WHEN WILL POLICY MATCH SCIENCE?

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REAPING THE WHIRLWIND

It is now 165 years since John Tyndall warned that 'Greenhouse Gases' could create dangerous atmospheric energy gain. But global anthropogenic CO_2 emissions have risen from 196.75 *million* tonnes in 1850 to 5.93 *billion* tonnes [Gt] in 1950, and 40.9 Gt in 2023 if land use change is included[1], with 20% remaining in our atmosphere for 33,000 years. Atmospheric CO_2 concentrations have thus risen from 280 parts per million (ppm) in 1850 to 424ppm in 2023[2], as have those of other GHGs such as methane (CH_4: 750 parts per billion [ppb] in 1800 to >2000 ppb in 2023)[3]. Earth's atmosphere is thus gaining ever more energy[4]: oceans alone have absorbed 345×10^{21} Joules since 1955 alone[2], the energy equivalent of 19 billion Hiroshima Bombs[2]. Ocean heat content to 2km depth, and surface temperature were, in 2023, the highest recorded[5] as was annual-mean global surface temperature (GST). Average land temperatures were 2°C above pre-industrial[2]. We will likely breach a 2°C average 10 year rise (the maximum which the Paris 2010 agreement sought) by 2030[6]. Ice stocks are melting rapidly[7]: from 1997-2021, Antarctica lost 7.5 trillion tonnes[8]; Greenland lost >1 trillion tonnes (5,091 km^2 area) from 1985-2022 and now 66 Gt annually[9]; Swiss glacier volume dropped 10% in 2022/23 alone[10]; 1.73m km^2 of Arctic January ice was lost since 1979; Antarctic sea ice is in decline[11]; and Arctic summer sea ice may have vanished by 2030[12]. With water added from land ice melt, and ocean thermal expansion, sea levels have risen 10cm since 1993[13].

Adding energy is driving increasingly severe and frequent and severe extreme weather events: global climate-related events rose 83% from 1980-1999 to 2000-2019 (3,656 to 6,681), the number of major floods has doubled in 20 years (1,389 to 3,254), and storm incidence has risen from 1,457 to 2,034[14]. In 2013-2022 (vs 1986-2005), the number of heatwave days (2 or more days where both the minimum and maximum temperatures exceeded the 1986–2005 95th percentile) rose 94%[15]. From 2019-2023, annual or seasonal temperature records were broken in every part of the world[16]. Wildfires are more frequent, extensive and intense across the globe[17, 18, 19]. Compared to the 10 years from 2001, the ten years to 2021 saw annual tree cover lost to wildfires rise 93% (2.86m to 5.5m hectares)[20, 21].

IMPACTS ON SOCIETY AND SURVIVAL

The climate stability which allowed human civilization to flourish for 11,700 years is now being lost. Impacts on human health and disease are well documented[15]. But impacts mediated through social and economic change (and resultant migration and war) may soon be catastrophic. The global land area affected by extreme drought annually rose 30% (18% to 47%) from 1951-1960 to 2013-2022[15]. This threatens global food supply, as do many other climate-related factors (reviewed in[22]) such as rising sea levels (loss of agricultural land/saltwater ingress); damaged soil quality, soil desiccation and loss; increased crop respiration/evapo-transpiration reducing water availability; impaired animal productivity/herd survival; crop loss to even short-lived single extreme weather event; changes in weed flora and animal/plant diseases, pests, parasites, and vectors; and inability to work outdoors (in 2022, heat exposure caused the loss of 490 billion potential labour hours, up 42% from the 1990s[15]).

From 1980-2022, climate-related weather extremes caused EUR 650 billion losses to EU member states, and EUR 59.4 billion and 52.3 billion in 2021 and 2022 respectively[23]. Heatwaves alone cut European annual GDP growth by 0.5% (1% in vulnerable regions) in the past decade[24]. The 2022 heatwave cost Italian farming EUR 6.6 billion[25]; Pakistan floods US$ 40 billion[26]; 2023 Florida flooding US$ 9.4 billion[27]; and the 2023 heatwave 0.6% of GDP worldwide- and <1.3% for China[28], with US$ 1.3 trillion losses over the last decade[29]. Losses of US$ 5 trillion are predicted within 5 years, with a 1-in-300 chance of a single event costing over US$17.5 trillion- circa 1/6th of current world GDP[30]. Insurance actuaries warn that "*our economy may not exist at all* if we do not mitigate climate change"[31].

Within 45 years, <3billion people (if surviving intervening climate catastrophe) would face mean annual temperatures >29°C - currently only found in 0.8% of land area (mostly Saharan), and likely incompatible with survival[32]. In 2023, the UN Security Council was warned that accelerating sea level rise could cause a "mass exodus of entire populations on a biblical scale", triggering massive global economic and social disruptions worldwide[33]. War will result[34,35], and climate change is already a "national security threat to Europe"[36].

Finally, human survival depends upon that of the global ecosystem. Vertebrate species' abundance fell 69% between 1970-2018[37]. On top of this, even "moderate" climate change might drive 16% of all species to extinction within 50 years, and fully 1/3rd if emissions continue to rise[38, 39]. Indeed, Earth's five past mass extinctions were associated with global heating of circa 5.2°C: this level over the preindustrial temperatures would today cause a mass extinction event "rivalling those in Earth's past"[40, 41].

WORSE STILL

Impacts may, in fact, occur far faster than this. Earth's energy imbalance is accelerating due to the triggering of multiple (and cross-interacting) positive feedback loops. Heat gain has accelerated as snow/ice loss reflects less back into space (albedo effect), adding an energy gain equivalent of an extra 100ppm CO_2[42]. Rises in atmospheric methane (83x as potent a GHG as is CO_2 over its first 20 years[43] from human activity are augmenting global heating[44], with release from warming permafrost[45, 46], carbonate rocks[47], and wetlands[48]. Increasing wildfires release carbon monoxide (which extends methane's atmospheric lifespan [49]) and more (heating) CO_2: forest fires emitted nearly 33.9 Gt CO_2 in 2021-2022[50] and, in 2023, Canadian fires released 22 Gt[51]. Global wildfire emissions may double within decades[50]. Smoke aerosols create ozone holes[52, 53], short-term accelerated heating detectable < 10km in altitude[54], and significant disruptions to global weather[55]. Soot landing on distant glaciers enhances their melt rate, and thus albedo effect even further[56]. Worsening storms inject water vapour < 19km into the atmosphere, where it acts as a GHG[57], while the ability of rainforests to draw down CO_2, is in decline[58], with some areas becoming net CO_2 emitters[59, 60]. Finally, burning 'dirty' fossil fuels to power shipping releases aerosols which can, paradoxically, help 'shield' the Earth and partially mitigate global heating. As such emissions fall, the full effects of GHG are felt and heating is, consequentially, accelerating[4].

Weather systems may also change abruptly[61]. As polar regions are warming 3-4x faster than the global average, the (moisture-laden) Northern Jet Stream will move progressively northwards- leading to worsening droughts in the Iberian Peninsula, and worsening winter flooding in Northern Europe[62]. Global heating is also driving acceleration in its windspeed, bringing more extreme weather events[63].

Inflow of cold ice meltwater is

disrupting flow of the Atlantic Meridional Overturning Circulation (AMOC, which transports ocean heat)[64], which is now at its weakest in at least 1000 years[65] and which may be at a point of critical transition[66]. Whenever this occurs, it will bring catastrophic disruption to global weather[67]. Likewise, the Antarctic Ocean circulation is slowing[68].

But we may have triggered rapid, severe and sudden Arctic heating, which would accelerate all these impacts[69, 70]. The last three years have seen sudden spikes in Greenland temperature with massive ice melt in days[71, 72, 73]. In 2023, Antarctic sea ice reached record lows, with evidence that the processes underlying polar ice formation have been significantly altered. In Antarctic mid-winter, a large portion of sea ice failed to reform, with 7% (1.25 million square kilometers) less ice than in 2022[74].

THE NEED FOR ACTION

We must save ourselves. As the chair of the intergovernmental Panel on Climate Change stated in 2022, "Any further delay in concerted global action will miss a brief and rapidly closing window to secure a *liveable future*"[75]. The much-trumpeted 'Paris Deal' targeted emissions reductions of 45% by 2030 from a 2010 baseline in order to keep emissions below 1.5°C but, by 2022, emissions had risen by 12.7% [76], '1.5°C' is no longer attainable, and we are likely to breech a 2°C rise by 2030 (above). Independent of party allegiance, politicians must show true leadership and act – whether out of beneficence, moral integrity, concerns for the UK economy or over mass migration, or self-interest for their own survival and that of their children.

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