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COMMENT

Overshoot: Cognitive obsolescence and the population conundrum

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Abstract

The human enterprise is in overshoot; we exceed the long-term carrying capacity of Earth and are degrading the biophysical basis of our own existence. Despite decades of cumulative evidence, the world community has failed dismally in efforts to address this problem. I argue that cultural evolution and global change have outpaced bio-evolution; despite millennia of evolutionary history, the human brain and associated cognitive processes are functionally obsolete to deal with the human eco-crisis. *H. sapiens* tends to respond to problems in simplistic, reductionist, mechanical ways. Simplistic diagnoses lead to simplistic remedies. Politically acceptable technical 'solutions' to global warming assume fossil fuels are the problem, require major capital investment and are promoted on the basis of profit potential, thousands of well-paying jobs and bland assurances that climate change can readily be rectified. If successful, this would merely extend overshoot. Complexity demands a systemic approach; to address overshoot requires unprecedented international cooperation in the design of coordinated policies to ensure a socially-just economic contraction, mostly in high-income countries, and significant population reductions everywhere. The ultimate goal should be a human population in the vicinity of two billion thriving more equitably in 'steady-state' within the biophysical means of nature.

Keywords: carrying capacity; cognitive obsolescence; systems complexity; economic contraction; population planning.

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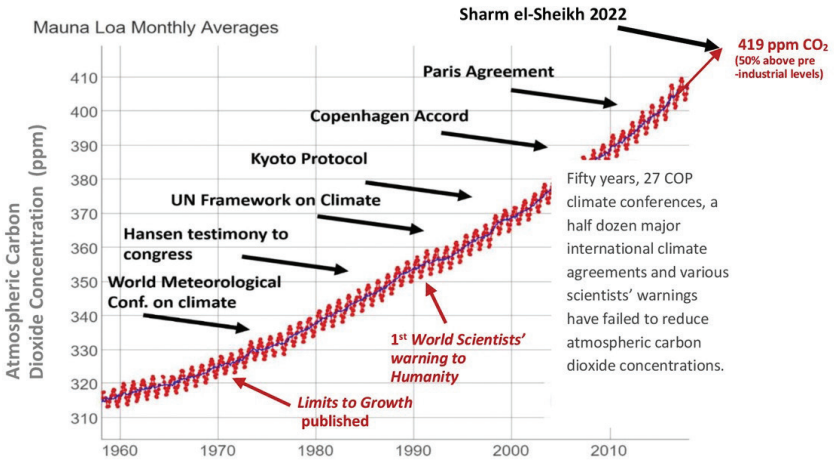
Introduction: Evolution and humanity's eco-predicament

This article attempts a more-than-usually systemic assessment of the human eco-predicament. It is inspired by two related facts: First, the human population substantially exceeds the long-term carrying capacity of Earth even at current average material standards. We are in overshoot, a state in which excess consumption and pollution are eroding the biophysical basis of our own existence (GFN, 2022a; Rees, 2020a). Second, national government and international community responses to even the most publicised symptom of overshoot, climate change, have been dismally limited and wholly ineffective (Figure 1).

Figure 1. Failed climate action – carbon dioxide levels still climbing



SOURCE OF CO2 DATA: NOAA (CURRENT)

Overshoot is a genuine existential threat. Climate change *alone* is capable of making large patches of Earth irreversibly uninhabitable for humans in this century and ultimately jeopardising global civilisation. How is it, then, that the wealthiest, most scientifically-aware, best-informed and globally hyper-connected generation of decision-makers and ordinary people seems incapable of applying the most basic rules of evidence to resolving this self-made predicament? Where in official circles is to be found even the *outline* of the cooperative international

strategy necessary to rescue modern civilisation and thousands of non-human species from probable ecological and geopolitical catastrophe?

There are many possible ways of addressing these questions but few seek answers in human nature itself. Modern techno-industrial (MTI) society is afflicted by human exceptionalism, the *beliefs* that *H. sapiens* is not really an 'animal-like-the-others', that human behaviour is determined by socio-cultural factors (nurture), and that humans are therefore somehow exempt from the laws of nature. Decision-makers thus operate from the implicit assumption that continuous economic growth enabled by greater efficiency and constantly improving technology – the motivational nerves of industrial capitalism and its handmaiden, neoliberal economics – is all we need to navigate the hazardous waters ahead. By contrast, this article argues, with illustrations, that the mainstream techno-optimist approach is not only delusional but threatens to sink the human ship of state. This argument is based partially on the *fact* that the human lineage, like those of all other species, has continuously evolved over millions of years and that our evolutionary history profoundly affects both our perception of crisis and how we respond to it. In short, to deny the implications of humanity's evolutionary heritage is to ignore a major key to our eco-predicament (and possibly how to resolve it).

The obsolescent human brain: Why our cognitive processing is not up to the task

> 'Nothing in biology makes sense except in the light of evolution'
> (Dobzhansky, 1964: 449)

My starting premise is that, despite their miraculous complexity accumulated over millennia, the human brain and associated cognitive processes are functionally obsolete to cope with the emerging eco-crisis. Functional obsolescence can occur by one of two mechanisms: either the entity of concern is superseded by a new version that operates more effectively or efficiently in performing functions essential to the entity's survival, or the entity's operating environment changes so dramatically that the entity is no longer capable of performing functions essential to its survival. In other words, the entity is maladapted to its changed circumstances. I argue, from available evidence: 1) that the putative obsolescence

of the human brain derives from the latter process and; 2) this reality poses a growing threat to the survival of *H. sapiens* – or at least MTI society – that may well play out by century's end.

As noted, this argument departs from the facts that modern *H. sapiens*, like all other species, is a product of organic evolution[2] and that human evolution has similarly been shaped by the forces of natural selection. Since both instinctive and emergent social behaviours are as much exposed to selective pressure as any other genetically-influenced human quality (Barash,1981), it is not much of a leap to extend Dobzhansky's (1964) principle to assert that *nothing in human affairs – including much of economic and socio-political behaviour – makes sense except in the light of evolution.* This is not to discount socio-cultural factors, which are also centrally involved. Rather, I am arguing that our understanding of humanity's ecological predicament and our ultimate fate is unintelligibly incomplete unless we factor in evolutionary considerations.

To begin, consider the social and ecological context that helped forge modern *H. sapiens'* central nervous system. The human brain evolved rapidly during the Palaeolithic (2.5 million to ~10,000 years ago) at least partially in response to selective pressure favouring increased social intelligence, the extra calories made possible by improving diet (due to the use of fire and cooking) and growing technological competence. The most rapid period of growth seems to have occurred with the challenges imposed by increasing climate variability 200,000 to 800,000 years before the present; the brain reached its current size ~500,000 years ago (DeSilva et al., 2021; MNH, 2022).[3]

Whatever the relative strength of various selection pressures, early hominids and even recent pre-agricultural human hunter-gatherers lived in tribal groups of perhaps a few dozen individuals in spatially limited, relatively knowable, predictably cyclical ecosystems. One would encounter only a few tens or hundreds of other people in his/her lifetime and would probably die within a few kilometres of place of birth. No doubt there was much about their limited

2 Culture, such as the shift to agriculture, may induce minor changes in human morphology (e.g., jaw structure) but even this process unfolds by natural selection.

3 However, there has been a rapid small but significant decrease in brain size in just the past three millennia (DeSilva et al., 2021)

'environments' that seemed fearsome and mysterious to early humans – indeed they developed various tribal myths, gods and other forms of magical thinking to cope with the unknown. However, *H. sapiens'* home-ranges were relatively small and consistently variable – even fearsome predators and other natural hazards would become familiar over the course of an individual's life-time, certainly that of several generations. In short, compared to contemporary, rapidly changing, mostly manufactured and unnaturally complex human environments, humanity's original natural habitats posed only limited challenges to the evolving brain and central nervous system.

One result of our evolutionary heritage is that contemporary humans tend to respond to problems in relatively simplistic, reductionist, mechanical ways. People don't generally think in terms of discontinuous behaviour – lags, thresholds (tipping points), and other non-linearities; we don't 'get' complexity. Humans have also evolved to develop habitual, socially-constructed (but neuro-synaptically embedded) patterns of group-think which often persist despite emerging contradictory evidence – consider political ideology, religious dogma, tribal myths, academic paradigm or even the 'latest thing' (Wexler, 2006); we are also innately short-sighted (Pratarelli, 2008). Many of our once-successful survival instincts, emotions and behaviours are ancient prescriptions of the human reptilian brain stem and limbic systems. Some may by now have outlived their 'best before' dates, but our primitive cognitive modes, shallow perceptions and resultant responses were perfectly adequate for 99.9 per cent of human evolutionary history. Is it any surprise that ordinary people today still seek explanations for unusual phenomena in terms of simple cause-effect relationships, that we deny uncomfortable truths, that we discount the future, and that many of our contemporaries are still given to mystical thinking?

'But wait', one might protest, 'surely MTI civilisation is not so constrained by humanity's early evolution; modern sensibilities developed in a dramatically different context.' True enough, the Enlightenment of the seventeenth and eighteenth centuries saw the new science begin to subdue superstition and demystify the natural world; literacy was becoming common; positive knowledge spread. Ironically, however, the emergence of Newtonian science, particularly analytic mechanics, actually reinforced *H. sapiens'* innate propensity for reductionist simplicity. Indeed, so-called 'normal' science was so extraordinarily

successful in generating successful predictive hypotheses, and in extending humanity's control over the physical world, that it spawned many intellectual imitations, including the neoliberal economic paradigm that is currently all but running the world. The latter pictures the economy as a self-perpetuating machine, separate and independent of nature, sustained by a simplistic myth of perpetual growth abetted by continuously improving technology.

And herein lies one proximate cause of the human eco-crisis. In just the past two centuries (0.08 per cent of human history) this socially-constructed economic *myth* has helped foster an eight-fold increase in human numbers (from one to eight billion) and a hundredfold expansion of real gross world product (GWP), all propelled by a >1,300-fold increase in climate-busting fossil energy (Rees, 2020a). Technology has expanded apace when not leading the way: most of the cultural artefacts that young people today take for granted – from jet planes to PCs, cell phones and the internet – were non-existent when this author was born.

The material result is a virtually alien world of mind-boggling complexity, an incomprehensible global concatenation of dynamically interacting and overlapping human and natural sub-systems. Each major sub-system is *in itself* so complex that no human mind can fully understand, let alone control, its structure or behaviour in isolation, far less as part of the integrated whole. Who fully understands the world economy or even the internet; does anyone really believe the climate system can be brought under human command and control? Only the hubris born of MTI sensibilities would argue the affirmative. The reality is that fast-paced cultural evolution, particularly the MTI variety, has so vastly outstripped our biological evolution (see Longrich, 2022), that *H. sapiens* is no longer adapted to the integrated socio-ecosystem that MTI culture has itself created.

Bottom line? MTI society is doubly compromised – both our heritable 'wetware' (the brain) *and* much of the socially-constructed cognitive software it has produced (particularly growthist economic theory) are functionally obsolete in the world we ourselves have created.

Climate change as fatal distraction

> 'If we are unable to identify reality and therefore unable to act upon what we see, then we are not simply childish but have reduced ourselves to figures of fun – ridiculous figures of our unconscious.'
> (Saul, 1995: 21–22)

We see solid evidence of reductionist simplicity in policymakers' (and mainstream media's) tendency to focus on one environment-related issue at a time. The past several years have seen a fixation on climate change. This was only briefly displaced by the Covid-19 pandemic, then the war in Ukraine but, with the fizzling out of COP-27 (November 2022), we are back to climate change as *the* existential threat to human civilisation. On rare occasions when analysts do see beyond their immediate concern, they usually make only one connection – e.g., food security to family planning (Owoo and Delacroix, 2022), climate change to population (O'Grady and Mahfouz, 2022) – and even then cause-effect relationships may be reversed or under-analysed. O'Grady and Mahfouz's (2022) report that the Egyptian government is worried that the country's expanding population is jeopardised by 'rising temperatures [which] increasingly threaten the country's food and water supplies', yet fail to acknowledge that it is growing human populations that are driving rising temperature and its negative impact on food and water supplies, while adding directly to the pressure on those same supplies.[4]

Why do simplistic hypotheses and explanations persist? Because human beings characteristically 'want simple answers to complex questions' (Kay and Schneider, 1995). This cognitive impairment is dangerously maladaptive for human societies in 2022. Climate change is indeed a horrific prospect, but it is only one symptom of a greater truly existential threat, ecological overshoot. *Overshoot implies overpopulation*: the bloated human enterprise is consuming even self-producing (renewable) resources faster than ecosystems can regenerate and dumping entropic wastes back into the ecosphere in excess of nature's assimilative

4 Similarly, reports of the role of climate change in the famines savaging the people of Ethiopia, Somalia, South Sudan, Yemen, and elsewhere rarely acknowledge that local water supplies and ecosystems productivity have been degraded, and relief operations complicated, by the doubling or trebling of local populations in recent decades.

capacities. Overshoot is therefore the *cause* of climate change[5] and numerous co-symptoms including plunging biodiversity, ocean acidification, tropical deforestation, landscape/soil degradation, contamination of food supplies, depleting aquifers, the pollution of everything – i.e., virtually all other so-called environmental problems including the pandemic. Contemporary MTI culture is literally consuming and polluting the biophysical basis of its own existence. (Arguably, overshoot is even one root of the Russo-Ukraine war, but that's a longer story.)

The continued erosion and contamination of the ecosphere is potentially fatal on several fronts. Formal acknowledgement that there are too many people consuming/polluting too much is therefore a crucial step toward assuring a future for global civilisation and restoring biodiversity. Nevertheless, policymakers and politicians at all levels still act as if population growth and overconsumption can be ignored, or, worse, that the resultant problems can be solved by yet more growth. Part of the reason is that bare-bones growth-oriented economic models totally ignore the spatial structure and complex dynamic behaviour of the biophysical systems – and even the social systems – with which the economy interacts in the real world (Rees, 2020a). Even those who acknowledge the ecological crisis are cognitively incapable of effective solutions, advancing instead the same '… old growth wine in new economy bottles – neo-Keynesian productivism, climate economy, Green growth, Green economy, Green new deal, new deal for nature, sustainable development, sustainable economic growth, bio-economy, circular economy, digital economy, knowledge economy' (Spash, 2021). Over-simplified and superficial, most contemporary MTI policy analysis, simply '…ignores data that do not fit with its [socially-constructed] myths and metaphors' (Washington et al., 2020).

These are serious assertions but well-supported by available evidence. Consider that mainstream, politically acceptable 'solutions' to global warming (e.g., wind turbines, solar panels, electric vehicles, green hydrogen, non-existent carbon capture and storage technologies, etc.) require major capital investment and are promoted on the basis of profit potential, thousands of well-paying jobs and bland assurances that climate change can readily be rectified. Non-experts are

5 Anthropogenic climate change is an excess waste problem; carbon dioxide is the greatest entropic waste by weight from industrialised economies.

readily persuaded that our future is assured by a deluge of promotional literature on allegedly green energy alternatives. Renewable energy (RE) advocates Breyer et al. (2022) review the literature on modern renewables and find that most of the studies show an energy future of 100 per cent renewables is economically feasible globally.[6] These authors present a vision of 'a net negative greenhouse gas emissions economy that can limit global warming to 1.5°C with a clearly defined carbon budget in a sustainable and cost-effective manner based on 100% renewable energy...' This comforting *one-issue* vision essentially proclaims that the solution to potential climate chaos lies in growth-bound 'business-as-usual-by-alternative-means'. Little wonder it has become the mainstream norm – indeed, most conventional efforts to address climate change, including the COP meetings, reflect MTI society's attempt to enshrine expansionist capitalism as the solution to, rather than the cause of, the problem (Spash, 2016).

Reductionist blinkers on, green energy advocates tend to gloss over or dismiss the evidence that the much-vaunted renewable energy transition isn't really happening as advertised. In 2021 fossil fuels still provided ~82 per cent of the world's primary energy; to put it in temporal terms, oil, coal and natural gas powered the globe for 300 of 365 days; hydro and nuclear power contributed forty days; modern non-hydro renewables – solar panels, wind turbines – where most investment is going *gave us just eighteen days*. Modern renewables produce electricity, but even in this domain fossil fuels are the largest contributors at 61 per cent of the world's power supply; non-hydro renewables provided twelve per cent wind and solar only about nine per cent (from data in BP, 2022).

A big part of the problem is that growth in demand for energy due to rising incomes and burgeoning populations in middle and low-income countries often outstrips the build-out of modern renewable sources (Chaurasia, 2020; Heinberg, 2022). But there are many other obstacles to a smooth energy transition: politically acceptable technologies are largely fossil-fuel (FF) dependent in manufacturing and installation; the associated mining, refining and transportation are otherwise ecologically problematic; renewables, hydrogen included, still face numerous technical problems; RE equipment/infrastructure is not 'renewable', it wears out and is merely replaceable (mostly using FF);

6 Note that Breyer et al. (2022) are also authors/co-authors of many of the studies reviewed.

grid-scale wind and solar generation is actually costlier than alternatives and becomes more expensive the higher their share of production; there are emerging supply-chain issues; and, in any case, electricity cannot substitute for many uses of FF (Heinberg, 2022; Schernikau et al., 2022; Seibert and Rees, 2021; Rees, 2022a; Michaux, 2021a,b; Turiel, 2020a,b). Even if all such problems were overcome, to replace just 45 per cent of FF use with electricity by 2030[7] would require building the equivalent of ~1.2 times the entire present cumulative global stock of wind and solar installations *every year* for the next seven years (based on data from BP, 2022), generously assuming that one unit of wind/solar electricity = ~2.6 units of FF energy; that all uses of FF can be electrified; and that there will be no increase in demand for energy).

This is obviously an impossible scenario. Indeed, there is no practical way to quantitatively substitute electricity for fossil fuels on a climate-friendly schedule. The fact is that, despite the significant uptake of modern renewables in the electricity sector and the ebullient assertions of RE advocates, atmospheric CO_2 concentrations are still increasing (Figure 1). We should also note that practical carbon-capture-and-storage techniques at scale continue to elude us; to imply that such non-existent technologies will help achieve net-zero emissions by 2050 adds to the dangerous illusion that a smooth energy transition is underway (Spratt and Dunlop, 2021; Dyke et al., 2021).[8] As matters stand, the world will blow past the 1.5 C° and likely also the 2.0 C° global warming limits set by the IPCC. Earth has already warmed by >1.1 C° and prominent climate scientists assert that, due to the prevailing energy imbalance and short-term lag effects, 'more than 0.5°C additional global warming is [already] in the pipeline' (Hansen, 2018: 9; see also Spratt and Dunlop, 2021). Indeed, we are currently on track for ~2.7 C° warming and catastrophic climate damage.

Overshoot: It's the population, stupid!

The foregoing analysis underscores why *H. sapiens'* innate myopia and naïve enthusiasm for technical fixes will not resolve our eco-predicament. Neither climate

7 Consistent with the Sharm el-Sheikh 2022/COP27 goal of reducing emissions sufficiently to limit mean global warming to 1.5 Co.

8 Another techno-fix, climate-changing geo-engineering (e.g., sun-blocking), is also narrowly focused and assumes there are no unknown, potentially disastrous, systemic feedbacks from the atmosphere/climate or connected bio-geo-systems.

change nor any other major symptom of overshoot can be solved in isolation from the others, particularly not by reference to the same beliefs, values, assumptions, narratives and behaviours that caused the problems in the first place. Overshoot is a complex systems problem; only by taking a systematic frontal approach can we hope to reduce or eliminate all co-symptoms simultaneously.

The proximate driver of overshoot is excess economic throughput, i.e., excess energy and material consumption and pollution. Both rising incomes and growing populations are contributing factors – high-income consumer societies account for 74 per cent of the problem historically (see Hickel et al., 2022a) – but population growth in all income quartiles is currently the greater contributor at the margin (grotesque inequality is a separate socio-political issue) (Rees, 2022b). Certainly population growth has been seen as 'a leading cause of increased greenhouse gas emissions and accelerating global climate change' (Cafaro, 2022; also Laublichler, 2022).

It follows that the best results from efforts to resolve the human eco-predicament will come from addressing overconsumption and overpopulation directly. The Global Footprint Network shows that the world is in overshoot by ~75 per cent (GFN, 2022b). This implies that global energy and material throughput must be reduced by disheartening 43 per cent for sustainability, much more in high-income countries.[9] Obviously, wasteful over-consumption by the wealthy and egregious inequality must be addressed but the world cannot afford to ignore the population component. The human family passed the eight billion mark in November 2022 and is still expanding. While the United Nations suggests that the growth rate has fallen below one per cent (80 million per year), other authorities argue that UN demographers understate population growth for political reasons and that the annual increment is closer to 90 million (O'Sullivan, 2022a).

Whatever the growth rate, overshoot makes clear that Earth is already significantly overpopulated. While estimates of the sustainable population vary from a paltry ~50 million to a truly ludicrous one trillion, there is some gravitation toward the

9 These data, while alarming, are almost certainly conservative. For several practical and theoretical reasons ecological footprint assessments characteristically underestimate the human demand for biocapacity (Rees, 2022b).

view that Earth might support ~two billion people indefinitely at a satisfactory material standard of living (e.g., Cafaro, 2021; Rees, 2022b). This implies a reduction of at least 75 per cent in human numbers.[10]

It is difficult to imagine a politically more daunting challenge. No secular wealthy society or country anywhere, has ever voluntarily permanently renounced its hard-won material wellbeing for the future greater good of humanity at large. Humans are temporal, social and spatial discounters *by nature* – we would rather risk uncertain future catastrophe that (we hope) will mostly affect total strangers and distant places than accept material sacrifice that would certainly affect our families and home communities today. (Discounting is a prime example of a once-adaptive human trait that may well be obsolete in the modern world.) And of course, the three billion people who still struggle at $5.50 per day to meet basic needs can hardly be expected to douse their flames of hope for a materially brighter future.

Managing populations is equally intractable. In many countries, calling for population planning would constitute political suicide. Even the United Nations Population Fund recently 'decried any expressed concern about population growth as "alarmist"' (O'Sullivan 2022b); strong advocates of population reduction strategies policies risk being vilified as racist, eco-fascists, eugenicists, anti-human or worse. Such attitudes and accusations are yet another manifestation of innate reductionist simplicity exacerbated by socially-constructed ideological blinders. Bajaj (2022) argues that the UN's taunt of population alarmism springs from widespread pro-natalist ideology 'which results in unrelenting pressures – a globally pervasive form of reproductive coercion – experienced primarily by women'. She further emphasises that that 'pronatalism is integral to our current growth-based economic system, which relies on constant population growth to supply new consumers continually'. Indeed, corporations in the US [and other countries experiencing 'peak population'] are sensationalising the idea of an economic 'baby bust' that threatens the nation with a paucity of workers, a

10 Alternately, Hickel et al. (2022) suggest that, for a just sustainability, wealthy nations need to reduce resource consumption by at least 70%. (Typically, these authors ignore the population question.) In the same vein, O'Neill et al. (2018) found that, with redistribution, Earth could provide basic needs for everyone. However, they suggest that to achieve qualitatively higher life satisfaction would require resource consumption six times above sustainable levels (or, they failed to add, a reduced population in the range of two billion).

reduced tax base and the loss of international economic clout. Many governments are responding with incentives to increase national fecundity.

Regrettably, rhetoric on the 'need for more workers, consumers, and taxpayers goes beyond just pushing women to have children and supports recent successful moves to ban contraception and abortions' (Dillard, 2022). It is also ecologically destructive. Bajaj and Stade (2022) posit that addressing overpopulation, and the pronatalism that drives it, must be central to international conservation and development efforts to elevate reproductive rights while also promoting planetary health. Similarly, Shragg (2022; also 2015) argues that taming human population growth is not only decidedly pro-human but also pro-nature in that it slows human-induced ecocide.

Bottom line? Pronatalism and similar socially-constructed single-focus beliefs are tragic from the perspective of controlling overshoot. Population stabilisation and decline in rich countries should actually be cause for celebration – each high-income consumer imposes ecological pressure on Earth equivalent to that of ten to twenty people living near-subsistence lifestyles. The greatest ecological leverage would come from absolute population reductions in high-income countries. But that does not mean low-income countries with higher birth-rates get a pass. Human exceptionalism notwithstanding, there is a greater systemic dynamic in play here. Many non-human species experience population outbreaks or 'booms' during favourable resource-rich periods. Booms are invariably followed by 'busts' as various forms of negative feedback – e.g., resource depletion, competition for habitat, predation, disease – re-assert themselves. There is no reason to believe that human population dynamics differ significantly from those of other species. Most importantly, populations of *H. sapiens* have the same potential to grow exponentially when relieved of natural negative feedback controls (e.g., disease, food/resource shortages, etc.). In fact, because resources have been plentiful for the past 200 years, and *population planning has not been an acceptable policy focus,* human numbers are now arguably in the boom phase and, nearing the peak of, a (likely one-off) population boom-bust cycle (Rees, 2020b). As previously noted, *H. sapiens* has increased eight-fold to eight billion since 1810, in just one 1250th as much time as it took our species to reach its first billion. The dramatic economic and population growth that the past few generations take to be the norm actually define the single most anomalous period in human history.

The recent boom was made possible by the scientific revolution – e.g., improved population health – and technologies based on abundant cheap energy, primarily fossil fuels (FFs). The latter: a) provided access to all the other resources necessary to grow the human enterprise and thus; b) temporarily relieved humanity of many forms of pre-industrial negative feedback.

This explains the population component of human eco-overshoot.

It is also exposes the closing jaws of an unprecedented technological trap. Modern civilisation depends utterly on abundant cheap energy. Consider the fate of the bloated human enterprise, in the absence of a 'Plan B', if we are forced to abandon FFs to avoid catastrophic climate change or if FFs become economically depleted – as is inevitable. Without climate-friendly quantitative substitutes for FF, it will not be possible to maintain anything like the present human population at acceptable material standards or to maintain the scale of the human economy. With failing energy supplies, humanity faces the prospect of broken supply lines, food and other resource shortages, local famines, reduced production, declining incomes, rising inequality, widespread unemployment, civil unrest, abandoned cities,[11] mass migrations, collapsed economies and possible geopolitical chaos.

On the other hand, if the world maintains its fossil-fuelled trajectory in blind allegiance to the growth paradigm and the illusion that 'technology-will-save-the-day (MTI society's apparent default position [Figure1]), we risk more and longer heat waves/droughts, accelerated desertification, melting permafrost, methane releases, water shortages, failing agriculture, famines, rising sea levels, the flooding (and eventual loss) of many coastal cities, uninhabitable regions, mass migrations, collapsed economies and possible geopolitical chaos. And we'd still run out of energy. Are not all these things not already emerging in nascent form?

In short, pursuit of either narrowly-conceived pathway suggested by our obsolete instincts and MTI sensibilities exposes humanity to the likelihood of a major, potentially catastrophic, population correction (the inevitable bust phase of our one-off global cycle) later in this century (Rees, 2020b).

11 Modern cities and mega-cities of millions are the creation of fossil fuels and provisioning cities remains dependent mostly on diesel-powered highway, train and marine transportation (see Friedemann, 2016).

One (the only?) way out

> 'Late capitalist society is a coyote suspended above an abyss, believing he still stands on solid ground. We are in the interval before he notices he is in thin air and plummets to the canyon floor'
> (Robbins 2022: 26)

The more attractive alternative is to engineer a deliberate, controlled, global-scale 'soft landing,' a radically transformative 'Plan B'. Any system dominated by positive feedback is self-destructive; avoiding chaotic collapse means that we must reintroduce negative feedback to the runaway human enterprise (see Rees, 2020a; 2022a). The necessary systematic frontal approach to overshoot would require a period of unprecedented international cooperation in structuring a socially-just economic contraction, mostly in high-income countries, and significant population reductions everywhere. This might well require declaration of a global 'wartime' emergency mindset and an intensive effort over several decades.

To begin, national governments, the United Nations and other international development-oriented organisations should formally acknowledge the reality of overshoot and the end of growth (i.e., neoliberal capitalism should be put to rest). We then need to initiate a global population reduction strategy, and a plan to restructure national and global economies, with the goal of remaining within global carrying capacity. This will require programmes to facilitate the adoption of sustainable lifestyles (even North Americans lived happily on half the energy/cap in the 1960s); a graduated approach to full-cost pricing of goods and service (abetted by ecological tax reform); learning to live on any 'allowable' carbon budget (while developing/improving sustainable energy alternatives); and limiting FFs use to essential needs – e.g., food production, home heating, essential transportation to provision cities – through rationing, quotas, etc. It will also be essential to implement programmes/policies for income/wealth redistribution; greater equality is not only ethically justifiable, but is psycho-socially better for everyone (Wilkinson and Pickett, 2010).

The ultimate goal should be a much-reduced human population (~ two billion) thriving more equitably in a sustainable 'steady-state' (Daly, 1991) well within the biophysical means of nature. Is there any other feasible way that post-MTI peoples can hope to enjoy both economic security and long-term ecological stability on

a (shrinking) finite planet? Is this not a more attractive prospect than staying the course and tempting chaotic collapse?

Time is clearly a crucial factor; there can be little delay. The growth momentum generated by the sheer numbers of people of reproductive age means that population growth 'will take decades to arrest, and even longer to reverse, making it virtually impossible for policymakers to respond dynamically to miscalculations or unforeseen challenges relating to a society's ability to provide for the needs of all its people' (Kuhlemann, 2023). Indeed, simulations suggest that, even under a successful universal one-child per couple policy, the population would continue to increase for 25 years and would take a century to achieve a 75 per cent reduction; that is, 'the total human population would peak in about 2047 and reach a (sustainable?) two billion in 2122' (Hughes, 2022). And there *will* be 'unforeseen challenges'.

Such data underscore the importance of mustering globally, urgently, every manner of non-coercive population planning strategy available. The world needs universal public education on overshoot as meta-problem; programmes to ensure greater economic independence and freedom of choice for women; specific education on contraception methods and family planning for all, accompanied by general access to – and preferably free distribution of – the means for birth control. Even if successful, the unavoidable lag before even a high-compliance strategy takes effect means that, *whatever we do*, billions of people will likely be exposed to accelerating climate change; energy, food and other resource shortages; and growing geopolitical tensions as the century unfolds. Never before has there been so urgent a need for universal human population planning and creation of a global social safety-net.

Bottom line? The future holds daunting prospects for humanity even in best-case scenarios. Earth will ultimately survive any human folly; the question is: will humans survive themselves? In theory, *H. sapiens* has the capacity for high intelligence, the ability to act upon the evidence and to change the future that would otherwise unfold. And, as suggested here and in many other recent publications (e.g., Hayden and Dasilva, 2022; Hickel et al., 2022a,b; Rees, 2020a), we know much of *what* needs to be done. But *how* to get it done is another matter entirely. Humans are cognitively-limited creatures driven (often unconsciously) by simple instincts, tribal myths/

suspicions, divisive competitiveness, careless emotions and impossible aspirations. We cannot really see the whole picture and what we do see, we often deny; how many policymakers and politicians effectively 'connect the dots' among our many ecological and socio-political crises? On the whole, our cognitive capacities are deficient; our dominant tribal myth is self-destructive. These factors, acting beneath consciousness, may well override humanity's collective intelligence in coping with the eco-crisis. Regrettably so – only serious self-examination, a colossal global exercise of consciousness-raising, clear-headed analysis of biophysical data/trends, a rethink of the economy-as-subsystem of the ecosphere and an unprecedented degree of international agreement and selfless cooperation for the common good (of humanity and nature) can succeed in taming overshoot.

And what if reason does fail to trump ideology and the urgings of those primitive 'whisperings within' (Barash, 1981)? Then brace yourself as humanity 'plummets to the canyon floor'.

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