basics of physics. In this document we try not to use the word nonlinear as much as possible because there are simply other words and phrases that communicate a nonlinear relationship more clearly.
Warming Increases Extremes Nonlinearly: For an in depth look at how warming in creases extremes nonlinearly, see the IPCC Special Report on our Oceans and Cryosphere, Chapter 6, Extremes, Abrupt Changes and Managing Risks.
IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, 2019
https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/10_SROCC_Ch06_FINAL.pdf
Nonlinear Geophysical Processes: The Nonlinear Processes in Geosciences (NP) Division of the European Geosciences Union (EGU) is an extremely valuable resource to understand the wide and very meaningful concept of nonlinearity of impacts with climate warming. From the NP EGU, "This blog serves as a platform for the nonlinear processes community to share news, events, and activities, as well as updates on the latest research being undertaken."
Division of Nonlinear Geophysical Processes, European Geophysical Union
https://blogs.egu.eu/divisions/np/
Heat extremes 10 to 100 times more extreme: NASA and Columbia University say a very specific study on increasing heat extremes in the last 30 years mentions the Texas/Oklahoma 2011 drought that showed this event was made 10 to 100 times more likely with already experienced warming. Also, extreme heat that once happened across 0.1 to 0.2 percent of the Northern Hemisphere now happens across ten percent–every year. (Hansen 2012)
Hansen et al., Public Perception of Climate Change, PNAS, September 11, 2012.
https://www.pnas.org/content/109/37/E2415
For heat extremes: Rahmstorf and Coumou tell us about heat extremes, "For extremes exceeding a predefined threshold, the dependence on the warming trend is highly nonlinear."
Rahmstorf and Cuomou, Increase of extreme events in a warming world, PNAS, November 1, 2011.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3207670/pdf/pnas.1101766108.pdf
Hansen – Heat extremes have already increased by up to 100 times in the Texas Oklahoma heat wave of 2011.
For precipitation: Basic physics tells us that evaporation increases nonlinearly with warming… Vapor pressure defines evaporation. At 0 degrees C (freezing, 32 F,) water vapor pressure is near zero, but at 30 C (86 F) water vapor pressure is over 30 times greater than at freezing. "The relationship between vapor pressure and temperature is not linear -- the vapor pressure of water increases more rapidly than the temperature of the system."
http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch14/liquids.php



Tipping Points, Earth Systems Collapses, Climate Tipping Thresholds - Earth systems like oceans, forests, ice sheets, and other physical systems, all have limits of existence in their current states. When perturbed strongly enough they change to different states. In the case of our climate, different states are hostile to the ecologies and cultures that evolved in the previous state, leading to collapse of Earth systems services critical to survival of species, including humans. An example is the Amazon, where its carbon capture capacity has collapsed three times since 2005 from ever increasing drought beyond the 100-year event, each time flipping from a carbon sink to a carbon source then back again because of the extremely rapid ecological cycling of a tropical rainforest. By 2035, new projections show the Amazon to flip permanently on our present warming trajectory. (See Reference 7, Section 1.1) UPDATE: New work in Nature bu Gatti et al, July 14, 2021, shows the Amazon is now emitting, not sequestering, one gigaton of CO2eq annually. (See Reference 8, Section 1.1) If the Amazon flips permanently, loss of carbon capture from the forest, and greenhouse gas emissions from the collapsed system will likely substantially exacerbate global warming. It is this forcing, tipping or threshold crossing, that is what is referred to as climate tipping and these systems exist with ice sheets, terrestrial and subsea permafrost and frozen methane clathrates, temperate and boreal forests, oceans, beaches, deserts, plains, etc. Some Earth systems tipping is irreversible and cannot be reversed in time frames that matter. Forty-five percent of identified Earth systems are interrelated so that when one collapses, many collapse creating a cascade with even greater implications than the sum of their parts. (See more on tipping at reference 8, Vision Statement)

Irreversible Tipping, Point of No Return - The point of no return or the point that Earth systems or climate tipping becomes irreversible is misleading because of physical systems bifurcation or physical state changes. The point of no return is exactly as it sounds, a point from which there is no going back. Physical systems bifurcation is tricky however. All, or at least most physical systems and Earth systems are little different; they all generally have multiple states, like the Amazon that is either a carbon sink or a carbon source. The bifurcation, or the division of the Amazon's states from sink to source is not a finite thing. In other words, the bifurcation or tipping generally happens over time. We are seeing this with a 33 percent degradation of the Amazon's carbon sink over the last 30 years. Projections are for the Amazon to completely fail as a carbon sink by 2035, therefore the point of no return is 2035 even though tipping started 30 years ago. The bifurcation, or collapse, tipping or threshold crossing etc., is something that started before 2000 and will not complete until 2035 or thereabouts. This period between the beginning of tipping and the point of no return is referred to as tipping initiation, or Earth systems collapse initiation, threshold crossing initiation, etc. This absolutely means that once tipping has begun, it can be reversed. But to reverse it, the perturbation must be removed. In other words, the warming must be removed so the systems can exist under the conditions where they evolved. A very large precaution is appropriate here: all systems do not have obvious tipping initiation periods. There is much we do not know about Earth's systems collapses and this lack of knowledge is predominant. We cannot yet robustly model any tipping systems and nascent modeling has only been done on a few. What is fundamentally important with the point of no return is that risks are outsized. That is, completion of tipping initiation in any one system may create societally untenable and unrecoverable scenarios.

Repeatedly Unprecedented - This term deserves discussion as it is something we have not experienced in our advanced civilization. It refers to recurring unprecedented weather extremes that have never before been recorded by our advanced civilization. When we say "repeatedly" unprecedented weather extremes, we are talking about the seemingly unbroken string of new weather records that are constantly falling around us. The trend in setting new weather records one after another has great meaning. It tells us we are no longer in the stable climate where our advanced civilization evolved.

Safety Factors - Safety factors in our climate culture are egregiously low and relative to risks of failure, almost non-existent. An example is the IPCC 1.5°C report telling us that to limit warming to below 1.5°C, we have a remaining carbon budget of "420 $GtCO_2$ for a 66% probability (medium confidence)… and 580 $GtCO_2$ for a 50% probability of limiting warming to 1.5°C." These two scenarios represent net-zero 2050 (50% chance of occurrence or probability) and net-zero 2040 (66% chance...) This means there is a one in three chance or one in two chance of failing to prevent warming of 1.5°C above normal if we achieve the target budget of net-zero 2040 or net-zero 2050. In the insurance industry, we as a culture have adopted the 100-year event as the standard of safety, an event that has a 1% chance of occurrence or a safety factor that is 30 to 50 times greater than the safety factors we are being given with net-zero 2040 and 2050. In addition, risks with climate change failure are far more meaningful than classic risks of the insurance industry that deal with individuals or individual things. With failure to control climate change we risk large parts of Earth becoming uninhabitable. In summary, we know that there is a high probability that even the latest climate science understates because of its track record. We know that the future risk avoidance industry (insurance industry) uses worst or worse than worst-case scenarios on the order of a one-percent occurrence to ensure safety. Assuming a chance of failure of one in three or one in two for a target of 1.5°C is egregiously unacceptable relative to the normal risk avoidance behaviors we have agreed upon as a society. Our climate culture must immediately and abruptly move to incorporate our traditional risk avoidance behaviors and this can be done addressing by worst-case, or worse than worst-case scenarios in planning and action for climate change.
IPCC 1.5°C Report, Summary for Policy Makers, C.1.3, page 12.
https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf

Time Frames that Matter – Generally speaking, time frames that matter are shorter rather than longer. An example is the 2100 time frame in most future climate scenarios is not really applicable to many things we do, like our utility bills, the car we drive, or the risks posed by extreme weather. An example would be migration from chronic sunny day high tides that are expected to drive substantial resource abandonment by 2030 with 1.5 feet of Sea level rise and chronic sunny day high tide flooding that increases by 25 times (as per NOAA's Sweet 2017.) In addition, the same example can be used to describe economic pressures that will degrade local as well as the global economy, that at some time that is likely sooner rather than later results in economic failure. Once our economy fails, longer time frames beyond economic failure don't really matter any longer. More specifically with larger goals of climate restoration, time frames that matter are related to climate tipping and associated impacts. Climate tipping systems have become active a century ahead of projections. These systems were not supposed to become active until after 5 C warming and they complete their activations with the results of likely irreversible scenarios. This activation completion may have already been surpassed with things like ice sheet and permafrost collapse, but collapse may still be reversible if we lower Earth's temperature below the tipping activation threshold fast enough. We do not know the time frames involved with lower Earth's temperature to avoid or reverse tipping yet, but we do know that risks increase greatly with time. Therefor time frames that matter, matter most the longer we delay action.

SI (metric system) prefix scaling factors -

symbol	name	English word
k	kilo	thousand
M	mega	million
G	giga	billion

Understating (Conservative) Climate Science –

Scientific American – Climate Science Predictions Prove Too Conservative… "Across two decades and thousands of pages of reports, the world's most authoritative voice on climate science has consistently understated the rate and intensity of climate change and the danger those impacts represent, say a growing number of studies on the topic."
Climate Science Predictions Prove Too Conservative, Scientific American, December 6, 2012, first sentence.
http://www.scientificamerican.com/article.cfm?id=climate-science-predictions-prove-too-conservative
Asymmetry of Scientific Challenge Understates Climate Science… Top of the abstract: "Mass media in the U.S. continue to suggest that scientific consensus estimates of global climate disruption, such as those from the Intergovernmental Panel on Climate Change (IPCC), are 'exaggerated' and overly pessimistic. By contrast, work on the Asymmetry of Scientific Challenge (ASC) suggests that such consensus assessments are likely to understate climate disruptions."

Last part of the abstract: "…new scientific findings were more than twenty times as likely to support the ASC perspective than the usual framing of the issue in the U.S. mass media. The findings indicate that supposed challenges to the scientific consensus on global warming need to be subjected to greater scrutiny, as well as showing that, if reporters wish to discuss ''both sides'' of the climate issue, the scientifically legitimate ''other side'' is that, if anything, global climate disruption may prove to be significantly worse than has been suggested in scientific consensus estimates to date."

From the bottom of the second paragraph of the Introduction on page 1: "Precisely because of the ongoing pattern of criticisms toward climate science in general, and the IPCC in particular, work on the Asymmetry of Scientific Challenge (ASC) predicts that the overall effect on science will be precisely the opposite of the usual charges in the U.S. mass media—that is, that scientific consensus estimates such as those from the IPCC should be expected to underestimate the severity of climate disruption taking place."

Freudenburg and Muselli, Global Warming estimates, media expectations and the asymmetry of scientific challenge, Global Environmental Change, August 2010. (This paper is backed up with 75 references.)

http://gpwayne.files.wordpress.com/2010/09/freudenburg_2010_asc.pdf

Erring on the least side of drama – understating climate science… From the abstract: "Over the past two decades, skeptics of the reality and significance of anthropogenic climate change have frequently accused climate scientists of "alarmism" … However, the available evidence suggests that scientists have in fact been conservative in their projections of the impacts of climate change. … We suggest, therefore, that scientists are biased not toward alarmism but rather the reverse: toward cautious estimates, where we define caution as erring on the side of less rather than more alarming predictions."

Another quote from the paper definitively spells out the authors findings on page 330, section 3.0, first sentence: "Our analysis of the available studies suggests that if a bias is operative in the work of climate scientists, it is in the direction of under-predicting, rather than over-predicting, the rate and extent of anthropogenic climate change."

Brysse et al., Climate change prediction: Erring on the side of least drama? Global Environmental Change, February 2013. (This paper is backed up by 113 references.)

http://www.sciencedirect.com/science/article/pii/S0959378012001215

Understating Seepage... Climate change counter-movement arguments in the media have created a prolonged stereotype threat, pluralistic ignorance, and a form of projection (the third-person effect) that may cause scientists to take positions that they would be less likely to take in the absence of outspoken public opposition. In other words, the climate change debate is so widespread and accepted in our culture, it has influenced climate scientists in their findings so they understate.

Lewandowsky et al., Seepage - Climate change denial and its effect on the scientific community, Global Environmental Change, May 15, 2015.

https://www.sciencedirect.com/science/article/pii/S0959378015000515

Scientific Reticence – Classic understatement across the industry of science… James Hansen discusses scientific reticene at length via the background of climate change caused sea level rise and explains why scientists are reticent, that they understate, because if they are wrong their credibility is diminished.

Hansen, Scientific reticence and sea level rise, Environmental Research Letters, May 24, 2007.

https://iopscience.iop.org/article/10.1088/1748-9326/2/2/024002/pdf

Permafrost collapse, Glenn Highway Alaska, 2018. More than 2.3 gigatons of CO_2 were emitted annually across the Northern Hemisphere from collapsing permafrost on average 2004 to 2017. Methane emissions have not yet been quantified. Today there are 1.2 billion acres at risk from abrupt thaw and it is important to note these findings only describe the average annual emissions. Because abrupt thaw is progressing rapidly, much more than 2.3 gigatons of CO_2 are being emitted annually today. Natali et al., Large loss of CO_2 in winter observed across the northern permafrost region, Nature Climate Change, October 21, 2019.

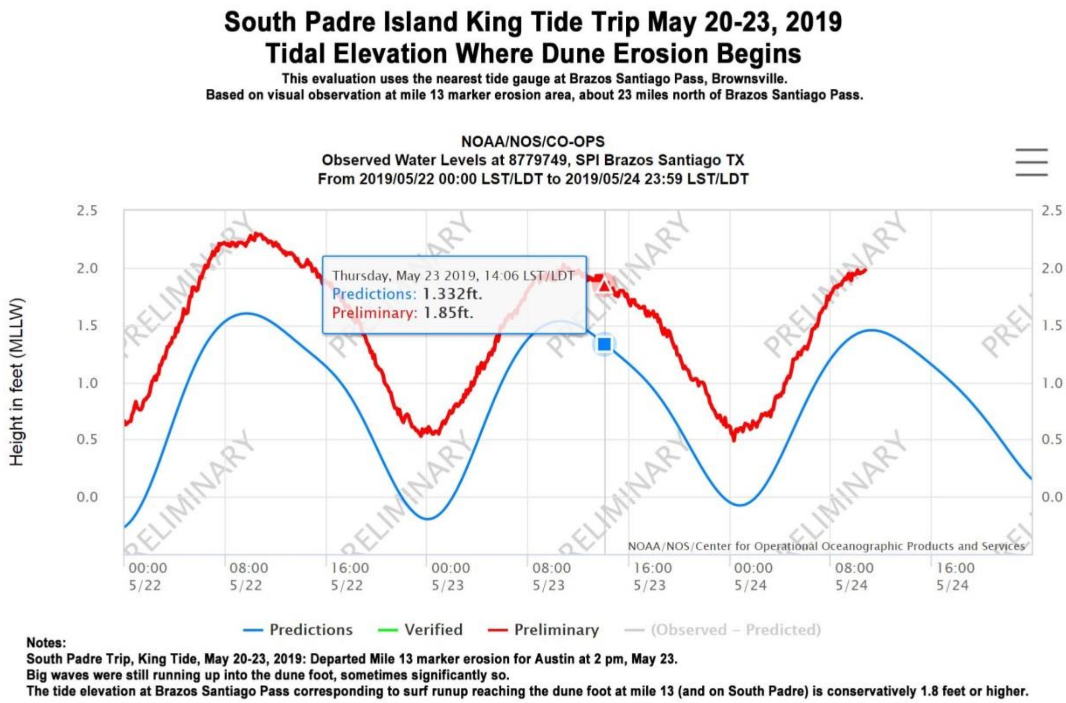
Appendix 2 - References

Climate science is changing rapidly. References below are not the last word and may not be the most current works, but they are significant and meaningful. They are provided here with summaries and other information to allow deep thought and interpretation. The concepts we have presented in this report are new to many, and new things that are as yet robust are often suspect and create skepticism. This is a normal part of scientific research and unfortunately it is a large part of how we find ourselves in this climate change conundrum because it allows understatement.

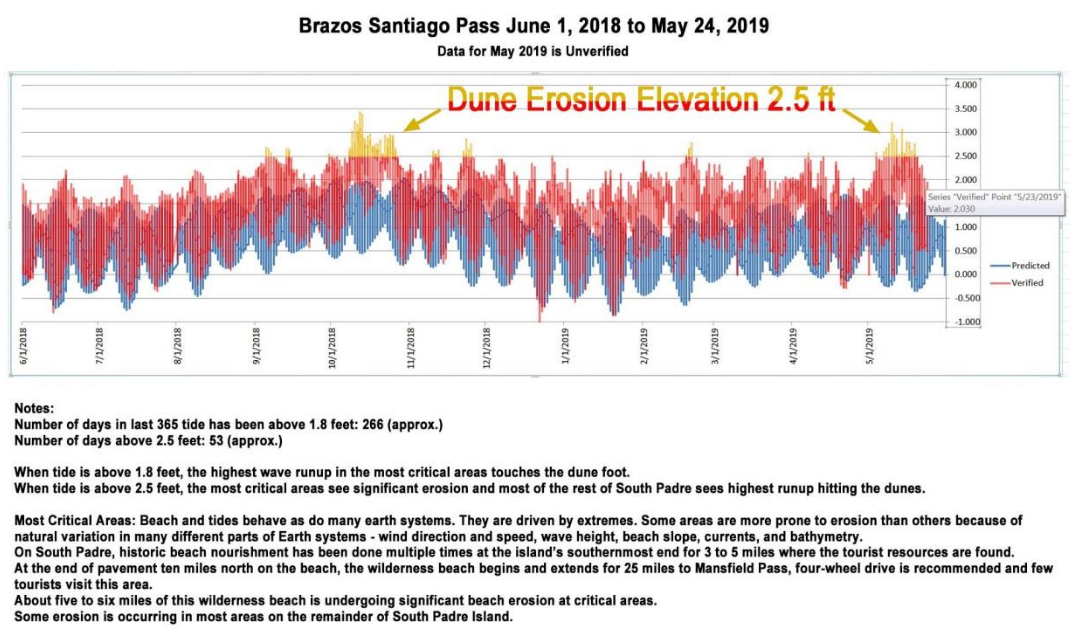
Though climate change is not new, it is new to us. We try here to represent the leading edge of science, where interpretation is still evolving, and through interpretation where great meaning can be found – far greater than the significantly reticent meaning available from consensus reporting where new science is rarely included except in caveats.

The bottom line is that not only is consensus science understating, science as an industry and especially climate science is understating. To avoid the great risks that we are now seeing globally because of scientific understatement, leading science must be aggressively interpreted with significant safety factors applied. See the bulleted list on page 22 for more on reticence and understatement in climate science and for an even deeper view, see Hansen 2007: Scientific reticence and sea level rise and also see the discussion on "Safety Factors" in the glossary above.
https://pubs.giss.nasa.gov/docs/2007/2007_Hansen_ha01210n.pdf

Cover Image



King Tide Erosion… June 2018 to May 2019 saw 53 days where non-storm high tides (King Tides) reached an elevation high enough to cause dune erosion on South Padre Island according to tide data from the Brazos Santiago Pass tide gauge (graphic on the right). The graphic on the right is show a single point confirmation of tide elevation and erosion on South Padre. On May 23, 2019 at 2:06 pm, the surf on South Padre was running up the very foot of the dunes. The top graphic shows the elevation at the Brazos Santiago Pass tide gauge at this time was 1.85 feet and the peak just prior was about 2.0 feet. The graphic on the bottom shows a year of tides, with blue being the modeled tide, red being the actual and yellow being excursion above 2.5 feet where erosion was occurring.



Prologue

At the peak of the storm, 69 percent of Texans, 20 million people, were without power… "More than two out of three (69%) Texans lost electrical power at some point February 14-20, for an average of 42 hours, during which they were without power on average for one single consecutive bloc of 31 hours, rather than for short rotating periods."
The Winter Storm of 2021, Hobby School of Public Affairs, University of Houston
https://uh.edu/hobby/winter2021/storm.pdf

Up to 978 people died in the Texas Ice Disaster in 2021… Buzzfeed conducted an excess deaths analysis for the ice disaster where they compared previous year's total deaths to those during the disaster, with illness such as cardiovascular disease and diabetes. They found between 426 and 978 more people than expected died in Texas in the week ending February 20 alone. This work was reviewed by individuals at University of California at Berkeley, Virginia Commonwealth University, and University of Jerusalem.
Popular press article –
Aldhous et al., The Graveyard Doesn't Lie - The Texas Winter Storm And Power Outages Killed Hundreds More People Than The State Says, May 26, 2021.
https://www.buzzfeednews.com/article/peteraldhous/texas-winter-storm-power-outage-death-toll
Technical Analysis - https://buzzfeednews.github.io/2021-05-tx-winter-storm-deaths/

The disaster cost $200 to $295 billion… The Perryman Group is an economic research and analysis firm based in Waco, Texas, serving the needs of more than 2,500 clients, including two-thirds of the Global 25, over half of the Fortune 100, the 12 largest technology firms in the world, 10 US Cabinet Departments, the 9 largest firms in the US, the 6 largest energy companies operating in the US, and the 5 largest US banking institutions.
https://www.perrymangroup.com/media/uploads/brief/perryman-preliminary-estimates-of-economic-costs-of-the-february-2021-texas-winter-storm-02-25-21.pdf

Most expensive disasters… Harvey $125 billion, Katrina $125 billion
https://en.wikipedia.org/wiki/List_of_disasters_by_cost#cite_note-200_billion-10

73 degrees in 5 days… The polar vortex, sudden stratospheric warming and La Nina.
L'Heureux, On the sudden stratospheric warming and polar vortex of early 2021, NoOAA, Climate.gov, January 28, 2021.
https://www.climate.gov/news-features/blogs/enso/sudden-stratospheric-warming-and-polar-vortex-early-2021
Sudden Stratospheric Warming, Bomb Cyclone… "Sudden Stratospheric Warmings (SSWs) are occasions in the winter (~6 times per decade), when the polar stratosphere warms and the winds that normally flow from west to east around the pole weaken dramatically and even reverse direction, corresponding to a breakdown of the polar vortex."
L'Heureux , On the sudden stratospheric warming and polar vortex of early 2021, NOAA, January 28, 2021.
https://www.climate.gov/news-features/blogs/enso/sudden-stratospheric-warming-and-polar-vortex-early-2021
Sudden Stratospheric Warming predicted to be stronger in a warmer climate… Given that periodic weather cycles that move west to east across the globe every 30 to 60 days (Madden-Julian Oscillations) are predicted to be stronger in a warmer climate, modeling of sudden stratospheric warming events too will become more frequent, with possible implications on tropospheric high-latitude weather.
Kang and Tziperman, More Frequent Sudden Stratospheric Warming Events... in a Warmer Climate, American Meteorological Society, November 1, 2017.
https://journals.ametsoc.org/view/journals/clim/30/21/jcli-d-17-0044.1.xml
Bomb Cyclone - What is Bombogenesis? … Bombogenesis occurs when a midlatitude cyclone rapidly intensifies, dropping at least 24 millibars over 24 hours. The formation of this rapidly strengthening weather system is a process called bombogenesis, which creates what is known as a bomb cyclone.
https://oceanservice.noaa.gov/facts/bombogenesis.html
Polar Vortex Weakening… (abstract) "The wintertime Arctic stratospheric polar vortex has weakened over the past three decades, and consequently cold surface air from high latitudes is now more likely to move into the middle latitudes… Here, through the analysis of various data sets and model simulations, we show that the Arctic polar vortex shifted persistently towards the Eurasian continent and away from North America in February over the past three decades. This shift is found to be closely related to the enhanced zonal wavenumber-1 waves in response to Arctic sea-ice loss, particularly over the Barents–Kara seas (BKS). Increased snow cover over the Eurasian continent may also have contributed to the shift. Our analysis reveals that the vortex shift induces cooling over some parts of the Eurasian continent and North America which partly offsets the tropospheric climate warming there in the past three decades. The potential vortex shift in response to persistent sea-ice loss in the future and its associated climatic impact, deserve attention to better constrain future climate changes."
Zhang et al., Persistent shift of the Arctic polar vortex towards the Eurasian continent in recent decades, Nature Climate Change, October 24, 2016.
https://www.nature.com/articles/nclimate3136.epdf?referrer_access_token=-b-kbNWfGACHTN1tqzVkztRgN0jAjWel9jnR3ZoTv0MkzCzc3z7ZLHX13VkjcRLMAvMosySuuqodqaHrWHQhAY51g2pg56yzacxacAKiOjJuteu81ceDVPD7hOY3JuZaDKBPGP3djXFQ7OCiAR31ioUK4G6lFU6XDb1VwI-AjpZXFyJWsWnT4hkHAv-f97soVbUjiFCeF75Wqfm75OJCcMEbkI-j-aC56KgXct3YKRPmAocKk9iNSyTKjkfJmS678TCU8EypsQMr5w7hQ-CE7A8SJwhVJS6j1aSAuP4Ac_R0pXLz5p93vz230ZTiVqE8g4YaqAccgt4Hp_n1hE-GA2qhHV9Ubv1AoGUuYUEPXe5fgpDGGonem8pIPrgRVFguJTlPpiQFRbEcxqLtqjIR4Xet4Mpsf6qOqO0OqyvL5Go%3D&tracking_referrer=www.washingtonpost.com
Arctic Amplification and polar vortex collapse… Increased snowfall in Siberia and in general a warmer arctic creates polar vortex collapse conditions responsible for increase in acute cold events in lower latitudes and specifically the Texas Ice Disaster in 2021**.** (Abstract) "The Arctic is warming at a rate twice the global average and severe winter weather is reported to be increasing across many heavily populated mid-latitude regions, but there is no agreement on whether a physical link exists between the two phenomena. We use observational analysis to show that a lesser-known stratospheric polar vortex (SPV) disruption that involves wave reflection and stretching of the SPV is linked with extreme cold across parts of Asia and North America, including the recent February 2021 Texas cold wave, and has been increasing over the satellite era. We then use numerical modeling experiments forced with trends in autumn snow cover and Arctic sea ice to establish a physical link between Arctic change and SPV stretching and related surface impacts."
Cohen et al., Linking Arctic variability and change with extreme winter weather in the United States, Science, September 3, 2021.
https://www.science.org/doi/epdf/10.1126/science.abi9167
Austin Bergstrom 164 hour below freezing record…
South-Central Texas Winter Storm Event, Event Summary, National Weather Service New Braunfels, February 10-18, 2021.
https://www.weather.gov/media/ewx/wxevents/ewx-20210218.pdf
Seven Day boil water notice for Austin, Texas…
https://www.austintexas.gov/news/boil-water-notice-lifted-all-customers
Over 1 million served by Austin Water…
https://www.austintexas.gov/department/austin-water-utility/divisions#:~:text=For%20over%20100%20years%2C%20Austin,more%20than%2048%20square%20miles.
Over 14.9 million without safe drinking water…
McNamara, Over 14 million Texans are still without safe water as officials grapple with crisis, CBS News, February 20, 2021.
https://www.cbsnews.com/news/texas-boil-water-notices-winter-storm/

Vision Statement

(1) **2,484 Net-zero Plans…** One-hundred twenty countries, 823 cities, and over 1,541 companies have net-zero plans in 2020.
Accelerating Net Zero, Data-Driven EnviroLab and New Climate Institute, 2020.
https://theconversation.com/net-zero-emissions-targets-are-everywhere-we-need-to-sort-the-genuine-from-the-greenwash-150127

(2) **Emissions are 57% behind 1992 Best-case scenario…**The 1992 IPCC Best-case scenario shows 2020 should see 7.5 Gt C (27.5 Gt CO_2) emissions. Current 2019 CO_2 emissions including Forests, Land Use and Other (FLUO) as per the Global Carbon Project are 43.1 Gt CO_2 or 57% greater than projected for a 2.0 C limit to warming from 1992 where the best-case IS92c scenario should be at 7.5 Gt C emissions in 2020, or 27.5

Gt as CO_2. Most likely scenario IS92b was 10.5 Gt C, or 38.5 Gt as CO_2. Worst-case IS92e was 53.1 Gt as CO_2.
Emissions Scenarios for the IPCC, an Update, IPCC, 1992
https://www.ipcc.ch/site/assets/uploads/2018/05/ipcc_wg_I_1992_suppl_report_section_a3.pdf
43.1 Gt CO_2 emissions in 2019, from FLOU (Forests, Land and other Uses)…
Greenhouse gas emissions to set new record this year, but rate of growth shrinks, Science, December 4, 2019.
https://www.sciencemag.org/news/2019/12/greenhouse-gas-emissions-year-set-new-record-rate-growth-shrinks#:~:text=Global%20carbon%20emissions%20are%20expected,carbon%20dioxide%20into%20the%20atmosphere.
Based on Global Carbon Project Budget 2019
https://www.globalcarbonproject.org/carbonbudget/index.htm

(3) **Austin Emissions Reductions behind 2.0°C path by 10%...**
Austin's 1990 emissions were 10 million tons CO_2eq as per the Austin Community Climate Plan 2015 backcast, see figure 1.3.3a. As per IS92c, the emissions reduction path showed a 15 percent increase in emissions at 2020 over 1990. Therefor in 2020, for Austin to be on the 1992 path to 2.0°C, we should be at an emissions level that is 15 percent greater than 10 million tons CO_2eq, or 11.5 million tons. Austin is at 12.7 million tons CO_2eq in the *Climate Equity Plan 2020* and 10 percent behind the best-case 2.0°C path.

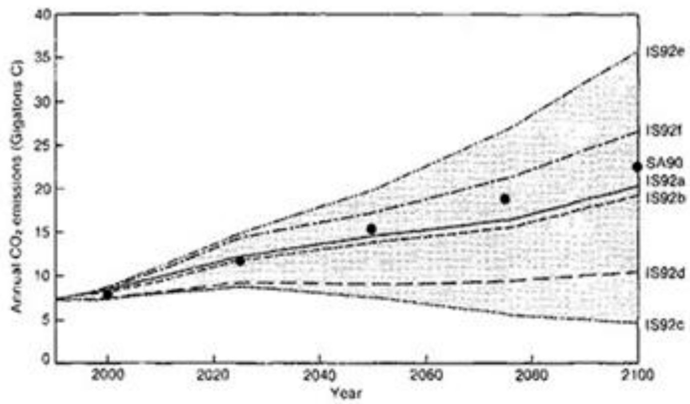
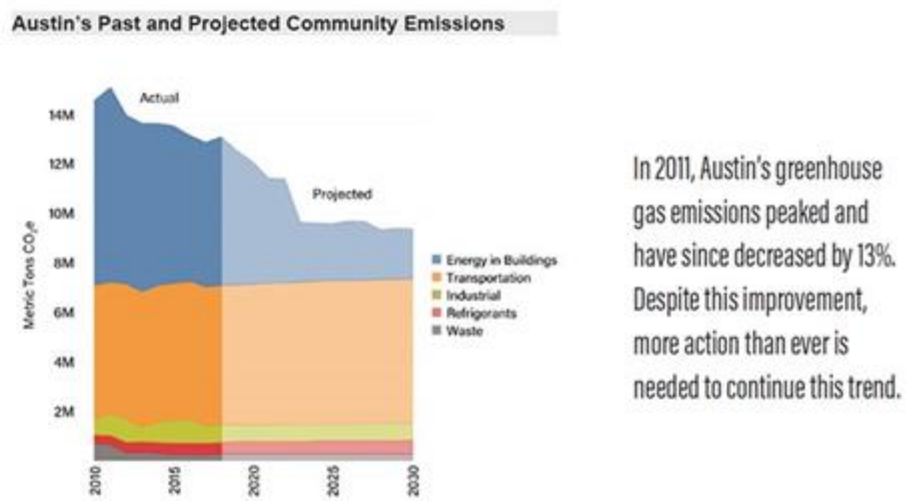


Figure A3.1: Annual CO_2 emissions from energy, cement production and tropical deforestation for the six IPCC 1992 scenarios (IS92a-f) and for the 1990 IPCC Scenario A (SA90).



(4) **More than half of known climate tipping systems are now active more than 100 years ahead of schedule…** Nine Earth systems collapse tipping points have been identified by scientists as active: Arctic sea ice, Greenland ice sheet, boreal forests, permafrost, the Gulf Stream, the Amazon, coral, the West Antarctic Ice Sheet and parts of the East Antarctic Ice Sheet. Until 2018, the Intergovernmental Panel on Climate Change (IPCC) has assumed that tipping would not occur before 5°C of warming above pre-industrial times, something that the worst-case scenario put well into the 22nd century. In 2018 however, IPCC lowered this limit to between 1 and 2°C above pre-industrial times in both the 1.5°C Report and the Cryosphere Report. Lenton 2019 tells us, "The Intergovernmental Panel on Climate Change (IPCC) introduced the idea of tipping points two decades ago. At that time, these 'large-scale discontinuities' in the climate system were considered likely only if global warming exceeded 5.0°C above pre-industrial levels. Information summarized in the two most recent IPCC Special Reports (published in 2018 and in September this year) suggests that tipping points could be exceeded even between 1 and 2°C of warming." Climate tipping is now active greater than 100 years ahead of projections. Quotes from the Exeter press release: "More than half of the climate tipping points identified a decade ago are now "active", a group of leading scientists have warned. This "cascade" of changes sparked by global warming could threaten the existence of human civilization, Evidence is mounting that these events are more likely and more interconnected than was previously thought, leading to a possible domino effect. It is not only human pressures on Earth that continue rising to unprecedented levels. It is also that as science advances, we must admit that we have underestimated the risks of unleashing irreversible changes, where the planet self-amplifies global warming. This is what we now start seeing, already at 1°C global warming. No amount of economic cost–benefit analysis is going to help us. We need to change our

approach to the climate problem." Perhaps the most salient part of this work is that tipping points seem to be interrelated. The authors make strong links that 45 percent of tipping points create cascading feedbacks that increase the tipping response of other tipping systems through dynamic global effects.
Lenton et al., Climate tipping points-too risky to bet against, Nature, November 27, 2019
https://www.nature.com/articles/d41586-019-03595-0

(5) **"Climate Emergency Warning"…** Over 13,000 scientists have signed a letter declaring a climate emergency is underway in the journal Biosciences. Quotes: "Scientists have a moral obligation to clearly warn humanity of any catastrophic threat and to "tell it like it is." On the basis of this obligation and the graphical indicators presented below, we declare, with more than 11,000 scientist signatories from around the world, clearly and unequivocally that planet Earth is facing a climate emergency." "The climate crisis has arrived and is accelerating faster than most scientists expected…. It is more severe than anticipated, threatening natural ecosystems and the fate of humanity…. Especially worrisome are potential irreversible climate tipping points and nature's reinforcing feedbacks (atmospheric, marine, and terrestrial) that could lead to a catastrophic 'hothouse Earth,' well beyond the control of humans…. These climate chain reactions could cause significant disruptions to ecosystems, society, and economies, potentially making large areas of Earth uninhabitable. An immense increase of scale in endeavors to conserve our biosphere is needed to avoid untold suffering due to the climate crisis."
Ripple et al., World Scientists' Warning of a Climate Emergency, Bioscience, November 5, 2019.
https://academic.oup.com/bioscience/article/70/1/8/5610806
Over 13,000 signatories (updated)
Alliance of World Scientists
https://scientistswarning.forestry.oregonstate.edu/

(6) **California fires over 4 million acres…** According to CalFire, 4.3 million acres burned in 2020, approaching the annual average from over 100 years ago when a bad fire year was 11 million acres. It is believed that this amount of fire is a good thing, and that because of the lack of fire, fuels have accumulated and increased the fire risk. (See the Mercury news article linked below.) The reality is that warming and drought, because of the nonlinear relationship with dryness and temperature, has created record low fuel moisture. In essence then, without climate change, overly dense fuel loads being the problem would be valid. Forestry scientists are beginning to understand that the magnitude of the problem is not represented by too much fuel however, it is too much dryness caused by climate change.
CalFire 2020, https://www.fire.ca.gov/incidents/2020/
Mercury News, August 23, 2020 - https://www.mercurynews.com/2020/08/23/california-fires-state-feds-agree-to-thin-millions-of-acres-of-forests/
CalFire Spent $1.3 billion in 2020 on fighting wildfires along… With a total 2020 budget for CalFire of $3.5 billion.
https://lao.ca.gov/Publications/Report/4285

(7) **Five hurricanes struck Louisiana in 2020**…
https://www.nola.com/news/hurricane/article_d17ea1e2-2e5b-11eb-bcf4-f70bcbd968ee.html

(8) **Permafrost emissions possibly rivalling global transportation…** Across the Northern Hemisphere, permafrost melt emitted 630 TgC, or 2.3 Gt CO_2 (not including methane). "We estimate a contemporary loss of 1,662 TgC per year from the permafrost region during the winter season (October–April). This loss is greater than the average growing season carbon uptake for this region estimated from process models (−1,032 TgC per year)." Of critical note, emissions are average per year from 2003 – 2017. With permafrost melt increasing rapidly today, this means emissions in 2017 were much more than in 2003, therefore emissions today are much more than the average of 2.3 Gt per year 2003 to 2017.
Natali et al., Large loss of CO_2 in winter observed across the northern permafrost region, Nature Climate Change, October 21, 2019.
https://www.uarctic.org/media/1600119/natali_et_al_2019_nature_climate_change_s41558-019-0592-8.pdf
Global transportation emissions… 7 GT CO_2eq or 6.7 Gt CO_2 annually,.
IPCC 2013, Physical Science Basis, Chapter 8, Transport
https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf
Alaskan Permafrost Flipped from Carbon Sink to Carbon Source in 2012… Alaskan permafrost is now emitting more greenhouse gases than it is storing according to work from Harvard, the Dublin Institute of Technology, Universities of Alaska, Colorado at Boulder, California at Irvine, NOAA and others in 2018. This wasn't supposed to happen before the end of the century. The findings show, "Long-term records at Barrow, AK, suggest that CO_2 emission rates from North Slope tundra have increased during the October through December period by 73% ± 11% since 1975." The temperature within permafrost increased by nearly 2°C at a depth of 10 m near Barrow since 1950. As recently as 2011, carbon flux in tundra ecosystems was neutral. In 2012, total Alaska carbon emissions, considering terrestrial ecosystems and humans, were 23 megatons of CO_2 equivalents (CO_2e.) In 2013 it was 248 megatons CO_2e. In 2014 it was 114 megatons. The average of 106 Mt CO_2 is more than twice New York City annual emissions.
Commane et al., Carbon dioxide sources from Alaska driven by increasing early winter respiration from Arctic Tundra, PNAS May 23, 2017.
https://www.pnas.org/content/pnas/114/21/5361.full.pdf
Permafrost collapse is 70 years… "Observed maximum thaw depths at our sites are already exceeding those projected to occur by 2090 under representative concentration pathway version 4.5."
Farquharson et al., Climate Change Drives Widespread and Rapid Thermokarst Development in Very Cold Permafrost in the Canadian High Arctic, Geophysical Research Letters, June 10, 2019.
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019GL082187
University of the Arctic Press Release... "Today winter CO_2 emissions are ~30% more than the CO_2 assimilated by these regions during summer-The North is a net emitter of CO_2-C adding to a rising CO_2 concentration in the atmosphere-a critical feed-forward process associated with warmer winters."
https://www.uarctic.org/news/2019/10/large-loss-of-co2-in-winter-observed-across-the-northern-permafrost-region/
5.8 billion acres of permafrost globally…
https://nsidc.org/cryosphere/frozenground/whereis_fg.html
20% of permafrost susceptible to abrupt thaw… "Around 20% of frozen lands have features that increase the likelihood of abrupt thawing, such

as large quantities of ice in the ground or unstable slopes." 1.16 billion acres of 5.8 billion total, 1.8 million square miles, 270% larger than Alaska's 665,000 square miles."
Turetsky, Permafrost collapse is accelerating Carbon Release, Nature, May 2, 2019.
https://ecoss.nau.edu/wp-content/uploads/2019/08/Turetsky-et-al.-2019_Nature_Comment.pdf
Abrupt permafrost thaw not accounted for in models releases seven times more GHGs than current modeling suggests…
Turetsky et al., Carbon release through abrupt permafrost thaw, Nature Geoscience, February 3, 2020.
(Paywall) https://www.nature.com/articles/s41561-019-0526-0
(National Geographic Review, free account) The Arctic's thawing ground is releasing a shocking amount of dangerous gases, February 5, 2020.
https://www.nationalgeographic.com/science/2020/02/arctic-thawing-ground-releasing-shocking-amount-dangerous-gases/
Permafrost up to 4,000 feet thick… In Alaska, permafrost on the North Slope can be over 2,000 feet thick and in Siberia it can be 4,000 feet.
NOAA
https://www.pmel.noaa.gov/arctic-zone/detect/land-permafrost.shtml#:~:text=Typical%20thickness%20of%20permafrost%20around,up%20to%20650%20meters%20thick.
Siberia (Britanica) - 1500 meters or nearly 5000 feet – nearly a mile deep.
https://www.britannica.com/science/permafrost

(9) **West Antarctic Ice Sheet Collapse Began Shortly After the Turn of the Century**… Scientists have been warning since 2006 that the West Antarctic Ice Sheet was collapsing. Vaughan summarized the science around WAIS collapse beginning in 1981. While the mechanisms for ocean melt were present in publication from the early 1990s, it was not until the early 2000s that work first showed definitive evidence of thinning, grounding line retreat, and ice stream acceleration in one of the most sensitive area of West Antarctica, the Amundsen Sea Embayment. Vaughan concludes that if these symptoms are indeed precursors to collapse, then collapse has begun. From what we know today, he was absolutely correct.
Vaughan, West Antarctic Ice Sheet collapse – the fall and rise of a paradigm, Climatic Change, 2006.
http://www.researchgate.net/publication/225166993_West_Antarctic_Ice_Sheet_collapse_-_the_fall_and_rise_of_a_paradigm
From the University of California Jet Propulsion lab and the California Institute of Technology (abstract)… "Upstream of the 2011 grounding line positions, we find no major bed obstacle that would prevent the glaciers from further retreat and draw down the entire basin."
Rignot et al., Widespread, Rapid Grounding Line Retreat of Pine Island, Thwaites, Smith and Kohler Glaciers, West Antarctica From 1992 to 2011, Geophysical Research Letters, May 27, 2014.
http://onlinelibrary.wiley.com/doi/10.1002/2014GL060140/pdf
From the Polar Science Center at the University of Washington… From the Abstract, "Except possibly for the lowest-melt scenario, the simulations indicate that early-stage collapse has begun."
Joughin et al., Marine ice sheet collapse potentially underway for the Thwaites Glacier, Science Express, May 12, 2014.
(paywall) https://www.science.org/doi/abs/10.1126/science.1249055
December 2018 American Geophysical Union Fall meeting… Carlson et al., showed that previous findings that the WAIS had already initiated its collapse are now backed up by sediment core data with a sea level contribution of up to 30 feet and 8.5 feet per century. Their findings indicate a full WAIS collapse occurred 125,000 years ago between our latest ice age period and the previous ice age period, when the temperature was similar to Earth's temperature today. However, the warming rate today is much faster than 125,000 years ago when Earth was transitioning back to orbital cycles that promoted cooling, not additional warming as is being caused by mankind's greenhouse gas emission today.
Carlson, et al., Absence of the West Antarctic ice sheet during the last interglaciation, Presented to the American Geophysical union Annual Fall meeting, December 10, 2018.
https://agu.confex.com/agu/fm18/meetingapp.cgi/Paper/421418
Two reviews of Carlson's AGU Presentation… Paul Voosen, Antarctic ice melt 125,000 years ago offers warning, Science 2018.
http://science.sciencemag.org/content/362/6421/1339
Rice, Ancient Antarctic ice sheet collapse could happen again, triggering a new global flood, Phys Org, December 21, 2018.
https://phys.org/news/2018-12-ancient-antarctic-ice-sheet-collapse.html

(10) **NOAA 1.5 inches sea level rise - Sweet 2019, and 14 inches of Sea level Rise by 2030 - Sweet 2017**…
Sweet 2019… "In 2019 (12) the national (median) HTF [high tide flooding] occurrence along U.S. coastlines as a whole was 4 days. This is 1 day less than the record reached in 2018 as measured by 98 NOAA tide gauges (13) (Figure 3a). Assessed over several decades, the national trend in HTF frequency is accelerating, and HTF is more than twice as likely now as it was in 2000. The rapid growth is in response to RSL rise, which is occurring along most U.S. coastlines. (Our study does not include Alaska, where land-based ice melt is contributing to land rebound (14)). In 2019, RSL along U.S. coastlines (median value) reached an all-time record of 0.34 m since 1920 (last 100 years), which is about 4 centimeters (1.5 inches) higher than it was in 2018. The national RSL (linear) trend along U.S. coastlines examined here is 2.8 millimeters/year over this period (not shown). Inherent to the RSL measurement in Figure 3a is the effect of land subsidence, which nationally (median plus or minus standard deviation value of the 98 tide gauges monitored) is occurring at a rate of 0.7 ±1.4 mm/year, but can be as high as 7 mm/year along the coastline of Louisiana (Zervas et al., 2013; Sweet et al., 2017). Annual mean RSLs at most East and Gulf Coast tide gauges (57 of the 62) broke their historical records (Figure 3b) in 2019 by (median value) 2.6 cm (about 1 inch)." [emphasis added]
Press Release - NOAA, U.S. high-tide flooding continues to increase, July 14, 2020
https://www.noaa.gov/media-release/us-high-tide-flooding-continues-to-increase
NOAA 2019 State of U.S. High Tide Flooding with a 2020 Outlook, TR 092, July 2020
https://tidesandcurrents.noaa.gov/publications/Techrpt_092_2019_State_of_US_High_Tide_Flooding_with_a_2020_Outlook_30June2020.pdf
Ice Sheet Collapse Not included in IPCC Fifth Assessment of 29 inches of sea level rise by 2100… the IPCC did not include ice sheet collapse in their 2013 report. From Chapter 13, Sea Level Change, page 1173, "Literature investigating the relation between the SLR generated by dynamical change and emission scenario does not currently exist. There is also a lack of literature on the relation between emission scenario and the intrusions of warm water into ice-shelf cavities thought to be important in triggering observed mass loss (Jacobs et al., 2011) and potentially important in the future (Hellmer et al., 2012). It is therefore premature to attach a scenario dependence to projections of dynamical change, even though such a dependency is expected to exist."
From page 1174, paragraph 4… " In summary, it is likely that dynamical change within the Antarctic ice sheet will lead to SLR during the next

century with a range of –20 to 185 mm. SLR beyond the likely range is poorly constrained and considerably larger increases are possible (the underlying probability distribution is asymmetric towards larger rise), which will probably be associated with the MISI (Box 13.2). Although the likelihood of such SLR cannot yet be assessed more precisely than falling above the likely range, literature suggests (with medium confidence) that its potential magnitude is several tenths of a metre. We are unable to assess SLR as a function of emission scenario, although a dependency of SLR on scenario is expected to exist. In addition, coupling between SMB and dynamical change is likely to make a further contribution to SLR of 0 to 35% of the SMB. All the available literature suggests that this dynami¬cal contribution to sea level rise will continue well beyond 2100."
From the Summary, page 1174, paragraph 9,"In summary, ice-dynamics theory, numerical simulations, and paleo records indicate that the existence of a marine-ice sheet instability associated with abrupt and irreversible ice loss from the Antarctic ice sheet is possible in response to climate forcing. However, theoretical considerations, current observations, numerical models, and paleo records cur¬rently do not allow a quantification of the timing of the onset of such an instability or of the magnitude of its multi-century contribution."
IPCC Fifth Assessment Report, Chapter 13, Sea Level Change, 2013
https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf

(11) **NOAA Sweet 2017 Includes ice sheet collapse with their 14 inches by 2030 projection…** NOAA's sea level rise report in 2017 moves significantly forward in including ice sheet collapse in future sea level rise projections. The following are quotes from the report on why and how ice sheet collapse was included. "Decision-makers charged with planning for upgrades to existing long-life critical infrastructure… need to consider the risks across a broad range of possible outcomes, including those associated with high-consequence, low-probability situations." and "To obtain GMSL rise estimates whose ranges extend beyond AR5, additional assumptions are included within a particular probabilistic framework. A few examples include reliance on structured expert elicitation of potential ice-melt contributions not captured in the process models (Bamber and Aspinall, 2013) or from geologic evidence comparing past sea levels and atmospheric greenhouse gas concentrations (Rohling et al., 2013) or temperature (Kopp et al., 2016a). Under such frameworks, estimates of high-end GMSL rise by 2100 under RCP8.5 include ~1.8 m [95th percentile] (Jevrejeva et al., 2014, Rohling et al., 2013 and Grinsted et al., 2015), ~2.2 m [99th percentile] (Jackson and Jevrejeva, 2016), and ~2.5 m [99.9th percentile] (Kopp et al., 2014)." and "Recent modeling of physical feedbacks related to marine ice-cliff instabilities and ice-shelf hydrofracturing (rain and meltwater-enhanced crevassing and calving) used within the physical process models generating GMSL estimates are being incorporated into ice-sheet models (Pollard et al., 2015). With such feedbacks modeled for Antarctica, additional GMSL rise upwards of 0.6–1.1 m to median estimates under RCP8.5 are possible by 2100 (DeConto and Pollard, 2016), potentially raising median GMSL projections for RCP8.5 of Kopp et al. (2014) as high as 1.9 m by 2100. Meanwhile, in Greenland, there are indications that processes already underway have the potential to lead to an accelerating high-end melt risk. Important changes in surface albedo are occurring in response to ice melt and associated unmasking and concentration of impurities in snow and ice (Tedesco et al. 2016). At the base of the ice sheet, important changes in ice dynamics are occurring, through interactions with surface runoff and a warming ocean, which may make the Jakobshavn Isbræ, Kangerdlugssuaq Glacier, and the Northeast Greenland ice stream vulnerable to marine ice sheet instabilities (Khan et al., 2014)." and "The growing evidence of accelerated ice loss from Antarctica and Greenland only strengthens an argument for considering worst-case scenarios in coastal risk management. Miller et al. (2013) and Kopp et al. (2014) discuss several lines of arguments that support a plausible worst-case GMSL rise scenario in the range of 2.0 m to 2.7 m by 2100." and "This report recommends a revised worst-case (Extreme) GMSL rise scenario of 2.5 m by 2100."
Sweet et al., Global and Regional Sea Level Rise Scenarios for the United States, NOAA, January 2017.
https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

(12) **Sea level rise risk of $14.2 trillion with 10 to 20 inches of sea level rise by 2030…** Sea level rise impacts are not time and scenario dependent, they occur whenever sea level rise reaches a certain level associated with whatever scenario is being evaluated and by the same token, temperature is not meaningful indicator of sea level rise. NOAA's Sweet 2017 (Reference 6 in Vision Statement) tells us to expect 14 inches of sea level rise by 2100 with the RCP8.5 scenario that suggests an average of 29 inches by 2100, but RCP8.5 takes into consideration only a very small amount of ice sheet collapse that we now know is underway. NOAA's Sweet 2017 considers at least some of this ongoing ice sheet collapse. Therefore, considering NOAA's Sweet 2017 worst-case scenario of 14 inches of sea level rise by 2030, and because of vastly understated climate impacts we must be considering the worst-case scenario, and that we are on path to achieve this level considering NOAA/s 1.5 inches of sea level rise in 2019 (Reference 10, Vision Statement), ice sheet collapse was considered in sea level rise costs, the latest publishing shows $14.2 trillion assets at risk with 10 to 20 inches of sea level rise at 2050 to 2080 based on the worst-case RCP8.5 scenario. This is far higher than consensus impacts because it is a more robust analysis using latest publishing knowledge. Compounding the understatement of consensus impacts though is ice sheet collapse that is disregarded by the consensus. NOAA includes some ice sheet collapse and their Sweet 2017 projections (see next reference) of 14 inches worst-case by 2030. Because prudent planning considers a relatively rare 100-year event, and worst-case projections are similar in probability of occurrence, we should absolutely be using 14 inches by 2030 for $14.2 trillion in sea level rise impacts annually. (See more at the Safety actor discussion in Appendix 1)
From Kirezci 2020 (press release), Using RCP8.5 projections of 10 inches by 2050 and 20 inches by 2080, assets at risk will rise up to $US14.2 trillion. It mostly does not matter when sea level rise happens, damages will be the same in $US today. RCP8.5 and the IPCC work defining impacts with this scenario are significantly understated because they do not take into consideration ice sheet collapse. NOAA is not as understated as IPCC and their Sweet 2017 includes some ice sheet collapse with their worst-case projection of 14 inches by 2030. (Worst-case is similar to the 100-year storm and must be used for planning purposes) So by based on NOAA, we can expect $14.2 trillion of damages to at risk assets by 2030, not 2050 to 2080. It is also important to note that this is the one time value of these assets. Rebuilding after damages puts many of these assets at risk again, and because the risks increase nonlinearly with further warming, they can be expected to recur thus increasing the $14.2 trillion figure considerably.
Kirezci et al., Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st Century, Nature, July 30, 2020.
https://www.nature.com/articles/s41598-020-67736-6.pdf
Press Release, University of East Anglia
https://www.eurekalert.org/pub_releases/2020-07/uoea-cfs072920.php

(13) **Tipping activated 100 years ahead of projections…** See Reference 4 in this section.

(14) **Large areas of Earth uninhabitable…** See Reference 5 this section.

(15) **Global Restoration Burden vs. Net-zero Burden, 8 to 12 times more…** (Note: The following is based on less than 1.0°C warming by 2100. To ensure safety, we must achieve less than 1.0°C by 2040 and there are no global scenarios for less than 1.0°C by 2040.) To achieve less than 1.0°C our CO2 burden globally is to achieve net zero 2040 to 2050, and remove an average of 7 to 11 Gt CO_2 from the atmosphere annually through 2100 (for the net zero 2050 and 2040 scenarios, Hansen 2017.) The global net-zero burden alone for 2040 and 2050 is 0.93 and 0.84 Gt annual emissions reductions, or negative emissions are 8 to 12 times more than net-zero, based on a 2100 effective date. Critically important to the short term are cooling aerosols that will be removed from emissions with net zero. These are vastly from fossil fuel emissions and when indirect effects (water vapor and clouds) are considered account for cooling of (-) 0.9 Wm2, with total greenhouse gas forcing (CO_2, CH4, N2O, and Halocarbons) being 3.0 Wm2. The short term warming pollutants total radiative forcing: Black Carbon (0.30 Wm2), Methane (0.90 Wm2 - includes Ozone), halocarbons (0.36 Wm2) = 1.56 Wm2. Net zero cancels 58 percent of the warning reduction earned from short term warming pollution management.
Hansen, Young People's Burden: Requirement of Negative CO_2 Emissions, Earth Systems Dynamics, July 18, 2017.
https://www.earth-syst-dynam.net/8/577/2017/esd-8-577-2017.pdf

(16) **Climate Change now first priority among likely to vote dems…** Above Trump, Economy and Covid-19.
Poll: Climate Becomes Top Priority For Democrats; Trump Struggles On Race, COVID-19, NPR/PBS Marist Poll, September 19, 2020.
https://www.npr.org/2020/09/19/914233038/poll-climate-becomes-top-priority-for-democrats-trump-struggles-on-race-covid-19

(17) **Sierra Club Ground Breaking Climate policy of "Less than 1.0°C warming above normal"…** Adopted March 2020.
https://www.sierraclub.org/sites/www.sierraclub.org/files/2020-Sierra-Club-Climate-Resilience-Policy.pdf

(18) **Microsoft Adopted a climate policy of 0.0°C warming…**
https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/

(19) **Microsoft emissions 11.5 million tons in 2018…** 2020 Microsoft Sustainability Report, slide 6
https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE4Mxso
Austin Emissions 13.1 million tons in 2018… *Austin Climate Equity Plan* 2020 Draft, page 30.
https://www.speakupaustin.org/4872/widgets/22575/documents/13638

(20) **We treat 116 Gt potable;e water and human sewage globally every year…**
Human sewage treatment - https://www.epa.gov/nutrientpollution/sources-and-solutions-wastewater/
Potable water treatment - https://www.infrastructurereportcard.org/cat-item/drinking_water/

(21) **Air Capture of CO2 for $100 per ton…** Also see DAC Cost Controversy, Reference 7, Section 2.2.
Keith et al., A Process for Capturing CO_2 from the Atmosphere, Joule, August 15, 2018.
https://www.sciencedirect.com/science/article/pii/S2542435118302253

(22) Carbon dioxide removal costs will be reduced by at least 90%... David Keith says the "reasonable" costs of carbon dioxide removal with their recyclable lime-potash process is $100 per ton in a personal communication on 12/09/2018. It is important to understand 1) academic findings are almost always poorly reported upon in popular media, and 2) that academic findings are almost always conservative. Here's why:
1) Keith's Costs -
- The $232 high end reflects the high end energy cost of the cheapest fracked gas energy alternative at the time of $0.03 to $0.06 kWh. • The low end is $94 at $0.03 kWh natural gas energy.
- Keith includes a 10% carbon penalty for the natural gas energy, in other words, his paper says it takes 10 percent more process to remove the carbon emitted from burning the natural gas to create the energy to run the process.
- The IEAs hot off the press levelized cost of new solar energy has plummeted to $0.02 kWh.
- Keith includes 8% profit.

Taking the above into consideration, today's (2018) costs for the commons with no profit, purpose built on-site utility scale PV at $0.02 kWh (a thirty percent reduction in the largest cost component) with no energy company transmission costs or profit, a ten percent increase in efficiency from eliminating the carbon penalty for natural gas, all total about a 50% cost reduction or $50 per ton.
2) Scaling - Carbon Engineering's pilot facility is a 1,000 ton per year facility. Keith's +/- $100 ton costs are for a 1 million ton per year facility built with off the shelf components with known scaling factors. The 1 million ton per year target will quite likely be scaled upwards to 10 million tons per year facilities with 100 million tons per year facilities as soon as we the people show motivation to address our historic climate pollution, and with the way Earth systems collapses are accelerating this will likely be well within the next ten years. Scaling from 1,000 tons per year to 100,000,000 tons per year or a 100,000 times increase in production, like with transistors, automobiles, solar panels, gigabattery factories, etc., results in wildly plummeting costs where at the nth iteration, when production is maximized, costs are not really meaningful any longer. The costs of solar cells has fallen from $76 per watt in 1976 to 0.21 per watt in 2020, or 99.7 percent. (See reference 2, Section 2.2) There are still costs, but as is very likely in the next few years with batteries, costs become radically more competitive than the tech that is being replaced.
3) The Bottom Line - Because realistic costs today for a 1 million ton per year facility (like is being built in the Permian Basin by Carbon Engineering and Occidental Chemicals) is at $50 per ton without profit and considering purpose built utility scale on-site solar energy, scaling 100,000 times and nth process iterations will reduce costs to very low levels, like so many things we have done in our culture. This is not a matter of uncertainty. It is a matter of motivation.
Keith et al., A Process for Capturing CO_2 from the Atmosphere, Joule, August 15, 2018.

https://www.sciencedirect.com/science/article/pii/S2542435118302253

Executive Summary

(1) **1.5 inches sea level rise…** (See Reference 10, Vision Statement)

Section 1
A Safe and Equitable Target of Less Than 1.0°C Warming Above Normal

1) **Emissions reductions 57% behind 1990 IS92c scenario…** The 1992 IPCC Best-case scenario shows 2020 should see 7.5 Gt C (27.5 Gt CO_2) emissions in 2020. Current 2019 CO_2 emissions as per the Global Carbon Project are 43.1 Gt CO_2 or 57% greater than projected for a 2.0°C limit to warming in 1992.
Figure A3.1 shows best-case IS92c scenario should be at 7.5 Gt C emissions in 2020, or 27.5 Gt as CO_2.
Most likely scenario IS92b was 10.5 Gt C, or 38. 5 Gt as CO_2.
Worst-case IS92e was 53.1 Gt as CO_2.
Emissions Scenarios for the IPCC, an Update, IPCC, 1992.
https://www.ipcc.ch/site/assets/uploads/2018/05/ipcc_wg_I_1992_suppl_report_section_a3.pdf
Journal Science in 2019 was 43.1 Gt CO_2…
Greenhouse gas emissions to set new record this year, but rate of growth shrinks, Science, December 4, 2019.
https://www.sciencemag.org/news/2019/12/greenhouse-gas-emissions-year-set-new-record-rate-growth-shrinks#:~:text=Global%20carbon%20emissions%20are%20expected,carbon%20dioxide%20into%20the%20atmosphere.
Scientific American article above based on Global Carbon Project Budget 2019.
https://www.globalcarbonproject.org/carbonbudget/index.htm

1.1 Why 1.5°C Is Not Safe

(1) **Warming rose above the normal range of natural variability about 2000…** There is an overarching need to restore our current climate to within the boundaries of the natural variability of our old climate. This is the tenth grade science concept of collapse of biologic systems when they move beyond their evolutionary boundaries. When systems collapse, or re-evolve to meet new boundary conditions, their environmental services are degraded, lost, and often reversed. With greenhouse gases, this means loss of ecological services provided by natural systems (like carbon sequestration), and likely greenhouse gas emissions instead of sequestration. These systems are, or are related to Earth systems and climate tipping, and we know that more than half of climate tipping systems are now active at 1.0°C, when widespread consensus science reporting suggested tipping would not occur until after 5°C warming. (See Reference 4, Vision Statement) There are a number of papers that can be interpreted to identify this evolutionary boundary at about 0.5°C degrees warming above pre-industrial times, which is fundamentally the natural variability of our old climate.
King 2015 defines "anthropogenic emergence"… as the point where our climate warmed beyond its stable natural variability, as some point near or not too long after the year 2000, where we warmed beyond the 0.5°C.
King et al., The timing of anthropogenic emergence in simulated climate extremes, Environmental Research Letters, September 10, 2015.
https://iopscience.iop.org/article/10.1088/1748-9326/10/9/094015/pdf
Hansen 2017 "Young people's burden..." defines he maximum warming or our old climate, or the maximum range of natural variability of our old climate as 0.25 to 0.75°C warming, with a midpoint of 0.5°C.
Hansen, Young People's Burden: Requirement of Negative CO_2 Emissions, Earth Systems Dynamics, July 18, 2017, Fig. 10 and Fig. 11.
https://www.earth-syst-dynam.net/8/577/2017/esd-8-577-2017.pdf
Lenton's tipping point article tells us more than half of known tipping points have activated since about 2010, which coincides well with climate change warming beyond 0.5°C…
Lenton et al., Climate tipping points-too risky to bet against, Nature, November 27, 2019.
https://www.nature.com/articles/d41586-019-03595-0
Randers and Goluke 2020 have identified a tipping point with permafrost collapse of 0.5°C warming...
Randers and Goluke, An earth system model shows self-sustained melting of permafrost even if all man-made GHG emissions stop in 2020, Nature Scientific Reports, November 12, 2020.
https://www.nature.com/articles/s41598-020-75481-z
West Antarctic Ice Sheet (WAIS) collapse triggers East Antarctic Ice Sheet (EIAS) collapse… Work from the German Environmental Institute (Potsdam) and Princeton shows that if ocean warming, the main trigger in the collapse of the WAIS, is not returned to the natural variability of our climate of about 0.5°C maximum warming above normal, by mid-century, complete collapse of the WAIS will be initiated. The authors' state that their modeling show that loss of the WAIS would trigger collapse of the EAIS.
Feldmann and Levermann, Collapse of the West Antarctic Ice Sheet after local destabilization of the Amundsen Basin, PNAS, November 17, 2015.
https://www.pnas.org/content/pnas/112/46/14191.full.pdf

(2) **Event Attribution science developed to understand if weather was enhanced by or caused by climate change…** World Weather Attribution – Rapid Climate Change Weather Event Attribution (A few samples below)
- Siberian heatwave of 2020 almost impossible without climate change.
- Australian Fire Weather Index as high as in 2019/20 catastrophic fire season has increased by more than a factor of four since 1900.
- The chance that rainfall of 14 inches in 24 hours and 28 inches in 48 hours experienced with Hurricane Imelda in southeast Texas in September

2019 has increased by 260 percent since 1900.
- The 2019 European heat wave's most extreme conditions in France and the Netherlands were made 100 times more likely with climate change. Https://WorldWeatherAttribution.org

(3) **Weather extremes increase much faster than the rate of warming because of the basics of physics…**
Basic physics tells us that evaporation increases nonlinearly with warming. Vapor pressure defines evaporation. At 0°C (freezing, 32°F) water vapor pressure is near zero, but at 30°C (86°F) water vapor pressure is over 30 times greater than at freezing. (See also the discussion of Nonlinear, Exponential, Asymptotic in the glossary.) http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch14/liquids.php
"For [heat] extremes exceeding a predefined threshold, the dependence on the warming trend is highly nonlinear."
Rahmstorf and Cuomou, Increase of extreme events in a warming world, PNAS, November 1, 2011.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3207670/pdf/pnas.1101766108.pdf

(4) **NPR and PBS Poll: Climate change now first priority among Democrats that are likely to vote…**
Poll: Climate Becomes Top Priority For Democrats; Trump Struggles On Race, COVID-19, September 19, 2020.
https://www.npr.org/2020/09/19/914233038/poll-climate-becomes-top-priority-for-democrats-trump-struggles-on-race-covid-19
NPR/PBS NewsHour/Marist Poll Results: Election 2020 & President Trump
http://maristpoll.marist.edu/npr-pbs-newshour-marist-poll-results-election-2020-president-trump/#sthash.vDZdQlL6.dpbs

(5) **Antarctic Ice Sheet Collapse is 100 years ahead of schedule…** Antarctic surface mass balance (SMB) in the 2007 IPCC Report was supposed to increase, not decrease, for all scenarios, through 2100. This means that snow accumulation was supposed to be more than melt, evaporation and iceberg discharge combined: "All studies for the 21st century project that Antarctic SMB changes will contribute negatively to sea level, owing to increasing accumulation exceeding any ablation increase (see Table 10.6)." (See also Reference 9 in Vision Statement)
Intergovernmental Panel on Climate Change, Fourth Assessment Report, Climate Change 2007: Working Group I: The Physical Science Basis, 10.6.4.1, Surface Mass Balance, fifth paragraph.
https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter10-1.pdf
The 2013 IPCC report tells us that Antarctic ice loss has almost caught up with Greenland. Summary for Policy Makers, E.3 Cryosphere, page 9, third bullet. "The average rate of ice loss from the Antarctic ice sheet has likely increased from 30 [–37 to 97] Gt yr–1 over the period 1992–2001 to 147 [72 to 221] Gt yr–1 over the period 2002 to 2011." Greenland, second bullet: "The average rate of ice loss from the Greenland ice sheet has very likely substantially increased from 34 [–6 to 74] Gt yr–1 over the period 1992 to 2001 to 215 [157 to 274] Gt yr–1 over the period 2002 to 2011."
http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

(6) **Permafrost collapse is 70 years…** (See Reference 8 in Vision Statement)

(7) **Amazon collapse is more than 100 years ahead of schedule Flipping From Carbon Sink to Carbon Source three times since 2005…** The Amazon has flipped from carbon sink to carbon source three times 2005, 2010, 2016, with 100-year or more extreme drought, each increasing in severity from the previous event. Flipping three times is a fair enough interpretation. In 2010, the Amazon was near neutral with carbon emissions of 0.07 gigaton C (256 megatons CO_2 equivalent.) The 2005 drought created emissions of 0.43 gigaton C (1.6 PgC reduction – 1.1 PgC) or 1.6 gigatons C. The 2016 drought was more severe than either, but the quantity of emissions has not yet been published.
2005 and 2010 Droughts… (Abstract) "Based on these ground data, live biomass in trees and corresponding estimates of live biomass in lianas and roots, we estimate that intact forests in Amazonia were carbon neutral in 2010 (-0.07 Pg C yr1 CI: -0.42, 0.23), consistent with results from an independent analysis of airborne estimates of land-atmospheric fluxes during 2010. Relative to the long-term mean, the 2010 drought resulted in a reduction in biomass carbon uptake of 1.1 Pg C, compared to 1.6 Pg C for the 2005 event." Therefore, if the 2010 drought was carbon neutral, the 2005 drought resulted in carbon emissions.
Feldpausch, Amazon forest response repeated droughts, Global Biogeochemical Cycles, July 1, 2016.
https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015GB005133
Yang et al. 2018, say that the 2005 Amazon drought continued to create carbon emissions through 2008 of 1.1 gigatons CO_2 per year.
Yang et al., Post-drought decline of the Amazon carbon sink, Nature, August 9, 2018.
https://www.nature.com/articles/s41467-018-05668-6
2016 Drought… (Abstract) Tropical and sub-tropical South America are highly susceptible to extreme droughts. Recent events include two droughts (2005 and 2010) exceeding the 100-year return value in the Amazon and recurrent extreme droughts in the Nordeste region, with profound eco-hydrological and socioeconomic impacts. In 2015–2016, both regions were hit by another drought. Here, we show that the severity of the 2015–2016 drought ("2016 drought" hereafter) is unprecedented based on multiple precipitation products (since 1900), satellite-derived data on terrestrial water storage (since 2002) and two vegetation indices (since 2004). The ecohydrological consequences from the 2016 drought are more severe and extensive than the 2005 and 2010 droughts. Empirical relationships between rainfall and sea surface temperatures (SSTs) over the tropical Pacific and Atlantic are used to assess the role of tropical oceanic variability in the observed precipitation anomalies. Our results indicate that warmer-than-usual SSTs in the Tropical Pacific (including El Niño events) and Atlantic were the main drivers of extreme droughts in South America, but are unable to explain the severity of the 2016 observed rainfall deficits for a substantial portion of the Amazonia and Nordeste regions. This strongly suggests potential contribution of nonoceanic factors (e.g., land cover change and CO_2-induced warming) to the 2016 drought.
Erfanian et al., Unprecedented drought over tropical South America in 2016 significantly under-predicted by tropical SST, Nature scientific Reports, July 19, 2017.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5517600/

(8) **A permanent Amazon flip now projected by 2035…** "The carbon sink in live aboveground biomass in intact African tropical forests has been stable for the three decades to 2015, at 0.66 tonnes of carbon per hectare per year (95 per cent confidence interval 0.53–0.79), in contrast to the long-term decline in Amazonian forests. Therefore the carbon sink responses of Earth's two largest expanses of tropical forest have diverged. The

difference is largely driven by carbon losses from tree mortality, with no detectable multi-decadal trend in Africa and a long-term increase in Amazonia."

Decline of the Amazon sink of 33 percent since 1990... "In summary, our results indicate that although intact tropical forests remain major stores of carbon and are key centres of biodiversity, their ability to sequester additional carbon in trees is waning. In the 1990s intact forests removed 17% of anthropogenic CO_2 emissions. This declined to an estimated 6% in the 2010s, because the pan-tropical weighted average per unit area sink strength declined by 33%, forest area decreased by 19% and anthropogenic CO_2 emissions increased by 46%. Although tropical forests are more immediately threatened by deforestation and degradation, and the future carbon balance will also depend on secondary forest dynamics and forest restoration plans, our analyses show that they are also affected by atmospheric chemistry and climatic changes. Given that the intact tropical forest carbon sink is set to end sooner than even the most pessimistic climate-driven vegetation models predict, our analyses suggest that climate change impacts in the tropics may become more severe than predicted."

Future of the tropical forest carbon sink… "Our carbon gain and loss models (Table 2) can be used to make a tentative estimate of the future size of the per unit area intact forest carbon sink (Fig. 3). Extrapolations of the changes in the predictor variables from 1983–2015 forward to 31 December 2039 (Extended Data Fig. 5) show declines in the sink on both continents (Fig. 3). By 2030 the carbon sink in aboveground live biomass in intact African tropical forest is predicted to decline by 14% from the measured 2010–15 mean to 0.57 Mg C ha^{-1} yr^{-1} (2σ range, 0.16–0.96; Fig. 3). The Amazon sink continues to rapidly decline, reaching zero in 2035." Interpretation – Hubau et al modelled past carbon sink decline into the future. This means that if current temperature and climatic trends continue, the Amazon sink will flip to emissions in 2035.

Hubau, Lewis et al., Asynchronous carbon sink saturation in African and Amazonian tropical forests, Nature, March 4, 2020.
(Researchgate free subscription)
https://www.researchgate.net/publication/339927383_Asynchronous_Carbon_Sink_Saturation_in_African_and_Amazonian_Tropical_Forests

UPDATE: Amazon collapse of 1 Gt annual CO2eq emissions 2010 to 2018… The current emissions are likely greater because this 1 Gt is an average, and the averaging period stopped in 2018 and it's not at all likely things have gotten better since. Tropical forests in Africa are a bit behind the Amazon, but couldn't be far and Asian tropical forests likely similar to the rest of the world.

Gatti et al., Amazonia as a carbon source linked to deforestation and climate change, Nature, July 14, 2021.
https://www.nature.com/articles/s41586-021-03629-6.epdf?sharing_token=lsfPlVRsW05dUMB_VD-zItRgN0jAjWel9jnR3ZoTv0NILaci0q8CXtVe4JKM-xF0Z0ZQpmJpnpSclAjJeIV-vCjviXK_Mb9hvvU5C3CiJVgu82-RGuHR01gFiQZAVMzDCCxiRyvlh0MBQxTvGN2oHmf2jIOC7MEEGXrOPGIblsh57v9qXkkZbM7U0OH8zbdQ4jnVO1zD9R1jeDcUVBS22YVLkjWEvC5vrNMdQ416fmEBL9kIHYs2ptVibFKXLxEuh-TQ08w-QGSFzN6221KgguYTe0Q9FoZ1J-Wksf4tWXrjv-xu34UpgYqxQWwLTTbTgHYTuglT_tSVd4WaweL9fg%3D%3D&tracking_referrer=www.theguardian.com

(9) **Globally, major hurricanes have increased 32 to 60 percent…** Findings in the Proceedings of the National Academy of Sciences in May 2020 (Kossin) showed major Cat 3 through 5 hurricane intensity has increased 32 percent average up to 60 percent globally from 1979 to 2017. Previous work showed only increases in intensity of Atlantic Basin hurricanes. Knutson 2020 showed a theoretical average intensity increase of 13 percent in Cat 4 and 5 tropical storms with 2°C warming. Considering 2°C would happen late 21st century, increasing hurricane intensity is more than 50 years ahead of projections.

Kossin et al, Global Increase in Major Tropical Cyclone Exceedance Probability Over the Last Four Decades, PNAS, May 4, 2020.pdf
(Paywall) https://www.pnas.org/content/117/22/11975
PNAS Press Release: Trends in tropical cyclone intensity
https://www.eurekalert.org/pub_releases/2020-05/potn-tit051320.php

Theoretical increase of 15% average for major hurricanes Cat 4 and 5 with 2°C warming…
Knutson et al., Tropical Cyclones and Climate Change - Part II, Projected Response to Anthropogenic Warming, BAMS, March 2020.
https://journals.ametsoc.org/bams/article/101/3/E303/345043/Tropical-Cyclones-and-Climate-Change-Assessment

(10) **Intense rainfall today is already triple the IPCC 2100 projection in Houston and double in Austin…** The 2013 IPCC report tells us that by 2081 to 2100, Houston will see up to a ten percent increase in total 5-day, 20-year precipitation accumulation. The USGS published total 5-day precipitation for the 25-year storm in our old climate was about 12 inches in Houston. In Atlas 14, the 25-year, 5-day storm depth is about 16 inches (interpolated), an increase of 39 percent — already, in 2018, not 2081 to 2100. The actual measured increase in precipitation extremes are 60 to 80 years ahead of schedule and three times as much as IPCC projected for 2100.

Austin… Austin increase ahead of projections: IPCC fig 12.26 shows up to a 10 percent increase in 5-day, 20-year precipitation maximum precipitation. Austin's 2004 5-day, 25-year was 9.5 inches. Atlas 14 shows the 5-day 25-year at about 11.4 inches (interpolated), an increase of 20 percent, double what IPCC projected for 2100.

Austin 100-year now the 25-year - http://www.austintexas.gov/page/flood-risk-and-atlas-14-details
IPCC AR5 2080 to 2100 projection: Scientific Basis, Chapter 12, Figure 12.26, page 1083.
https://www.ipcc.ch/report/ar5/wg1/
USGS, 5-day, 25-year event, 12 inches in Houston. 9.5 inches in Austin. Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas, USGS, 2004, Figure 50, page 57.
https://pubs.usgs.gov/sir/2004/5041/pdf/sir2004-5041.pdf
NOAA Atlas 14, 5-day, 25-year event, 16 inches in Houston, 11.4 inches in Austin…
https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html

Canada's forests are now emitting more CO2 than they are absorbing… Emitting 250 Mt annually, started net emissions in 2002 because of beetle kill. The rate of climate change is 10 to 100 times faster than Canada's forests can adapt. "Scientists predict that increasing temperatures and changes in weather patterns associated with climate change will drastically affect Canada's forests in the near future. With the rate of projected climate change expected to be 10 to 100 times faster than the ability of forests adapt naturally." And, "Traditionally, foresters have used local tree seed for planting seedlings, as local populations were generally thought to be best adapted to the climate conditions of the site. However, with a rapidly changing climate, these local populations may not be able to adapt quickly enough, and while well-established adult trees can often withstand increased stress, seedlings are highly vulnerable." From Seamus O'Regan, Minister of Natural Resources, Introductory Letter.

The State of Canadas Forests, Canadas Forests, Adapting to Change, Canadian Forest Service, 2020.
https://d1ied5g1xfgpx8.cloudfront.net/pdfs/40219.pdf

(11) **Southwestern North America in megadrought, currently worse than last 1200 years… S**outhwestern North America is 20 years in to a megadrought that rivals the worst megadrought in the last 1200 years. Naturally, these droughts can last for hundreds of years and are ten to a hundred times worse than the Dust Bowl, but this one is caused by human warming.
Williams, Large contribution from anthropogenic warming to an emerging North American megadrought, Science, April 17, 2020.
(Research Gate Free Subscription)
https://www.researchgate.net/publication/340697253_Large_contribution_from_anthropogenic_warming_to_an_emerging_North_American_megadrought

(12) **Not Smokey Bear's fault, wildfires increasing because of drying from perpetual drought…** In our old climate wildfires were increasing because of excess fuels accumulation because of fire suppression policies, but no longer. Most recent literature now says that drying, dryer fuels, bigger winds and easier ignition with warmer temperatures have created a world where climate change is now in charge of wildfires, and excess fuels are no longer of critical importance.
Lamont-Doherty Earth Observatory, Columbia University – Increased western wildfire due to increased aridity…
Abstract "Recent fire seasons have fueled intense speculation regarding the effect of anthropogenic climate change on wildfire in western North America and especially in California. During 1972–2018, California experienced a fivefold increase in annual burned area, mainly due to more than an eight fold increase in summer forest-fire extent. Increased summer forest-fire area very likely occurred due to increased atmospheric aridity caused by warming. Since the early 1970s, warm-season days warmed by approximately 1.4°C as part of a centennial warming trend, significantly increasing the atmospheric vapor pressure deficit (VPD). These trends are consistent with anthropogenic trends simulated by climate models. The response of summer forest-fire area to VPD is exponential, meaning that warming has grown increasingly impactful. Robust interannual relationships between VPD and summer forest-fire area strongly suggest that nearly all of the increase in summer forest-fire area during 1972–2018 was driven by increased VPD. Climate change effects on summer wildfire were less evident in nonforested lands. In fall, wind events and delayed onset of winter precipitation are the dominant promoters of wildfire. While these variables did not change much over the past century, background warming and consequent fuel drying is increasingly enhancing the potential for large fall wildfires. Among the many processes important to California's diverse fire regimes, warming-driven fuel drying is the clearest link between anthropogenic climate change and increased California wildfire activity to date."
Williams et al., Observed Impacts of Anthropogenic Climate Change on Wildfire in California, Earth's Future, August 4, 2019.
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019EF001210
Westerling - large California wildfires are increasing nonlinearly with drying and earlier onset of spring... "Increases in large wildfires associated with earlier spring snowmelt scale exponentially with changes in moisture deficit, and moisture deficit changes can explain most of the spatial variability in forest wildfire regime response to the timing of spring."
Westerling, Increasing western US forest wildfire activity, sensitivity to changes in the timing of spring, Philosophical Transactions of the Royal Society B, May 23, 2016, abstract.
http://rstb.royalsocietypublishing.org/content/371/1696/20150178
Climate Change Caused Wildfires: Columbia University, University of Idaho, Scripps Institution of Oceanography, University of Colorado Boulder... "During 1972–2018, California experienced a fivefold increase in annual burned area, mainly due to more than an eightfold increase in summer forest-fire extent. Increased summer forest-fire area very likely occurred due to increased atmospheric aridity caused by warming. Since the early 1970s, warm-season days warmed by approximately 1.4 °C as part of a centennial warming trend, significantly increasing the atmospheric vapor pressure deficit (VPD). These trends are consistent with anthropogenic trends simulated by climate models. The response of summer forest-fire area to VPD is exponential, meaning that warming has grown increasingly impactful. Robust interannual relationships between VPD and summer forest-fire area strongly suggest that nearly all of the increase in summer forest-fire area during 1972–2018 was driven by increased VPD. Climate change effects on summer wildfire were less evident in nonforested lands. In fall, wind events and delayed onset of winter precipitation are the dominant promoters of wildfire. While these variables did not change much over the past century, background warming and consequent fuel drying is increasingly enhancing the potential for large fall wildfires. Among the many processes important to California's diverse fire regimes, warming-driven fuel drying is the clearest link between anthropogenic climate change and increased California wildfire activity to date."
Williams et al., Observed Impacts of Anthropogenic Climate Change on Wildfire in California, American Geophysical Union, Earths Future, August 4, 2019.
https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019EF001210
A paper in the Journal Fire, by a team from the Cooperative Institute for Mesoscale Meteorological Studies… Summary and Conclusions: "most acute fire weather in over two decades… longest duration Santa Ana wind event in the 70-year record… the most extreme drought on record… lowest fuel moisture on record… driest March through December since 1895."
Nauslar et al., The 2017 North Bay and Southern California Fires, A Case Study, Fire, June 9, 2018.
https://www.mdpi.com/2571-6255/1/1/18/htm
400 Degrees Hotter - Wildfires are burning 400 degrees hotter because of drier fuels...
Wallace-Wells, Los Angeles Fire Season Is Beginning Again. And It Will Never End. A bulletin from our climate future.
By David Wallace-Wells, NYMag, May 12, 2019.
http://nymag.com/intelligencer/2019/05/los-angeles-fire-season-will-never-end.html

(13) **Forests failing to regenerate after fire have doubled since 2000…**
Stevens-Rumann et al., Evidence for declining forest resilience to wildfires under climate. Ecology Letters, December 12, 2017.
https://www.researchgate.net/profile/Monica_Rother/publication/321753770_Evidence_for_declining_forest_resilience_to_wildfires_under_climate_change/links/5a315ae90f7e9b2a284cea8f/Evidence-for-declining-forest-resilience-to-wildfires-under-climate-change.pdf

(14) **New drought type - ecological drought…** "Droughts of the 21st century are characterized by hotter temperatures, longer duration and greater spatial extent, and are increasingly exacerbated by human demands for water. This situation increases the vulnerability of ecosystems to drought, including a rise in drought-driven tree mortality globally (Allen et al. 2015) and anticipated ecosystem transformations from one state to another, e.g., forest to a shrubland (Jiang et al. 2013)."
Crausbay et al, Defining Ecological Drought for the Twenty-First Century BAMS, December 2017.
https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-16-0292.1

(15) **Sea level rise is currently following the Intergovernmental Panel on Climate Change (IPCC) worst-case scenario…**
Slater et al., Ice-sheet losses track high-end sea-level rise projections, Nature Climate Change, August 31, 2020.
(Paywall) https://www.nature.com/articles/s41558-020-0893-y

(16) **Sea level rise in Continental US average 2018 to 2019 an astonishing 1.5 inches or 38 mm, ten times the global long term average…** (See Reference 10 in the Vision Statement.)

(17) **Impacts from sea level rise to risk $14.2 Trillion across the globe with 10 to 20 inches of rise…** See Reference 7 in Vision Statement. Sea level rise impacts are not time and scenario dependent… Temperature is not meaningful indicator metric … Example: if ice sheet collapse was considered in sea level rise costs, the latest publishing shows $14.2 trillion assets at risk with 10 to 20 inches of sea level rise at 2050 to 2080 based on the worst-case RCP8.5 scenario. This is far higher than consensus impacts because it is a more robust analysis using latest publishing knowledge. Compounding the understatement of consensus impacts though is ice sheet collapse that is disregarded by the consensus. NOAA includes some ice sheet collapse and their Sweet 2017 projections (see next reference) of 14 inches worst-case by 2030. Because prudent planning considers a relatively rare 100-year event, and worst-case projections are similar in probability of occurrence, we should absolutely be using 14 inches by 2030 for $14.2 trillion in sea level rise impacts annually. (See more at the Safety actor discussion in Appendix 1)
From Kirezci 2020 (press release), Using RCP8.5 projections of 10 inches by 2050 and 20 inches by 2080, assets at risk will rise up to $US14.2 trillion. It mostly does not matter when sea level rise happens, damages will be the same in $US today. RCP8.5 and the IPCC work defining impacts with this scenario are significantly understated because they do not take into consideration ice sheet collapse. NOAA is not as understated as IPCC and their Sweet 2017 includes some ice sheet collapse with their worst-case projection of 14 inches by 2030. (Worst-case is similar to the 100-year storm and must be used for planning purposes) So by based on NOAA, we can expect $14.2 trillion of damages to at risk assets by 2030, not 2050 to 2080. It is also important to note that this is the one time value of these assets. Rebuilding after damages puts many of these assets at risk again, and because the risks increase nonlinearly with further warming, they can be expected to recur thus increasing the $14.2 trillion figure considerably.
Kirezci et al., Projections of global-scale extreme sea levels and resulting episodic coastal flooding over the 21st Century, Nature, July 30, 2020.
https://www.nature.com/articles/s41598-020-67736-6.pdf
Press Release, University of East Anglia
https://www.eurekalert.org/pub_releases/2020-07/uoea-cfs072920.php

(18) **NOAA's 2017 sea level rise report projects worst-case of 14 inches by 2030…** NOAA defines this rate of tidal flooding as when the 5-year tide becomes the tide that happens five or more times per year. "The median value in Figure 15d is about 0.35 m, with a range from about 0.1 m to 1.1 m. Thus, for most of U.S. tide gauge locations examined (108 locations; 90 along U.S. coastlines outside Alaska), with an additional 0.35-m rise (<14 in) in RSL, exposure to disruptive/damaging tidal flooding will become much more commonplace… Considering RSL under the Low, Intermediate-Low, Intermediate and Intermediate-High scenarios (Figure 16a–d), disruptive/damaging tidal flooding will occur five or more times a year at most locations (90 cities) along the U.S. coastline (outside Alaska) by or about (±5 years) 2080, 2060, 2040 and 2030, respectively." The importance of the worst-case scenario cannot be understated. The extremes are the driving force in damages and climate science and policy do not meaningfully consider safety factors. (See more at the Safety Factor discussion in Appendix 1)
NOAA Sweet 2017 Includes ice sheet collapse… NOAA's sea level rise report in 2017 moves significantly forward in including ice sheet collapse in future sea level rise projections. Below are quotes from the report on why and how ice sheet collapse was included. "Decision-makers charged with planning for upgrades to existing long-life critical infrastructure… need to consider the risks across a broad range of possible outcomes, including those associated with high-consequence, low-probability situations." … "To obtain GMSL rise estimates whose ranges extend beyond AR5, additional assumptions are included within a particular probabilistic framework. A few examples include reliance on structured expert elicitation of potential ice-melt contributions not captured in the process models (Bamber and Aspinall, 2013) or from geologic evidence comparing past sea levels and atmospheric greenhouse gas concentrations (Rohling et al., 2013) or temperature (Kopp et al., 2016a). Under such frameworks, estimates of high-end GMSL rise by 2100 under RCP8.5 include ~1.8 m [95th percentile] (Jevrejeva et al., 2014, Rohling et al., 2013 and Grinsted et al., 2015), ~2.2 m [99th percentile] (Jackson and Jevrejeva, 2016), and ~2.5 m [99.9th percentile] (Kopp et al., 2014)." … "Recent modeling of physical feedbacks related to marine ice-cliff instabilities and ice-shelf hydrofracturing (rain and meltwater-enhanced crevassing and calving) used within the physical process models generating GMSL estimates are being incorporated into ice-sheet models (Pollard et al., 2015). With such feedbacks modeled for Antarctica, additional GMSL rise upwards of 0.6–1.1 m to median estimates under RCP8.5 are possible by 2100 (DeConto and Pollard, 2016), potentially raising median GMSL projections for RCP8.5 of Kopp et al. (2014) as high as 1.9 m by 2100. Meanwhile, in Greenland, there are indications that processes already underway have the potential to lead to an accelerating high-end melt risk. Important changes in surface albedo are occurring in response to ice melt and associated unmasking and concentration of impurities in snow and ice (Tedesco et al. 2016). At the base of the ice sheet, important changes in ice dynamics are occurring, through interactions with surface runoff and a warming ocean, which may make the Jakobshavn Isbræ, Kangerdlugssuaq Glacier, and the Northeast Greenland ice stream vulnerable to marine ice sheet instabilities (Khan et al., 2014)." … "The growing evidence of accelerated ice loss from Antarctica and Greenland only strengthens an argument for considering worst-case scenarios in coastal risk management. Miller et al. (2013) and Kopp et al. (2014) discuss several lines of arguments that support a plausible worst-case GMSL rise scenario in the range of 2.0 m to 2.7 m by 2100."
Sweet et al., Global and Regional Sea Level Rise Scenarios for the United States, NOAA, January 2017.
https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf

(19) **Sea level rise costs of $10.2 trillion with 20 inches sea level rise, $14 trillion with 34 inches up to $27 trillion per year with 70 inches…** Sea level rise cost projections are based on scenarios where a certain amount of sea level rise occurs at a certain time with a certain amount of

warming according to the scenario. Because ice sheet collapse can disconnect from total warming and proceed far faster than simply ice cube melt modeling, and because there are yet no climate models that robustly project ice sheet collapse. Scenario-based sea level rise cost projections need to be interpreted with caution because whenever sea level rises by a certain amount –regardless of the time frames—most if not all of projected damages will occur. Jevrejeva 2018 evaluated annual sea flood costs with total annual coasts projected under global sea level of 0.52 m (20 inches) with warming of 1.5 ◦C, 0.63 m (25 inches) with warming of 2 ◦C (table 1), 0.86 m (34 inches) for RCP8.5_J14 (median) and 1.8 m (70 inches) RCP8.5_J14 (95th percentile.) By the end of the 21st century global annual flood costs are projected to be US$ 10.2 trillion per year (1.8% of GDP) under 1.5 ◦C and US$ 11.7 trillion per year (2.0%GDP) under 2 ◦C scenario, if no further adaptation is undertaken. If the 2 ◦C target is missed, and we follow the RCP8.5_J14 scenario (median sea level rise of 0.86m and 95th percentile of 1.8m in 2100), global annual flood costs without additional adaptation are projected to be US$ 14.3 trillion per year (2.5% of GDP) for the median scenario and up to US$ 27.0 trillion per year for the 95th percentile (figure 4(a)), accounting for 4.7% of global GDP (table S4).
Jevrejeva et al., Flood damage costs under the sea level rise with warming of 1.5 and 2C, Environmental Research Letters, July 4, 2018.
http://iopscience.iop.org/article/10.1088/1748-9326/aacc76/pdf
IPCC - Maximum Adaptable Sea level Rise of three feet per century, with exceedance resulting in economic collapse… Adaptability limit to SLR of three feet per century: Greater than three feet per century results in unrecoverable economic scenarios… IPCC tells us that "Nicholls et al. (2011) show that only a limited number of adaptation options are available for specific coastal areas if sea level exceeds a certain threshold (1 m) at the end of the century."
Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, page 393, paragraph 10.
https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf
Nichols et al., Sea-level rise and its possible impacts given a beyond 4C world in the twenty-first century, Phil Trans Royal Society, 2011. ResearchGate (Free Subscription required) https://www.researchgate.net/publication/49643248_Sea-level_rise_and_its_possible_impacts_given_a_'beyond_4_degrees_C_world'_in_the_twenty-first_century

(20) **More than half of Earth systems collapse climate tipping systems are now active more than 100 years ahead of schedule…** (See reference 4, Vision Statement)

(21) **Climate Change Countermovement…** From 2003 to 2010, $7 billion in climate change counter-movement funding has been identified from revenues reported in IRS tax returns for 91 of 118 organizations and institutions identified in the academic literature as being involved. The research from Drexel and Stanford concludes: "With delay and obfuscation as their goals, the U.S. CCCM has been quite successful in recent decades. However, the key actors in this cultural and political conflict are not just the "experts" who appear in the media spotlight. The roots of climate-change denial go deeper, because individuals' efforts have been bankrolled and directed by organizations that receive sustained support from foundations and funders known for their overall commitments to conservative causes. Thus to fully understand the opposition to climate change legislation, we need to focus on the institutionalized efforts that have built and maintain this organized campaign. Just as in a theatrical show, there are stars in the spotlight. In the drama of climate change, these are often prominent contrarian scientists or conservative politicians, such as Senator James Inhofe. However, they are only the most visible and transparent parts of a larger production. Supporting this effort are directors, script writers, and, most importantly, a series of producers, in the form of conservative foundations. Clarifying the institutional dynamics of the CCCM can aid our understanding of how anthropogenic climate change has been turned into a controversy rather than a scientific fact in the U.S."Brulle, Institutionalizing delay: foundation funding and the creation of U.S. climate change counter-movement, Climatic Change, December 2013. https://climateaccess.org/system/files/Brulle_Institutionalizing%20Delay.pdf

(22) **False Balance in the Media Reduces Climate Science Credibility…** "Journalists have struggled historically to apply the notion of balance to the reporting of climate change science, because even though the overwhelming majority of the world's experts agree that human-driven climate change is real and will have major future impacts, a minority of scientists dispute this consensus. Reporters aimed to be fair by giving both viewpoints equal attention, a practice scholars have labeled false balance." This report from The Oxford English Dictionary by Declan Fahy of Dublin City University.
Objectivity, False, Balance, and Advocacy in News Coverage of Climate Change, Oxford English Dictionary, March 2017.
http://climatescience.oxfordre.com/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-345
Manipulated Public Opinion… Public knowledge is over 30 years behind climate scientists'; concern has only increased four percent since in 30 years... Americans who worried about global warming a "great deal" or a "fair amount" -- 1989, 1990, 1991, 63%, 57%, 62% (average 61%); 2017, 2018, 2019 – 66%, 63%, 65% (average 65%)
Americans' Views on Global Warming, Trends (2019), Gallup.
https://news.gallup.com/poll/248030/americans-views-global-warming-2019-trends.aspx
Data: https://news.gallup.com/file/poll/248030/190325ClimateChange.pdf
Authority Figures and Weather Extremes Can Influence Public Opinion on Climate Change… "When elites have consensus, the public, follows suit and the issue becomes mainstreamed."
Climate Change Cues: Brulle et al., Shifting public opinion on climate change. An empirical assessment of factors influencing concern over climate change in the US 2002 to 2010, Climatic Change, Feb 2012, conclusions.
http://www.pages.drexel.edu/~brullerj/02-12ClimateChangeOpinion.Fulltext.pdf
Only one percent of climate scientists rate broadcast or television news as very reliable … "Only 1 percent of climate scientists rate broadcast or television news as very reliable and 3 percent rate local newspapers as very reliable, while 26 percent rate Al Gore's An Inconvenient Truth as very reliable."
Climate Scientists Agree on Warming, Disagree on Dangers, and Don't Trust the Media's Coverage of Climate Change, George Mason University, STATS, 2008.
http://web.archive.org/web/20080516220640/http://www.stats.org/stories/2008/global_warming_survey_apr23_08.html
Not all climate scientists are equal, and the media does not know enough about their subject… Media tendencies to present both sides in the climate change debate skews public knowledge, which can contribute to continued public misunderstanding. The relative climate expertise and scientific prominence of the researchers unconvinced of ACC are substantially below that of the convinced researchers.

Anderegg, et. al., Expert Credibility in climate change, PNAS April 2010.
https://www.pnas.org/content/pnas/early/2010/06/04/1003187107.full.pdf
False balance in the media, still bad… Since the 2000s, False balance seems to have been reduced in the media, maybe a little, but the scope of this work as stated by the authors is not complete enough to include far right media outlets in the U.S. My interpretation is that false balance is getting better, but false bias is still really bad.
Brueggemann and Engesser, Beyond false balance, How interpretive journalism shapes media coverage of climate change, Global Environmental Change, January 2017.
(Researchgate free subscription required)
https://www.researchgate.net/publication/312015168_Beyond_false_balance_How_interpretive_journalism_shapes_media_coverage_of_climate_change
The perceived Debate and the Fairness Bias…"Through content analysis of US prestige press— meaning the New York Times, the Washington Post, the Los Angeles Times, and the Wall Street Journal—this paper focuses on the norm of balanced reporting, and shows that the prestige press's adherence to balance actually leads to biased coverage of both anthropogenic contributions to global warming and resultant action."
Boykoff and Boykoff, Balance as Bias Global warming and the US Prestige Press, Global Environmental Change, 2004.
https://www.eci.ox.ac.uk/publications/downloads/boykoff04-gec.pdf
Data mining to show bias in media reporting of climate change… Abstract - Although agreement among scientists on anthropogenic climate change is clear, national surveys show that the American public's perceptions on the science of climate change diverge significantly from the "consensus view". Some scholars point to the mass media as being largely responsible for this divergence. By providing disproportionate amounts of attention to climate change contrarians, many news outlets are, in effect, presenting a "biased" view of climate science. This paper applies automated text analytic techniques to compare levels of information bias" in American television news coverage over the period January 2000-February 2013.
Coan, Balance as Bias Revisited, Harnessing the Power of Text Mining to Understand Media Coverage of Climate Change, Harvard, Western Political Science Association Conference, March 30, 2013.
http://www.wpsanet.org/papers/docs/boussalisandCoan.pdf

(23) **Climate Emergency Declaration by 13,000 scientists…** (see Reference 5, Vision Statement)

1.2 The Inequity of 1.5 C

(1) **The 25% gap between world's richest and poorest countries…** "The gap between the economic output of the world's richest and poorest countries is 25 percent larger today than it would have been without global warming, according to new research from Stanford University."
Stanford Press Release
https://earth.stanford.edu/news/climate-change-has-worsened-global-economic-inequality#gs.gq085l
Diffenbaugh and Burke, Global warming has increased global economic inequality, PNAS, May 14, 2019.
https://www.pnas.org/content/116/20/9808

(2) **In the United States, climate change already impacts the poorest most**… "In the United States, for example, the effects of climate change are disproportionately felt by the least privileged, and so climate becomes another conduit for reinforcing existing inequalities."
The Conversation, Inequality and climate change: the rich must step up, June 23, 2019.
https://theconversation.com/inequality-and-climate-change-the-rich-must-step-up-119074
Hsiang et al., Estimating economic damage from climate change in the United States, Science, June 30, 2017.
https://science.sciencemag.org/content/356/6345/1362/tab-pdf

(3) **IPCC, Net-zero cannot meet 1.5 C target, up to 1,000 Gt CO2 removal required…** Between 100 and 1000 gt CO_2 must be removed from the atmosphere, in addition to achieving net zero emissions, so as to limit warming to 1.5 C, according to the executive summary of the IPCC 1.5 C Report. At 1,000 Gt, this is basically all of the CO_2 ever emitted that remains in our sky. (See Section 1.3.3 reference 4) **Half of CO_2 remains in our sky for 300 years, the rest forever.)** It is very important to note that the body of the IPCC report seems to indicated the amount of CO_2 we must remove from the sky is much nearer 1,000 Gt CO_2 than 100. The reason why the resulting temperature is not lower than 1.5 C if we removed all of the CO2 ever emitted is the other excess greenhouse gases that humankind has emitted that remain in our sky, like methane nitrous oxide and chlorofluorocarbons (refrigerants.)
IPCC 1.5 C Report Executive Summary 100 to 1,000 Gt CO_2 removal, Page 15.
https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf
Deeper analysis of the 1.5 C report shows that the 100 Gt range is not generally a part of the detailed presentation in the remainder of the report. Figure 2.13.c, Chapter 2, Mitigation Pathways, shows the cumulative amount of CDR needed to achieve 1.5 C by 2100 that includes a range of 100 to 1,250 Gt, not 100 to 1,000 Gt as stated in the Summary for Policymakers. Graph c in Figure 2.13 depicts this range with the blue dashed lines, with the green dashed line the most likely outcome.
IPCC 1.5 C, Chapter 2, Figure 2.13, page 128:
https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter2_Low_Res.pdf
Carbon Brief Summary of 1.5 C Report – IPCC's 100 to 1,000 Gt CDR Understatement…Carbon Brief interview with Oliver Greden, head of the research at the German Institute for International and Security Affairs say, "Compared to the full report, the SPM paints too rosy a picture on this. The SPM talks about 100-1,000Gt CO_2 removal by 2100. But the report itself shows a mean CDR value much closer to the upper end of the 100-1,000GtCO_2 range."
In-depth Q&A: The IPCC's special report on climate change at 1.5C, Carbon Brief, August 10, 2018.

Quote from Section: What role will 'negative emissions' play in limiting warming to 1.5C? Seventh paragraph.
https://www.carbonbrief.org/in-depth-qa-ipccs-special-report-on-climate-change-at-one-point-five-c

Section 1.3 – A Safe and Equitable "Less Than 1.0°C Warming Target"

(1) Hansen's 1988 Testimony… One of the first national calls to address climate pollution.
New York Times article, June 24, 1988.
https://www.nytimes.com/1988/06/24/us/global-warming-has-begun-expert-tells-senate.html
Testimony Transcript - U.S. Senate Committee on Energy and Natural Resources, The greenhouse effect impacts on current global temperature and regional heat waves, James Hansen Testimony, June 23, 1988.
http://image.guardian.co.uk/sys-files/Environment/documents/2008/06/23/ClimateChangeHearing1988.pdf

(2) Origin of the 350 ppm CO_2 warming target… James Hansen's "Target Atmospheric CO_2: Where Should Humanity Aim?" published in *Open Atmospheric Science*, was the first time a limit to warming had been suggested in the literature that was less that the 525 ppm CO_2 of 2.0 C degrees above normal.
Hansen et al., Target Atmospheric CO_2: Where should humanity aim?, Open Atmospheric Science, March 15, 2008.
https://pubs.giss.nasa.gov/docs/2008/2008_Hansen_ha00410c.pdf

1.3.1 Target Atmospheric CO2

(1) Origin of 350 ppm CO2 Target… See Section 1.3, reference 2.

(2) Mauna Loa 411 ppm CO_2 **2019…** The average CO_2 concentration at Mauna Loa Earth System Research Observatory in 2019 was 411 ppm.
https://gml.noaa.gov/webdata/ccgg/trends/co2/co2_annmean_mlo.txt

(3) Normal CO_2 **of 280 ppm prior to 1850…** NASA
https://climate.nasa.gov/vital-signs/carbon-dioxide/

(4) Rijsberman and Swart 1990 on 2.0 C degrees above normal limit to dangerous climate change, not arbitrary but a reasoned scientific evaluation… The actual designation of the 2C dangerous limit to warming comes from Stockholm Institute and is not arbitrary but a reasoned scientific evaluation. This evaluation was sponsored by the World Meteorological Organization (WMO) and United Nations Environmental Program (UNEP) very specifically for the new Intergovernmental Panel on Climate Change (IPCC) to assign a warming limit to dangerous climate change.
The results of this effort were from a working advisory group and edited by Rijsberman and Swart. The considered not only 2C, but 1C too and when reflected upon today the 1 C limit was very insightful and accurate far beyond the knowledge of the day, Whereas the 2 C limit was just the 1 C limit carried a slight bit further. Below are the money shots from the report:
"Beyond 1.0°Cmay elicit rapid, unpredictable, and non-linear responses that could lead to extensive ecosystem damage."
"An absolute temperature limit of 2.0 °C can be viewed as an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly."
These rapid, unpredictable, and non-linear responses are what we are seeing today as active climate tipping or abrupt Earth systems collapses. They happen 10 to 100 times faster and more extreme than what we see in climate modeling upon which our climate polices are based.
Melton Opinion -- This wording is in my opinion simply extraordinary. And the fact that it has been the guiding basis for everything we have attempted to do in our efforts to keep our world from being harmed is even more extraordinary. In that, how in the world did we decide that 2 degrees C was an appropriate target? instead of 1 degree C? Golly.
Rijsberman and Swart, Targets and Indicators of Climate Change, The Stockholm Environmental Institute, 1990. One degree C is page viii, last paragraph, 2 degrees C is first paragraph, page ix.
https://mediamanager.sei.org/documents/Publications/SEI-Report-TargetsAndIndicatorsOfClimaticChange-1990.pdf

(5) Intergovernmental Panel on Climate Change 1.5 C Report… This report did not set a new target for warming of 1.5 C. What it did was to lay out the lesser impacts on a 1.5 C degrees above normal world as compared to a 2 C world. Because their findings were so compelling, our climate culture has popularly adopted 1.5 C as the new de facto limit to climate warming. The report is based on observations from 6,000 peer-reviewed publications.
Masson-Delmotte et al., Global Warming of 1.5°C : An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, IPCC, 2018.
https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

(6) 10 to 100 times more extreme… Specifically, heat extremes are happening 10 to 100 times more frequently. Abstract: "This hot extreme, which covered much less than 1% of Earth's surface during the base period, now typically covers about 10% of the land area." Discussion, page 6 of 9, third paragraph: "These extreme temperatures were practically absent in the period of climatology, covering only a few tenths of one percent of the land area, but they are occurring over about 10% of global land area in recent years…. It follows that we can state, with a high degree of confidence, that extreme anomalies such as those in Texas and Oklahoma in 2011 and Moscow in 2010 were a consequence of global warming because their likelihood in the absence of global warming was exceedingly small."
Hansen, Sato, Ruedy, Perception of Climate Change, Proceedings of the National Academy of Science of the United States of America (PNAS), August 2012. http://www.pnas.org/content/early/2012/07/30/1205276109.full.pdf+html

1.3.2 "Young People's Burden: Requirement of Negative CO2 Emissions"

(1) **First modeling of temperature response with 350 ppm CO_2…** James Hansen's "Young people's burden" paper in 2017 was the forest modeling of what temperature response occurred with 350 ppm CO_2.
Hansen et al., Young people's burden-requirement of negative CO_2 emissions, Earth Syst. Dynam., July 18, 2017.
https://www.earth-syst-dynam.net/8/577/2017/esd-8-577-2017.pdf

1.3.3 Austin's Historic Climate Pollution Burden (Legacy Emissions)

(1) **Baked in warming, warming in the pipeline, or committed warming…** Range of additional warming with zero further meissions of greenhouse gases is 0.5 C to 4.3 C, but 4.3 C is equilibrium sometimes post 2300.
IPCC 1.5 C Report committed warming of 0.5 C average, up to 1.2 C above 2020… Beginning in 2020, zero CO_2 and aerosol emissions, and constant non-CO_2 GHG forcing equals 0.5 C average additional warming by 2100, up to 1.2 C above 2020 max.
Worst-case IPCC, Zero CO_2 and aerosol emissions, constant non-CO_2 GHG forcing (green line) = 2.2 C above pre-industrial at 2100.
IPCC 1.5 C, Chapter 1, Figure 1.5, page 65.
https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter1_Low_Res.pdf
Committed warming of up to 7.5 degrees F in the pipeline … (no cooling from aerosols) "The observed increase in the concentration of greenhouse gases (GHGs) since the pre-industrial era has most likely committed the world to a warming of 2.4°C (1.4°C to 4.3°C) above the pre-industrial surface temperature. The estimated warming of 2.4°C is the equilibrium warming above pre-industrial temperatures that the world will observe even if GHG concentrations are held fixed at their 2005 concentration levels but without any other anthropogenic forcing such as the cooling effect of aerosols."
Ramanthan and Feng, On avoiding dangerous anthropogenic interference with the climate system-Formidable challenges ahead, *PNAS*, September 2008, abstract.
http://www.pnas.org/content/early/2008/09/16/0803838105.full.pdf
Hansen 1.4 C committed warming at 385 ppm CO_2**…** The remaining gap between equilibrium temperature for current atmospheric composition and actual global temperature is ~1.4°C. This further 1.4°C warming still to come is due to the slow surface albedo feedback, specifically ice sheet disintegration and vegetation change.
Hansen et al Target Atmospheric CO_2 Where Should Humanity Aim Open Atmospheric Science Journal, November 2008 Highlights.
http://pubs.giss.nasa.gov/docs/2008/2008_Hansen_etal_1.pdf
Committed Warming with Net Zero… With zero emissions beginning immediately, global temperature will only fall back to 2000 levels in the next 200 years.
Mathews and Weaver, Committed Climate Warming, Nature, March 2010.
http://tinyurl.com/zyrq5m8

(2) **30 to 50 years for oceans to come into equilibrium…**
Hansen - "The lag could be as short as a decade, if climate sensitivity is as small as 0.25-C per W/m2 of forcing, but it is a century or longer if climate sensitivity is 1-C perW/m2 or larger (1, 3). Evidence from Earth_s history (3–6) and climate models (7) suggests that climate sensitivity is 0.75- T 0.25-C perW/m2, implying that 25 to 50 years are needed for Earth's surface temperature to reach 60% of its equilibrium response (1)."
Hansen, Earth's Energy Imbalance: Confirmation and Implications, Science, June e, 2005.
https://pubs.giss.nasa.gov/docs/2005/2005_Hansen_ha00110y.pdf
Zickfeld - Abstract, "In a recent letter, Ricke and Caldeira (2014 Environ. Res. Lett. 9 124002) estimated that the timing between an emission and the maximum temperature response is a decade on average. In their analysis, they took into account uncertainties about the carbon cycle, the rate of ocean heat uptake and the climate sensitivity but did not consider one important uncertainty: the size of the emission. Using simulations with an Earth System Model we show that the time lag between a carbon dioxide (CO_2) emission pulse and the maximum warming increases for larger pulses. Our results suggest that as CO_2 accumulates in the atmosphere, the full warming effect of an emission may not be felt for several decades, if not centuries. Most of the warming, however, will emerge relatively quickly, implying that CO_2 emission cuts will not only benefit subsequent generations but also the generation implementing those cuts."
Zickfeld and Herrington, The time lag between a carbon dioxide emission and maximum warming increases with the size of the emission, Env. Research Letters, March 10, 2015.

https://iopscience.iop.org/article/10.1088/1748-9326/10/3/031001/pdf

(3) **693 MmtCO2eq (million metric tons) and as CO2 about 576 million tons…** Derived from a straight-line backcast of the Austin Community Climate Plan 201, Implementation, Phase 1, page 1. Backscasting of emissions growth of CO2eq was done from existing 2010 to 2015 emissions from the 2015 plan with a linear inflection at about 1940. A more accurate evaluation would likely show a different emissions trajectory based on nonlinear population growth and carbon intensity. CO2eq to CO2 was calculated using the NOAA Greenhouse Gas Index in the Glossary on page 71.

(4) **Half of CO_2 remains in our sky for 300 years, the rest forever** - Atmospheric life of CO_2 and Methane… Carbon dioxide stays in our sky for 300 years … "In fairness, if the fate of anthropogenic carbon must be boiled down into a single number for popular discussion, then 300 years is a sensible number to choose, because it captures the behavior of the majority of the carbon. … However, the 300 year simplification misses the immense longevity [10,000 years] of the tail on the CO_2 lifetime, and hence its interaction with major ice sheets, ocean methane clathrate deposits, and future glacial/interglacial cycles … A better approximation of the lifetime of fossil fuel CO_2 for public discussion might be 300 years, plus 25% that lasts forever."
Archer, Fate of fossil fuel CO_2 in geologic time, Journal of Geophysical Research, vol. 110, 2005, page 5 of 6, Summary, final Paragraph.
https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2004JC002625

(5) **Earth systems absorb half of CO_2 emissions instantaneously for emissions accounting and discussion of reemissions…** Half of emitted CO_2 is absorbed or made harmless by Earth's systems once it is emitted. All CO_2 behaves the same no matter its age (fossil or contemporary). Half is absorbed "instantly" or apparently, for accounting warming purposes, because current emissions are only a tiny fraction of warming forcing, and because greenhouse gas warming is a net effect system. So instead of our historic CO_2 burden being all of the greenhouse gases we have ever emitted, it is approximately only half of what we emitted or 288 Mt in Austin. (See reference 3 above)
Total CO2 in our atmosphere and fraction of CO2 emitted by humans annually… 1 ppm CO2 is equal to 7.8 Gt CO2 and our current atmospheric concentration of CO2 in 2020 was 411 ppm which is 3206 Gt CO2. human's annual emissions of 40 Gt is 1.3 percent of all the CO2 in the sky.
Think of it this way… If all of us removed all of the CO2 we ever emitted from our sky, or 2404 Gt CO2 emissions from humans equals 308 ppm CO2 at 7.8 Gt CO2 per ppm, our atmospheric CO2 concentration would be 103 ppm, considering it was 411 ppm in 2019. This would be far less than half the 280 ppm CO2 concentration of pre-industrial times.
Total Global Emissions: "From 1750 to 2011, CO2 emissions from fossil fuel combustion and cement production have released 375 [345 to 405] GtC to the atmosphere, while deforestation and other land use change are estimated to have released 180 [100 to 260] GtC. This results in cumulative anthropogenic emissions of 555 [470 to 640] GtC."
555 GtC at 3.667 GtCO2 per GtC – 2035 Gt total global CO2 Emissions from 1750 to 2011.
IPCC 2013, Scientific Basis, Summary for Policymakers, page 12, second bullet.
http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf
Emissions from 2011 to 2020: 9 years at an average of 39 Gt CO2 emission per year globally from fossil fuels, agriculture, forests, and land use changes is 351 Gt CO2.
http://cms2018a.globalcarbonatlas.org/en/content/global-carbon-budget
TOTAL CO2 emissions from fossil fuels, cement, ag, forests, land use changes 1750 through 2020 is 2035 + 351 = 2386 Gt CO2
Re-emissions: Some of the half of CO2 that is "instantaneously" absorbed by Earth systems will return to the atmosphere once atmospheric CO2 returns to a level below the equilibrium concentration. Because it takes about 50 years for our Earth systems and climate to come into equilibrium, outgassing and re-emission of CO2 from oceans, soils and forests will commence when our CO2 concentration falls to the level it was 50 years ago, about 325 ppm CO2. Once outgassing and re-emission begins it will proceed along time frames similar to or slower than the rate it was absorbed because much of the CO2 in our oceans is sequestered at depth with a many century circulation time, and much was stored in forests that are long-lived, and much was sequestered in soils as minerals that return to the atmosphere with difficulty.
Oceans and land absorb half of CO_2 - Ocean Carbon Cycle IPCC AR5, 2013, Chapter 6, Figure 6.1
https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter06_FINAL.pdf
NOAA Annual Greenhouse Gas Index, AGGI, CO_2 **and** CO_2eq **-**
CO_2/CO_2eq based on radiative forcing interpolated from Figure 5
https://www.esrl.noaa.gov/gmd/aggi/aggi.html
CO2 lower than the last 300 million years…
Mills, Modelling the long-term carbon cycle, atmospheric CO2, and Earth surface temperature from late Neoproterozoic to present day, Gondwana Research, December 11, 2018.
https://reader.elsevier.com/reader/sd/pii/S1342937X18302818?token=687B2C7D944159B49FD669749D7CD27FDC5E432BA69F52D2FCFDBE6D40B7EC5012E06012CA445AE945308D67F4159279
US historic CO2 emissions…
https://www.epa.gov/ghgemissions/overview-greenhouse-gases#carbon-dioxide

(6) **Comparison of Future and Historic Emissions Reductions…** There are two ways to compare historic and net-zero climate pollution burden. Historic burden is easy, you remove it from the atmosphere and it's gone. With emissions reductions though, some are replaced with new tech, some with behavioral changes and some cannot be halted so we must offset those, at least until new tech comes along. And of course, the results of removing historic pollution are a lowering of Earth's temperature, whereas net-zero allows further warming because of warming in the pipeline. Caveats - The above is simplified. Removing CO2 from the sky and emissions reductions are not directly comparable. Lowering Earth's temp with CDR only happens when we remove enough CO2 to balance the disequilibrium we are currently experiencing. The offsets needed to achieve net-zero must occur continually, until tech is developed to decarbonize. Net-zero can also not stop unrecoverable tipping, which is very difficult to compare with some things like CDR that can stop tipping. But the goal here is to compare the relative amount of effort required to deal with historic and future emissions responsibly, so that we can understand the amount of priority we place on either action. So how do we most meaningfully compare the two? The average annual CDR required to achieve historic climate pollution responsibility and deal with 288 Mt

Co2 remaining in our atmosphere from all of our (Austin Region) emissions is 14.4 Mt per year until 2040. The annual emissions reductions increment is about 0.54 Mt per year until 2040 to reduce to zero the 10 Mt CO2 pollution Austin produces every year. In other words, we have to deal with 27 times more CO2 to achieve historic climate pollution responsibility as we do to achieve net-zero climate pollution responsibility. The abbreviated table below demonstrates:

Year	Annual Net-zero Increment	Total Net-zero Reduction Annual	Annual Historic Emissions Removal	Total Historic Emissions Removal
1	0.5 Mt	0.5 Mt	14.4	14.4
2	0.5 Mt	1 Mt	14.4	28.8
3	0.5 Mt	1.5 Mt	14.4	33.2
...	...	...	...	...
19	0.5 Mt	9.5 Mt	14.4	273.6
20	0.5 Mt	10 Mt	14.4	288

If one looks volumetrically however, the historic emissions removal stays the same, but emissions reduction volume increases by nearly an order of magnitude as shown in the table below. This calculation though is fraught with variables listed above: much of net-zero is from energy source switching, but mush is from behavioral and other tech innovations and much (30 percent in Austin's case) must be provided with offsets which continue every year until new tech is developed.

	Emissions Reductions Mt CO2 per year
2020	10.764
	9.70416
	8.64432
	7.58448
	6.52464
2025	5.4648
	4.90176
	4.33872
	3.77568
	3.21264
2030	2.6496
	2.3184
	1.9872
	1.656
	1.3248
2035	0.9936
	0.79488
	0.59616
	0.39744
	0.19872
2040	0
Total	77.832

1.3.4 The Gap and Worst-case Scenario Planning

(1) **As much CO_2 emitted in the last 30 years as in the previous 250 years…** From 2020 to 1990 we emitted 887 Mt CO2 from fossil fuels and cement. From 1750 to 1990 we emitted 803 Mt.
Data from Global Carbon Project
https://www.globalcarbonproject.org/carbonbudget/20/data.htm

(2) **National Academy of Sciences says the sustainable and equitable global nature-based CDR is 2.75 Gt** CO_2 **per year…** Many studies suggest much greater nature-based CDR is possible. There is a big difference however, between theoretical nature-based CDR capacity and plausible capacity, and an even further difference between plausible and sustainable and equitable capacity. Our Earth systems have an enormous amount of theoretical capacity to absorb extra CO_2 through the enhancement of Earth systems: Forests, soils (agriculture), and oceans. Evaluation of the societal, economic and environmental consequences of "enhancing" these Earth systems yields a much smaller amount of "plausible" CDR because of the very large land use footprint of removing agricultural lands for the sole purpose of CDR, of the environmental consequences of changing global-scale earth systems to uses that are foreign and novel to those earth systems functions, and considering societal equity implications of challenging traditional low wealth cultures create CDR when their responsibility for the creation of climate pollution is almost zero. This is why the National Academy of Sciences quantity of nature-based CDR is so important, as it addresses the sustainable and equitable quantity, where other studies only address feasible or plausible nature-based CDR, or are consensus reports on nature-based CDR that do not differentiate the sustainable and equitable findings.

Quick Summary:

- The National Academy of Sciences Negative Emissions Technologies report in 2018 says 2.75 Gt plausible CDR per year globally is the safe, equitable atmospheric carbon dioxide removal with afforestation, reforestation, forest management, agriculture and soils.
  Negative Emissions Technologies and Reliable Sequestration, A Research Agenda, Consensus Study Report, Highlights, National Academy of Sciences, October 2018, Summary, page 2, paragraph 2 and 3, and Table.
  https://www.nap.edu/resource/25259/Negative%20Emissions%20Technologies.pdf
- IPCC says 4.4 Gt from AFOLU (agriculture, forestry and other land uses)
  Chapter 2, IPCC SR15, Mitigation Pathways Compatible with 1.5 C in the Context of Sustainable Development, October 2018. Table 2.13c, page 128.
  https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter2_Low_Res.pdf
- Hansen's 2017 Young People's Burden says 4.6 Gt plausible CDR annual from forests and soils across the globe.
  Hansen et al., Young people's burden-requirement of negative CO2 emissions, Earth Syst. Dynam., July 18, 2017, page 591, paragraph 1.
  https://www.earth-syst-dynam.net/8/577/2017/esd-8-577-2017.pdf
- Paul Hawken's 2017 Drawdown says 10 Gt plausible CDR annually from 23 forest, soils and agriculture strategies.
  Hawken, Drawdown—The Most Comprehensive Plan Ever Proposed to Reverse Global Warming, Penguin Books, 2017.
  https://www.drawdown.org/solutions
- Dicaprio's One Earth Climate Model (Teske 2018) says 5.3 Gt plausible CDR per year, IMPORTANT - This work explicitly states that their 1.5 C scenario, "Refers to technically possible measures and options without taking into account societal barriers."
  Teske et al., Achieving the Paris Climate Agreement Goals, DiCaprio One Earth Climate Model, Springer Open, February 5, 2019.
  https://link.springer.com/content/pdf/10.1007%2F978-3-030-05843-2.pdf
- Rocky Mountain Institute 2018 says 0.6 to 1.4 Gt CDR plausible per year from land-based negative emissions in the US.
  Rocky Mountain Institute, Negative Emissions and Land Based Sequestration, November 2018, page 5.
  https://www.rmi.org/wp-content/uploads/2018/11/RMI_Negative_Emissions_Scenarios_Report_2018.pdf
- Roe 2019, Contribution of the land sector to a 1.5C world… 6.5 Gt annual carbon dioxide equivalents (CO_2eq) sequestration (CO_2, CH4, N2O, etc.) feasible and sustainable nature-based strategies in the land sector.
  Roe et al., 2019 Contribution of the land sector to a 1.5C world, Nature Climate Change, October 21, 2019.
  (paywall) https://www.nature.com/articles/s41558-019-0591-9
  Phys.org editorial – https://phys.org/news/2019-10-15c-experts.html

(3) **330,000 tons Plausible equitable limit to nature-based in Austin…** Net-zero 2050 globally requires we address our current annual 49 gigatons CO2eq, or a total from 2020 to 2050 of 760 Gt. Austin's share considering 91 Mt total net-zero emissions reductions by 2040 is 0.012 percent, meaning our maximum share of natural systems emissions reductions according to NAS is 0.33 Mt annually or 330,000 tons.
49 Gt Annual Emissions CO2eq globally from fossil fuels and AFOLU (Agriculture, Forests, and other land uses) … IPCC Fifth Assessment, Working Group 3, Mitigation of Climate Change, Technical Summary, Figure TS.1, 2014, page 42.
https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_technical-summary.pdf

(4) **Climate tipping is now underway…** See Vision Statement, Reference 4.

(5) **Limits to natural variability**… See Section 1.1, Reference 1.

(6) Natural Systems already flipped from carbon absorption to emissions: permafrost, Amazon, Canadian forests… These three systems have flipped from sequestration to emissions with a total reported annual emissions of about 3.5 Gt CO2 (CO2eq) per year. Considering the rest of our worlds similar ecologies are behaving likewise, the annual emissions are at least 5.5 Gt, net.
Permafrost collapse of 2.3 Gt CO2 annual emissions, averaged 2003 to 2017… Since permafrost was stable in 2003, the annual in 2017 was much higher than 2.3 Gt, and today the acceleration in warming is even greater than in 2017.
Natali et al., Large loss of CO2 in winter observed across the northern permafrost region, Nature Climate Change, October 21, 2019.

https://www.uarctic.org/media/1600119/natali_et_al_2019_nature_climate_change_s41558-019-0592-8.pdf
Amazon collapse of 1 Gt annual CO2eq emissions 2010 to 2018… The current emissions are likely greater because this 1 GT is an average, and the averaging period stopped in 2018 and it's not at all likely things have gotten better since. Tropical forests in Africa are a bit behind the Amazon, but couldn't be far and Asian tropical forests likely similar to the rest of the world.
Gatti et al., Amazonia as a carbon source linked to deforestation and climate change, Nature, July 14, 2021.
https://www.nature.com/articles/s41586-021-03629-6.epdf?sharing_token=lsfPlVRsW05dUMB_VD-zItRgN0jAjWel9jnR3ZoTv0NILaci0q8CXtVe4JKM-xF0Z0ZQpmJpnpSclAjJeIV-vCjviXK_Mb9hvvU5C3CiJVgu82-RGuHR01gFiQZAVMzDCCxiRyvlh0MBQxTvGN2oHmf2jIOC7MEEGXrOPGIblsh57v9qXkkZbM7U0OH8zbdQ4jnVO1zD9R1jeDcUVBS22YVLkjWEvC5vrNMdQ416fmEBL9kIHYs2ptVibFKXLxEuh-TQ08w-QGSFzN6221KgguYTe0Q9FoZ1J-Wksf4tWXrjv-xu34UpgYqxQWwLTTbTgHYTuglT_tSVd4WaweL9fg%3D%3D&tracking_referrer=www.theguardian.com
Canadian Forest Collapse 250 million tons CO2eq annually in 2018…
Canada has been emitting since about 2002. It's the beetles. They peaked about 2007 when the beetles finished dinner on all the lodgepole forests susceptible in Canada - they killed almost all the large continuous stands lodgepole pine across all of Canada. Now we have new bark beetle species on the rise: spruce and fir beetles. They are not as aggressive as the pine bark beetle responsible for the earlier mayhem, but there are more species of each and far more trees to eat so the risk is much greater. See page 39 in the Canadian Forest Report. Also note that the Canada data is through 2018 . There were huge new attacks in 2018 and we all know the direction the trend is headed, nonlinearly. Canadian forests are also likely identical to the great Russian forests and in total across the globe, emissions are likely 1 Gt from high latitude or high altitude forests.
The State of Canada's Forests, Adapting to Change, Canadian Forest Service, 2020.
https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/16496
Total new annual emissions CO2 (CO2eq) from Earth's natural systems, considering global conditions are similar…
Permafrost: 3 GT annually
Tropical forests: 1.5 Gt annually
High latitude and high altitude forests: 1 Gt annually
Fire: unknown
Oceans: unknown
Soils beyond permafrost: unknown
Total: 5.5 Gt

(7) **Cascading tipping response** - See Vision Statement, Reference 4.

(8) California Low Carbon Fuels Standard… California Low Carbon Fuels Standard Carbon Capture and Sequestration Incentive… The carbon sequestration incentive of about $200 per ton in October 2020 is paid to applications successfully demonstrating their sequestration used to enhance oil recovery is greater than the net emissions from sequestration procedures and burning the recovery hydrocarbons.
California Air Resources Board, Carbon Capture and Sequestration
https://ww2.arb.ca.gov/our-work/programs/carbon-capture-sequestration

1.4 Local Climate Pollution Responsibility and Leadership, and Global Negative Emissions Equity

(1) **Big Bend National Park Air Pollution Boot Canyon photo comparison 1986 and 2016 -**
BRAVO Study Final Report, Pitchford et al., Big Bend Regional Aerosol and Visibility Observational Study, September 2004.
Final Report - http://vista.cira.colostate.edu/Improve/final-report-bravo/
Website - http://vista.cira.colostate.edu/Improve/big-bend-regional-aerosol-and-visibility-observational-bravo/

(2) **Houston, Dallas, Austin, and San Antonio's greater than $434 million police budget each…**
Cai and Garnham, Texas' largest cities spend more on police than anything else. Activists want more of those funds spent on the social safety net instead, Texas Tribune, August 14, 2020.
https://www.texastribune.org/2020/08/14/texas-police-budgets-austin-dallas-houston-san-antonio/

(3) **We treat 116 gigatons of potable water and human sewage annually in the US…** This giga scaling is something we know how to do well. We have done it with computer chips, solar cells and giga battery factories. We have giga scaled other things as simple as the 53 gigatons of aggregates that we mine every year to make concrete and roads. We treat about 52 gigatons of human sewage every year in the U.S. alone, and about 64 gigatons of potable water in the U.S. alone – 116 Gt total every year.
Aggregates - https://www.thefreelibrary.com/Global+sales+of+construction+aggregates+to+reach+53.2+billion+metric...-a0369069284
Human sewage treatment - https://www.epa.gov/nutrientpollution/sources-and-solutions-wastewater
Potable water treatment - https://www.infrastructurereportcard.org/cat-item/drinking_water/

(4) **California Low Carbon Fuels Standard Carbon Capture and Sequestration Incentive…** The carbon sequestration incentive of about $200 per ton in October 2020 is paid to applications successfully demonstrating their sequestration used to enhance oil recovery is greater than the net emissions from sequestration procedures and burning the recovery hydrocarbons.
California Air Resources Board, Carbon Capture and Sequestration
https://ww2.arb.ca.gov/our-work/programs/carbon-capture-sequestration

1.5.1 Climate Emergency

(1) **Covid-19 and Climate Change…** Habitat loss from human encroachment causes animal stress. Habitat loss from climate change causes animal stress. Changing habitat from habitat loss and migration from climate change causes stress. Increased animal numbers in smaller habitat areas causes stress. Warming causes stress. Stress allows greater amounts of disease. More humans and closer contact with animals increases the likelihood of zoonoses, or animal to human transmission of disease.
Zoonoses, Blurred Lines of Emergent Disease and Ecosystem Health, United Nations Environemntal Program, UNEP Frontlines Report, 2016.
https://wedocs.unep.org/bitstream/handle/20.500.11822/32060/zoonoses.pdf?sequence=1&isAllowed=y
Santos et al., Viruses in Food and Water, Chapter 20, Epidemiology, control, and prevention of emerging zoonotic viruses, Science Direct, Woodhead Publishing, 2013.
https://www.sciencedirect.com/science/article/pii/B9780857094308500204

(2) **Austin Climate Emergency Declaration…**
https://www.austintexas.gov/edims/document.cfm?id=325549

(3) **Carbon budget exceeded by 2030…**
Masson-Delmotte et al., Global Warming of 1.5°C : An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, IPCC, 2018.
https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

1.5.2 Climate Change Ethics, the Moral Hazard and Precautionary Principle

(1) **The Moral Hazard with climate change solutions…** "The Intergovernmental Panel on Climate Change (IPCC) Special Report on 1.5 ◦C of global warming is clear. Nearly all pathways that hold global warming well below 2 ◦C involve carbon removal (IPCC, 2015)… In this perspective, we argue that debates over "moral hazard" in response to carbon removal and solar geoengineering are both unhelpful and potentially counterproductive. The reason for this is that they frame the relevant policy questions in terms of whether we should substitute mitigation efforts for carbon removal and solar geoengineering technologies or vice versa. Yet, if the IPCC report is to be taken seriously, such questions are ones we no longer have the luxury to consider: the only live question is which combination of available mitigation, adaptation, and technological strategies is most likely to ensure a sustainable, climate-resilient future."
Jebari, et al., From moral hazard to risk-response feedback, Climate Risk Management, 33, 2021.
https://reader.elsevier.com/reader/sd/pii/S221209632100053X?token=B4BA93F241146EBF4551B99253D27BEB4763252D0FDCF7DE0CA37009171A4FA3AC6A70945848CDAB9547A87C927630B0&originRegion=us-east-1&originCreation=20210628233942

(2) **The Pope and United nations on the moral Imperative of climate change action**…
Our moral imperative to act on Climate Change - TED Talk with Pope Francis. October 11, 2020.
https://www.ted.com/talks/his_holiness_pope_francis_our_moral_imperative_to_act_on_climate_change_and_3_steps_we_can_take/transcript?language=en
Note to Correspondents: Joint Appeal from the UN System to the Secretary-General's Climate Action Summit, United Nations Systesm Organization, May 9, 2019.
https://www.un.org/sg/en/content/sg/note-correspondents/2019-05-09/note-correspondents-joint-appeal-the-un-system-the-secretary-general%E2%80%99s-climate-action-summit

(3) **Sierra Club Climate Policies, March 2020, Less than 1.0 degrees C warming...** For the first time, a limit of less than 1.0°C degrees above normal.
Climate Resilience, Carbon Dioxide Removal, and Geoengineering Policy, Sierra Club, March 6, 2020.
https://www.sierraclub.org/sites/www.sierraclub.org/files/2020-Sierra-Club-Climate-Resilience-Policy.pdf
Also See Sierra Club Climate and Energy Policies…
https://www.sierraclub.org/policy/energy

(4) **Precautionary Principle…**
Kriebel et al., The Precautionary Principle in Environmental Science, Environmental Health Perspectives, National Institute of Environmental Health Sciences, September 2011.
https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.01109871

2.1 What is CDR?

(1) **See the Institute for Carbon Removal Law & Policy for an in-depth look at CDR from the American University, Washington, DC…**
https://www.american.edu/sis/centers/carbon-removal/
(2) **Scaling carbon dioxide removal, current megaton industrialization of air capture CDR…** Industrialization is moving forward fast indicating that these processes are revenue generating programs.
Occidental Chemicals and Carbon Engineering…
https://www.technologyreview.com/s/613579/why-the-worlds-biggest-cosub2-sub-sucking-plant-would-be-used-to-err-dig-up-more-oil/
https://digital.olivesoftware.com/olive/ODN/HoustonChronicle/shared/ShowArticle.aspx?doc=HHC%2F2020%2F12%2F03&entity=Ar01500&sk=EFF8B3CA&mode=text#=undefined
Carbon Engineering Funders… Occidental Chemicals, Bill Gates, Murray Edwards, BHP, Chevron Technology Ventures, Oxy Low Carbon Ventures, LLC, Bethel Lands Corporation Ltd, Carbon Order, First Round Capital, Lowercase Capital, Rusheen Capital Management, LLC, Starlight Ventures, Thomvest Asset Management and others.
https://www.globenewswire.com/en/news-release/2019/03/21/1758562/0/en/Carbon-Engineering-concludes-USD-68-million-private-investment-round-and-proceeds-with-commercialization-of-carbon-dioxide-removal-technology.html#:~:text=CE's%20investors%20now%20include%3A%20Bill,an%20affiliate%20of%20Peter%20J.
Exxon Mobile and Global Thermostat… Undisclosed amount.
https://www.technologyreview.com/f/613901/another-major-oil-company-tiptoes-into-the-carbon-removal-space/
University of Arizona (Klaus Lackner) and Silicon Kingdom Holdings (SKH)… Undisclosed amount
https://www.reuters.com/article/us-usa-climatechange-carboncapture/do-mechanical-trees-offer-the-cure-for-climate-change-idUSKCN1S52CG
Blue Planet and Mitsubishi, September 23, 2020… Mitsubishi is working to develop technology for locking CO2 in concrete as part of a separate project with Japanese construction group Kajima and Hiroshima-based utility Chugoku Electric Power
https://asia.nikkei.com/Spotlight/Environment/US-startup-s-carbon-capture-concrete-wins-Mitsubishi-s-backing
Blue Planet and Chevron… Houston, Texas, January 14, 2021… Chevron Corporation (NYSE: CVX) today announced a Series C investment in San Jose-based Blue Planet Systems Corporation ("Blue Planet"), a startup that manufactures and develops carbonate aggregates and carbon capture technology intended to reduce the carbon intensity of industrial operations.
https://www.chevron.com/stories/chevron-invests-in-carbon-capture-and-utilization-startup
ExxonMobil, February 1, 2021… $3 Billion, mostly on 20 direct air capture projects. "ExxonMobil has more than 30 years of experience in CCS technology and was the first company to capture more than 120 million tonnes of CO2, which is equivalent to the emissions of more than 25 million cars for one year. The company has an equity share in about one-fifth of global CO2 capture capacity and has captured approximately 40 percent of all the captured anthropogenic CO2 in the world."
https://corporate.exxonmobil.com/News/Newsroom/News-releases/2021/0201_ExxonMobil-Low-Carbon-Solutions-to-commercialize-emission-reduction-technology
Climeworks... $76 million 2020, Microsoft and Shopify
https://i3connect.com/company/climeworks

2.2 CDR Quantities, Strategies, Cost/Benefit

(1) **Texas Forest Service 301 million trees killed in the 2011 drought...**
https://tfsweb.tamu.edu/content/article.aspx?id=27436

(2) **Austin Climate Equity Plan natural systems CDR prescription and needed increase…** Austin could sequester about 5.25% of the city's total carbon emissions, or 682,738 tons of CO2 if by 2030 they were to legally protect an additional 20,000 acres of carbon pools on natural lands and manage all new and existing natural areas (approximately 70,000 acres total) with a focus on resilience, and also by 2030 protect 500,000 acres of farmland in the 5-county region through legal protections and/or regenerative agriculture programs.
Austin Climate Equity Plan (Draft 2020) page 74 Natural Systems.
Increasing this amount of natural systems by 10 times would yield 6.9 million tons seq1uestration annually.
Important Note: Natural systems are currently degraded from warming and ecological degradation limits or eliminates sequestration. Ecologies globally have passed tipping points where they have flipped and are now emitting greenhouse gases instead of absorbing them. Natural systems are susceptible to sudden losses that degrades, eliminates or reverses permanence. Permanence of 100 years is emerging as the standard for sequestration. Additional warming to 1.5 C degrades, eliminates and reverses even more of natural systems abilities to function as carbon sinks and this relationship is nonlinear with further warming.

(3) **Nature-based sequestration limitations…** See Section 1.3.4, Reference 2.

(4) **Gigascaling Solar PV, a 35,000 price reduction…** We can look to many other industries to find how dramatically costs fall when their production is giga-gigasized. During the oil embargo in 1976 when Jimmy Carter was President, solar photovoltaic cells were $76 per watt. In 2020 their cost had fallen to $0.21 per watt, over a 35,000 percent decline in price.

(5) **Nature-based sequestration about 5% or less of what is needed…** To remove 1,000 Gt CO2 (See Section 1.2, reference 3) from the atmosphere in time frames of 10 to 20 year to stop irreversible tipping by mid-century, we need to remove 50 to 100 Gt CO2 per year. From Section 1.3.4, Reference 2, we see that the maximum equitable nature-based sequestration is 2.75 Gt per year which is 2.75 to 5.5%.

(6) **$500 billion for ensuring safe drinking water across the planet every year…** Cleaning up climate pollution through existing means and technologies will cost no more than the $500 billion we spend annually on ensuring clean drinking water through the installation of our civilization's water and wastewater infrastructures.
Alley, Earth: The Operators' Manual, WW Norton, 2011, chapter 16: Costs, page 209; costs of water/wastewater infrastructure, page 217.
"The Clean Water and Clean Air Acts each cost about one percent of G.D.P.," Ken Caldeira quote from an interview in the New Yorker: paragraph 38. The US GDP in 2020 was $21.4 trillion, one percent would be $210 billion for the US alone. "There is another way to look at this, though,'' he said. "And that is to compare it to the subprime-mortgage crisis, where you saw that a few million bad mortgages led to a five-per-cent drop in gross domestic product throughout the world. Something that was a relatively small knock to the financial system led to a global crisis. And that could certainly be the case with climate change. But five per cent is an interesting figure, because in the Stern Report''—an often cited review led by the British economist Nicholas Stern, which signaled the alarm about greenhouse-gas emissions by focusing on economics—"they estimated climate change would cost the world five per cent of its G.D.P. Most economists say that solving this problem is one or two per cent of G.D.P. The Clean Water and Clean Air Acts each cost about one per cent of G.D.P.," Caldeira continued. "We just had a much worse shock to our banking system. And it didn't even get us to reform the economy in any significant way. So why is the threat of a five-per-cent hit from climate change going to get us to transform the energy system?"
Specter, The Climate Fixers, May 14, 2012.
http://www.newyorker.com/reporting/2012/05/14/120514fa_fact_specter?currentPage=all

(7) **CDR Cost Controversy Summary…**
Direct Air Capture Cost Controversy
August 2018, Bruce Melton
Climate Change Now Initiative, 501c3
(Revised January 2018, February 2017, September 2016, December 2015, December 2013)
Update August 2018: A paper in the journal Joule describes a carbon dioxide air capture industrial scale trial at the existing Carbon Engineering facility in Squamish, British Columbia that is removing 1,000 tons of CO_2 per year, scaled using off the shelf processes and known scaling factors to the 1 million gigaton per year rate for $100 per ton. The process uses potassium hydroxide (potash) similar to that used in World War II in submarines to keep our sailors safe from carbon dioxide poisoning. This industrial trial uses $0.03 to $0.06 kWh natural gas energy with a 10 percent carbon penalty. With $0.01 kWh zero carbon energy (the cheapest wind and solar energy today is $0.02 to $0.03 kWh) costs will easily fall by half. Because large energy usage is required, it is very likely that site built utility scale generation will come with capture projects which eliminates transmission and energy company profits. Scaling from the megaton level today to the gigaton level required will easily drop prices by half again creating sub $12.50 per ton CO_2 removal. This process also uses a 6 to 7 percent return on investment as profit which would not be included in costs for removal of already emitted climate pollution as a service to the commons. With disposal at 15 percent of removal costs, we are looking at total costs $15 per ton CO_2 or less. To remove 1,000 gigatons then, would costs $15 trillion or $750 billion per year for 20 years. The U.S. military budget is $750 billion per year. We spend $500 billion a year on ensuring safe drinking water across the planet every year.

Keith et al., A Process for Capturing CO_2 from the Atmosphere, Joule, August 15, 2018.
https://www.sciencedirect.com/science/article/pii/S2542435118302253
Keith 2018 costs of $94 to $232 per ton CO2 removal - Derivation of costs of $94 to $232 per ton CO2 and future projection for costs to the commons considering site-built utility scale alternative energy generation and no profit:

- The $94 to $232 per ton range reflects the low and high energy costs of the cheapest fracked gas at the time of $0.03 kWh to $0.06 kWh.
- Keith includes a 10% carbon penalty for the natural gas energy, in other words, his paper says it takes 10 percent more process to remove the carbon emitted from burning the natural gas to create the energy to run the process.
- The best cost of new solar energy has fallen to $0.02 kWh - https://www.pv-magazine.com/2020/06/16/global-solar-capacity-may-reach-1448-gw-in-2024/
- Engie France $0.01 kWh Solar - https://cleantechnica.com/2017/01/03/engie-sees-free-energy-10-per-barrel-oil-prices-2025/
- Keith includes 8% profit which is irrelevant with DAC for the commons.
- Keith includes a 7.5 to 12.5 percent capitol recovery factor which is irrelevant with DAC for the commons.
- The process has a levelized efficiency of 90 percent considering upstream and fugitive emissions in the process and sequestration transportation and injection.
- 87 percent of total costs are energy related.

Summary: Because DAC process use a significant amount of energy, any process scaled to a useful level with climate restoration will use the cheapest energy generation of on-site utility scale wind, solar and batteries, where batteries are at parity now in the most favorable locations and will be generally in a few years. On-site generation eliminates transmission costs and energy generator profit costs. With ENGIE forecasting $0.01 kWh wholesale, this means $0.075 kWh energy at the production facility.

Table 2 in Keith 2018, Summary Performance of Various Plant Configurations: Energy is about 80 percent of costs. Reducing energy costs from $0.03 kWh to $0.01 kWh is a two thirds reduction which puts the best-case cost of $94 per ton at $31 per ton.

For production to the commons, where no revenue generation/profit is required, backing out Keith's 10 percent carbon penalty natural gas and his 8 percent assumed profit reduces the $31 per ton costs by 18 percent to $25 per ton. Process refinements and scaling to meaningful levels for climate restoration have the capacity to reduce costs by orders of magnitude as we see common in any gigascaling process. the closets example is solar PV that costs 35,000 percent more in 1976 than it does today.

Discussion… The economically infeasible theoretical evaluations of direct air capture (DAC) of carbon dioxide by the American Physical Society (APS) and Massachusetts Institute of Technology (MIT) from 2011 have now been disproven by industrial scale field processes installed and operational. MIT and APS hypothesized that direct air capture of carbon dioxide (DAC) would cost $600 to $1,000/ton. New, already completed and operational industrial scale DAC facilities are removing CO_2 from the atmosphere today for $100/ton at Carbon Engineering in British Columbia, and $75 a ton at Global Thermostat in California with $25/ton using waste heat. These are both first run industrial designs with a likely 10x cost efficiency reduction possible with future generations of design. The processes also run on $0.07 to $0.10 kWh energy. New utility scale solar energy will be $0.01 in 2025 (ENGIE France), at about the time we can feasibly get large scale DAC into operation. This $0.01 kWh price is for all intents and purposes "waste heat," because even waste heat has a price. The current reduction of solar to $0.01 kWh will approximately equal the cost of getting waste heat from where it is generated to where it is used.
The challenges with the theoretical MIT and APS works follow:

1) MIT and APS only discussed the basic physics of CO_2 air capture of mature World War II era technology using sodium hydroxide.
2) Because of the outsized capacity for DAC to solve the climate pollution problem, the APS and MIT hypotheses garnered very significant press. Their costs were 10 times greater than the researchers studying the processes and their logic appeared sound: the basic physics of low concentration of CO_2 in air is much harder to address than higher flue gas concentrations from power plant smokestacks.
3) Press coverage did not mention that new technologies were not evaluated, or that APS and MIT had made basic physics errors in enthalpy.
4) Several academic rebuttals did not make the news cycle and as a result, climate advocates, the public, and policy makers believe that the APS and MIT work is valid and DAC of carbon dioxide is cost prohibitive.

To their credit, and to the media's discredit, APS and MIT works caveated appropriately saying they only evaluated mature processes and "new technologies could be game changers." But more important, their basic physics was flawed as was pointed out by Realff and Eisenberger 2012. When valid physics is evaluated, the costs of new technology DAC is very similar to what the physics shows (see also Holmes and Kieth 2012) regardless of atmospheric concentration.
Because none of the rebuttal work was captured in the media cycle, the damage from incorrect media reporting was done and it persists in force today as even most climate scientists understand only what was captured in the media cycle and not the underlying science. The reason is because digging out the underlying science is simply not a priority for most climate scientists who must focus their energies on other disciplines. They trust the media to at least be fairly accurate. This trust allows invalid science to make its way into other academic work, repeated by other scientists who are not specialists in the DAC field, increasing the reach of the invalid science. As a consequence, public knowledge and most importantly--climate policy--are greatly hindered and our ability to move climate policy forward is badly diminished.
Hansen: How much does it cost to remove CO_2 at $200 per ton?
50 ppm CO_2 for $21 trillion using existing technologies … "Desire to reduce airborne CO_2 raises the question of whether CO_2 could be drawn from the air artificially. There are no large-scale technologies for CO_2 air capture now, but with strong research and development support and industrial scale pilot projects sustained over decades it may be possible to achieve costs ~$200/tC or perhaps less. At $200/tC, ($55 per ton CO_2) the cost of removing 50 ppm of CO_2 is ~$20 trillion."
Hansen et al., Target Atmospheric CO2 Where Should Humanity Aim? Open Atmospheric Science Journal, November 2008, page 226 and 227, Section 4.4 Policy Relevance, page 227, paragraph.
https://openatmosphericsciencejournal.com/contents/volumes/V2/TOASCJ-2-217/TOASCJ-2-217.pdf#:~:text=sheet%20and%20species%20loss.,even%20lower%20level%20of%20GHGs.

DAC Basic Direct Air Capture Research (Literature Summary)
Direct air capture (DAC) costs… Goeppert et al., produced a literature summary of current DAC findings in 2012.
Goeppert et al., Air as the renewable carbon source of the future - CO_2 Capture from the atmosphere, Energy and Environmental Science, May 1, 2012.
Abstract only: http://pubs.rsc.org/en/Content/ArticleLanding/2012/EE/c2ee21586a#!divAbstract
$20 per ton (just over) capture and storage… Section 5.10 paragraph 2, "using the K2CO3/KHCO3 cycle is described as being able to capture CO_2 from air for less than $20 per ton. The total cost including sub-surface injection was estimated to be slightly above $20 per ton." COAway LLC
$49 to $80 per ton… Section 5.10 paragraph 3: "An air capture system designed by Keith et al. using a Na/Ca cycle was estimated to cost approximately $500 per ton C ($140 per ton CO_2).81,98 The authors added that about a third of this cost was related to capital and maintenance cost. Further development and optimization of the system by Carbon Engineering Ltd.113 for the effective extraction of CO_2 from air resulted in the decrease of the estimated cost to $49–80 per tonne CO_2."

Stolaroff, Capturing CO_2 from ambient air: a feasibility assessment, PhD thesis, Carnegie Mellon University, Pittsburgh, PA, 2006. https://www.cmu.edu/ceic/assets/docs/publications/phd-dissertations/2006/joshuah-stolaroff-phd-thesis-2006.pdf

$53 to $127 per ton… Section 5.4.1, second paragraph: "The cost of CO_2 capture in this case (excluding CO_2 solution recovery and utilization or sequestration) was estimated to be between $53 and $127 per ton of CO_2 depending on operating conditions, capital costs and mass transfer rate." Stolaroff, Keith and Lowry, Environ. Sci. Technol., 2008. https://keith.seas.harvard.edu/files/tkg/files/97.stolaroff.aircapturecontactor.e.pdf

$30 per ton long term… Section 5.10, paragraph 5: "Lackner and co-workers developed an anionic exchange resin able to release CO_2 in a moisture swing process. The cost of only the energy required per ton of CO_2 collected was around $15. The initial cost of air capture including manufacturing and maintenance can be estimated at about $200 per ton of CO_2. However, this cost is expected to drop considerably as more collectors are built, possibly putting CO_2 capture in the $30 per ton range in the long term."

Lackner, Eur. Phys. J. Spec. Top., 2009, 176, 93–106.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.468.9580&rep=rep1&type=pdf (paywall).

Conclusion, first paragraph (Goeppert)... "Despite its very low concentration of only 390 ppm, the capture of CO_2 directly from the air is technically feasible. Theoretically, CO_2 capture from the atmosphere would only require about 2 to 4 times as much energy as capture from flue gases, which is relatively modest considering that at the same time the CO_2 concentration is decreased by roughly a factor of 250–300."

American Physical Society (APS) and MIT say DAC is Cost Infeasible:

American Physical Society Study… $80 per ton from Flue gas, $600 per ton for DAC using "mature technologies."

Socolow et al., Direct Air Capture of CO_2 with Chemicals, The American Physical Society, June 2011.

http://www.aps.org/policy/reports/assessments/upload/dac2011.pdf

MIT Study… $1,000 per ton

House et al., economic and energetic analysis of capturing CO_2 from ambient air, PNAS, September 2011.

http://sequestration.mit.edu/pdf/1012253108full.pdf

Rebuttals: APS research revealed as significantly incomplete by Nature… Socolow 2011 [APS] evaluated existing WWII Era atmospheric removal technology and not surprisingly found them economically infeasible to address climate pollution.

Van Norden, Sucking carbon dioxide from air too costly, say physicists, Nature, May 11, 2011.

http://blogs.nature.com/news/2011/05/sucking_carbon_dioxide_from_ai.html

Further rebuttal of APS and MIT (Holmes and Keith 2012)…Holmes and Keith identify short fallings of MIT and APS work calling out different design choices, insufficient optimization, and use of higher cost processes. When new DAC technologies are evaluated, costs are at or below those of mature DAC removal technology.

Holmes and Keith, An air-liquid contactor for large-scale capture of CO_2 from air, Philosophical transactions of the Royal Society A, 370, 4380-4403, 2012.

http://rsta.royalsocietypublishing.org/content/370/1974/4380

Flawed analysis of the Basic physics of enthalpy (Realff and Eisenberger 2012)… These researchers point out a fundamental flaw in the work of APS and MIT showing direct air capture takes more energy than flue capture because of CO_2 concentration: "The notion of minimum work does not apply to the capture of CO_2, because the capture process is exothermic." When CO_2 is reacted with something to remove it from air or flue gas, the reaction creates heat, "is exothermic." So instead of 400 kJ or work per mole CO_2 energy required the actual energy required involves moving air over whatever process is used to remove the CO_2 from the air. This is 6 kJ per mole CO_2. This relationship of the actual costs of removal of CO_2 from the atmosphere being 1.5 percent of the costs suggested by APS and MIT corresponds very well to the costs assumed by research evaluating new technologies of +/- $20 per ton. It is important to note that the cost of regenerating the chemicals used to capture the CO_2, whether for flue gas or atmospheric capture, is identical.

Realff and Eisenberger, Flawed analysis of the possibility of air capture, June 19, 2012.

http://sequestration.mit.edu/pdf/2012_PNAS_StorageCapacity_LetterToEditor.pdf

Response to Realff and Eisenberg… Herzog et al. (House 2012) responded to Realff and Eisenberger's circular argument by declaring that the excess energy from the exothermic reaction was not used as an input into the process because it was considered an inefficiency. This is not the point. The enthalpy was used backwards, and required heat be delivered to this portion of the process when none was required, significantly biasing the results. See the discussion in the link below—scroll down for the rebuttal rebuttal by Herzog et al.

http://sequestration.mit.edu/pdf/2012_PNAS_StorageCapacity_LetterToEditor.pdf

(8) **Disposal of CO2, Sequestration, Saline Aquifer CO2 storage…**

Over 2,500 gigatons storage capacity in the US at less than $5 per gigaton, and over 5,000 gigatons storage capacity in the US at $10 gigaton.

Vidas, et al., Analysis of the Costs and Benefits of CO2 Sequestration on the U.S. Outer Continental Shelf, Depertment of the Interior, OEC BOEM 2012-100, September 2012.

https://www.boem.gov/sites/default/files/uploadedFiles/BOEM/Oil_and_Gas_Energy_Program/Energy_Economics/External_Studies/OCS%20Sequestration%20Report.pdf

Sequestration, Deep Underground - Literature Summary 2013… In depleted oil and gas formations, unminable coal seams and saline aquifers: "The literature summarized here suggests that -- depending on the stringency of criteria applied to calculate storage capacity global geologic CO2 storage capacity could be: 35,300 GtCO2 of theoretical capacity; 13,500 GtCO2 of capacity; 3,900 GtCO2, capacity."

Dooley, Estimating the supply and demand for deep geologic CO2storage capacity over the course of the 21stCentury, Energy Procedia, 37, 2013.

https://www.sciencedirect.com/science/article/pii/S1876610213006723?via%3Dihub

2.3 Funding and Revenue Generation for Less Than 1.0°C Warming

(1) **$37 trillion per year for 7 years in WWII…** In WWII we spent $19 trillion dollars globally (2019 dollars) in 7 years, 1939 through 1945, on industrial expansion and mostly heavy manufacturing or $2.71 trillion 2019 US dollars per year. Total global GDP 1939 through 1945 in 2019 US Dollars was $44.6 trillion in 7 years or an average of $6.37 trillion 2019 US dollars per year. Average annual global WWII spending then, was 43 percent of global GDP. If we were to mimic WWII industrialization infrastructure spending today at 43 percent of global GDP of $87 trillion annually in 2019, this would be $37 trillion per year, or $261 trillion in seven years. It's all about motivation, not money.

(2) **Austin's share of high motivation spending relative to WWII…** Austin's GDP was $147 billion in 2018, the Global GDP in 2018 was $136 trillion, so Austin's 0.11 percent of annual GDP adjusted WWII spendings is $40 billion per year.

(3) **Every year, 5.75 million cubic yards of concrete are placed in Central Texas…**
Low Carbon Concrete for City Construction Projects, Tom Ennis PE, June, 19 2019.
http://www.austintexas.gov/edims/document.cfm?id=322447

(4) **Blue Planet Aggregates…** Carbon negative concrete from CO_2 capture aggregates.
http://www.blueplanet-ltd.com/#services

(5) **$250,000 design costs for synthetic aggregates facility…** Personal communication to Bruce Melton in 2019 from Dr. Brent Constantz, Blue Planet Founder & Chief Executive Officer.
http://www.blueplanet-ltd.com/?page_id=54

(6) **Carbon negative enhanced oil recovery (EOR)…** About half of injected CO2 is returned to the surface with recovered oil. It is widely believed that EOR cannot be carbon negative, leaving more carbon in the ground, because it recovers oil to be burned again releasing more greenhouse gases, but it can be and the solution is very simple. Academic research, not research from industrial consortiums, says most EOR is either slightly negative or positive in net carbon removal when all the recovered hydrocarbons are burned, and taking into account all emissions from the supply chain. The simple solution is that EOR research is based on the CO2 that is left in the well when about half of injected CO2 is recovered with the hydrocarbons. This means that if the producer closes the valve on the well before all the last potion of recovery takes place, or simply reinjects some of the separated from the oil/CO2 mixture being recovered, carbon negative oil is not only achievable, but a significant sources of net negative sequestration.
Guarina-Medimurec et al., Carbon Capture and Storage, CSS, Geologic Sequestration of CO2, Chapter, 2019.
(ResearchGate free account required)
https://www.researchgate.net/publication/332176970_Carbon_Capture_and_Storage_CCS_Geological_Sequestration_of_CO_2

(7) **IRS 45Q - $35 per ton for hydrocarbon recovery, $50 per ton for direct sequestration…**
https://uscode.house.gov/view.xhtml?req=(title:26%20section:45Q%20edition:prelim)
Congressional Research Service Summary:
https://sgp.fas.org/crs/misc/IF11455.pdf

(8) **Revenue positive, carbon negative enhanced oil recovery in the Permian Basin…** personal communication with Geoffrey Holmes, Carbon Engineering, 2019.
https://carbonengineering.com/our-team/

(9) **Liquid hydrocarbon fuels…** REME - Eisenberger, Renewable Energy and Materials Economy, the Path to Energy Security, Prosperity and Climate Stability, Columbia University, May 2014.
https://arxiv.org/pdf/2012.14976.pdf
https://energynorthern.com/2019/06/28/exxonmobil-and-global-thermostat-to-advance-atmospheric-carbon-capture-technology/

(10) **Carbon nanotubes cheaper than aluminum…** Vanderbilt University
(Press Release) https://www.kurzweilai.net/high-quality-carbon-nanotubes-made-from-carbon-dioxide-in-the-air-break-the-manufacturing-cost-barrier#:~:text=Vanderbilt%20University%20researchers%20have%20discovered,and%20more%20conductive%20than%20copper.
Douglas et al., Toward Small-Diameter Carbon Nanotubes Synthesized from Captured Carbon Dioxide: Critical Role of Catalyst Coarsening, American Chemical Society Applied material Interfaces, May 1, 2018.
https://pubs.acs.org/doi/10.1021/acsami.8b02834

(11) **REME Study, Renewable Energy and Materials Economy…**
REME Eisenberger, Renewable Energy and Materials Economy, the Path to Energy Security, Prosperity and Climate Stability, Columbia University, May 2014.
https://arxiv.org/pdf/2012.14976.pdf

(12) **Carbon Capture News Headlines July 6 through 19, 2021…** *Carbon Capture Journal* is the world's leading magazine for carbon capture storage and utilization, published by Future Energy Publishing in London. We have been publishing since 2007. Press below is from a two week period, July 6 through 19, 2021:

Sembcorp collaborates on UK net zero power plant
(Jul 19 2021) The company is exploring a potential 300MW Net Zero emissions NET Power station at Wilton International, Teesside with carbon capture technology.
https://www.carboncapturejournal.com/news/sembcorp-collaborates-on-uk-net-zero-power-plant/4707.aspx?Category=all

ExxonMobil to participate in Acorn project
(Jul 16 2021) The project plans to capture and store approximately 5-6 million tons of CO2 per year by 2030 from gas terminals at the St Fergus complex at Peterhead, Scotland, which includes ExxonMobil's joint venture gas terminal.
https://www.carboncapturejournal.com/news/exxonmobil-to-participate-in-acorn-project/4706.aspx?Category=all

Carbon Clean selected for Acorn project carbon capture
(Jul 15 2021) Carbon Clean has been awarded the contract to carry out the Front End Engineering Design (FEED) services for the Acorn carbon capture plant at St Fergus, Scotland.
https://www.carboncapturejournal.com/news/carbon-clean-selected-for-acorn-project-carbon-capture/4705.aspx?Category=all

Shell proposes large-scale CCS project in Alberta
(Jul 14 2021) The proposed Polaris CCS project, the largest in a series of low-carbon opportunities Shell is exploring at Scotford, would capture CO2 from the Shell-owned Scotford refinery and chemicals plant.
https://www.carboncapturejournal.com/news/shell-proposes-large-scale-ccs-project-in-alberta/4704.aspx?Category=all

Aker Carbon Capture launches Carbon Capture as a Service
(Jul 12 2021) The company has launched an integrated offering that 'covers everything a customer needs to reduce emissions by CCS' called Carbon Capture as a Service; Carbon capture made easy™.
https://www.carboncapturejournal.com/news/aker-carbon-capture-launches-carbon-capture-as-a-service/4702.aspx?Category=all

Air Liquide, Borealis, Esso, TotalEnergies and Yara collaborate
(Jul 12 2021) The companies have signed an MoU collaborating on decarbonizing the industrial basin of Normandy in France.
https://www.carboncapturejournal.com/news/air-liquide-borealis-esso-totalenergies-and-yara-collaborate/4703.aspx?Category=all

INEOS and Petroineos at Grangemouth join the Scottish Cluster
(Jul 11 2021) The companies are partnering with the Acorn Project to capture and store up to one million tons of CO2 by 2027.
https://www.carboncapturejournal.com/news/ineos-and-petroineos-at-grangemouth-join-the-scottish-cluster/4699.aspx?Category=all

Gulf Coast ready to develop Carbon Storage Hub
(Jul 11 2021) The stage is set for a new carbon storage economy to emerge along the Gulf Coast, according to a study led by The University of Texas at Austin.
https://www.carboncapturejournal.com/news/gulf-coast-ready-to-develop-carbon-storage-hub/4700.aspx?Category=all

Aker Carbon Capture and Carbfix to explore CCS with Elkem Iceland
(Jul 11 2021) Norway's Aker Carbon Capture has joined forces with Carbfix and Elkem Iceland to reduce CO2 emissions at Elkem Iceland's ferrosilicon plant through carbon capture and mineral storage in basalt structures.
https://www.carboncapturejournal.com/news/aker-carbon-capture-and-carbfix-to-explore-ccs-with-elkem-iceland/4701.aspx?Category=all

Svante receives $25 million from Government of Canada
(Jul 09 2021) The Government of Canada made a CDN$25 million investment to support the industrialization and commercialization of its novel low-cost carbon capture technology within the North American market.
https://www.carboncapturejournal.com/news/svante-receives-25-million-from-government-of-canada/4698.aspx?Category=all

CCUS scale-up could create 10,000 UK jobs this decade
(Jul 08 2021) If the UK Climate Change Committee's 2030 CO2 capture target is delivered, 10,000 new green jobs could be created in industrial heartlands by the middle of this decade.
https://www.carboncapturejournal.com/news/ccus-scale-up-could-create-10000-uk-jobs-this-decade/4697.aspx?Category=all

Aker Carbon Capture to explore CCS with BIR
(Jul 07 2021) Waste management company BIR has signed an agreement with Aker Carbon Capture to explore possibilities for a future carbon capture plant at their waste to energy plant in Rådal outside Bergen on Norway's west coast.
https://www.carboncapturejournal.com/news/aker-carbon-capture-to-explore-ccs-with-bir/4695.aspx?Category=all

Crown Estate launches forum to unlock CCUS
(Jul 07 2021) The Offshore Wind and CCUS Co-location Forum which will identify the key challenges and opportunities associated with the co-location of Offshore Wind and CCUS.
https://www.carboncapturejournal.com/news/crown-estate-launches-forum-to-unlock-ccus/4696.aspx?Category=all

Sinopec launches China's first megaton scale CCS project
(Jul 06 2021) China Petroleum & Chemical Corporation (Sinopec) has begun the Qilu-Shengli Oilfield CCUS project, set to become China's largest whole industrial chain CCUS demonstration.
https://www.carboncapturejournal.com/news/sinopec-launches-chinas-first-megaton-scale-ccs-project/4693.aspx?Category=all

(13) **Gulf Coast Ready to Develop Carbon Storage Hub…** First published on July 5, 2021, by University of Texas News - The stage is set for a new carbon storage economy to emerge along the Gulf Coast, according to a study led by The University of Texas at Austin (see reference 14)
July 05, 2021, Gulf Coast Ready to Develop Carbon Storage Hub
https://news.utexas.edu/2021/07/05/gulf-coast-ready-to-develop-carbon-storage-hub/
Basis for UT News in reference 13 above, Gulf Coast Ready to Develop Carbon Storage Hub…
Meckel et al., Carbon capture, utilization, and storage hub development on the Gulf Coast, Greenhouse Gases, Science and Technology, May 19, 2021. https://onlinelibrary.wiley.com/doi/10.1002/ghg.2082?af=R

2.4 Implementing a Climate Emergency Response to Limit Warming to Less than 1.0°C

(1) **Emergency Deployment of direct air capture…**
Hanna et al., Emergency deployment of direct air capture as a response to the climate crisis, Nature Communications, January 14, 2021.
https://www.nature.com/articles/s41467-020-20437-0

2.4.1 Ranked Actions - Implementing a Climate Emergency Response

(1) **Greyrock Energy M Class Platform…** The direct conversion of associated gas to synthetic fuels at oil wellheads in the US could reduce the emissions of CO_2 and CH_4 by 26.8 and 0.45 million tons, respectively, resulting in the reduction of GHGs by about 113.3 and 92.2% (20 year global warming potential) and 73.8 and 50.7% (100 year global warming potential) when compared to petroleum-derived gasoline fuels, respectively. Globally, the emissions of CO_2 and CH_4 could be reduced by up to 356 and 5.96 million metric tons, respectively.
Tan et al., Reduction of greenhouse gas and criteria pollutant emissions by direct conversion of flare gas to synthetic fuels, Intl Jrnl Energy and Env Engineering, February 8, 2018.
https://link.springer.com/content/pdf/10.1007/s40095-018-0273-9.pdf

Section 3, Austin Climate Equity Plan 2020, Topics That Merit Additional Attention

3.1 Emissions Pricing

(1) **REACH 480,000 tons emissions reduction…**
https://www.austinmonitor.com/stories/2020/08/austin-energy-price-on-coal-energy-reduces-emissions-20-percent-since-march/#:~:text=In%20a%20little%20over%20four,since%20the%20end%20of%20March.

3.3 Decarbonize City Investment Portfolios

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