Climate Change Expectations

Bruce Parker

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http://ccdatacenter.org/documents/ClimateChangeExpectations.pdf

There has been a spate of articles on climate change in the last few months and the news is not encouraging. It would be great if climate scientists could come up with a simple "fact sheet" that provides a realistic projection as what to expect the rest of this century, but, unfortunately, climate change is a very "wicked problem". Some of the "unknowns" (see Appendix A for a more detailed list) include:

1. The temperature increase target that will prevent "severe" or "catastrophic" climate change
2. How sensitive the temperature increase will be from increased greenhouse gas emissions
3. The speed at which our civilization can reduce greenhouse gas emissions
4. The quantity of greenhouse gases that will be emitted from natural sources

Even given all of the unknowns, climate scientists have done a pretty good job of forecasting the temperature increase of the last 20-30 years. And based on the insights from computer models, it appears that, essentially, there is no carbon budget left. That is, if we want to prevent severe climate disruption, we need to remove the equivalent of all future CO2 emissions. (See Appendix B)

Based on analysis of many recent articles on climate change we should plan on the following for happening well before 2100 (see Appendix C for a more detailed list):

1. Severe (and potentially catastrophic) global warming (with a temperature increase over 3° C)
2. Severe (and potentially catastrophic) changes to the Earth's weather patterns
3. Potentially catastrophic sea level rise (4-8 feet) and the abandonment of trillions of dollars of coastal property
4. Potentially catastrophic ocean acidification

Most important expectations
Oceans/land absorb 130 GTC of future CO2 if emissions goto zero CO2 60 PPM
350 PPM (1.0) to really solve - no budget
2.0 by 2100 - no budget left
x.0 by 2100 - current path (even with renewables, per ...)
Cost to "save" -

Climate change is a political problem because only governments can raise the funds (likely hundreds of trillions of dollars) needed for both GHG mitigation and carbon dioxide removal. But because climate scientists have been reluctant to explain how dire our situation is (for fear of people just giving up), most people are clueless as to how much "solving" climate change will cost and assume that it can be done almost painlessly with just technology, a carbon tax, and very slight changes to their lifestyles. So given vested interests in the status quo, the inertia in the climate system, the lack of any significant progress in the last 30 years, and the scale of what needs to be done, we should be preparing for severe climate change in the coming decades while working to reduce GHG emissions in order to provide as much time as possible to get ready.

Appendix A - Some of the "unknowns" for projecting the future temperature increase

1. The temperature increase target that will prevent "bad" or "catastrophic" climate change

2. How sensitive the temperature increase will be from increased greenhouse gas emissions
    a. How clouds will change in a warming world (the primary uncertainty)
    b. How quickly the Arctic's albedo will change as sea ice and snow cover are reduced
    c. How the CO2 uptake by oceans and the biosphere will change as the Earth warms
3. The speed at which our civilization can reduce greenhouse gas emissions
    a. The speed at which our civilization can reduce CO2 emissions ("decarbonize")
    b. The speed at which our civilization can reduce the emissions of greenhouse gases other than CO2 (primarily methane)
    c. How successful we will be in stopping deforestation and desertification
    d. How successful we will be in removing CO2 from the atmosphere by natural means (reforestation, agricultural changes , etc.)
    e. How successful we will be in removing CO2 from the atmosphere by technological means (carbon capture at fossil fuel plants, direct air capture, ocean sequestration, etc.)
    f. How much the cost of capturing and sequestering CO2 can be reduced
    g. How much our society will be willing to pay for mitigation, CO2 capture, etc.
    h. How much people in different parts of the world will be willing to sacrifice to prevent catastrophic climate change
    i. The size of the remaining "carbon budget" is likely around zero GTC
    j. How successful "entrenched interests" will be in slowing down mitigation efforts
4. The quantity of greenhouse gases that will be emitted from natural sources
    a. "Feedbacks" from permafrost thawing, soils, etc.
    b. The temperature increase that will cause significant releases of methane from ocean floor

5. How fast the sea level will rise in response to global warming
6. The response of the weather to the reduction of the temperature difference between the Arctic and the equator
7. The expected costs from future weather disasters
8. The impact of global warming on food production
9. How much the speed of the Gulf Stream will change
10. The impact of pollution, ocean acidification, and warmer oceans on oceanic food production
11. How much the population will grow
12. How much the world's GDP will grow

Appendix B

Assuming that future CO2 emissions this century will very likely exceed 700 GTC, there is not much of a "carbon budget" left and, as a result, we will need to capture and sequester the equivalent of all future emissions:

Target:	350 PPM	1.5° C	2.0° C	INDC
Anthro. CO2 Emissions 2018-2100 (GTC)	Likely > 500	Likely > 500	Likely > 500	
Natural Emissions	0	100	100	100
CO2 Removals	=Anthro. emissions	=Anthro. emissions	=Anthro. emissions	0
Atmospheric CO2 (PPM)	350			670
Atmospheric CO2 e(PPM)				855
Non-CO2 RF	N/A			
Surface Albedo Changes in the Arctic	N/A			
Climate Sensitivity	3			

CDR $/Ton C	300			
CDR Cost ($Trillion)	150			
Temperature (°C)	1.0			

Assumptions:

Fossil fuels phased out well before 2100

Negative radiative forcing from aerosols will be close to zero in 2100

Radiative forcing from NO2 and CFC's will be about 0.4 W/m-2 in 2100 (per RCP 4.5)

Radiative forcing from CH4 will be about 0.4 W/m-2 in 2100 (per RCP 4.5)

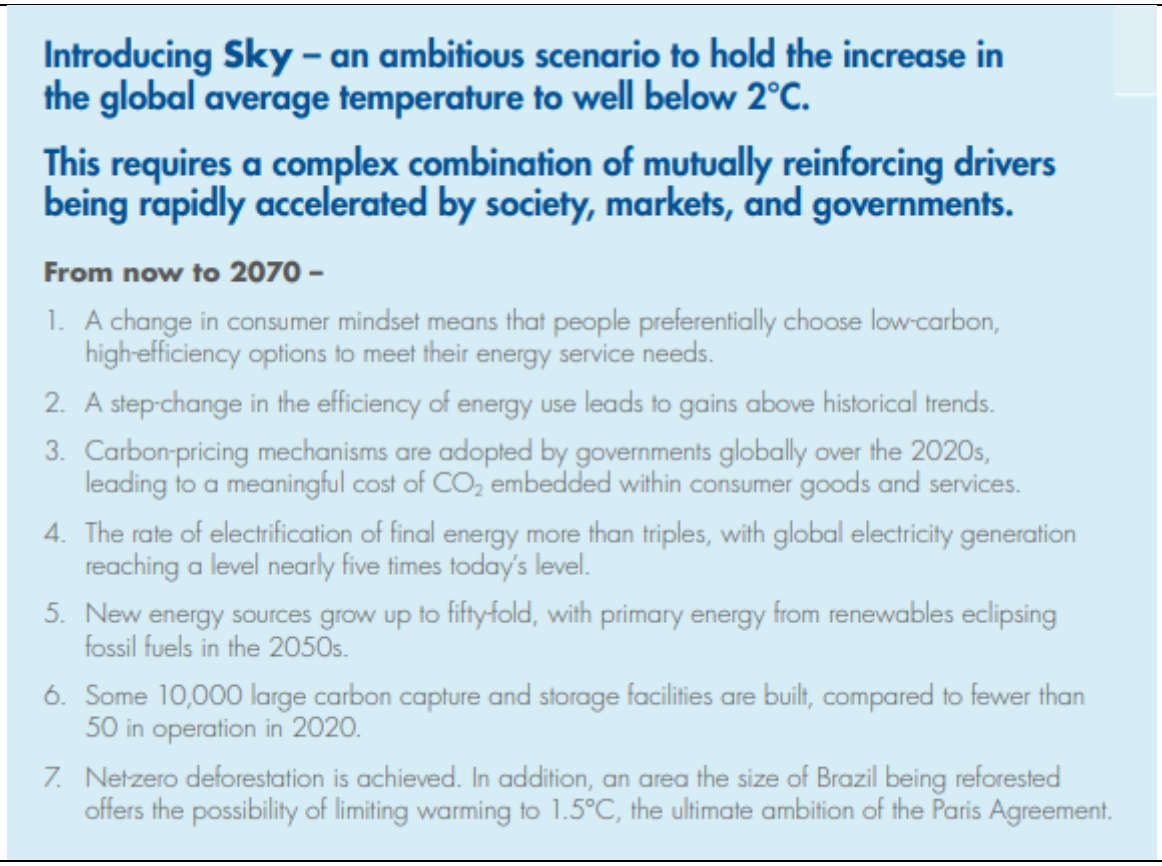
Appendix C - Climate Change Expectations

1. Severe (and potentially catastrophic) global warming (with a temperature increase over 3° C)
    a. "The hardest thing for policy[makers] to understand is the incredible inertia in the [climate] system that makes it so hard to really change the climate outcome for 30 or 40 years no matter what we do about it"
    b. Most climate scientists do not think that the emissions targets of the Paris Agreement will be met (meeting the targets would result in a temperature increase of at least 3.2° C by 2100)
    c. The temperature has increased about 1.1° C since pre-industrial times
    d. The global average temperature has increased at an average of about 0.17° C since the 1970's
    e. The global temperature is likely increasing at a faster rate today
    f. The global temperature is likely to reach 1.5° C around 2030
    g. The global temperature is likely to reach 2.0° C around 2050
    h. The global temperature is likely to exceed 3.2° C by 2100
2. Severe (and potentially catastrophic) changes to the Earth's weather patterns
    a. A global average warming of 1–2 °C with strong polar amplification has, in the past, been accompanied by significant shifts in climate zones and the spatial distribution of land and ocean ecosystems.
    b. [M]odel-based climate projections may underestimate long-term warming in response to future radiative forcing by as much as a factor of two
3. Potentially catastrophic sea level rise (4-8 feet) and the abandonment of trillions of dollars of coastal property
4. Potentially catastrophic ocean acidification

	Climate expert warns of more 'Beasts from the East' and says humans will struggle to produce food and clean water within 50 years March 2018
	Flooding and heavy rains rise 50% worldwide in a decade, figures show March 2018
	At this rate, it's going to take nearly 400 years to transform the energy system March 2018
	Collapse of Industrial Civilization ~ Finding the Truth behind the American Hologram March 2018

	Your burning climate question: Can carbon dioxide be removed? Feb 2018
	Models developed to explore how the world might limit future warming to the "well below 2C" target of the Paris Agreement on climate change typically employ large amounts of "negative emissions" later in the century. Feb 2018
	On determining the point of no return in climate change 2017 As the planet continues to warm, it may be approaching a critical climate threshold beyond which rapid (decadal-scale) and potentially catastrophic changes may occur that are not anticipated—because of complex feedback dynamics and existing computational limitations—by climate models that are tuned to modern conditions
	Climate change escalating so fast it is 'beyond point of no return' December 2016 "It's fair to say we have passed the point of no return on global warming and we can't reverse the effects, but certainly we can dampen them," said the biodiversity expert.
	Soil Cannot Halt Climate Change March 2018 Unique soils data from long-term experiments, stretching back to the middle of the nineteenth century, confirm the practical implausibility of burying carbon in the ground to halt climate change, an option once heralded as a breakthrough.
	Top Climate Scientist: Humans Will Go Extinct if We Don't Fix Climate Change by 2023 February 2018 Recovery is all but impossible, he argued, without a World War II-style transformation of industry—an acceleration of the effort to halt carbon pollution and remove it from the atmosphere, and a new effort to reflect sunlight away from the earth's poles. This has do[sic] be done, Anderson added, within the next five years. "The chance that there will be any permanent ice left in the Arctic after 2022 is essentially zero," Anderson said, with 75 to 80 percent of permanent ice having melted already in the last 35 years.
	Countries made only modest climate-change promises in Paris. They're falling short anyway. February 2018 By 2020, countries are expected to actually ramp up the promises they made in Paris. The problem, experts say, is that if the world's emissions don't start declining decisively by then — and declining fast — it may be too late to stave off devastating sea level rise, crippling droughts and storms, and other catastrophic effects of climate change.
	We Can't Engineer Our Way Out of Climate Change February 2018 This laudable sentiment may also be a little naive. As Ryan Gunderson of Miami University in Ohio and colleagues argue, geoengineering will also provide a convenient excuse to keep using fossil fuels. It won't solve the problem of global warming and, more generally, humanity's ever-growing impact on the planet, which has already exceeded several safe boundaries. By obscuring such issues, technological patches will steer people away from pursuing difficult social and economic change.
	11 takeaways from the draft UN report on a 1.5C global warming limit Feb 2018 UN draft report says missing 1.5C warming target will multiply hunger, migration and conflict, but staying under will require unprecedented global cooperation 1. We're close to the line 2. 1.5C is risky 3. 2C is riskier 4. Poor and coastal communities will be hit hardest 5. "Rapid and deep" emissions cuts are needed… It implies cutting greenhouse gases faster than ever before across all sectors of the economy. With the exception of recent upheaval in electricity supplies, the rate of change required "has no documented historic precedents". These shifts "require more planning, coordination and disruptive innovation across actors and scales of

	governance than the spontaneous or coincidental changes observed in the past". They won't happen by chance. 6. …and negative emissions… 7. . …and luck 8. It's all about the overshoot 9. Radical action has trade-offs Scaling up negative emissions in line with the 1.5C goal may clash with efforts to end hunger. "There is a high chance that the levels of CO2 removal implied in the scenarios might not be feasible due the required scale and speed of deployment required and trade-offs with sustainable development objectives," the draft states. 10. Beware techno-fixes 11. Prepare for social change That means the rich eating less meat, using energy sparingly and forgoing private cars. And it means tackling institutional barriers to action like public attitudes
	Reaching global warming targets under ice-free Arctic summers requires zero emissions by 2045 January 2017 'The sooner the sea-ice-free condition occurs, the more difficult it will be to control climate change, especially if sea-ice recovery does not occur,' the study reads. 'Emissions reductions should increase significantly compared to current mitigation scenarios that do not include Arctic sea-ice loss.' 'We find that global CO2 emissions would need to reach zero levels 5–15 years earlier and that the carbon budget would need to be reduced by 20%–51% to offset this additional source of warming,
	A farewell to ice. January 2017 Losing the last few million km2 of sea ice will have the same warming effect as the last 25 years of carbon dioxide emissions, Wadhams writes.
	Here's How Much CO2 Will Make the Arctic Ice-Free November 2106 The further accumulation of 1,000 gigatons of carbon dioxide [, or272 GTC] — about the limit that would keep global temperature rise under 2°C — would leave the Arctic Ocean effectively ice-free in the summer
	CO2 loss by permafrost thawing implies additional emissions reductions to limit warming to 1.5 or 2 °C February 2018 [For 2 °C ,] including the permafrost carbon pool in the model increases the land carbon emissions at stabilization by between 0.09 and 0.19 Gt C year−1 ... [B]etween 225 and 345 Gt C ... are in thawed permafrost and may eventually be released to the atmosphere for stabilization target of 2 °C. This value is 60–100 Gt C less for a 1.5 °C target. The inclusion of permafrost carbon will add to the demands on negative emission technologies which are already present in most low emissions scenarios.
	Do we have the capability to reverse global warming within a meaningful timeframe? 12 February 2018 To have any realistic chance of staying below the upper Paris objective of 2°C – which itself now represents extremely dangerous warming – we have no global carbon budget left today. To avoid this catastrophic future, man-made greenhouse gas emissions have to be reduced, and the concentration of greenhouse gases in the atmosphere drawn down on an emergency basis – far faster than currently contemplated. Emissions must be cut faster than the current market economic system can achieve under its short-term profitability imperative.
	Keeping the world below 2°C of warming needs tech we don't have Feb 2018 In the two-degrees emissions scenarios, these techniques have to start soaking up at least 11 billion tons of carbon dioxide per year around 2050 in order to offset our continued emissions. If we bank on that future offset, but it fails to materialize, we will find that it's too late to cut our emissions and limit global warming to two degrees Celsius.
	Shell — yes, that Shell — just outlined a radical scenario for what it would take to halt climate change



Negative emissions are like negative absolute temperature--possible in theory, but very difficult to achieve in practice.(Tweet 20 Mar 2018)

If we take BECCS out of the equation, rich nations need to reduce their emissions by 10+ %/yr. A strong critique of the #ParisAgreement by @jasonhickel, built around the 'misguided' use of "speculative 'tech fantasies'" at scale! (Tweet Glen Peters @Peters_Glen Mar 18,2018)

Why current negative-emissions strategies remain 'magical thinking' FEBRUARY 2018
It's not hard to see why many climate scientists have dismissed the near-impossible scale of required negative emissions as "magical thinking". Or why the European Academies' Science Advisory Council said in a report this month: "Negative emission technologies may have a useful role to play but, on the basis of current information, not at the levels required to compensate for inadequate mitigation measures."

EARTH WILL START BECOMING A DESERT BY 2050 IF GLOBAL WARMING ISN'T STOPPED, STUDY SAYS Jan 2018
More than 25 percent of the Earth will experience serious drought and desertification by the year 2050 if the attempts made by the Paris climate agreement to curb global warming are not met, according to a new study by the journal Nature Climate Change.

Observed vs 'Real' Global Temperature. What thermometers do & don't yet show! August 2016

If atmospheric CO2 is stabilised around the current level (404 ppm) there is an uncertain, but possibly large amount of 'pipeline warming'. This warming in the pipeline may lead to an additional temperature rise of more than 1 degree Celsius – additional warming that will manifest itself after stabilisation of the CO2 concentration. The final temperature rise of the current CO2 concentration could be up to 2 or 3 times as high as the warming that is currently observed(!)

If we keep measuring climate change by the observed rise in live temperatures and the Earth & climate system responses this temperature rise causes (including extreme weather events) we keep underestimating the real scientific climate urgency.

What's Blocking Sustainability? Why is the world sleepwalking into an Ecological Crisis? 2014 (?)
At the 1hr 10min mark William Rees says "The Scientifically necessary is politically unfeasible. The politically

	feasible is scientifically irrelevant". Therein lies the nub of the predicament we find ourselves in. Nothing being proposed is relevant to the severity of the multitude of converging crises we face.
	Palaeoclimate constraints on the impact of 2 °C anthropogenic warming and beyond Our observation-based synthesis .. suggests that there is a low risk of runaway greenhouse gas feedbacks for global warming of no more than 2 °C. A global average warming of 1–2 °C with strong polar amplification has, in the past, been accompanied by significant shifts in climate zones and the spatial distribution of land and ocean ecosystems. [M]odel-based climate projections may underestimate long-term warming in response to future radiative forcing by as much as a factor of two
	Cardinal Peter Turkson, the head of the dicastery, opened the event by saying the planet is "on the brink of an unprecedented global catastrophe." He said effects of climate change, including warming temperatures and rising sea levels, "place a question mark on the very future of human existence." https://www.ncronline.org/news/environment/cardinal-warns-possible-collapse-earths-livability-vatican-event Jul 5, 2018
	What do you think is the biggest misperception about global warming even among people who think it's a problem? The hardest thing for policy[makers] to understand is the incredible inertia in the [climate] system that makes it so hard to really change the climate outcome for 30 or 40 years no matter what we do about it" https://www.youtube.com/watch?v=PIWzNTbZvDI&feature=youtu.be&t=23s
	1.5°C of Warming is Closer than We Imagine, Just a Decade Away
	Saving Earth: Don't Fall Into Climate Change Fatalism August 2018 It's too late to stop severe climate change.... But it is absolutely not too late to slow the rate of climate change... We can, and must, still act. As the Times piece notes, we've lost the opportunity to prevent one degree Celsius of warming and without prompt and dramatic efforts almost certainly cannot prevent two degrees of warming. That's bad enough: It's probably sufficient to destroy the Arctic ice cap, most shallow tropical reefs, much of the snowpack in the world's mountain ranges and lead to more extreme floods and droughts. But continued inaction will lead to much worse. Three or four degrees warming – which by the way was enough to mark the difference between planetary ice ages and warm interglacial periods – would wipe out all major coastal cities that can't spend the literally hundreds of billions of dollars or more needed to build massive seawalls, destroy dozens of low-lying island nations, and make vast areas near the equator brutally – and perhaps unbearably – hot. Five degrees is simply unthinkable. The good news is that these doomsday scenarios are not inevitable. Progress is being made almost everywhere, except at the national level of the U.S. Other nations, many U.S. states, local governments, responsible companies and individuals are moving forward. Emissions have flattened over the last several years and are starting to come down in many places. The delays of the past 40 years have committed the planet to unprecedented changes and will impose severe costs on all of us, especially on the poorest populations without the resources to adapt. But even more extreme costs can still be prevented if our politicians and the public can put aside blind ideology, anti-science rhetoric and short-term thinking for the sake of our children and the planet.
	Ecosystems across Australia are collapsing under climate change July 2018 The Great Barrier Reef has become a notorious victim of climate change. But it is not the only Australian ecosystem on the brink of collapse
	The Collapse of Global Civilization Has Begun Nov 2017
	Extinction vs. Collapse: Does it matter? McDonald, Samuel Miller | May 8, 2018 |

	What Will It Really Take to Avoid Collapse? Dec 2017
	Humans Are Blind to Imminent Environmental Collapse November2017 William Rees
	Tweets on 16 August 2018 Glen Peters @Peters_Glen I don't think many scientists think that if we met our Paris commitments [well below 2°C], we would end up in a #HothouseEarth" (& certainly not before 100s, 1000s years). David Wallace-Wells @dwallacewells You're probably right, but how many of them think we will meet those targets? The actual commitments only bring us down to ~3.2C or so, remember, and no major industrial country is on track to meet those—let alone the much more aggressive benchmarks necessary to get well below 2. Morgan Hope Phillips @MorganHPhillips The question for me is how many scientists think that we will meet our Paris commitments? Glen Peters Replying to @MorganHPhillips Not many...
	How much of the UK's emissions are nearly impossible to decarbonise? AUGUST 2018 We can envisage decarbonisation of electricity production, of most transport requirements and much of our heating needs. But even after the obvious sectors have been shifted to zero carbon sources, the UK and other societies will still have very substantial emissions. I estimate in this article that CO2 emissions from energy use, which are currently running at about 367 million tonnes a year, are going to be very difficult to cut below 115 million tonnes, about 30% of today's total.[1]
	Europe mulls stripping carbon from the skies August 2018 Cutting emissions isn't enough to tackle global warming, so the EU is taking a closer look at how to remove carbon from the atmosphere. Carbon removal schemes range from planting lots of trees to more experimental methods to artificially suck up carbon. "Any scenario close to 1.5 degrees [requires a] pretty radical overhaul in the way we think about economic solutions," "Carbon dioxide removal is … no longer a choice, but a necessity for limiting warming to 1.5 degrees Celsius," it wrote in a commentary to accompany a paper in Nature Climate Change.
	The end of the oceans August 2018 Half of all marine vertebrates gone in 40 years. A third of large fish in Australian waters gone in the past decade. Ninety per cent of the world's fisheries already at their limits or beyond. In recent years, however, concern about oil spills has been overtaken by growing alarm about the impact of plastic upon marine environments. The threat posed by plastics, PCBs and other forms of marine pollution may be immense, but it pales into insignificance against that of climate change Yet the most insidious and dangerous effect of climate change may lie elsewhere, in what Eelco Rohling calls the "silent killer" of ocean acidification.

	Yet there is no question we are on the brink of a moment unimaginable even a generation ago. “We’re at a point of complete transformation,”
	'Hothouse Earth' Co-Author Says 'People Will Look Back on 2018 as the Year When Climate Reality Hit' August 2018 "Collective human action is required to steer the Earth System away from a potential threshold and stabilize it in a habitable interglacial-like state," the report's abstract declares. "Such action entails stewardship of the entire Earth System—biosphere, climate, and societies—and could include decarbonization of the global economy, enhancement of biosphere carbon sinks, behavioral changes, technological innovations, new governance arrangements, and transformed social values."
	Arctic Permafrost May Belch Huge Emissions Of Methane In The Future Aug 2018 She says that the large releases of permafrost carbon will happen in her lifetime and continue throughout the generations to come. She goes on to point out that the releases aren’t happening at a fast rate at the moment, “but within a few decades, they should peak.” ... whether we are successful at curbing global carbon emissions or continue business as usual, it won’t make a difference. ...“abrupt thawing more than doubles previous estimates of permafrost-derived greenhouse warming.”
	Mitchler: With climate change, there will never be a 'new normal' August 2018 Acclaimed climatologist and geophysicist Michael Mann, a professor of atmospheric science and the director of the Earth System Science Center at Penn State University, recently said, “A new normal makes it sound like we've arrived in a new position and that's where we're going to be. But, if we continue to burn fossil fuels and put carbon pollution into the atmosphere, we are going to continue to warm the surface of the Earth. We're going to get worse and worse droughts and heat waves and superstorms and floods and wildfires."
	Defining dangerous anthropogenic interference Michael E. Mann PNAS March 17, 2009 If the lower-end or even midsensitivity models are correct, we would (13) avoid 1 °C additional warming by stabilizing greenhouse gas concentrations at <450 ppm “CO2 equivalent” (henceforth, “CO2eq”—this represents the concentration of CO2 that would give an equivalent radiative forcing to that provided by some basket of anthropogenic greenhouse gases). However, if the upper-range sensitivity models are correct, stabilization at 450 ppm CO2eq would barely keep the future warming <2 °C (12). So regardless of one's precise definition of DAI, stabilizing greenhouse gas concentrations much above 450 ppm CO2eq would be a terribly risky prospect.
	Strange Lakes Are Speeding Up Arctic Permafrost Melt, And That's Really Bad News AUG 2018 "Instead of centimetres of thaw, which is common for terrestrial environments, we've seen 15 metres of thaw beneath newly formed lakes in Goldstream Valley within the past 60 years." "We don't have to wait 200 or 300 years to get these large releases of permafrost carbon. Within my lifetime, my children's lifetime, it should be ramping up … Within a few decades, it should peak," Walter Anthony added.
	The 1.5 Generation - My generation is radically remaking climate activism. Will it be enough? Aug 2018 "The aim of climate activism isn’t to erase the sins of the previous generations; it’s to ensure that future generations are handed a world that isn’t at the threshold of going to hell. That won’t happen in my lifetime without a truly radical remaking of the global economy. And if it doesn’t happen in my lifetime, then it’s very likely future generations won’t get another chance."
	Avoiding the climate failsafe point Aug 2018 Today, many researchers are concluding that ecological systems around the planet will not be able to tolerate temperature rise much beyond 1.5°C.
