ARE WE DOOMED? A CLIMATE CONVERSATION

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ABSTRACT: Currently there is significant disagreement among climate scientists about how much aggregate global temperature is likely to change by the end of the century, and what the direct impacts such changes will look like. There is also to date little sustained systematic discussion, including within academia, and within that, amongst environmental humanists, of the extent to which climate change poses a challenge for human civilization as a whole. Given the disagreement about temperature rise and its impacts, how should interested non-specialists approach these crucial issues that depend upon a baseline knowledge of climate science and predicted scenarios generated by international bodies such as the IPCC? Given the importance of credible threats to civilization from various global heating scenarios, how should we engage seriously with such an interdisciplinary issue? In this article we present and model a dialogue between two environmental humanists, where the dialogue is based on incommensurate views regarding perceived climate futures and their impacts on global civilization. One interlocutor is a philosopher with a background in environmental ethics, who tends to accept the projections of large assessments like that of the IPCC. The other is a religion and nature scholar who accepts that such large assessments are likely too conservative in their predictions about the impacts of climate change come 2100 CE. In doing so, we rehearse the substantive issues of debates around temperature rise and climate change's risk to civilization in language aimed at non-specialists. We also explore various meta-level questions about how non-specialists should best engage with these debates within the academy.

KEYWORDS: Climate change; Climate science; Interpretation of science; collapse, IPCC

1 INTRODUCTION

Does climate change spell likely doom for civilization? As two co-authors we disagree significantly on this question. Our disagreement on this matter might be surprising, given how similar our backgrounds and perspectives are. We both fully accept that human activity is significantly heating the planet through the

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greenhouse effect. We both have PhDs in adjacent disciplines – religious studies and philosophy – and both have had some training in scientific disciplines. Lastly, we have both been following climate change research as committed scholar-activists for at least 25 years.

No single discipline, or even small groups of disciplines, has a handle on the likelihood of civilizational collapse when faced with climate change. And disagreement on this matter amongst fellow travelers such as the two of us is mirrored by even greater disagreement among the academy, and society at large. The importance of this question of the likelihood of anthropogenic climate change leading to civilizational collapse leads us to try to unpack the differences in how two reasonable, relatively well-informed scholars interpret the climate science, and also the social science, relative to anthropogenic climate warming. This reading of data and responding to it via a dialogue, we think, will be valuable in two ways. First, as an introduction to key arguments about the likelihood of civilizational collapse triggered by rapid global heating. Second, it can act as a model for the even more difficult interdisciplinary conversations between scholars as diverse as anthropologists, historians, climate scientists, economists and political scientists, for example.

We now start our discussion with an overview of our respective assessment of temperature rise by 2050 and 2100, as summarized in table 1. We invite readers to draw their own tables and then at the end of the article to revisit those starting points, to see how those figures might have changed, and why, if at all, during the course of reading our dialogue.

	Ewan best guess	Ewan 10%-90% range	Todd best guess	Todd 10-90% range
Temp above baseline 2050	1.9	1.6- 2.2	2.2	1.8- 2.5
Temp above baseline 2100	2.7	2.0 - 3.6	3.25	3.0 - 4.0

Table 1. Our respective estimates of temperature increases in 2050 and 2100 in degrees Celsius above a pre-industrial baseline.

We now go on, in Section 2, to unpack what is behind our differences in how we see the temperature rise.

2 ATTENDING TO OUR DIFFERENCES ABOUT THE LIKELIHOOD OF 3°C RISE

Ewan's defense of his temperature forecast

As far as temperature projections go, a helpful table can be found in the Summary for Policymakers of the Intergovernmental Panel on Climate Change (IPCC 2023) Sixth Assessment Report (released in 2021). I reproduce the relevant figures below.

IPCC Scenario	Nickname	Best estimate for 2041-2060 (all in °C)	10-90% range 2041-2060	Best estimate 2081-2100	10-90% range 2081-2100
SSP1-2.6	Taking the Green Road	1.7	1.3 -2.0	1.8	1.3-2.4
SSP2-4.5	Middle of the Road	2.0	1.6 -2.5	2.7	2.1-3.5
SSP3- 7.0	Regional Rivalry	2.1	1.7-2.6	3.6	2.8-4.6
SSP5-8.5	Taking the Highway	2.4	1.9-3.0	4.4	3.3-5.7

Table 2. IPCC estimates of changes from 1850-1900 baseline in centigrade. Figures from IPCC (2023).

When comparing across scenarios, at least according to the IPCC, the very likely range for the temperature increase in 2100 ranges from 1°C to 5.7°C compared to pre-industrial baseline averages. That's a wide range! It's not just that there is scientific uncertainty about how much a given increase in greenhouse gases will affect temperature, but also on how much greenhouse gas is emitted (or removed) from the atmosphere. That part is represented by the "Scenario" in the far-left column. These include what are known as the "shared socioeconomic pathways": four storylines of how global socioeconomic development could proceed. SSP1, for instance, is known as "taking the green road" in which the

world shifts to focusing much more on education and health and less on material development. SSP3 is known formally as "regional rivalry" (and sometimes informally as "Trump world" (Coren 2021)) in which countries become more insular, focus on domestic goals, rather than shared global goals like combating climate change and economic development slows. SSP2 is a "Middle of the Road" scenario, in which "social, economic and technological trends do not shift markedly from historical patterns" (Riahi et al. 2017: 157); and SSP5 is called "Taking the Highway" and is essentially a fossil fuel supercharged economy, including significant use of coal.[2] The IPCC do not give any clear assessment of the likelihood of the various SSPs, although they do stress that SSP5-8.5 is not the most likely outcome. In fact the IPCC suggests it is quite unlikely given the rapid development of clean energy technology and climate policy since the scenario it is based on, RCP 8.5, was developed in the early 2000s.

Todd's temperature projections match most closely to the IPCC's temperature projections under SSP3: in which countries focus on domestic goals, rather than shared global goals like combating climate change and "economic development is slow." But I see no reason to privilege that scenario over other scenarios, such as SSP2.

While the IPCC projects a large range of possible temperature increases, other bodies try to make more substantive forecasts. The non-profit Climate Action Tracker applies projections of current policies and pledges to the MAGICC [3] integrated assessment model. Climate Action Tracker's projections for 2100 (last updated in November 2024) given only current concrete policies and actions (rather than pledges) also roughly track the IPCC's projections for SSP2: a 2.7°C warming by 2100, with a 10-90% range of 2.2 – 3-4°C. That number drops significantly (to a median of 2 degrees) if countries follow through on the 2030 pledges they have made under the Paris system, as well as more long-term targets.

Another large and reputable organization that projects a similar middle of the road use of fossil fuel compared to SSP3 and SSP5 is the International Energy Agency. The IEA project not temperature but fossil fuel demand to 2050. The

[2] For detailed narratives of these SSPs, see Riahi et al. (2017).

[3] MAGICC stands for Model for the Assessment of Greenhouse Gas Induced Climate Change

more realistic IEA scenario, STEPS[4] is like the Climate Action Tracker's "Policies and action" scenario. It models "the trajectory implied by today's policy settings" i.e., only those policies that have either been implemented or are on the books (International Energy Agency 2022: 20). The good news for those worried about fossil fuel consumption trends, is that fossil fuel use is projected, even under STEPS, to shrink by 2050.[5]

While the IEA does not convert this fossil fuel use projection into a temperature increase, Burgess et al. (2000) demonstrate that such an increase maps much more closely onto the IPCC's SSP1 and SSP2 scenarios than SSP3 or SSP5.

In the absence of any better information, I tend to think that we should take seriously the IPCC's "middle of the road" scenario. After all, this is the one in which "social economic and technological trends do not shift markedly from historical patterns" (Riahi et al. 2017: 157). And that pathway the IPCC has estimated to produce, at best estimate, a 2.7°C rise, with a very likely range of 2.1 to 3.5 °C. Focusing on the CAT thermometer suggests a similar landing zone by 2100 is quite a reasonable assumption. Assuming countries will meet their Paris pledges might point towards a best estimate of 2.4 degrees rise, but talk is cheap. If we look at actual decarbonization policies already in place, 2.7 degrees Celsius by 2100 seems like a more likely outcome.

For the sake of argument and given the uncertainty, I'm willing to consider a world of 3 degrees rise by 2100 as a likely future and consider what that might mean for civilization in Section 3. I will note that for me it's probably on the high end of outcomes, and I know for you Todd, it's below your current best estimate. I'm curious to hear more about why.

Todd's Defense of a Higher Temperature Projection

Thanks, Ewan. In short, after following climate science and reports generated by such science as well as international efforts to slow, let alone halt, anthropogenic

[4] The acronym is formed from StaTEd PolicieS.

[5] It is true that the IEA is not the only organization that produces credible forecasts of world energy use. The US's Energy Information Administration has a much more sobering forecast. See Energy Information Administration.

climate change for 25+ years now, I'm dubious about two things that you have much more confidence in: (1) the ability of the IPCC reports to capture sudden and catastrophic tipping points given the conservative nature of the overall excellent science undertaken by the IPCC; and (2) seeing that many countries, especially the developed ones like the USA, Canada, and Russia, that have per capita emitted the most greenhouse gases since the 1950s, and more recent dominant emitters like China, have to-date underperformed on almost all of the non-binding pledges agreed upon during COP21 in Paris.[6] Let me unpack this a bit more:

CLIMATE FEEDBACK ARGUMENT

Key for my position in our dialogue is accepting that for a variety of climate feedback loops, the predicted futures of such feedbacks are likely too conservative. Given space constraints, only some of these are shared in this section. Note, too, that for me this includes IPCC predictions,[7] where for example two atmospheric scientists and an international relations expert wrote "the latest IPCC special report [released in 2017] underplays another alarming fact: global warming is accelerating. Three trends — rising emissions, declining air pollution and natural climate cycles — will combine over the next 20 years to make climate change faster and more furious than anticipated" (Xu, Ramanathan, and Victor 2018: 30). This is soberingly echoed by a 2023 report that claims "we are pushing our planetary systems into dangerous instability" (Ripple, et al. 2023: 1), where in 2023 global mean temperature increase already eclipsed 1.5C for 38 days.

Another study notes that methane release is significantly worse than predicted. This gap in models actually portends that the higher end predictions of IPCC scenarios may very well be met in part just because of how much methane is spiking, especially compared to modeled predictions and levels of "uncertainty in climate datasets" (Zhang, et al. 3 2023). As CO_2 is the greenhouse

[6] According to Climate Tracker, as of July 30, 2023, every country ranges from critically insufficient (including especially Russia), to highly insufficient (including Canada and China), to insufficient (including USA, European Union, Australia, and Brazil) in their efforts to-date to meet pledges made at Paris to stay under 1.5C warming. See https://climateactiontracker.org/, but note the home page graphic is updated every few months.

[7] Note that even if the IPCC predictions hold, "if all net zero pledges and nationally determined contributions are implemented it could reach just below 2°C. This would lower tipping point risks somewhat but would still be dangerous as it could trigger multiple climate tipping points" (McKay et al 2022: 377).

gas actually most associated with anthropogenic climate change, then consider that anthropogenic carbon release is occurring at an "unprecedented" rate as compared to the past 66 million years (Zeebe, Ridgwell, and Zachos 2016). This geologically unique rate of accelerated release will impact other tipping points and weather events. Civilization developed on a planet with less than 350 ppm of CO_2; I do not think it will handle the new, emerging, unfolding weather regimes of a planet that has levels of CO_2 (most studies suggest a minimum, best case scenario of 550ppm) release never before seen in human history. Also note that these authors state that "the present anthropogenic carbon release rate is unprecedented during the past 66 million years. We suggest that such a 'no-analogue' state represents a fundamental challenge in constraining future climate projections" (Zeebe, Ridgwell, and Zachos 2016: 325).

Then there is the slowing of a key deep ocean current in Antarctica, which if countries continue on IPCC upper emissions trajectories until 2050 (which is currently the case), will be shut down by 40%. This will likely trigger a variety of sobering tipping points which will have ramifications on the oceanic food web and the global climate, both, while also leading to faster warming of the deep ocean, thus speeding glacial melt.[8] As the ocean becomes more and more heat saturated, the collapse of the Antarctic current featured in the study will speed that process along, which in turn will amplify terrestrial warming while also leading to more coral bleaching.[9] Note this heat saturation of the ocean is also very alarming, as once oceans reach a certain level of saturation, then excess heat from global warming will amplify terrestrial heating and further drive earth's energy imbalance.[10] This will also speed up polar amplification, the latter which models have already under predicted (Nature Climate Change 2023).

Given space constraints, I can only share one more data point on feedbacks: James Hansen and a team of scientists, based on their models, conclude that

[8] See Lyne (2023). As with most of the data shared in this section, this appears to be happening faster than had been previously predicted. The original study is by Li, et al. (2023)

[9] From Harvey and E&E News (2019) Note this is a 2019 study, and that they point out the IPCC (at that time at least) had underpredicted the speed of ocean warming from climate change. For an updated version, see Hansen, et al. (2023b). For an overview of where all the heat caused by human release of greenhouse gases since 1960 has gone, see von Schuckmann, et al. (2023)

[10] On ocean tipping points overall, especially when aggregated and their overall impacts at such aggregated scales, see Heinze, et al. (2021)

"Global warming in the pipeline is greater than prior estimates. Eventual global warming due to today's GHG forcing alone -- after slow feedbacks operate -- is about 10°C [in a few hundred years]," and according to their models they predict that the best-case scenario is we appear to be locked in to minimum 3.5C to 5.5C global warming, surpassing 2°C by 2050 and very likely rising to 6 to 7 C by 2100.[11]

AN ARGUMENT FROM POLITICAL ECONOMY

My view regarding overall temperature rise by 2100 is also informed by the reality that despite knowing as a species we need to emit less CO_2 (let alone CH_4 and other greenhouse gases), and while having the most robust data set ever about the climate system, as a species, yes we have plateaued, but are nonetheless still emitting the highest amounts of CO_2 held constant (outside of a COVID dip) for the past few years.[12] That there are trillions of dollars to be made by selling off pledged fossil fuel reserves, and given the entrenched power of fossil fuel companies and their ready access to military and governmental power and policy, suggests to me that fossil fuels will continue to be used at record numbers in the years to come, despite record gains in the use of renewables. This of course will further bake in the likelihood of 3°C warming.[13]

I want to wrap up my reply to you with a convincing analysis from the economic anthropologist and degrowth advocate Jason Hickel who argues that the only way to stop possible runaway global warming is to immediately dismantle the global fossil fuel industry. While I agree with his analysis and implications of required tactics, at the time of this writing I see nothing on the horizon that suggests to me this intervention has any chance of occurring. This

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[11] Hansen, et al (2023a) and (2023c). They continue, stating "The large global warming in the pipeline today is not widely appreciated. *Civilization and its infrastructure are not set up for a 2×CO_2 world* [note: italics added by me]." On the 10C forcing, see also Hansen, et al. from 2022. Hansen also opines that based on emerging data, we may be heading into new temperatures not seen in a million years: "Suspicion that we are headed into new climate territory, not seen in the past million years, is fueled by the present extraordinarily large Earth's energy imbalance (EEI)." On this, see Hansen, et al. (2023b).

[12] Hausfather and Friedlingstein (2022). Data suggests that CO_2 emissions from fossil fuels coupled with cement in 2022 were a record high, but overall CO_2 emissions did not top the record set in 2019.

[13] For a sobering exploration of such revenues and entrenched power, see Hayes (2014), and for an insightful study on possibilities, and difficulties, of generating behavior change, let alone at global scales, for hopes of a 1.5 degree only warming (a position neither of us hold), see Newell, et al (2021).

is another reason why I am confident we will approach 3°C, possibly by 2100: we will not stop using fossil fuels anytime soon, let alone in the time needed to stop such a rise in warming as amplifying trends I cite throughout our dialogue begin to accelerate throughout the rest of this century.

Taken together, I find that the emerging science and multiple studies around climate tipping points to be conclusive that future climate events later this century will be extremely threatening to civilization. I also find that political responses—both to date, and in the very critical next five to ten years—have been and will continue to be anemic, especially from politically and economically dominant countries who perpetuate "carbon colonialism."

Any thoughts on what I've shared in this section?

A reply by Ewan

Thank you for elucidating your position, Todd. You see an upward trend of GHG emissions, despite all the promises of climate summits, net zero pledges, and warnings of countless scientific papers. This is true, and unfortunate. However, while anthropogenic GHG emissions trending downward is the ultimate *goal*, there are other indicators that are crucially important. For me, the levelized cost of clean energy is a crucial metric. The levelized cost of energy is the cost of building a new wind or solar plant averaged over its lifetime. This is instructive when compared with the cost of building a fossil-burning power plant, since when the levelized cost of energy of renewable energy drops below that of fossil energy, building the renewable plant will make economic, and not just ethical sense.

This metric will differ regionally of course, since a solar plant in the Sahara will provide cheaper electricity than one in Norway, but it is a useful tool nonetheless. So how does the levelized cost of energy look? Not bad! Per data from Lazard, since 2009, the cost of producing a Megawatt-hour of electricity by solar has gone from a mean of $359 in 2009 to a mean of $60 in 2023. Onshore wind has also dropped dramatically, from $135 in 2009 to $50 in 2023 (Lazard 2023). This is counted *without* subsidies or significant new carbon taxes. This means that since around 2015, if you wanted to add an extra fifty megawatts to the grid (and you had access to up-front capital) it would be a better bet to do so by building an industrial solar plant or wind farm than by building a gas-fired powerplant. Getting over that hurdle is a huge achievement. It does very little to

the emissions humanity is producing now, but is part of what keeps the demand for fossil fuel energy that the IEA projected (see section 2.1) flat to 2050.

Of course, cheap renewable energy has a significant constraint: storage. But that has now turned a massive problem (make renewable energy economically viable at the margins) into a smaller one (find ways of coping with the intermittency of renewable energy). And there are promising avenues for solving the second: Pumped hydro, Power-to-X synthetic fuels, electrolysis to hydrogen, and/or using nuclear or small amounts of fossil fuels with carbon-capture-and-storage to provide "firm resources" as needed.

I reiterate, emissions trending downward (or better, concentrations of CO_2 trending downwards!) is the ultimate metric we need to watch. What the decrease in the cost of renewables has meant is that the world can continue to develop, lifting literally hundreds of millions of people out of extreme poverty, with only a relatively slow rise in global emissions and a projection of emissions bending down in coming decades with only policies already on the books.

There are other emissions sources of course, including cement and steel production, livestock and fertilizers which might be harder to tame than electricity generation. However, there are promising technologies in those areas as well, which, depending on support from governments, will reduce those emissions substantially (Gates 2021, Hawken 2017).

You raise another concern, that political factors such as gridlock in the US federal system and fossil fuel interests, mire us into the status quo. To that I make a few quick points. First, a revolution in costs of clean energy clearly *has* been happening despite a history of relatively minor policy pushes from the federal US government. Subsidies in countries such as Japan and Germany, as well as states including Texas and California, have done a lot to incubate the energy innovations that are now competing with fossil energy in the electricity generation landscape. Second, the power of fossil majors can be overstated. Tech firms now dwarf fossil fuel firms in terms of market capitalization, and tech firms are not particularly wedded to fossil fuel interests. As Madison Condon (2020) points out, powerful institutional investors such as Blackrock own a great many assets that will be harmed by global heating. This explains the relatively aggressive stances such funds and the business group Climate Action 100+ have been taking to pressure fossil fuel companies to take steps such as disclosing

climate risks in their business, disclosing their anti-climate policy lobbying, and reducing expenditure on exploration of new fossil resources.

All this is why I think that a world of continually increasing emissions (until we collapse) is unlikely.

3. CHANCE OF COLLAPSE AT ~3°C BY 2100

Definition of civilization

We need to define civilization, as this is the key sticking point of our ongoing conversation over the past few years. I (Todd) have been invited to define what this means, as I am the one constantly telling Ewan civilization is doomed, for reasons articulated throughout this article. I take my understanding of the term "civilization" from the ecoanarchist writer Derrick Jensen,[14] who points out that linguistically civilization means a collection of humans living at a threshold of population size/numbers, and therefore by definition living in cities, that require the importation of resources from somewhere else, to keep that civilization (those cities) going. And that related, this importation is always based on violence: both on the human communities where the "resources" originate; and then on all the other species and ecosystems that are the "resources" and that have their habitats destroyed, or as ecosystems are destroyed outright.[15] The majority of humans today live in urban, suburban, or peri-urban areas, often near the coast (where subsidence and sea level rise is going to rapidly increase by 2100), with these demographic trends predicted to continue over the coming decades. In short, this is civilization: dense collections of humans living off of imported resources and ancient sunlight.[16]

This thus raises a key question of our dialogue: can civilization continue on a

[14] A note to readers: Jensen is a co-founder of Deep Green Resistance and has been charged with being a TERF and thus being exclusive of transgender people. My use of Jensen's definition of civilization should not be read as an endorsement of Jensen's or Deep Green Resistance's views on transgender people and policies.

[15] https://www.youtube.com/watch?v=UYRsPep86TU&t=4s For Jensen's exploration of civilization, see this video (link active as of March 21, 2023).

[16] A reminder to readers from Todd that in saying civilization will largely collapse does not mean I am arguing that near-term human extinction is likely, or that there may not be humans flourishing even on a much warmer planet in post-civilization regions/living adaptive post-civilization lifeways that are bioregionally attuned.

planet that may warm 3°C? My position is no, it cannot, and to borrow a line from the author and essayist Jonathan Franzen, it is time to stop pretending[17] catastrophe is still far in the future. I will add a bit of nuance here, as the planet is big, and we are predicted to approach 10 billion humans. I accept the likelihood that there will be some pockets of "civilization" in various places throughout the planet–cities of some sort will exist, yes, especially in places like New Zealand, or Scotland, or Alaska. However, these will be outliers, especially when compared to the flourishing of civilization (leaving aside colonial and imperial trajectories) and growth of cities in the 1800s, 1900s, and the first part of the 2000s.

Todd's argument for civilizational collapse

As I continue in this section, I think it important to recognize what environmental philosopher Stefan Skrimshire calls "the paradox of catastrophism" (2009: 4). Here he explains that, "The category with which we communicate dangerous climate change, like historical change and social change, is that of linear progression. With this emphasis comes the modernist imperative to *predict*" (4). However, climate change is not linear, and it is hard to predict future weather events, let alone their impacts. One result of this is that there are "multiple margins for disagreement" (5), as evidenced by me and Ewan on many of these post-2°C climate impacts that may or may not threaten civilization. Given my position, then what weather events, already at 1.1 to 1.3°C warming (with sustained times in 2023 now up to 1.5°C warming, although a 2024 study by McCulloch, et al. using data from sea sponges suggests we are actually at 1.7 C warming already and they suggest our climate models are therefore inaccurate), will likely become more pronounced and generate positive feedback loop tipping points at 3°C, leading to sobering collapse scenarios? Or let me reframe: at what point does the climate change so much, that the agriculture, shipping and transport, fresh water, stable weather, and energy all required to prop up civilization, in part or combined, no longer function at the scale, speed, patterns, and/or efficiencies needed to maintain it?

I note that there are already regional food shortages, lower crop yields (Kornhuber et al. 2023), and supply chain issues in 2022 and 2023, at current planetary temperatures. There is also the prediction of a 40% freshwater deficit,

[17] See also Jackson and Jensen (2022).

globally, by 2030 from increased demand and decreased supply[18], where, of the two, the freshwater deficit from prolonged droughts[19] and also lack of freshwater from melted glaciers are the most problematic and concerning, leading to very real war game-type scenarios. Also, entire cities and agricultural regions will very likely be without water, given predicted and observed rates of glacial and snowpack melt and changing rain patterns: the Andes, the Himalayas[20] (impacting hundreds of millions in China, India, and Pakistan), the Iberian peninsula, large parts of Africa, and the US Southwest (not to mention the unsustainable drawdown of the Ogallala aquifer in the US Midwest) will all be areas undergoing major freshwater stress by 2050 (note that some cities in these regions have such stress already, like Mexico City in 2024). Civilization cannot exist without fresh water. Models of rainfall, glacial melt, and drought suggest that by the 2050s, many parts of the inhabited world will be with either much lower levels of water, or for all intents and purposes, no water at all.

I note, too, that overall climate trends and related weather events are worse, faster, than commonly predicted, and the world they portend is one that I struggle to comprehend, let alone to name.[21] Civilized humans before the century is out will have to adapt to wet bulb temperatures that will increase heat stress[22], while heat waves will impact and threaten the wellbeing and livability of another 1.5 billion people by 2100 throughout South Asia (while the region also has to adapt to sea level rise and drought).[23] Meanwhile a study published in *Science* in 2023 by Rounce, et al., found that "up to half of glaciers could be lost by the end of

[18] See Fiona Harvey (2023)

[19] On drought overall, a study published in 2023 by Yin, et al. suggests that a warming climate will impact up to 90% of humans and that the economy will be heavily compromised due to risks from drought and heat waves, and that "relative to the current climate, future compound events would disproportionately affect the global terrestrial carbon sink" (1), potentially leading to further amplifying trends of carbon overload and runaway heating.

[20] Which are sadly melting faster than predicted, in part driven by the warming of and deforestation of the Amazon–which itself may tip into a savannah by the end of the century (Liu, et al. 2023).

[21] On the lack of appropriate language to make sense of the sixth extinction, and migrations and habitats and weather that is all off kilter, see Badkhen (2023)

[22] See Shulmeister (2020)

[23] See DW (2017). Note this study is from 2017, and not the time period of being released during the writing of this article like the other data shared in this list. On the increasing speed and severity of "flash droughts," see UT News (2022)

the century, even if the world's ambitious global climate targets are met."[24] War game scenarios on lack of water occupy numerous governments as is, as they recognize exactly how precarious lack of water (which based on models, will happen) is to social, economic, political, and ecological stability. On the other end of the extreme are "rain bomb" events, where "atmospheric rivers" fall in torrential downpours of a few hours to a few days, as tragically seen in the Pakistan flooding of 2022 where rain waters covered up to half the country. This is obviously a threat to civilization, where it could be argued that for a period of weeks, half of Pakistan was collapsed and lacked civilization, while the other half hosted displaced climate refugees. Similar rain bomb events are now regularly occurring throughout the world, and are predicted to become more frequent and grow more catastrophic. Speaking of water, sea level rise is predicted to be worse, and to happen faster, than currently modeled[25]. This will impact the global supply chain, especially docking and container terminals for shipping that will be underwater, manufacturing plants in flood plains and on coasts that will be unable to manufacture consumer goods and process food stuffs, and sea level rise will threaten nuclear reactors that are at sea level leading to possible meltdown scenarios. Moreso, thermal expansion of water leads to faster sea level rise, and the warming oceans will also speed up ice cap and glacial melt[26], thereby accelerating sea level rise while also reducing albedo at the poles, thus ramping

[24] The cited quote comes from a CNN article: (Paddison 2023). Of specific concern is the loss of the Thwaites ice sheet, which will add 10 feet of sea level rise. The summers of 2022/2023 showed an alarming melt of Thwaites, and the loss of the Amundsen "cork" that helped to protect the Thwaites. For record melt in that region and a marine heatwave that caught scientists entirely off guard during the Antarctic summer of 2023, see Berwyn (2023a).

[25] https://phys.org/news/2023-01-worst-impacts-sea-earlier.html Accessed March 27, 2023, but link is no longer active. Another study suggested that if humans cannot get to net zero by 2060 and if we hit 1.8C rise then almost 40 inches of sea level rise will be baked in, and happen within 130 years, which is faster than predicted (Institute for Basic Science 2023). Note Todd thinks it is certain, and Ewan thinks it is likely that we will overshoot a 2°C temperature rise. Another web-based summary of the same study quoted UN secretary-general Antonio Guterres, who said if such warming and sea level rise were to occur then, "We would witness a mass exodus of entire populations on a biblical scale." See Koumoundouros (2023). Meanwhile, according to a summary of another study that was published in early 2023 about increased sea level rise happening faster, and its impact on both developing and developed countries, "Rising seas will swamp farmlands, pollute water supplies and displace millions of people much sooner than expected" (Berwyn 2023b). And for a study that suggests glacial melt rate may be 20x faster than any prior study has predicted, see Jacquez (2023).

[26] Melting faster than predicted, at surprisingly accelerated rates. See Chudley, et al. (2023)

up faster melting and warming of the oceans. This in turn may collapse the Atlantic meridional overturning circulation part of the larger Gulf Stream[27], which would be catastrophic for civilization, especially along the Eastern USA seaboard and northern and northwest Europe. Note, however, and this is a key theme of mine, a 2023 study finds that most current models that predict Arctic Sea level melt are entirely too conservative and are thus flawed as they do not incorporate accurate enough data (Heuzé, et al. 2023).

I think these are enough brief data points here to share why I am fearful for the collapse of civilization by the 2050s in a world likely to surpass 2°C by that decade [28], on the way to surpassing 3°C by 2100. I also want to quickly point out that these unfolding scenarios do not "game out" collapsing insurance industries, who will eventually stop insuring properties and industries at the coast[29] and will likely offer no policies to customers in drought and fire-prone regions. It also does not "game out" cascading and "stacked" climate catastrophes that may very likely cripple governmental responses to these catastrophes over a short time period, where such cascades may quickly lead to collapsed governance/government, food and water[30], and/or finance scenarios.

When viewed in such totality, and given climate metrics and tipping points, to say nothing of possible future virus vectors and hundreds of millions of climate refugees[31], then yes, I think civilization as we know it will be collapsing by the 2050s[32] in many parts of the world. Indeed, such collapse scenarios to me are much more likely than, for example, global leadership getting us collectively to stop at 1.5 to 2°C/550 ppm and the "blah blah blah," as Greta Thunberg adroitly put it; of various speculative fairy tales that the human animal can have its climate

[27] See Chi, Wolfe, and Hameed, (2021) and also Saba, et al. (2016)

[28] Parts of the world are predicted to surpass 1.5C rise during the El Nino cycle of 2023-2024. See Cuff (2023).

[29] For an analysis of this written for mainstream audiences, see Bittle (2023a).

[30] Or at least the infrastructure needed for these; for example: drought leading to lack of water for shipping down rivers and canals; or destroyed pipes and highways and bridges that are unable to be rebuilt.

[31] For a sobering news article on internal climate migration already occurring in the USA, and for which markets and policy mechanisms are entirely ill prepared to handle, see Bittle (2023a).

[32] Note that in the process of being in dialogue with Ewan on this paper, my own views have shifted some and have been impacted by his points. When we first began I was pre-2050, and comfortable saying "No way civilization makes it to 2050." I now use "2050s," based on points Ewen has made. I currently believe it will be by the 2050s, even though our time horizon for this article is 2100, so I will use 2050s here. I recognize this can, and does, weaken my position in Ewan's eyes.

cake, and eat it, too.[33] In fact, as sustainability researchers Andrew Fanning and others conclude when applying the "doughnut [sic] model[34]" of ecological overshoot and social floor to years of data from 1992 to 2015 across 140 countries, "we find no evidence that any country is currently moving towards the doughnut-shaped safe and just space. Current trends are likely to deepen the climate and ecological crisis while failing to eliminate social shortfalls" (31).[35] Has any of this moved your needle, Ewan, regarding your thoughts about civilizational collapse?

Ewan's Response to Todd on Civilizational collapse: Is climate change already much worse than expected?

Among other things, Todd argues above that current climate impacts are much worse than have been predicted suggesting models of climate impacts are systematically conservative. Further, Todd claims that because of this bias towards underestimation of risks, climate impacts at ~3°C are likely to be far more severe than anticipated and global collapse of civilization is highly likely.

I think we need to be much more cautious about both the claim that (a) current climate impacts as a whole are significantly worse than modelers have predicted and (b) with severe climate impacts, global collapse of civilization is highly likely.

How much worse are current climate impacts than modelers have predicted? This is a complex question. The huge range of climate impacts makes it an impossibly large question to assess piecemeal. There have been 17,000 papers published *since the beginning of 2022* with the word string "climate change impacts"[36]. Given this, there are several ways a non-expert might try to assess it. One would be to *absorb* – to draw conclusions from the most prominent individual studies one comes across. Another would be to *seek consensus* – finding large scale expert assessments that speak to this question. A third would be to *research* – to

[33] See these two interviews from Greta Thunberg as the basis of my (Todd) framing of her position shared in them (both live as of March 21, 2023): https://www.youtube.com/watch?v=UryIL4kUcx8 ; https://www.youtube.com/watch?v=TMrtLsQbaok&t=107s. On why many ignore climate change because of the desire to avoid the cultural trauma it will bring, see Brulle and Norgaard (2019).

[34] For an overview of this model, see https://www.kateraworth.com/doughnut/ Accessed March 23, 2023.

[35] See for example in March of 2023 President Biden first approving the Willow lease to drill for oil in Alaska, and then opening an area the size of Italy in the Gulf of Mexico to further oil leases.

[36] Author's Google Scholar search in July 2023.

look for studies that ask this meta level question about whether climate science has underestimated climate impacts so far.

The first approach, absorbing, seems deeply unsatisfying. One can find many individual scientific studies, like those that Todd cites, that show developments in particular areas that have progressed faster than anticipated. But there is likely to be significant bias in the studies that one finds. Publication bias privileges the novel and surprising, so studies that show observations have been roughly in line with prior predictions are less likely to be published than those that show a dramatic and worrying development. And the dynamics of social and traditional media might amplify those "it's worse than expected" type papers since their authors will be more motivated to sound the alarm by speaking online or to journalists.[37]

So, what about seeking consensus? Since I am not a climate scientist, I rely heavily on major assessments that attempt to collate current climate science, such as the IPCC. But the IPCC does not typically ask our meta- question about how climate change impacts in 2023 match its predictions of impacts in 2023 in say, 2000. It's true that one can find many articles in the popular media, that include quotes from single IPCC authors which imply that the IPCC assessments are clearly saying that impacts are going to be worse than expected. But if there are such meta-assessments of past predictions in the Assessment Reports, they are well hidden.[38] This is not that surprising – for better or worse the IPCC tries to assess current scientific projections for future trends rather than score how well climate science has done as a whole at predicting current impacts. Perhaps an IPCC special report on this topic is warranted. But in general, the current IPCC reports we have are unhelpful for tracing the trajectory of most metrics, since their projections are rarely precise or fine-grained enough to be tested on year-to-year impacts.

That leaves the third approach – looking for individual studies that attempt

[37] Increases in connectivity, technology such as drone footage and the like bring disasters like the floods in Pakistan and the wildfires in Australia and California more vividly to life than in previous years, making the impression that the whole *world* is on fire harder to shake.

[38] As Kemp et al (2022) points out, there are some very broad scale changes in the "burning embers" diagram that tracks causes for concern in the Working Group II reports of the IPCC. "In the Sixth Assessment Report, all five concerns were listed as very high for temperatures of 1.2 °C to 4.5 °C. In contrast, only two were rated as very high at this temperature interval in the previous Assessment Report" (57).

to answer this meta-question about the success of past predictions. Working from the landmark paper by Brysse et al. (2013) and searching forward on Google Scholar revealed few results, with one prominent exception being by Hausfather et al. (2020). This study compared the predictions of climate models published between 1970 and 2007 with the actual levels of warming observed and found a close correlation between prediction and actual changes, with more models *overestimating* the temperature increase than underestimating it.

On the other hand, Brysse et al. themselves point out that the IPCC underestimated the actual rate of sea level rise by 50% as well as the risk of West Antarctic Ice Sheet collapse[39], but they also note that there is significant disagreement about other issues, such as whether models have *overestimated* hurricane activity compared with current measurements.

My point is not that I believe everything is proceeding climate-wise largely as expected. My own judgment from using the *absorbing* strategy is that heat waves (especially in Europe, and globally in 2023), temperatures at the poles, and glacier and ice melt have been significantly worse than predicted, while the drop in the cost of clean energy has improved the outlook for future emissions. But I also stress that climate science is vast and varied, and we should be careful about trusting that the loudest voices claiming climate change has been much worse than expected are necessarily the most accurate.

COLLAPSE AND HUMAN RESPONSE

But even if the impacts of climate change are much worse at 3 degrees than we imagined a few years ago, are we headed for civilizational collapse? Again, it is extremely hard to judge the likelihood of this. Todd has sketched some mechanisms by which this *could* happen, but I don't see a clear argument that collapse is *likely.*

In many ways we are groping in the dark here. The IPCC has not tried to predict the likelihood of global civilizational collapse, perhaps in part due to the extreme difficulty of the task and the lack of source material. As Steel et al. put

[39] There is a proposed mechanism as well. Scientists face pressures to be non-alarmist individually due in part to the risks of being shown to be wrong. Relevant to the IPCC, further pressures to be "univocal" tend to crowd out the most extreme views when scientists gather to make assessments.

it, "Although a body of scientific research exists on historical and archeological cases of collapse, discussions of mechanisms whereby climate change might cause the collapse of current civilizations has mostly been the province of journalists, philosophers, novelists, and filmmakers" (2).

So little serious scientific attention has been given to the possibility of societal collapse due to climate change that I think responsible scholars should currently withhold judgement on its likelihood and call for more research.

One thing that is obviously missing from Todd's assessment is the social response and adaptation to climate changes. Such responses may take the form of technological innovations or social changes.

Regarding technological resilience, I cannot go piece-by-piece through each of the seven concerns that Todd raises and argue that there is a certain technological "fix" for all of them. That would be cornucopian. But the existence of technological responses at least raises questions about the likelihood of collapse. Will desalinization, drought resistant crops, and improved irrigation techniques mean that we avoid massive conflicts over water resources? Will the rise in incomes in developing countries in the tropics mean that populations have near-universal access to air conditioning (run off clean energy) to withstand the dangerously high wet-bulb temperature while robots tend their crops? Will further increases in yields and shifts to meat substitutes offset the arable land lost to sea-level rise? Will urban defenses against sea level rise be effective enough to allow many coastal cities to remain functional or buy time for citizens to retreat to higher ground? None of this is clear to me, and I'm not sure why Todd rules out the possibility of technological solutions.

Technological responses however won't solve every problem, and as Steel et al. point out, there probably has already been cases of local collapses of functioning civilization that are already at least partly a result of climate change, such as the Syrian civil war. So if there are likely to be states and cities that collapse under the strain of climate change, does this spell disaster since the remaining regions of stability become inundated with climate displaced persons? First it is important to note, as well, that a large number of climate migrants remain within country borders. Many countries will have regions that are threatened less by climate change, to where people will retreat.

Todd implicitly acknowledges that climate change will not be an existential

threat for all regions *directly*. He mentions small land masses like Scotland, New Zealand and Alaska. But there are huge landmasses in the northern latitudes, namely Canada and Russia, that are likely to be habitable even at temperatures well above 3 degrees. Wet bulb temperatures are not likely to be an issue in Siberia or the Yukon, and melting permafrost, with all its dangers, actually opens up arable land for farming in northern regions. Even a 3-degree level of warming will have some good effects somewhere. Of course, it is deeply unfair that the regions that are likely to be affected the least by climate change are often regions that have historically much higher carbon emissions, but that is an issue for another dialogue.

Undoubtedly though, there will be increased numbers of people fleeing uninhabitable areas, some of whom will seek a new home in increasingly desirable higher latitudes. How will those regions respond? This question seems even harder to answer than the first question about technology. Part of it depends on our moral development. Currently, attitudes in wealthy, stable states towards migrants fleeing social turmoil exacerbated by climate change are mixed. But think how much cultural attitudes have shifted since the 1980s. Is it not at least possible that states will become more receptive of climate displaced persons in the future? A lot depends on the way we build the groundwork for such changes. As birth rates continue to fall, there might also be self-interested reasons for states to relax their current immigration restrictions significantly. In any case, arguing that because some regions might become uninhabitable, this will cause a domino effect that leads to global collapse appears to be unduly pessimistic.

What about ecosystem resilience? We rely on ecosystems for a huge range of services, from pollination to flood control, to resources for food, fiber and medicine. It's abundantly clear that climate change is leading to a significant increase in the rate of extinctions, although the rate is a matter of significant debate. Regardless of the scale of the impact, this is something to mourn, regardless of whether one thinks species mainly have aesthetic value, instrumental value, or intrinsic ethical value. However, the increase in extinction rate over a matter of decades does not automatically mean that ecosystems themselves will collapse. Some theories in ecology suggest that ecosystems contain far more species than is necessary for healthy functioning. The extent to which ecosystems, like civilizations, will adapt to a changing climate, is another

reason I think we should see civilizational collapse as a concern, but not a given.

Overall, Todd, I haven't seen you give a strong argument why civilization will probably collapse at (or before 3°C). I think you have a hunch, collated from absorbing widely, but focused on the worst possible effects, many of which are modeled using RCP 8.5, which neither of us think is a particularly plausible pathway[40]. That doesn't mean we should rule out the possibility of civilizational collapse. We should study it carefully, and Kemp et al. (2022) provide a good roadmap for doing so.

The key piece of disagreement that I am most interested in here is probably your lack of optimism about our ability to adapt, as a species, to these changes, at least to the level of allowing civilization for most of humanity. Why the pessimism here?

Todd Reply

Ahhh, the red herring of "pessimism." Having heard this often before from other interlocutors, a part of me wants to respond back, why are you so set in your confidence about the ability of humans to figure this all out, despite all the data points I've shared throughout the paper (entirely limited by word count–I could keep providing data point after data point)? Why the technotopian ecological modernization "hopium" and faith in technological interventions that can somehow scale out to reduce greenhouse gases and offset the nested tipping points that are already freaking climate scientists out now (Sobel 2024)?

Rather, to me, my position is "realistic." It's based on years of researching social movements, environmental movements, capture of governance systems by fossil fuel lobbyists, insights from Jevon's Paradox, and based on the data that suggests that at its core, civilization exists at odds with the laws of thermodynamics and with the resilience of ecosystems. Furthermore, despite countless meetings and articles and memos saying we need to STOP, humans are

[40] For a number of path-dependent reasons, literally thousands of scientific studies use an RCP 8.5 or SSP 5 as a likely "business as usual" or "no-policy" scenario (Pielke and Ritchie 2021). This is highly misleading, both because RCP8.5/SSP5 was never intended to play the role of a business-as-usual scenario (Pielke and Ritchie 2021) but importantly because its high GHG emissions rest on what would now be a major *renaissance* of coal, projecting a five-fold increase in coal use by 2100 (Ritchie and Dowlatabadi 2017; Hausfather and Peters 2020)

nonetheless continuing, aggressively, with business as usual, because for civilization to continue requires us to continue to live in such ways; ways entirely at odds with how the planet itself seems to work (or at least requires living in ways that ignore physics, chemistry, and biology). We are also living through the resurgence of right-wing populism, which is entirely going to influence the politics and cultures of Russia, Canada, and elsewhere; those countries with some capacity to deal with 3°C temperature increases, who will be tasked with letting large populations of non-white climate refugees into their borders. Given all of this, I am swayed by that sentiment of past behaviors predicting current and future ones.

But to your articulate and heartfelt points, directly. Is it possible there could be a moral awakening? One would (could?) hope. Could there be some brilliant scientist tinkering in some lab figuring out a way to rapidly capture carbon and methane, and to bring ocean acidification under control? Sure. And if so, would I be the first one to celebrate both of those scenarios, and to wish most of my labor in teaching and research and publishing over my career to-date (2014; 2015; 2017; 2020; 2021a; 2021b; 2021c; 2023; 2024) would be no longer needed and entirely wrong? Yes, and yes! However, if I have hope about humans figuring it out, it will not be from civilization. It will be from whatever comes after that, as many humans hopefully reattune to their places, develop mutual-aid based economies of equality, care, compassion, and thrift, and develop ways of living that live off of real time sunlight, but that will sadly be entirely constrained by the triage of a 3°C planet. We need the majority of humans living this way now, even, to have hopes of transitioning into any type of flourishing that may be possible at 3°C.[41]

To the pessimism, as you call it, it is informed by encountering views like the two shared below:

1. the position of William Rees, Professor Emeritus of human ecology, ecological economics, and regional planner, who co-developed the concept of the "ecological footprint," and who writes, "Overshoot is a meta-problem: climate change; plunging biodiversity; pollution of land,

[41] In a similar vein, the professor of energy and climate change Kevin Anderson (2023) heavily criticizes the IPCC project as being political (possibly unconscious) and based on flawed assumptions about future negative emissions technologies; and more so, heavily criticizes its models as embedding colonial assumptions, power dynamics, and trajectories.

> air and waters; tropical deforestation; soil/land degradation etc., etc., are all co-symptoms of overshoot. Climate change is an excess waste problem — CO_2 is the greatest waste by weight of modern techno-industrial (MTI) economies. We cannot solve any major symptom of overshoot in isolation. Indeed, the mainstream approach to emissions reductions will not only fail to subdue climate change but, by promoting material growth, will *exacerbate* overshoot" (Rees 2014), plunging humans into what he calls a "plague phase," as at an aggregate species level our overshoot is equivalent to a plague wiping out ecosystems throughout the world.
>
> 2. The IPCC commissioned a group of 234 scientists to write Working Group I of the Sixth Assessment Report[42], and of the 90 who responded, when anonymously surveyed, 60% of that subcategory of IPCC scientists who answered felt we will end up at minimum 3°C warming by 2100.[43] Of these, some even answered 4C by 2100, and overall 82% felt that they would see "catastrophic" impacts from climate change in their lifetimes.

In reading studies and claims like these, it may be that my brain, like yours, is already "wired" down neural pathways and emotionally laden lived experiences, that respectively nudge us further into a worldview orientation about climate change. Yours seems to be, "Things for some people in some places will get bad, but we'll figure it out with science and technology and at some point some enlightened policies, and I put my faith in the middle ground of consensus IPCC science." Mine is what's been shared throughout this dialogue/paper, where I see overwhelming evidence of planetary catastrophe and suffering and collapse occurring, right around the geological corner. And as we wrap up our dialogue, I think that it is ok if our worldviews are incommensurate. This is because I know we both come from a place of informed care in trying to make the best possible future world–this is a daunting, vast, scary, sobering reality we are living through, and that only gets worse from here, by definition, at least for most currently evolved organisms above the size of bacteria. Given this position of mine, what I wouldn't give for you to be right. I am just not seeing it, even after this rich dialogue with you.

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[42] https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

[43] See Tollefson (2021). Meanwhile another team (Glavovic, Smith, and White 2022) said climate scientists need to stop generating more data until governments finally take the data-to-date seriously, pointing out that almost all metrics have only gotten worse, despite the science on climate getting better.

CONCLUSION

In drawing a conclusion to our dialogue, we want to highlight three broad lessons from the process of this dialogue.

First, there is a significant lack of serious interdisciplinary scholarly discussion of the risks of civilizational collapse that climate change poses. Consider the survey Todd cited just previously. It showed most of the IPCC authors surveyed expected to see "catastrophic" outcomes within their lifetimes. But the scale of these catastrophes was never specified. More generally, study of the impacts of climate change and society have been dominated by "integrated assessment models" which try to put a dollar value on each marginal tonne of CO_2 (or equivalent) that is released. However it has been well understood in the modeling community that these struggle to represent the risks of local or even global societal collapse (Kemp et al. 2022, Steel et al. 2022). While we have a wealth of models, projections and integrated assessments to discuss in Section 2, on temperature rise, we lack similar models, projections and assessments of the effects of any given temperature rise on the likelihood of civilization continuing. We agree with Kemp et al., who state that "Facing a future of accelerating climate change while blind to worst-case scenarios is naive risk management at best and fatally foolish at worst" (Kemp et al. 2022: 8) and Steel et al., who suggest that "A sober assessment of the risk of climate collapse…may help to settle nerves and spur action" (Stell et al. 2022: 4).

Second, in our own discussion as two non-specialists on this topic, we both feel we gained significantly from the process of formally trying to make the best case for our position. It wasn't until we started to fill out tables and graphs of our own best guesses at future temperatures that one of us (Todd) realized the other (Ewan) was not naively assuming humanity would likely keep temperatures below 1.5 degrees. Both of us found that having a skeptical eye on their evidence they saw as solid led to a greater sense of epistemic humility, and better understanding of the strengths and weaknesses of their evidence base. This process also helped both of us realize that climate change is communal–it will impact everyone (although not equally) in our communities, and that therefore everyone in the community must be at the table. Even if they have differences in interpretation of the science and of presumed impacts. Rather, collaborating on minimizing suffering and generating resilience unites us, much more, than some of our

incommensurate differences that still remain after our discussion.

Third, the dialogue acted as a case study of different approaches to scientific expertise. While one of us (Ewan) takes the attitude that where there is controversy among scientists (for instance about how bad climate change will be), relying on comprehensive assessments, in particular that by the IPCC, and reputable modeling groups such as IEA, and Climate Action Tracker assessments is a far superior tactic than trying to gather evidence and synthesize it oneself. However, the other (Todd) believes that the rapid pace and severity of climate impacts surpass what models can cover, and this to him is evident already, and at only approximately 1.3°C warming; that the conservative nature of such large assessments struggle with modeling synergistic tipping points.

We end with another point, that is both ontological and epistemological. Rather, it is a question that we feel more people may want to reflect upon and engage. This is the tension point about at what point are we climate "experts," by default of being a human living through all this? Or to reframe this, does the lived experience of sobering climate events and worsening climate trends over the timeframe of our respective individual lives not count for evidence, as well, regardless of what models and climate experts tell us? And if it does count (and we are divided about the extent to which it does) where does the line end of the models and science as being more important as data, than one's community being razed to the ground by a global heating fire? Or of one's community being inundated by sea level rise? Sadly, such questions will likely become more germane in the decades to come, whether we halt global warming at 2°C by 2100, or we end up at 3°C and possibly beyond.

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