# The Inevitable Collapse of Advanced Industrial Society.

**By**

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**Abstract.**

**This paper will argue that the collapse of advanced industrial society is inevitable on a global scale in the near-term (i.e., in a matter of decades from present), and that, furthermore, it will be irreversible. Industrial society, generally, will be seen as an aberration or anomaly in human history, one costly in terms of human life and suffering, as well as ecological devastation, lasting no more than three hundred years from the start of the Industrial Revolution in Great Britain in 1750 CE to its terminus in *circa* 2050 CE. If humanity is to survive, it must be in much smaller numbers, and with far less impact on the planet.**

**Keywords: (advanced) industrial society; collapse; human (over-)population; ecological impact; carbon dioxide ($CO_2$) pollution; other forms of pollution; biodiversity loss; Industrial Revolution; global inequality.**

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## [1]. Introduction.

This paper means by social (or ‘societal’) collapse the complete breakdown of social order and organised economic activity, and of all political and legal institutions of social control, along with a more-or-less rapid decline in the size of the human population.

The thesis of this paper is straightforward: there are too many people on this planet, that have consumed, and are consuming, too much of its finite reserve of non-renewable resources, generating too much waste and pollution for the planet to cope with, and wantonly destroying far too many other species of life at the same time; all these processes endangering the existence of humanity itself, and certainly threatening what passes for our global, and highly inter-connected, technological civilisation.

This paper makes no reference to any current or potential geopolitical issues, or to persons having an impact upon them, such as Vladimir Putin or Xi Jinping; nor to the possibility of any possible ethnic, national or religious conflicts arising from mass migration resulting from climate change. To do so would be to pile Pelion on Ossa, as to a large degree societal collapse is 'over-determined'. Nor does it make any reference to secondary effects of climate change, e.g., climate-induced migration or health effects such as heat deaths or the spread of tropical diseases, as these are well-enough discussed in the literature.

It will be argued that that civilisation faces an inevitable collapse this century, and will prove a 'one-off' in the history of our species, which will face a severe cull in its numbers, which may – in fact – enable it to survive. The present world human population of ~8.1 billion (US Census Bureau, 2024 [1]), it will be argued, is beyond Earth's carrying capacity, and is unsustainable. The projected 2050 population of ~9.755 billion is even less sustainable (op.cit.).

## [2]. Carbon Dioxide and Aerosol Pollution.

According to Goosse *et al* (2022 [2], p.2958), atmospheric $CO_2$ levels between 1600-1750 varied between 273-278 ppm and rose steeply thereafter. The maximum prior to that was 285 ppm in the 12$^{th}$ Century, up from 276 ppm in the year 1 CE, and 280 ppm in 1000 CE (ibid.), making for a maximum $CO_2$ variability during those seventeen and a half centuries of 12 ppm.

The level of atmospheric $CO_2$ has now risen, according to the US National Oceanographic and Atmospheric Administration's Global Monitoring Laboratory (Mauna Kea Observatory, Hawaii) to 424.75

ppm, as of 29th March 2024 (NOAA, 2024a [3]). It was an average of 315.98 ppm in 1959 (NOAA, 2024b [4]).

In other words, the level of atmospheric $CO_2$ rose by 13.66% between 1750 and 1959, or 0.065% p.a., and by 34.423% since 1959, or ~0.538% p.a. The overall increase, in percentage terms, since 1750, is ~52.79%, or 0.193% p.a. These figures imply that, given a conversion factor of 2.13 GtC/ppm $CO_2$ (billion tonnes of carbon per ppm of carbon dioxide; see Global Commons Institute, no date [5]), 312.5775 GtC have been added to the atmosphere since 1750 – and this figure does not take account of the methane ($CH_4$) that has been added since then, but for this, see Etheridge *et al* (1998 [6]) and, more recently, Jones *et al* (2023 [7]). There is now more carbon dioxide in the atmosphere than at any time in the past 3.3 million years, and the last time the level was as high as it is now, during the Mid-Piacenzian Warm Period of the Pliocene Epoch, mean annual global surface temperatures were 3°C higher than the pre-industrial level (see de la Vega *et al*, 2020 [8]).

Hansen *et al* (2023 [9]) point out that the effect of the high $CO_2$ level is currently mitigated by cooling aerosols, such as particulates (fine particles, PM10s and PM2.5s), which reduce global warming by about half what it would be otherwise, but, as they point out, these cause millions of deaths per year, citing figures from the World Health Organisation (WHO, 2022 [10]). Hansen, Kharecha and Sato (2013 [11]) call the process of dumping both $CO_2$ and aerosols into the atmosphere a 'Faustian bargain', precisely because of the deleterious health effects of air pollution, which are only poorly constrained by current 'clean air' controls.

The health impact of air pollution on the poor is particularly marked (Rentschler and Leonova, 2023 [12]). Jafari, Charkhloo and Pasalari (2021 [13]) undertook a systematic review of policies to control air pollution in urban areas, finding that the largest share of air pollution, especially in large cities, is related to transportation – yet there are, according to the automotive market research firm, Hedges and Company (2024 [14]), 1.475 billion vehicles on the world's roads, yet only 17 million (1.5%) of these are electric vehicles (Ukpanah, 2024 [15]). Such vehicles are not without their own environmental and social costs, because of their requirement for lithium-ion batteries, and the impact of lithium mining (Agustinata *et al*, 2018 [16]; Mandoca, 2023 [17]).

Coal, oil and natural gas accounted for 76.71% of global primary energy consumption in 2022 (Ritchie, Rosado and Roser, 2020, 2024 [18]). They still account for 57.63% of global primary energy consumption in 2050, in spite of 'net zero' policies and the expansion of renewable energy supplies (Jaganmohan, 2024 [19]). The Secretary-General of the Organisation of the Petroleum Exporting Countries (OPEC), Haitham Al Ghais, told an oil and gas conference at Abuja, Nigeria, on Tuesday 11th July 2023 that he expected global energy demand to increase by 23% between 2023 and 2045 (i.e., by 1.045% p.a.), and claimed that the oil industry needed to invest $12.1 trillion during that twenty-two year period, or $550 billion p.a. (Bala-Gbogbo, 2023 [20]). This is 1.967% of the 2023 US GDP of $27.96 trillion (source: US Bureau of Economic Analysis [BEA], 2024 [21]). The OPEC *World Oil Outlook* for 2022 (OPEC, 2022 [22]) predicts that global oil demand will be 110 million barrels a day in 2045, or 40.15 billion barrels (5.4775 billion tonnes) for the year.

In the meantime, the world's governments, according to the IMF's researchers, continue to subsidise fossil fuels, spending $7 trillion doing so in 2022, or 7.1% of global GDP (Black, Parry and Vernon, 2023 [23]). $7 trillion is $221,968.54 *every single second*. It is little wonder, then, that the five largest stock market listed oil companies (Shell, BP, Chevron, ExxonMobil and TotalEnergies) made total profits of $281.474 billion between the second quarter of 2022 and the end of 2023, paying out $200 billion to shareholders during that time, $111 billion of it in 2023 – this coinciding with Russia's invasion of Ukraine, which served to increase fuel costs (Galey and Kirk, 2024 [24]).

This is the context in which Amin Nasser, President and CEO of Saudi Aramco, can describe phasing out fossil fuels as a 'fantasy' which should be 'abandoned' (Joselow, 2024 [25]). Fifty-seven oil, gas, coal and cement producers are directly linked to 80% of the world's greenhouse gas (GHG) emissions since the 2016 Paris Agreement on the climate, with the majority of both state- and private-owned fossil fuel companies increasing their production between 2016-2023 (Watts, 2024 [26]).

Other ‘well-mixed greenhouse gases’ (WMGHGs), such as nitrous oxide ($N_2O$), sulphur hexafluoride ($SF_6$) and hydrofluorocarbons (HFCs), have also been increasing (NOAA, 2024c [27]; NOAA 2024d [28]; Velders *et al*, 2022 [29]), but these are far from the only pollutants which our species has been inflicting on the planet since the Industrial and Agrarian Revolutions of the 18th-19th Centuries, as is only too clear.

## [3]. Other Forms of Pollution.

Other forms of pollution that we have inflicted on the natural environment, and on ourselves, to the detriment of both, include plastic pollution, and that includes microplastic pollution, and various forms of chemical pollution. This is by no means an exhaustive list, however – for few can escape the sight of litter and waste in our ‘throwaway’ consumer society, where the goods produced for our consumption have built-in obsolescence (Becher and Sibony, 2021 [30]).

Thushari and Senevirathna (2020 [31]), discussing plastic pollution in the marine environment, note that marine and coastal ecosystems provide ‘priceless services’ for the well-being of both humans and other organisms, and that aquatic ecosystems are interconnected with the terrestrial environment, but these systems are now stressed, and under threat, by various forms and sizes of plastic deposited within them. They also note that the density of microplastic (defined as particles of plastic between <1 mm – 6 mm in the literature) ‘is increasing in all oceans’, and that plastic harms organisms by both entanglement and ingestion.

Bodor *et al* (2024 [32]), inform us that 390.7 million tonnes of plastics were produced globally in 2022, with global production expected to reach 940 million tonnes annually by 2040 (an increase of 7.81% p.a.). Approximately 79% of the 6.3 billion tonnes of plastic waste cumulatively generated worldwide between 1950 and 2015 ended up in landfills ‘or other environmental compartments’, they tell us. As they say,

> **'it is not surprising that plastics are now ubiquitous in the Earth's ecosystems as a consequence of increased human activity.'**

Bodor *et al* note that the first industrialised, but bio-based, plastics were produced in the 19th Century, and included rubber, celluloid and viscose. It was not until the following century that fossil-based plastics became more prevalent, with the advent of large-scale extraction and refining of petroleum, the mass production of these accelerating from the 1950s onwards.

Examples of these fossil fuel derived plastics are the various types of polyethylene, plus polypropylene, polystyrene, polyvinyl chloride (PVC) and polyurethane. Approximately one third of the generated waste enters the natural environment, they say, the rest being either incinerated, recycled or re-used. Bioplastics, derived from biological feedstocks, exist, as an alternative to fossil fuel-based plastics, but these, they note, are not necessarily biodegradable.

Walker and Fequet (2023 [33]) tell us that micro- and nanoplastic pollution

> **'is pervasive and has caused widespread ecological impacts globally, including greenhouse gas emissions, contributing to climate change.'**

They note that current (global) plastic production and waste generation is outpacing existing regulations and strategies to curb the resulting pollution. They speak of a 'sustainable global plastics future', but admit that this will require 'ambitious... pollution reduction targets' to achieve.

A mostly anthropocentric view of the adverse effects of chemical pollution of the environment is given by Naidu *et al* (2021 [34]). They tell us that the scale of chemical release is estimated to be as high as 220 billion tonnes p.a., of which greenhouse gases (GHGs) only constitute 20% (i.e., 44 billion tonnes p.a.). Furthermore, this release is largely cumulative. As they say:

> **'The chemical signature of humans is now ubiquitous and has been detected in the upper atmosphere, on the highest mountains, in the deepest oceans, from pole to pole and in the most remote, uninhabited regions, in soil, water, air, and in the human food chain... There are more than 700 known "dead zones" in oceans and lakes, and pollution by fertilisers, agrochemicals and sediments is one of the factors most strongly associated with these habitat collapses... Industrial chemicals, including known carcinogens and their residues, have been detected in the blood and tissues of all populations, including the unborn and infants... and in mother's milk... They are found in aquatic biota, plants and wild animals, as well as foodstuffs... the combined and cumulative effects of all anthropogenic chemicals, acting together, can potentially impair human life itself.'**

Naidu *et al* claim that pollution-related deaths in the human population number at least 9-10 million a year, and point out that chemical pollution impairs human male reproductive ability and, *inter alia*, foetal and cognitive health.

Michelangeli *et al* (2022 [35]) note that there are now in excess of 350,000 chemical products marketed globally. Many pollutants degrade slowly and remain highly persistent in the environment, while others are released at a near-constant rate, making them 'pseudo-persistent'. Consequently, they say, (anthropogenic) chemical compounds 'have been detected in the tissues of a wide range of wildlife... pervading entire food webs'. They argue:

> **'Besides causing mortality at acutely lethal levels, chemical pollutants can elicit a range of sublethal effects on animals, even at minute concentrations – including disrupting their behaviour. Such effects may be hidden drivers of population declines and ecological instability.'**

The presence in the environment (particularly in water), of so-called 'forever chemicals' – per- and polyfluorinated alkyl substances (PFAS) – and their adverse impact on human and animal health, has been noted in the press (see Salvidge, 2022 [36]; Legendre, 2024 [37]). Legendre tells us that ‘today PFAS “forever chemicals” contaminate the environment from groundwater to Antarctic snow to turtle eggs,’ and that ‘concern over their possible toxicity is growing’. Fenton *et al* (2020 [38]) cite a variety of adverse health effects from specific PFAS,

> **‘including altered immune and thyroid function, liver disease, lipid and insulin dysregulation, kidney disease, adverse reproductive and developmental outcomes, and cancer.’**

Peritore *et al* (2023 [39]) point out that the 4,700 PFAS also have an adverse impact on marine and terrestrial animal health – on wildlife, farm stock and pets.

Marlatt *et al* (2022 [40]) discuss the adverse impacts of endocrine disrupting chemicals (EDCs), such as, but not limited to, alkylphenol ethoxylates, polychlorinated biphenols (PCBs) and brominated flame retardants, on human and non-human animal reproduction, showing, *inter alia*,

> **‘[the] long term effect of maternal occupational exposure to pesticides on low semen volume and total sperm count in their sons... there is considerable evidence that adult exposure to pesticides has adverse effects on male fertility by reducing sperm count and inducing azoospermia...’**

## [4]. The Fossil Fuel and Metals Limit.

Whether as a source of energy or of raw materials for plastics and chemicals, there is a strict, finite limit to the quantity of coal, oil and natural gas on this planet – a point which ought not to be controversial, but which has been the source of some dispute, at least since the petrogeologist M.K. Hubbert (Hubbert, 1956 [41]) published his peak theory relating to oil and natural gas fields (giving rise to the so-called ‘Hubbert curve’, which is an example of a logistic curve, see Cramer (2002 [42]).

The fact remains, however, that global oil and gas reserves are due to run out in about the 2070s, at the *current* rate of consumption.

See Miller and Sorrell (2014 [43]) on the future of oil (and liquid fuel) supplies. As of 2020, there were 54 years' supply of oil left, 49 years' worth of gas, and 139 years' supply of coal (MET Group, 2021 [44]), taking *no* account of the need to mitigate climate change or limit any other damage to the environment or public or animal health.

Furthermore, these are far from the only non-renewable resources that are being depleted, and at an ever-increasingly rapid pace by our advanced industrialised society. Consumer electronics, such as mobile phones, laptop computers, video games consoles, and so on, make extensive use of rare earth metals (or elements), as do many alternative energy technologies, yet these, as their name implies, are rare, although not as rare as silver or mercury. China is the dominant supplier, producing over 85% of the world's rare earth oxide, and this is problematic, for political reasons, given the complexion of China's government, and its disputes with Western ones. Global production peaks in 2041, and declines by 4% p.a. from 2050 onwards, with China retaining its dominant position (El Azhari *et al*, 2024 [45]).

Other metals, such as antimony, bismuth, boron, copper, zinc, lead and so on, are also becoming depleted over time, and are not being recycled as much as they ought to, or need to be, in our wasteful society – see Henckens, Driessen and Worrell (2014 [46]); Sverdrup, Olafsdottir and Ragnarsdottir (2019 [47]); and Sun (2022 [48]) points out the vulnerability of the supply of critical metals to the breakdown of global supply chains due to geopolitical crises.

By far the most important resource – indeed a vital resource for human life and health – is that of water, for drinking, hygiene, sanitation, irrigation of crops and industry, and the combination of increasing demand and climate change is making it increasingly scarce. The UN World Water Development Report, 2024 (UNESCO, 2024 [49]) states (Executive Summary, p.1):

> **'Roughly half of the world's population currently experiences severe water scarcity for at least part of the year. One quarter of the world's population face "extremely high" levels of water stress, using over 80% of their annual renewable freshwater supply.'**

The report notes (ibid.), 'Climate change is projected to... further increase the frequency and severity of droughts and floods.'

## [5]. The Biodiversity Crisis and the 'Sixth Extinction'.

There were five mass extinctions of life on Earth prior to the existence of humans – the Ordovician-Silurian, 440 million years ago (Mya); the Devonian (365 Mya); the Permian-Triassic (250 Mya); the Triassic-Jurassic (210 Mya); and the Cretaceous-Tertiary (also known as the Cretaceous-Paleogene; 65-66 Mya; American Museum of Natural History, no date [50]; International Commission on Stratigraphy, 2023 [51]). The first of these killed off 86% of species; the second, 75%; the third, 96%; the fourth, 80%; and the fifth, which killed off all the non-avian dinosaurs (the avian ones evolved into the birds, see Torres, Norell and Clarke, 2021 [52]), killed 76% of species. The background rate of extinctions is 5 families extinct per million years (Ritchie, 2022 [53]).

Ceballos *et al* (2015 [54]) estimate a background extinction rate of 2 mammal extinctions per 10,000 species per century, and claim that, during the century 1915-2015, the average rate of vertebrate extinctions 'is up to 100 times higher than the background rate', and that a sixth mass extinction is already under way. Among the vertebrate taxa evaluated by the International Union for the Conservation of Nature (IUCN), they tell us, 338 extinctions have been documented since 1500, with most occurring since 1900.

Ceballos, Ehrlich and Raven (2020 [55]) go further, informing us that more than 400 vertebrate species became extinct in the last century, extinctions that would have taken 10,000 years in the normal course of evolution. They list 515 species (74 mammal species; 335 of birds; 41 of reptiles; and 65 of amphibians) that have fewer than 1,000 remaining individuals, and are thus 'critically endangered', according to the criteria of the IUCN.

Cowie, Bouchet and Fontaine (2022 [56]) argue that the IUCN Red List of Endangered Species is 'heavily biased' because of its exclusion of invertebrate species, and that arguments to the effect that claims there is a sixth mass extinction are 'exaggerated', based on the Red List, fail because of this exclusion. They inform us that, since 1500, 'possibly as many as 7.5-13% (150,000-260,000) of all [~2.2] million known species' have already gone extinct (pp.640, 644). Furthermore, they say,

> **'Humans were instrumental in the global megafauna extinction almost as soon as they started migrating out of Africa... although within Africa some megafauna species (e.g. some proboscidians and sabretooth cats) had gone extinct prior to *Homo sapiens* expanding beyond the continent, perhaps related to evolution of *Homo erectus* into the carnivore niche space...' (p.645).**

Invertebrates constitute 95-97% of known animal species, they tell us (p.647). These include 1.05 million insect species (ibid.) and over 83,500 species of mollusc (p.649). 638 mollusc species were definitely known to be extinct in 2017, with a further 380 possibly extinct, and 14 extinct in the wild (p.650). Cowie, Bouchet and Fontaine conclude (p.651):

> **'our estimate of 150,000-260,000 extinctions of all species during the roughly 500 years since 1500 (300-520 extinctions per year) among ~2 million species equates to 150-260 E/MSY [Extinctions per Million Species per Year], far greater than even the high and conservative background rate of Ceballos *et al* (2015 [54]).'**

Ceballos and Ehrlich (2023 [57]) argue that 73 vertebrate genera have become extinct since 1500, and that this generic extinction rate is 35 times higher than background rates, in the absence of human influence. The genera lost in the last five centuries, they tell us, would have taken 18,000 years to vanish without the presence of human beings.

Raven and Wagner (2021 [58]) point out that humans and their domesticated mammals take up 95% of all mammalian biomass on the planet, leaving only 5% for wild mammals. With such a degree of human dominance, they say, 'it is no wonder that insect biodiversity is vanishing rapidly'. They state that:

> **'it appears likely that about a fifth of all species of eukaryotes will disappear within the next few decades and, perhaps, even twice that proportion by the end of the century.'**

The domain Eukaryotae includes the Kingdoms Protista, Fungi, Plantae and Animalia (University of California Museum of Paleontology, no date [59]). With regard to the decline in insect populations, Raven and Wagner (op.cit.) tell us

> **'In all parts of the world, agricultural intensification seems to be a prime driver in insect population declines... although climate change is also playing an increasingly important role in the process of extinction. As this situation develops, we should keep in mind the reciprocal importance of biodiversity for successful agriculture in providing pollination services, and many other ways as well...'**

Ozman-Sullivan and Sullivan (2023 [60]) argue that co-extinction is 'a major and growing threat to global biodiversity', giving the instance of the eriophyoid mites, found in tropical and sub-tropical regions, and their host plants.

## [6]. Too Many Humans.

The classic paper by Holdren and Ehrlich (1974 [61]) is perhaps overly familar, with its famous (or infamous) equation on p.288, namely:

Environmental disruption = population × consumption per person × damage per unit of consumption.

If Holdren and Ehrlich made an error here, it was in omitting the word 'average' in front of 'consumption per person' and 'damage per unit of consumption'. If they had done so, no-one could then have argued that affluence (per capita consumption) was more relevant to the issue of environmental impact than population, nor ignored the fact that the larger the environmental impact, the greater the danger to the human population.

Daily, Ehrlich, A.H. & Ehrlich, P.R. (1994 [62]) discussed the issue of optimum human population size twenty years later, based on the concept of carrying capacity, but this work needed updating, as argued by the present author (Blaber, 2022 [63]). If, according to [19], fossil fuels still account for 438 EJ (1 Exajoule = $10^{18}$ J) of the 760 EJ of primary energy consumed in 2050, i.e., 57.63%, and the population that year is as the US Census Bureau [1] predicts, ~9.755 billion, the ~77.91 GJ per capita energy consumption that year would have to be reduced by that percentage to be completely fossil-free, i.e., to just over 33.01 GJ per capita, and that is obviously quite impossible.

However, the global human population is likely to be very much smaller by that year, as argued by Blaber (2023a [64]), with climate change and the biodiversity crises both contributing to a global famine severely culling the excess numbers of humans in a catastrophe beyond anything than even Malthus could have envisaged (Malthus, 1798 [65]); those crises exacerbated by agricultural practices which destroy soil biodiversity and fertility, and kill insect pollinators through the use of neonicotinoid pesticides, thus also reducing crop production.

## [7]. Conclusion.

Ehrlich, P.R. and Erhlich, A.H. (2013 [66]) ask whether or not a collapse of global civilisation could be avoided. As they argue,

> **‘humanity’s global civilization – the worldwide, increasingly interconnected, highly technological society in which we all are to one degree or another, embedded – is threatened with collapse by an array of environmental problems... The most serious of these problems show signs of rapidly escalating severity, especially climate disruption. But other elements could potentially also contribute to a collapse: an accelerating extinction of animal and plant populations and species, which could lead to a loss of ecosystem services essential for human survival; land degradation and land-use change; a pole-to-pole spread of toxic compounds; ocean acidification and eutrophication (dead zones); worsening of some aspects of the epidemiological environment (factors that make human**

> **populations susceptible to infectious diseases); depletion of increasingly scarce resources... including especially groundwater, which is being overexploited in many key agricultural areas... and resource wars... These are not separate problems; rather they interact in two gigantic complex adaptive systems: the biosphere system and the human socio-economic system.'**

They note that the essential steps to limit $CO_2$ emissions to half their present levels by 2050 (assuming this would be sufficient, which is doubtful, see Blaber, 2023b [67]) would require fossil fuel companies to 'leave most of their proven reserves in the ground, thus destroying much of the industry's economic value'.

Bendell (2018, 2020 [68]) argues for a near-term collapse of society triggered by environmental catastrophe, but imagines that we would need to 'grieve' this situation. The present author, for one, will not 'grieve' the loss of consumerist, materialist, capitalist society in the least. As for the trinkets of that society – the fast cars, the long-haul air-flights, the mobile phones, tablet computers, convenience foods, and so on – humanity did without them before they were invented, and will learn to do without them after they have gone for good. What he *will* mourn is the great loss of human – and non-human animal – life.

Rees (2023 [69]) argues that *Homo sapiens* has evolved to reproduce exponentially, expand geographically, and consume all available resources. For most of humanity's evolutionary history, he tells us, 'such expansionist tendencies have been countered by negative feedback'. However, modern techno-industrial (MTI) society is in a state of overshoot, where

> **'even at current global average (inadequate) material standards, the human population is consuming even replenishable and self-producing resources faster than ecosystems can regenerate and is producing entropic waste in excess of the ecosphere's assimilative capacity... In short, humanity has already exceeded the long-term human carrying capacity of the earth... The fossil-fuelled eight-fold increase in human numbers and >100-fold expansion of real**

> **gross world product in the past two centuries are anomalies... Efforts to address the human demographic anomaly and resulting eco-crisis without attempting to override innate human behaviours that have become maladaptive are woefully incomplete and doomed to fail.'**

As he says, 'In the simplest terms, overshoot results from too many people consuming and polluting too much.' Furthermore, there is another factor at play, to which Rees refers, which is the inability of our essentially 'Palaeolithic brains' to grasp the complexity of the 'MTI' society cultural evolution has produced.

Insofar as humans 'evolve' via techno-cultural 'evolution', which is far faster than the biotic environment can evolve genetically, as Snyder (2020 [70]) notes,

> **'the analogy between a fast-evolving parasite (humans) and a slow-evolving host (the biotic environment) is apt[,]'**

as he says. Snyder tells us that, as human population size increases, humans demand more energy from the environment, but energetic resources are limited, and by the Second Law of Thermodynamics, they are zero-sum, meaning that, if humans consume more energy from the environment, there is automatically less available for other organisms.

Quilley (2011 [71], p.15, pdf.) had earlier argued that 'the biosphere can only absorb a certain amount of entropic disorder' and that 'humanity is now reaching the biophysical limits of growth'. The expansion of the 'Anthroposphere' was in an 'increasingly zero-sum relation to the biosphere as a whole' (ibid.). Snyder and Quilley would be more accurate if they spoke, not of a 'zero-sum' but of a negative-sum, however, for the combination of Earth + Sun is a closed thermodynamic system, and, by the Second Law of Thermodynamics, the total entropy of a closed thermodynamic system increases over time. Kleidon (2012 [72]) discusses how biological organisms on Earth achieve and maintain a thermodynamics far from equilibrium, but noted (in 2012) that 'human appropriated net primary productivity is of the order of 50 TW' and that this constituted 'a considerable term in the free energy budget of the planet' (p.1012). Kleidon says that the

Earth itself is ‘almost a closed system’ (p.1015). Kleidon asserts that human primary energy production exceeds ‘all free energy generated and consumed by geological processes of less than 40 TW in the Earth’s interior’ (p.1031). He concludes (p.1032):

> **‘human activity already consumes a considerable share of the free energy in relation to how much is generated within the Earth system. When we think about the future state of the planet, it would seem almost inevitable that human activity will increase further, in terms of population size and standard of living, among others. Both of these will require more free energy to sustain... If we think of the free energy budget... as a pie, then these questions amount to the issue of whether an increase in human activity in the future is going to decrease or increase the planetary pie of free energy generation, thereby depleting or enhancing the planetary disequilibrium.’**

He gives few grounds for optimism with regard to the prospects for enhancing it.

Rees (op.cit.) points out that cultural evolution does not entail an ability on the part of humans to overcome resource scarcities, nor transcend the laws and limits of nature. The weakening of our energy gradient will, he says, lead to a corresponding plunge in gross world product, global food shortages, and all the other fossil fuel dependent resources needed to run modern civilisation, even without taking account of global heating. He concludes:

> **‘Any reasonable interpretation of previous histories, current trends, and complex systems dynamics would hold that global MTI culture is beginning to unravel and that the one-off human population boom is destined to bust. *H. sapiens*’ innate expansionist tendencies have become maladaptive. However, far from acknowledging and overriding our disadvantageous natural predispositions, contemporary cultural norms reinforce them. Arguably, in these circumstances, wide-spread societal collapse cannot be averted – collapse is not a problem to be solved, but rather the final stage of a cycle to**

> **be endured. Global civilizational collapse will almost certainly be accompanied by a major human population "correction". In the best of all possible worlds, the whole transition might actually be managed in ways that prevent unnecessary suffering of millions (billions?) of people, but this is not happening – and cannot happen – in a world blind to its own predicament.'**

The present author has no doubt that the 'correction' Rees speaks of will be numbered in the billions, and is appalled by the blindness of so-called 'leaders' permitting such a calamity to happen.

The Industrial Revolution and its aftermath permitted an enormous expansion in human numbers, and an enormous increase in economic output, but has led to destruction and pollution of Earth's natural environment, and the loss of biodiversity, with increasing scarcity of resources.

Our global society is also one that is profoundly unequal, as indicated by the Gini Index ranking of countries (World Bank, 2024a [73]) and by the country rankings for GDP per capita (current US$, World Bank, 2024b [74]). Richards, Lupton and Allward (2021 [75]) argue that its high degree of social complexity enhances its vulnerability, and they argue for a scenario that links climate change to food insecurity and societal collapse, which would have the greatest impact on the poor, and the poorest countries. They thus support what the present author has argued in [64]. It is a very grim prospect indeed.

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