Sustaining civilization while stabilizing Earth

Adaptive mitigation – Concept note[1]

This project visualizes our options to sustain civilization and stabilize Earth. Can we build a humane world order, even as the international system buckles under the stress of biodiversity loss, pandemics, abrupt climate change, and the loss of trust in institutions? Based on transdisciplinary methods and system dynamics, including models like *Limits to Growth (LTG)* (Meadows et al. 2004), we propose building tools and planetary infrastructure to mitigate existential risk. Geographically we focus on China and Europe to understand feedbacks between urban to planetary scales.

This note invites dialogue, practicing ideas from post-normal science. To ease participation in problem-solving, an open version in Google Docs allows anyone to comment and suggest changes.

> Strictly extrapolative works of science fiction generally arrive about where the Club of Rome arrives: somewhere between the gradual extinction of human liberty and the total extinction of terrestrial life.
>
> *Introduction to: The Left Hand of Darkness*. Ursula Le Guin (1969). [323 ppm CO_2]

1. Possible futures: Complexity, simplification or collapse

1 **Problem:** Can we understand global dynamics and learn to predict the interactions of society, resource depletion and discovery, and climate change? Current theory cannot reliably generate this knowledge, threatening survival. Climate economics (Nordhaus 2017; Tol 2018) and the integrated assessment models (IAMs) of the Intergovernmental Panel on Climate Change (IPCC) underestimate economic damages from climate change by at least one order of magnitude. Actual damages may be so great as to threaten the survival of civilization (Keen 2020). Yet experts struggle to be heard as Earth unravels (Gergis 2020). A tremendous disconnect persists between the rising alarm of climate scientists who study planetary change, and climate economists who study models that trivialize climate impacts on population and infrastructure. To sustain humanity and stabilize Earth, we need theory—including economics—that reflects real-world constraints (Garrett et al. 2020).

2 **Solution:** We explore the idea of adaptive mitigation to build theory and discuss sustainable paths. A quasi-equilibrium is conceptually possible in our highly nonlinear world (Forrester 1971). Yet theory—reflecting planetary dynamics in narrative form—cannot be a solution in itself. Any new narratives must be powerful enough to replace the narratives that guided modern civilization to its current breaking point. We confront the immense power of organized denial and our innate drive to seek meaning and to tell ourselves the stories we want to hear—what Nietzsche (1873) saw as our *mobile army of metaphors, metonyms, and anthropomorphisms*. Our task is to learn to see our world through nonhuman eyes (Scranton 2015b), to rebuild the foundation of modern civilization itself.

3 **Methods:** To clarify our choices, this project reads science, philosophy, arts and the humanities to *understand* the limits of our language and agency; and learn to *act* within these limits. We can view civilization as a dissipative structure that consumes energy and matter from its environment to sustain itself and grow, and emits waste and dissipates heat. This view challenges many deeply held beliefs in society and economics (Hagens 2020), not least in the humanities (Chakrabarty 2017).[2]

[1] Paul Maidowski. "Sustaining civilization while stabilizing Earth. Adaptive mitigation: Concept note." 2/5/2021. This current version, and an open version for collaboration, are available at https://carbonlaw.eu/current

[2] Garrett (2019) et al. describe civilization as a thermodynamically open complex system, or *heat engine*, using physics to predict economics. Blog: http://nephologue.blogspot.com/2019/12/economic-growth-engine-of-collapse.html

4 **Contribution:** *Adaptive mitigation* is an integrated approach to mitigation, geoengineering, and adaptation that reflects energy, resource, and time constraints. Starting with *Limits to Growth (LTG)* simplifies this challenge (Sterman 2012) (see Figure 1). To sustain society as the climate crisis accelerates, we need to mitigate our most urgent existential risks. Earth's energy imbalance (EEI), the radiative imbalance at the top of the atmosphere, is the critical metric of future global warming. *Climate stabilization*, the goal of the Climate Convention (UNFCCC) and Paris Agreement, implies an EEI near zero (see Figure 2). This means that we must reduce CO_2 concentrations (pCO_2) from 414 parts per million (ppm) below 353 ppm (von Schuckmann et al. 2020). This is near-impossible, equivalent to *undoing the past several decades of civilization growth*. Such fantastically improbable change is routinely *assumed* in IAMs and policy. More robust theory will integrate economics, science, and humanities to reflect inertia in society and Earth's system. This project seeks to build such theory.

5 **Outlook:** Can society learn fast enough to preserve livable futures for life on Earth and ourselves? Global CO_2 levels exceed 414 ppm today, increasing exponentially at a rate of 2.5 ppm per year (2010-2020). Not even the cumulative effects of past recessions, pandemics or wars reversed the dynamics of exponential growth at planetary scale. pCO_2 increased by 5 ppm per decade since 1750 on average, more than offsetting the pCO_2 decline of the past 23 m.y. Current concentrations force Earth into *Miocene*-like climates (Cui et al. 2020). Yet states and the IPCC downplay the problem (Spratt and Dunlop 2018), upholding the illusion that *decarbonization-only policy* could succeed. In reality, decarbonization *and* immediate extraordinary measures like solar geoengineering and ocean deacidification—full planetary governance—are needed *now* to preserve humanity (see Figure 3).

6 **Short-term choices:** Even if the greenhouse effect did not exist and global warming posed no existential risk, we would still confront the human predicament of living in a *finite* world. *Climate* policy is a symptom rather than cause of unsustainability: Problem-solving institutions like empires or states remain structurally dependent on growth. (1) *Complexity* is a problem-solving strategy that often succeeds in the short run, but in the long run can prove counterproductive as it accumulates unsustainable structures and requires rising energy and resource subsidies. Civilization's other two possible future paths are (2) voluntary *simplification*, or (3) involuntary change: *collapse* (Tainter 2000).

7 **The long run:** Which of these futures—*complexity, simplification, collapse*—are still possible in 2021, and can we build them? In any case, billions of people will need new narratives over the course of this century. 50 years ago, the Club of Rome (1970) introduced *LTG* to a rapt but sharply divided international audience. It linked our *predicament*—the interacting dynamics of population, industrial activity, permanent pollution, food production, and resource depletion—to its common cause, exponential growth, to see at which point *collapse* would become inevitable. Meadows et al. (1972) found that leaving growth unmitigated even for a decade would commit the world to the dynamics of *ecological overshoot and collapse*. We still follow these business-as-usual *LTG* scenarios, where *collapse* is caused by leaving permanent pollutants like carbon dioxide unaddressed (Herrington 2020). This analysis matches the dynamic long-run evolution of the global economy (Garrett 2014, 2015).

> Thinking seriously about climate change forces us to face the fact that nobody's driving the car, nobody's in charge, nobody knows how to "fix it." And even if we had a driver, there's a bigger problem: no car. There's no mechanism for uniting the entire human species to move together in one direction. There are more than seven billion humans, and we divide into almost 200 countries, thousands of smaller sub-national states, territories, counties and municipalities, and an unimaginable multitude of corporations, community organizations, neighborhoods, religious sects, ethnic identities, clans, tribes, gangs, clubs and families, each of which faces its own disunion and strife, all the way down to the individual human soul in conflict with itself, torn between fear and desire, hard sacrifice and easy cruelty, all of us improvising day by day, moment to moment, making decisions based on best guesses, hunches, comforting illusions and too little data.
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> *Anthropocene City.* Roy Scranton (2018a). [403 ppm CO_2]

2. Simple theory

The rest of this concept note adds flesh to this analysis (§1-7) and invites dialogue. Our challenge is to write simple theory*: to integrate the existing literature into narratives that describe our dynamics and options in actionable form.*

8 **System dynamics:** Sustaining civilization requires systems thinking. Rapid cuts in energy use are needed to avoid extreme climate change; yet energy, most immediately electricity and food, sustains civilization and cannot be cut at planetary scale and for all future, even if doing so were legal or ethical. No historical precedents exist for a structure as large as civilization (20 TW primary energy demand, equivalent to the energy contained in 270 million barrels of oil *per day*) to overcome the tremendous inertia accumulated over past decades of exponential growth (Garrett et al. 2020). This inertia will propel civilization forward, growing far beyond Earth's carrying capacity. This dynamic pattern of behavior follows from three obvious, persistent, and common features of the global system: erodable limits, incessant pursuit of growth, and delays in society's responses—in both science and politics—to approaching limits. Thus, it is no surprise that we follow the *overshoot and collapse* scenarios of *LTG* (Meadows et al. 2004, p. xviii). They follow from cumulative decisions and the normal functioning of a system, not its malfunction; a case of continuity more than change.

9 **Economics:** As an alternative to *overshoot and collapse*, Jay Forrester defined necessary conditions for *sustainability* 50 years ago—before the word even got its present sense—and debated them with William Nordhaus (Bardi 2018; Forrester 1971; Forrester et al. 1974; Randers 2000). From the 1970s, with the first IAM, *DICE*, in the 1990s, Nordhaus set the tone in climate economics, trivializing that we are on track to annihilate the human and natural world. In his Nobel Prize lecture, Nordhaus (2018, slide 6+7) described 4°C warming (3.5°C in 2100) still as '*optimal*.' A 4°C world would *end* civilization and may annihilate intelligent life on Earth; self-reinforcing feedbacks can trigger further heating. Trees will die worldwide already in a 3°C world (Bradshaw et al. 2021; Brodribb et al. 2020). Any theory that seeks to define conditions for survival needs to account for how Nordhaus and neoliberalism (mainstream economics), despite its obvious shortcomings and incoherence, managed to marginalize Forrester and system dynamics from the 1970s until today.

10 **Research question:** Civilization can be seen to evolve in a spontaneous feedback loop sustained only by consuming energy and resources from its environment (Garrett 2011). My question is how to understand and change the dynamics of this feedback. Current primary energy consumption E scaled linearly with historically cumulative economic production W in each of the past 50 years. The present state of the system is tied to its unchanging past through a constant factor

$$\omega = W/E = 5.50 \pm 0.21,$$

with ω in units of trillion 2019 USD of *cumulative* production per Exajoule of energy consumed each year (Garrett et al. 2021). Planned cuts through policy—or spontaneous cuts through the depletion of resources, environmental decay, pandemics or war—will have to be deep, continuous, and cumulative to overcome the growth of civilization and avoid extreme climate change (Garrett et al. 2020). Such change, implying lower population and living standards, will be highly unpopular.

11 This project joins calls for a species-wide conversation to *rethink economics* by Nate Hagens (2020), Jason Hickel (2020) and Julia Steinberger (2020). Our challenge is to do so *now* or learn to live with involuntary future change. Transforming our industrial into an ecological civilization requires humanities and science. This calls for critical thinking, a broad philosophical and humanist project (Scranton 2018c). For a focused, applied view, Garrett et al. (2020; 2021) discuss foundational questions on efficiency and growth. This project seeks to engage them, starting at planetary scale:

> Humanity grows when more energy is available than it requires for its daily needs. Then work can be done not just for sustenance but for expansion. Because current sustenance demands emerge from past growth, inertia plays a much more important role in determining future societal and climate trajectories than has been generally acknowledged, particularly in the physically unconstrained models that are widely used to link the economy to climate (Nordhaus and Sztorc 2013; Tol 2009). *We have accumulated over history a long series of innovations in efficiency* that continue to propel us forward. *Without forgetting these advances*, we will maintain a continued ability to expand our interface with the primary resources we consume.
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> Eventually, of course, the interwoven networks of civilization will unravel and emissions will decline, whether it is through depletion of resources, environmentally forced decay or—as demonstrated recently—pandemics (Le Quéré et al. 2020). But the cuts will have to be deep, continuous, and cumulative to overcome the tremendous accumulated growth we have sustained up to this point.
>
> The formulations presented here are intended to help constrain the problem by reducing the number of available targets that can reasonably be expected to lead to avoidance of extreme climate change. Notably, gains in energy efficiency play a critical role in enabling increases in population and prosperity, and in turn growth of energy demands and carbon dioxide emissions, contrary to what would reasonably be assumed if civilization did not grow (Andreoni and Galmarini 2016; Koomey et al. 1998; Raupach et al. 2007). *What seems to be required is a peculiar dance between reducing the production efficiency* of civilization while simultaneously innovating new technologies that move us away from combustion. [*emphasis added*]

Past world economic production constrains current energy demands. (Garrett et al. 2020). [412 ppm CO_2]

3. Understanding

12 **Philosophy:** Global warming is highly *counterintuitive* as we accumulate wastes and produce entropy essentially for *all future human time*. Society started to face these immense stakes (Scheffler 2013). Yet current climate policy focuses on details like technological and social change, greenhouse gases or the climate regime. We remain philosophically unprepared to think the deeper systemic causes and implications of unsustainability in civilization (Chakrabarty 2019; Corry 2020; McLaren and Corry 2021). This has been evident to expert observers since the collapse of international climate negotiations in Copenhagen in 2009 (UNFCCC COP15) (Irwin 2010; Schellnhuber 2015). We overshot the range of the *mid Pliocene Warm Period*, 3.3–3 million years ago, when pCO_2 below 400 ppm caused global average warming of 2–3 °C. Continuing GHG emissions point to *early Eocene*-like climates, with pCO_2 >1000 ppm and global mean temperatures ~13 °C higher than now. We would reverse ~50 Ma of cooling within 200 years (Burke et al. 2018; Hansen et al. 2016, 2017).

13 **Science:** The *cumulative* nature of our predicament is widely misunderstood because our brains and stories never evolved to make sense of *accumulation* (Cronin et al. 2009; Sterman 2002; Sterman and Sweeney 2002). Society will lag reality as long as we cannot reflect biophysically possible futures. To sustain society and stabilize Earth, the *Miocene Climatic Optimum*, ~16.9–14.7 Ma, with higher temperatures and moderately higher pCO_2 (~400–600 ppm) is a good analog for near-term futures (Steinthorsdottir et al. 2020). Our most existential risk is the thermal intolerance of biological life, as the inertia of civilization threatens to increase pCO_2 to *Miocene* or *Eocene* levels (Garrett 2012). As part of planetary emergency measures, the Mirrors for Earth's Energy Rebalancing (MEER) project at Harvard Rowland Institute suggests *adaptive mitigation*, a systems approach that combines adaptation, mitigation, and geoengineering (meerreflection.com). I propose developing these ideas in further transdisciplinary research, using system dynamics as a powerful language (Sterman 2018).

14 **Art:** Philosophy and art may help some, as living and working with the end of the world leaves us disorientated (Benjamin 2017). Can we imagine building 100,000s of km^2 of glass mirrors per year, effectively *now*? Planetary emergency action at such scales and timescales may be needed to keep Earth habitable until we can reduce pCO_2 below 350 ppm. This changes our role in the *Anthropocene*. Art can help us understand our predicament, and life-saving or destructive choices, more clearly.

15 Can we avert *overshoot and collapse* trajectories within our resource, energy, and time constraints, via the MEER project or other policy? Climate policy reveals societies' conflicts. In the hegemonic state of complex *emergent* systems, internal contradictions tend to be suppressed, not resolved. The resulting lack of novelty, diversity, and performance can reveal an *ancien régime syndrome* (Funtowicz and Ravetz 1994a), where the regime refuses to face or admit its problems even if they become obvious to everyone else. Even today, economics reproduces *socially constructed ignorance* (Giampietro and Funtowicz 2020). The success of simplistic IAMs since 1970 (van Beek et al. 2020), until today (§1), merits reflection. Post-normal science and ecological economics can help us address the deep uncertainty and ethical ambiguity inherent in these questions (Funtowicz and Ravetz 1994b).

16 Even if analysis leaves little ground for hope, *emergent* systems are not fully deterministic. Emergent complexity allows for agency due to human consciousness, foresight, purpose, symbolic form, and morality (Funtowicz and Ravetz 1994a). Advanced governance systems based on cyclical—not linear—ideas of *growth* and *time*, and recurring debt jubilees, allowed ancient civilizations to sustain themselves for 5,000 years in Mesopotamia in ecologically fragile environments (Irwin 2017, 2020). To heed Ursula Le Guin's (1969) words and defy the dynamics identified in *LTG*, we can seek to influence global dynamics through ethics, to create sustainable *and* humane futures (Scranton 2020). This is the motivation for this project. Without powerful new narratives, civilization may strain.

> The real challenge will begin when growth ends. Eventually, we likely face a global depression and other challenging departures from our recent trajectory. Those who understand and care about these things, who have social support, a modicum of resources, and psychological health, have to step up.
>
> *Economics for the future – Beyond the superorganism*. Nate Hagens (2020). [412 ppm CO_2]

4. Action

17 **Can we think** the end of our world, and do the work necessary to avert it? Preserving humanity requires that we learn to govern society in the biosphere. We may be able to develop an ecological humanism if we learn from ancient civilizations (Bardi et al. 2019; Scranton 2015a; Tainter 1988). This requires rethinking the philosophical foundations of civilization and rebuilding its physical infrastructure, down to the roots of economics and humanities, climate and sustainability science.

18 We propose pursuing such ideas as potentially auto-catalytic or self-organizing projects. Hagens (2020) and King (2021) offer pragmatic starting points for analysis, in addition to introductions like (Daly 1991; Meadows and Meadows 2007; Odum 2007; Richardson 2014; Sterman 2002). Both argue that institutions—including academia and climate science—exhibit a *systems* and *energy blindness* that leads us to systematically underestimate the role of resources and energy in all we do.

19 To address our systems and energy blindness, we need to learn to see and act in new ways. Research that combines art, philosophy and science can offer us powerful, unconventional perspectives (Ghosh 2016; Oreskes and Conway 2016; Scranton 2018b; Williston 2021). We apply post-normal science (Funtowicz and Ravetz 2020) and see social movements like Fridays for Future, Deep Adaptation (Bendell 2020) and Extinction Rebellion (Read and Alexander 2019, 2020) as an extended peer community that complements the academic communities. This project adds to the transdisciplinary field *collapsology* (Servigne and Stevens 2020), rooted in system science, which calls for urgent research. We hope to work with those who offer guidance in a changing world.

Collaboration: An open version of this concept note is online at https://carbonlaw.eu/current. As a living document, it encourages anyone to comment and suggest changes or ideas.[3]

Project details and documentation are downloadable at https://carbonlaw.eu/current.
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Version history:

As this project invites dialogue, the current concept note outlines ideas in an experimental format. I am grateful for all questions, resources or help to translate it into published or practical projects. —4 May 2021, Berlin, Paul M.

v.1 Minor corrections, global CO_2 trend reference (ESRL) and literature added (van Beek et al. 2020; Funtowicz and Ravetz 1994b; Steinthorsdottir et al. 2020). —5 May 2021, PM

[3] Direct link: https://docs.google.com/document/d/1DGqk8fIO_3xlyGnHK_90-ZzsXFNTT9dOuoY3Xd26Y50

Figure 1: Linking human activity, carrying capacity and technology (World3)

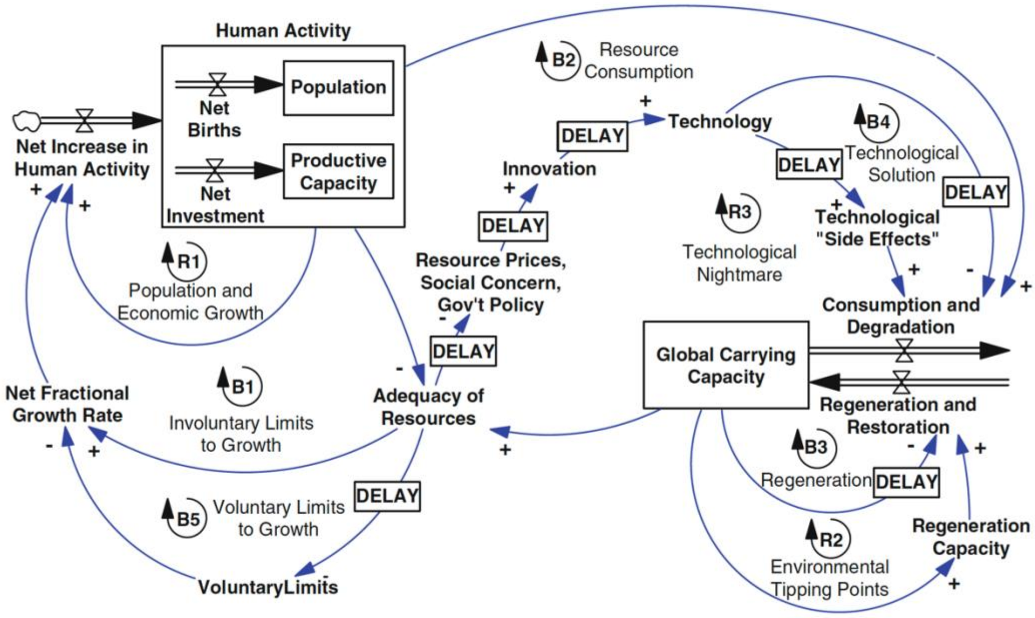

Figure 1: Growth, carrying capacity, technology: A simplified model of how growth in human activity interacts with Earth's carrying capacity (detailed World3 model in Meadows et al. 2004). *Source: Sustaining sustainability—Creating a systems science in a fragmented academy and polarized world. Sterman (2012, Figure 10).*

Figure 2: Change in Earth's energy imbalance

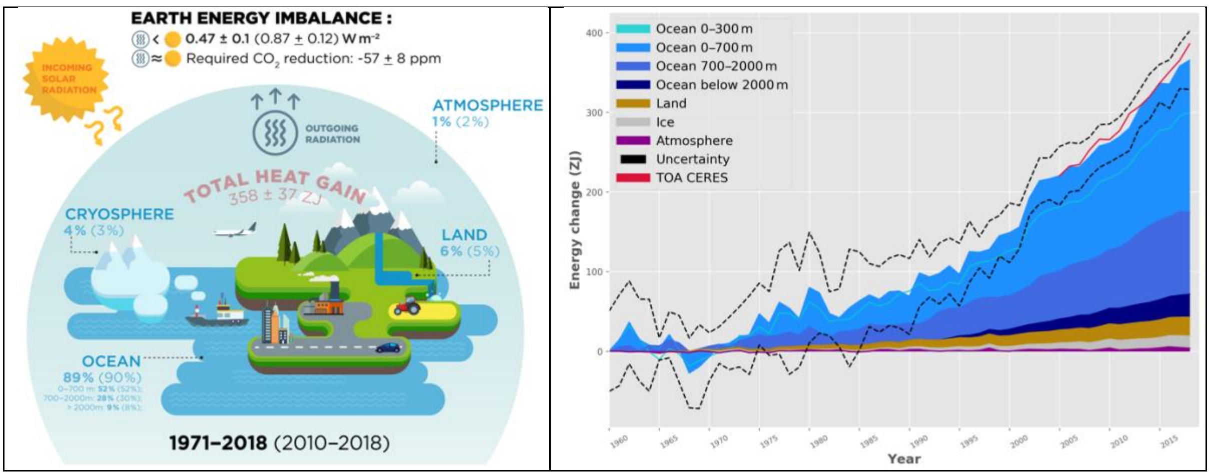

Figure 2: Left: Earth heat inventory for the current anthropogenically driven positive Earth energy imbalance (EEI) at the top of the atmosphere. To reduce the 2010–2018 EEI of 0.87± 0.12 Wm^2 towards zero, atmospheric CO_2 would need to be reduced by –57 ± 8 ppm. Right: Earth heat inventory (energy accumulation) in ZJ (1 ZJ = 10^{21} J) for Earth's climate system relative to 1960 and from 1960 to 2018. *Source: von Schuckmann et al. (2020)*

Figure 3: Ordering of anthropogenic environmental threats

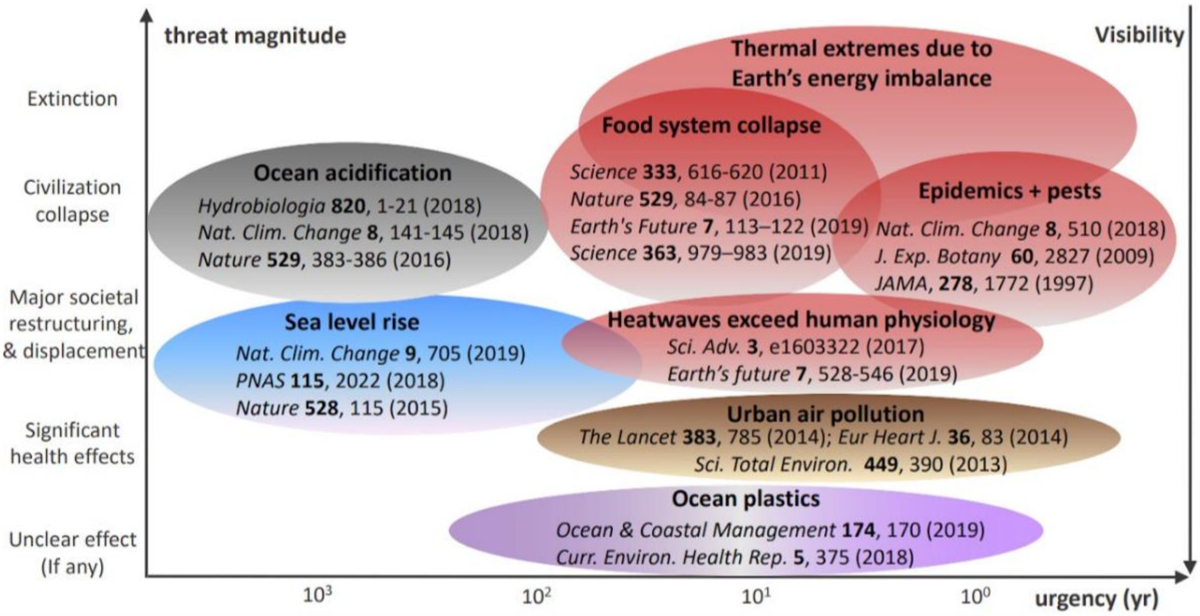

Figure 3: Urgency, threat, and visibility of human-caused environmental threats. Earth's energy imbalance is the radiative imbalance at the top of the atmosphere. *Source: Dr. Ye Tao, MEER project (https://meerreflection.com)*

Literature quoted in Figure 3:

Food system collapse	(Lobell et al. 2011), (Lesk et al. 2016), (Zampieri et al. 2019), (Free et al. 2019)
Ocean acidification	(Clements and Darrow 2018), (Kwiatkowski and Orr 2018), (McNeil and Sasse 2016)
Epidemics & pests	(MacFadden et al. 2018), (Gregory et al. 2009), (Bouma and Dye 1997)
Heatwaves	(Im, Pal, and Eltahir 2017), (Rohat et al. 2019)
Sea level rise	(Dangendorf et al. 2019), (Nerem et al. 2018), (Ritz et al. 2015)
Urban air pollution	(Beelen et al. 2014), (Newby et al. 2015), (Pascal et al. 2013)
Ocean plastics	(Tiller et al. 2019), (Smith et al. 2018)

Daily global CO_2 trend: https://www.esrl.noaa.gov/gmd/ccgg/trends/gl_trend.html

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