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In my last post, I sketched a few of the many intense tensions and contradictions swirling around this year’s Conference of the Parties (COP25) to the UN Framework Convention on Climate Change (FCCC). In this post, I’ll try to make some sense of the biggest tension of all, one that folks working on climate are asked about all the time – how to characterize the overall prospects for human welfare in the face of climate change. How bad is it? Is this our last chance to avoid catastrophe? Or is it already too late? And what do these questions even mean?

How Bad is it?

This big question has been around for 30 years, yet still comes up in various forms every day – now with increasing urgency and intensity, including this week at the COP. I’ll dig into it using as a hook an exchange that occurred a couple of months ago, which sharply illuminates the issues – a strange little essay in the New Yorker by novelist Jonathan Franzen, which triggered a firestorm of subsequent criticism.

Franzen opens with a bang, asserting that it’s too late to save the world from climate change – whatever that means – and based on that presumption, asks what is to be done. He rejects continued efforts to limit climate change by rapidly cutting emissions as futile, mainly based on the record of three decades of failure since broad scientific knowledge of the threat was rock-solid around 1990, and charges

climate activists with delusion and magical thinking. Instead of further efforts to stop climate change, he advocates accepting the prospect with equanimity, attending to things within our power to control – like Pangloss at the end of Voltaire’s Candide, cultivating his own garden. One witty commenter called the essay “stylish despair.”

Critics piled on enthusiastically, and Franzen gave them plenty to work with in the form of several large scientific errors. Critics correctly targeted his false dichotomy over whether climate “disaster” or “apocalypse” can or cannot be averted; his confident claim that beyond some relatively near “point of no return” in global temperature, natural positive feedbacks will take over to push climate to uninhabitable extremes; and his assertion that once the world has surpassed 2ºC of heating or so, it no longer matters how much further it goes, presumably because beyond that point everything of value is lost – this last claim managing to pack both a grave scientific error and a grave moral failing into a single statement.

But the science of climate and impacts is distinct from questions of feasible responses, which are mainly about how fast world emissions can be cut to limit further heating. Franzen’s description of the cuts needed to meet the Paris targets – limiting global-average heating to 1.5 to 2.0ºC – is that they remain technically possible but are unlikely to be achievable in the messy politics of the real world. In addition to calling out his scientific errors, critics responded that these targets are not just necessary to limit risks, but also achievable – some suggested even easy, “if we just get on with it” or words to that effect.

These are not mainly scientific matters. Rather, they concern knowledge and judgments about what rapidity of societal changes are possible, which are matters of technology, economics, and politics. They thus admit more room for conflicting interpretations and speculations than climate science. And on this point, in my view, Franzen is closer to being right than his critics: it takes strikingly implausible assumptions about rapid social and economic change to argue that these targets are achievable, and it gets harder with each passing year. Essentially no one with expertise on emissions and their determinants thinks these are achievable without an enormous fudge – and even the fudge depends on extreme and suspect assumptions.

Emissions Budgets and “Years Left”

The main currency of this argument is emissions budgets. It is well established that

total global heating depends on cumulative emissions, i.e., how much total greenhouse gases human activities will emit until they come to a complete and permanent stop. It doesn’t matter when the emissions occur, it’s the cumulative total over all time that counts. This is called an emissions budget because the analogy to financial budgets is quite precise. You have a fixed amount of money and can choose how much to spend each year, but when it’s gone it’s gone: spend more, and you use up your budget faster, slower and you get to keep spending longer.

Humanity’s current spending rate – total emissions each year – comes in two forms, a bigger number and a smaller one. The bigger one is emissions of all greenhouse gases from all sources, measured in terms of “CO_2-equivalent,” the amount of CO_2 that would exert the same total heating effect. In 2018 this number was 55.3 billion tons (Gt) CO_2-equivalent (denoted $GtCO_2e$) and increasing (at 1.3% per year over the past ten years). The smaller number is emissions of just CO_2 from energy and industry – i.e., it leaves out other greenhouse gases and CO_2 emissions from land-use and forestry. In 2018, that number was 37.5 $GtCO_2$ (no conversion and no final “e” needed, since these emissions are actually CO_2), increasing 1.5% per year over the past ten years. Although the larger number is what actually drives climate change, the smaller number is what most argument and response efforts has focused on. The smaller number is also the part for which the fixed-budget analogy is most strictly correct, since some non-CO_2 gases have substantial natural sinks that make the timing of emissions matter more. Since there is quite a bit of uncertainty about the size of the budgets, we don’t need to be completely precise, so just think of annual emissions as around 40 to 50 billion tons CO_2 pear year – and remember that for all the progress in some jurisdictions and sectors, this world total is still going up, not down.

Working at this level of (im)precision, the remaining emissions budget to limit heating to 2°C with “high” probability (2/3 or more), from now until whenever emissions cease forever, is about 1,000 Gt, or 20 to 30 years emissions at the present rate. The budget to limit heating to 1.5ºC with the same probability is about 200 – 250 Gt (4 to 6 years at the current rate), or about 400 Gt (8 to 10 years) to achieve 1.5°C with only 50/50 likelihood. When people say things like “only 5 years to avoid catastrophic climate change,” they are talking about these estimates. To focus on near-term actions, a UNEP report last month translated budget estimates (slightly different ones, but within the margin of fuzz we’re working with) into annual rates at which world emissions must fall over the next ten years to be on

track to meet these targets: 3% annual decrease through 2030 for 2ºC, 7.3% per year for 1.5°C (both at 2/3 likely), with similar or faster reductions continuing after 2030.

The uncertainty in these budget estimates, between different definitional assumptions and true scientific uncertainties, is something like plus or minus 50 percent. It would make a huge difference if the lucky end of these ranges turned out to be correct, but even staying within these larger budgets would require rapid technological and economic transformations that have few historical precedents, none that were sustained for the required multiple decades. These budgets are also much tighter than nations’ announced plans, which in turn are stronger than nations’ actual policies and actions. Even optimistic interpretation of current plans would only limit world emissions to slightly above present levels in 2030, not the 25 to 55 percent cuts needed to be on track to 2.0 or 1.5° And there are many signs of backsliding, including all the maneuvering at this week’s COP. Present commitments and trends are headed toward something like 3.0 to 3.5°C heating by end of century.

Roll-out and Heterogeneity: Stopping the Locomotive

That’s the bad news. There is also plenty of good news – most importantly, the rapid progress being achieved in technical performance and deployment of a bunch of low and non-carbon technologies such as solar and wind power for electrical generation and electric cars. These have experienced extreme gains in performance, cost, and deployment scale – perhaps the biggest piece of good climate news of the past ten years.

But this rapid progress only partly mitigates the dire situation presented by emissions budgets, for two reasons: scale-up, and heterogeneity. First, low-carbon innovations must be not just developed, but deployed at a scale to replace the entire installed capital stock in the economy. This is a stock-flow problem: there is an awful lot of steel and concrete out there, and even with extreme efforts it turns over slowly. Historical transitions among major energy technologies have taken 80 to 100 years. Solar and wind electricity, the area of greatest recent progress, illustrate the stock-flow problem: these sources have been more than half of world electricity investment over the past few years (Yay!), such that they contributed about 10% to world electricity generation in 2018 (What, so little? Boo!)

Second, rapid recent progress has been in areas where technical barriers to non-

carbon sources are smallest. These gains often have spillovers that make further gains easier, but other areas – e.g., transportation other than light vehicles, agriculture, industrial process heat, even the last 10 or 20 percent of electrical generation – will still be harder and slower. Much more progress is likely, but not at the scale and speed needed to stay within these budgets. Turning over the technological and energy base of the whole world economy – not to mention agriculture – is like steering a supertanker or stopping a speeding locomotive. You can do it, but it takes an intense effort sustained for a long time – in this case, over multiple decades.

The New Hope/The Fudge Factor: Negative Emissions

Over the past few years, these budget estimates have been shaken up by a surge of interest in a new set of technical options – or maybe a new fudge – carbon dioxide removal (CDR) or “negative emissions”. These terms cover a dozen-odd highly heterogeneous methods of removing CO_2 from the atmosphere after it is emitted, as opposed to not emitting it in the first place. These methods moved to center stage around Paris, as a way to surmount the growing gulf between the target of holding global heating below 2ºC and what looked possible in models of the economy and energy system. I will discuss these in more detail in future posts.

These methods look promising, although they are all at early stages of development and present various concerns including limited total scale, competing with food production for land and other resources, environmental or socio-economic impacts, or high cost. If these methods, in come combination, work and are acceptable, they can represent important expansion of climate response capability. Indeed, they are the only way to run climate change backwards and restore some prior, less perturbed climate, by removing CO_2 from the atmosphere faster than new emissions are adding to it.

But most present scenarios that achieve the Paris targets do so by relying on these removal methods at extreme scale. All scenarios that achieve 1.5 or 2.0°C limits involve emissions going net negative, by year 2050 in 1.5°C scenarios and by 2070 in 2.0°C scenarios, with cumulative removals by 2100 ranging from a few hundred Gt to more than 1,000. This represents an extreme degree of reliance on future deployment of a cluster of technologies, many of which are not yet developed or demonstrated (or barely so), which may exhibit serious scale limits or harmful impacts. Their contributions may be large, but reliance in present emissions scenarios is running far ahead of what can be confidently projected. And even if

some combination of these is effective and benign, they face the same scale-up issues as transforming the energy system to cut emissions: to be on track for the massive removals assumed for later in the century, these must scale from essentially zero today to billions of tons removals a year within one or two decades. There’s that locomotive again – except now I guess it’s the backwards locomotive and it needs to be accelerated, not decelerated. It still takes a long time, even with intense effort.

And Once Again: How Bad is it?

Pretty bad, but quite uncertain, not necessarily catastrophic in any global sense – and still absolutely worth intense efforts to make it less bad.

The question unpacks into several parts, each with multiple layers of complexity.

The scientific parts don’t give much comfort. The Paris targets don’t represent known boundaries of catastrophic change, but judgments of the aggregate severity of impacts at different levels of heating. Present judgments are that 2ºC looks pretty serious, 1.5°C looks substantially better while not fully avoiding serious impacts in particular places and sectors. How much worse 2.5 or 3.0 or 3.5°C are has been less studied, but all indications are that they will bring severe impacts. The step from temperatures to emissions budgets introduces a little wiggle room in the wide range of budget estimates, but this gives only a little comfort. More generous budgets give a couple more decades to get aggressive programs of mitigation and CDR scaled up, but these uncertainties, like all uncertainties, cut both ways. Humanity could be lucky – climate sensitivity and impacts could be lower than current best estimates, giving a little more time to massively cut emissions. But unlucky realizations of uncertainties would have the opposite effect, speeding up the required response schedule. Moreover, since the general pattern of recent scientific advances has been toward prospects looking more severe, not less, it is reckless to gamble on geophysical or climate uncertainty making things turn out OK.

The socio-economic parts – as the controversy over Franzen’s essay illustrates – admit a wide range of possibilities, which are not quite scientific uncertainties but more of a blend between those and the intensity of organized, competent human effort.

Could emissions drop much faster than present projections, through intense

commitments of resources and political attention to rapid innovation across non-carbon technologies, diffusion, and scaling? Sure, this is possible, but it would represent intensive political, business, and citizen mobilization, on a scale never previously seen and not assured of success – vastly beyond present simplistic calls to do it with one technology or one magic-bullet policy. Sorry, advocates of a $30 or $50 a ton carbon tax – this would be very helpful, maybe even close to necessary, but is far from sufficient.

Could such transformations occur so rapidly as to hold near 2.0°C even without gambling on billion-tons-a-year carbon removals deployed within a few decades? Yes, even that is possible – although every scenario that achieves this includes massive, worldwide behavior change: large drops in energy consumption, dietary shifts away from meat, etc. While rapid technology changes to cut emissions could plausibly be driven by strong, well-designed policies, adding in such extreme behavior changes probably moves these beyond the scope of policies and laws imaginable in liberal democracies, toward revolutionary change – with all the associated chaos and threat to other values.

Could atmospheric carbon removals be deployed and scaled up at the Herculean rate needed to close the gap and hold to 2.0 or 1.5°C without such revolutionary social changes? Again the answer is sure, maybe. But these approaches are presently at the peak of a hype cycle, with many methods being promoted far beyond their likely contribution. In the near term, further emissions cuts dominate CDR on grounds of technological readiness, cost, and likely side effects. CDR absolutely merits aggressive promotion, scale-up, and support to promote its development, testing, and expansion. But it is far more likely to contribute as an offset for the hardest, last parts of emissions cuts – or more dangerously, to bring the world back from an overshoot of a temperature target – than as something that replaces emissions cuts for the early steps.

Are there no other options? Yes, there is one, but it is a huge wild-card. The discussion up to here assumes no use of solar geoengineering – large-scale engineered interventions to modify the Earth’s energy balance by reflecting back a little sunlight.

I’ll comment on current debates on solar geoengineering in future posts, but there are three quick highlights. First, solar geoengineering could rapidly offset any projected amount of global-average heating, but its compensation for climate and other harms of elevated greenhouse gases is intrinsically imperfect, so it can only

supplement, not replace, emissions cuts or CDR. Second, within those intrinsic limits, early research suggests that solar geoengineering could effectively reduce climate change, relatively uniformly worldwide, with surprisingly small side effects – although many serious uncertainties need further study. And third, because of its high leverage and global effects, solar geoengineering would require global governance of a form and scale never previously seen – and if badly used or governed, could increase global injustice, conflict, and risk. Viewers of the TV show “The Good Place” may recall the iconic line of the character Jason, “Back on Earth, whenever I had a problem I would throw a Molotov cocktail – and then, right away, I had a different problem!” Solar geoengineering is like that: upon deployment, right away, the world would have a different problem. The ability of world governments and international institutions to manage that “different problem” is very much an open question.

Putting these pieces together, the main message is this: Absent extreme technological, economic, and social transformation – including some combination of rapid technology deployment, large-scale worldwide behavior change, or revolutionary social and political change – the world is very likely on track not to 1.5°C or 2.0°C heating by 2100, but something closer to 3.0 or 3.5°. Current efforts, even intense ones, are probably fighting for the difference between end-of-century heating of 3.5°C and 3.0°C, maybe with good fortune 2.5°C (Again, absent use of solar geoengineering).

Here, however, is a crucial point where Franzen and his critics fall into the same error. Franzen interprets this as grounds for passivity and despair: The world is unavoidably headed off a cliff, beyond which everything of human value is lost and further efforts are futile. His critics agree that the world headed for a single, catastrophic cliff, but think this can still, with intense efforts, be avoided. International affairs scholar Oliver Geden has criticized this rhetorical stance as “it’s always five minute to midnight,” and indeed similar claims of last-chance-to-avoid-catastrophe have been commonplace since the 1990s. I find they sound like the coach of a sports team that is behind at halftime, exhorting the team to stay focused and positive because they think this attitude will keep victory within reach – and suspect the reason for critics’ outrage at Franzen is not so much his errors, but that he is undermining the team’s morale.

Both sides here rely on the same, erroneous premise – the cliff. There is nothing in present scientific knowledge of climate change to support the image of a single, imminent, globally catastrophic cliff. Climate change is already catastrophic for an

increasing number of vulnerable people, communities, and ecosystems worldwide. Moreover, many geophysical processes at various spatial scales exhibit threshold behavior: some scientists argue from paleoclimatic evidence that even the 1.0°C heating that has already happened is beyond the long-term stability of the major ice sheets, and thus already locks in eventual sea-level rise of several meters (but this point is contested, and even if this is correct there is wide uncertainty on how fast it will happen).

But viewed globally, there is no known single threshold that looks like a cliff. As global heating proceeds, multiple impacts in multiple places will get worse, but the aggregate shape of impacts is more like a curved surface on which things get worse and worse at an increasing rate than like an abrupt cliff. Even if many desirable limits, including present targets, are out of reach; even if present efforts are fighting for the difference between end-of-century heating of 2.5 and 3.0°C, or 3.0 and 3.5, or even 3.5 and 4.0; these differences are of overwhelming value for human welfare and the natural environment, and are absolutely worth fighting for. Although these outcomes are all really bad, they are not the same, and the differences between them are of transcendent importance, for human welfare and ecosystems.

The claim that beyond present targets all is lost and we should give up is wrong, even dangerously wrong, because it justifies abandoning these essential continuing efforts. The analogy to a coach’s motivational talk in the locker room is also deeply misleading, because every game has an endpoint at which you add up the score and declare a winner, but Earth’s and humanity’s climate futures have no such endpoint.