# 1NC

#### Interpretation: debaters must not miscut evidence

Violation they did – screenshots from “unconditional” and “absolute” on Merriam Webster

Graphical user interface, text

Description automatically generated with medium confidence

Graphical user interface, text

Description automatically generated

#### Standards:

infinite abuse – you can get away with anything and we wouldn’t know

scholarship – encourages bad faith args

fairness

edu

dtd – 1) skewed 2) punishment 3) all args could be wrong

no RVIs 1) illogical 2) chilling

competing interps – 1) reas arbitrary 2) best norms

# Climate

#### CO2 is key to food production and biodiversity – it’s faster than their impacts.

Goklany 15 Indur, PhD, was a member of the US delegation that established the IPCC and helped develop its First Assessment Report, Fellow at the Political Economy Research Center, Senior Adviser for Program Coordination at the U.S. Interior Department’s Office of Policy Analysis, Global Warming Policy Foundation, October 2015, “CARBON DIOXIDE The good news”, http://www.thegwpf.org/content/uploads/2015/10/benefits1.pdf

That carbon dioxide is plant food has been known since the publication in 1804 of Nicolas-Théodore de Saussure’s Recherches Chimiques sur la Végétation. 12 Thousands of experiments since then have shown that the majority of plants grow faster and larger, both above and below ground, if they are exposed to higher carbon dioxide concentrations. The owners of commercial greenhouses routinely pump in carbon dioxide so as to enhance the growth rates of plants, and the optimal level for plant growth is considered to be between 700 and 900 parts per million (ppm),13 roughly twice today’s ambient concentration of 400 ppm. However, plants may continue to respond positively at even higher carbon dioxide levels. For some species such as loblolly pine14 and cuphea,15 growth tops out at around 20,000 ppm or more. Indeed, it has been shown that the addition of supplemental carbon dioxide to a greenhouse enhances the growth of lettuces even if the temperature of the greenhouse is lowered, thus causing a net decrease in the carbon footprint of the operation.16 A database of peer-reviewed papers assembled from studies of the effect of carbon dioxide on plant growth by the Center for the Study of Carbon Dioxide and Global Change (CSCDGC) shows that for the 45 crops that account for 95% of global crop production, an increase of 300 ppm of carbon dioxide would increase yields by between 5% and 78%.17 The median increase for these crops was 41% and the production-weighted yield increase was 34.6%. Experiments also show that the benefits of carbon dioxide for plants are not restricted to faster and greater growth; the efficiency with which they consume water is also increased. Consequently, all else being equal, under higher carbon dioxide conditions, less water is needed to increase a plant’s biomass by any given amount. In other words, higher carbon dioxide levels increase plants’ ability to adapt to water-limited (or drought) conditions, precisely the conditions that some environmentalists claim are already occurring – notwithstanding the finding of the Intergovernmental Panel on Climate Change (IPCC) to the contrary – or will occur in the future. A recent experimental study on grasslands found that elevated levels of carbon dioxide further lengthened the growing season under warming conditions.18 The reason for the increased adaptability is that the size and density of stomata – tiny pores on the underside of leaves, which allow air, water vapour, and other gases to enter and leave the plant – are typically reduced as carbon dioxide levels increase. Thus higher carbon dioxide levels reduce water loss from the leaves. For the same reason, higher carbon dioxide levels reduce the rate at which ozone and other gases toxic to plants enter the plant, reducing the damage they inflict. In fact, Taub, in a summary article notes, ‘Across experiments with all plant species, the enhancement of growth by elevated carbon dioxide is much greater under conditions of ozone stress than otherwise’.19 The IPCC AR5 WGI report acknowledges that ‘[f]ield experiments provide a [sic] direct evidence of increased photosynthesis rates and water use efficiency...in plants growing under elevated carbon dioxide’.20 It also notes that this effect occurs in more than two thirds of the experiments and that net primary productivity (NPP) increases by about 20–25% if carbon dioxide is doubled relative to the pre-industrial level.21 Previously it had been argued that these increases might not be sustainable over the long term, but AR5 reports that new experimental evidence from long-term free-air carbon dioxide enrichment (FACE) experiments in temperate ecosystems show that these higher rates of carbon accumulation can be sustained for ‘multiple years’.22 In AR5, the IPCC says that the reduced carbon dioxide fertilisation effect seen in some experiments and the complete absence in others is ‘very likely’ due to nitrogen limitation in temperate and boreal ecosystems, and phosphorus limitation in the tropics, with a possible effect due to interaction with deficiencies of other micronu trients such as molybdenum.23 The report concludes, ‘. . .with high confidence, the carbon dioxide fertilisation effect will lead to enhanced NPP, but significant uncertainties remain on the magnitude of this effect, given the lack of experiments outside of temperate climates’. But the IPCC protests too much. It overstates the uncertainty regarding the magnitude of the effect under real world conditions. Consider managed ecosystems, particularly agriculture and forestry. Nutrient and micronutrient deficiencies are among the many routine challenges faced by farmers and foresters. Managing them is not terra incognita. Moreover, adaptations to cope with such deficiencies become more likely as technology inexorably advances and societies become wealthier, as indeed they are projected to become under all IPCC emission scenarios.24,25 Therefore, farmers and foresters should be able to adapt successfully, unless some technologies are foreclosed under a perverse application of the precautionary principle.26 Such perversity, however, cannot be ruled out given the antipathy of many environmentalists towards biotechnology. Foreclosing options such as genetically modified (GM) crops that would be more resistant to drought, water logging, or other adverse conditions will increase the likelihood that environmentalists’ warnings – that AGW will lower food production and increase hunger – become self-fulfilling prophecies. It has also been suggested that carbon dioxide enrichment inhibits the assimilation of nitrate into organic nitrogen compounds, which then may be largely responsible for carbon dioxide acclimation, and a decline in photosynthesis and growth of C3∗ plants, as well as a reduction in protein content because of the resulting increase in the carbon/nitrogen ratio.27,28,29 While the precise cause(s) and biochemical pathway(s) responsible for such acclimation are still being investigated, several approaches have been proposed to limit, if not overcome, such acclimation. These include making more nitrogen available to the plant to match the increase in carbon, for example through increased nitrogen fertilisation, greater reliance on ammonium rather than nitrate fertilizers, or improving nitrogen uptake and nitrogen-use efficiency through the development of new crop varieties via conventional breeding or bioengineering.30,31 Present-day contribution of carbon dioxide to increases in crop yields If more carbon dioxide increases the productivity of plants, how much have crop yields increased so far because of carbon dioxide increases since pre-industrial times? Currently, the carbon dioxide level is at 400 ppm (0.04%). By comparison, the preindustrial level is estimated to have been 277 ppm (0.028%).32 If one assumes that the carbon dioxide fertilisation effect on productivity increases linearly, then the AR5 estimate of a 20–25% yield increase for a doubling of carbon dioxide levels since preindustrial times translates into a 9–11% yield increase so far. Alternatively, a 34.6% increase in yield from a 300-ppm increase in carbon dioxide concentration, as calculated by the CSCDGC,† translates into a 15% yield increase due to anthropogenic emissions to date. These are underestimates if the growth response to increasing carbon dioxide levels bends downwards at higher concentrations. These estimates suggest that a portion of the crop yield increases seen in recent decades, which most observers credit to technological change, should actually be credited to carbon dioxide fertilisation. A recent econometric analysis, which pooled sixty years of historical data on US crop yields with output from FACE trials and records of temperature, precipitation, and carbon dioxide levels, estimated that significant proportions of observed yield increases could be attributed to carbon dioxide rather than technological change (see Table 1).33 These estimates suggest that the beneficial effect of carbon dioxide could be even greater than the 9–15% yield increase estimated by CSCDGC. The same study also found that higher carbon dioxide levels are associated with lower variation in yields for each crop. This is consistent with the notion that increased carbon dioxide levels reduce the sensitivity of yield to other factors (e.g. water shortages and air pollution). All else being equal, lower variation translates into a more stable supply of food, as well as more stable food prices, which benefits all consumers everywhere. Idso (2013) has attempted to translate these yield increases into a monetary value. He finds that over 50 years the extra produce grown by farmers has been $274 billion for wheat, $182 billion for maize and $579 billion for rice, and that the current value of the carbon dioxide fertilisation effect on all crops is currently about $140 billion a year. Of course, these numbers cannot be precise, but note that they are based on actual experimental data and existing yields, so they are far less speculative than monetary measures of the harm due to future climate change and its impacts on food security using models that have not been externally validated (see Section 8).34 Impact of carbon dioxide enrichment on pests and weeds All crops are engaged in a battle of attrition with fungal parasites, insect predators and plant competitors, among other pests. Human intervention to help the crops prevail, using pesticides, genetic modification or by changing agronomic practices, is the main determinant of how much of the crop is lost. However, it is possible that carbon dioxide enrichment can improve the capacity of plants to resist pests.35 Insects do not grow faster in higher concentrations of carbon dioxide, and while some experiments show that carbon dioxide enrichment reduces crop resistance to pathogens,36 others show that it can help crops resist such enemies. For example, in one experiment doubling carbon dioxide levels in the air fully compensated for any growth reduction caused by a fungal pathogen in tomatoes.37 In another study, the parasitic weed Striga hermonthica, which devastates many crops in sub-Saharan Africa, was shown to do only half as much damage to rice yields when carbon dioxide concentrations are doubled.38 In another study, higher carbon dioxide levels were found to enhance the production of phenolic compounds in rice and, since these are known to inhibit the growth of the most noxious weeds in rice fields, the authors conclude that the rise in the air’s carbon dioxide concentration may well ‘increase plant resistance to specific weeds, pests and pathogens’.39 Moreover, many crops are C3 plants and many weeds are C4 plants, which respond less to carbon dioxide enrichment. Thus as carbon dioxide levels rise, C3 crops may enhance their growth rates more than C4 weeds do. A Chinese experiment tested this idea by enriching carbon dioxide levels over plots of rice to almost twice the ambient level. This enhanced the ear weight of the rice by 37.6% while reducing the growth of a common weed, barnyard grass, by 47.9%, because the faster-growing rice shaded the weeds.40 Figure 1 illustrates the differing responses to elevated carbon dioxide concentrations of rice, a C3 plant, and the green foxtail Setaria viridis, a grass sometimes proposed as a genetic model system to study C4 photosynthesis.41,42 It is worth noting that the vast majority of plants are C3, perhaps because higher carbon dioxide levels are more the norm in Earth’s history. Contribution of carbon dioxide to increases in biological productivity in unmanaged ecosystems As early as 1985, Bacastow and colleagues detected a steady increase in the amplitude of seasonal variation in the carbon dioxide levels in the northern hemisphere,43 and deduced that it implied an increase in summer vegetation. This was the first hint of global greening, a phenomenon now established by satellite observations. More recent aircraft-based observations of carbon dioxide above the north Pacific and the Arctic Ocean indicate that between 1958–61 and 2009–11 the seasonal amplitude at altitudes of 3–6 km increased by 25% for the northern hemisphere from 10◦N to 45◦N, and 50% from 45◦N to 90◦N.44 Satellite observations confirm that the increase in greenness of the globe is not confined to managed ecosystems (such as croplands), but is happening in unmanaged and lightly managed ecosystems too. Trend analysis of global greenness using satellite data indicates that from 1982 to 2011 – a period during which atmospheric carbon dioxide concentration increased by 15% – 31% of the global vegetated area became greener while 3% became less green (see Figure 2).45 The productivity of global ecosystems has increased by 14% in aggregate. Notably, all vegetation types have greened,46 including tropical rain forests, deciduous and evergreen boreal forests, scrubland, semi-deserts, grasslands and all other wild ecosystems, including those that do not even have indirect input of man-made nitrogen fertilizer. Some ecosystems show a relatively poorer response in NPP at higher carbon dioxide levels. The progressive nitrogen limitation (PNL) hypothesis47 argues that this is due to nitrogen deficiency. However, the human activities that are major emitters of greenhouse gases – fossil fuel consumption and the use of nitrogen fertilizers for agriculture – also emit so-called ‘reactive’ nitrogen, which can be used directly or indirectly by biological organisms to grow. The concentration of N2O has risen by 7% over those 30 years. However, the evidence regarding the PNL hypothesis is mixed.48,49,50,51,52,53,54 The increased greening detected via satellite and aircraft measurements is consistent with the increases in crop yields seen over the past 50 years or more,55,56 but also with a bottom-up estimate of changes in the amount of carbon sequestered in forests.57 These forest stock-and-flux estimates are derived from on-the-ground forest inventory data and long-term ecosystem carbon studies, and represent 3.9 billion hectares of global forests, or 95% of the total. They indicate that from 1990 to 2007 forests served as a net carbon sink, to the tune of 1.1 Pg C per year.‡ Other long-term on-the-ground observational records also find increased forest growth. For example, an analysis of data from unmanaged or lightly managed stands in central European forests, going back in some instances to 1870,§ indicates that the volume of 75-year-old stands of the dominant tree species grew 10–30% faster in 2000 than in 1960.58 The standing stock volumes were also greater in 2000 than in 1960, by 6–7%. Similarly, data ranging over 5–18 years indicate that carbon uptake increased in six out of seven forests across the northeast and midwest United States.59 However, the 14% increase in global vegetation cannot be attributed entirely to higher carbon dioxide levels and nitrogen deposition: part of it could also be due to a more equable climate for plant growth, possibly because of AGW. Donohoe et al. analyzed satellite observations after first processing them to remove the effect of variations in rainfall.60 Their results showed that the vegetation cover across arid environments, where water is the dominant constraint to growth, increased by 11% during the period 1982–2010, largely because of increased wateruse efficiency by plants at higher carbon dioxide concentrations. Unfortunately, estimates of productivity increases solely from carbon dioxide increases are not available for other ecosystems or the globe as a whole. Of course, increases in plant production are likely to result in increases in aggregate animal biomass too. In summary, higher carbon dioxide levels increase both crop yields and biosphere productivity more generally. 3 Ancillary benefits of increased biospheric productivity Improved human wellbeing Higher agricultural yields reduce food prices in general. This provides a double dividend for humanity. Firstly, it reduces chronic hunger, but secondly a reduction in chronic hunger is the first step toward improvements in public health.61,62 Reduced habitat loss and pressure on biodiversity No less important, higher yields also provide a double dividend for the rest of nature. Firstly, they free up habitat for the rest of nature, which reduces the pressure on ecosystems. Had it not been for the increase in yields of 9–15%, global cropland would have had to be increased by a similar amount to produce the same amount of food, all else being equal. That figure means that an area equivalent to the combined area of Myanmar, Thailand and Malaysia has been saved from the plough. Secondly, land that has not been appropriated by humans also produces more food for other species. Consequently, this increases the aggregate biomass – that is, the product of number of species and representatives of each species – that the planet can sustain. How much would the food available for other species have decreased in the absence of anthropogenic increases in atmospheric carbon dioxide? To calculate this figure, assume that: • the productivity of unmanaged ecosystems also increased by 9–15% because of higher carbon dioxide concentrations (as estimated for crops) • human beings currently ‘appropriate’ 25% of the earth’s NPP.63 Therefore, had there been no anthropogenic increase in carbon dioxide, satisfying current human demand for food, timber, feed for domesticated animals and other plant-derived product would have required the share of NPP available for the rest of nature to decline by 11–17%. Alternatively, if one assumes that human beings currently use 40% of global NPP64 and retain the other assumptions intact then the present share of NPP available for the rest of nature would have had to decline by 14–22%. In either case, in the absence of any carbon dioxide fertilisation there would have been a significant increase in the number of species at risk of extinction.

#### Extinction from warming requires 12 degrees, far greater than their internal link, and intervening actors will solve before then

Sebastian Farquhar 17, leads the Global Priorities Project (GPP) at the Centre for Effective Altruism, et al., 2017, “Existential Risk: Diplomacy and Governance,” https://www.fhi.ox.ac.uk/wp-content/uploads/Existential-Risks-2017-01-23.pdf

The most likely levels of global warming are very unlikely to cause human extinction.15 The existential risks of climate change instead stem from tail risk climate change – the low probability of extreme levels of warming – and interaction with other sources of risk. It is impossible to say with confidence at what point global warming would become severe enough to pose an existential threat. Research has suggested that warming of 11-12°C would render most of the planet uninhabitable,16 and would completely devastate agriculture.17 This would pose an extreme threat to human civilisation as we know it.18 Warming of around 7°C or more could potentially produce conflict and instability on such a scale that the indirect effects could be an existential risk, although it is extremely uncertain how likely such scenarios are.19 Moreover, the timescales over which such changes might happen could mean that humanity is able to adapt enough to avoid extinction in even very extreme scenarios. The probability of these levels of warming depends on eventual greenhouse gas concentrations. According to some experts, unless strong action is taken soon by major emitters, it is likely that we will pursue a medium-high emissions pathway.20 If we do, the chance of extreme warming is highly uncertain but appears non-negligible. Current concentrations of greenhouse gases are higher than they have been for hundreds of thousands of years,21 which means that there are significant unknown unknowns about how the climate system will respond. Particularly concerning is the risk of positive feedback loops, such as the release of vast amounts of methane from melting of the arctic permafrost, which would cause rapid and disastrous warming.22 The economists Gernot Wagner and Martin Weitzman have used IPCC figures (which do not include modelling of feedback loops such as those from melting permafrost) to estimate that if we continue to pursue a medium-high emissions pathway, the probability of eventual warming of 6°C is around 10%,23 and of 10°C is around 3%.24 These estimates are of course highly uncertain. It is likely that the world will take action against climate change once it begins to impose large costs on human society, long before there is warming of 10°C. Unfortunately, there is significant inertia in the climate system: there is a 25 to 50 year lag between CO2 emissions and eventual warming,25 and it is expected that 40% of the peak concentration of CO2 will remain in the atmosphere 1,000 years after the peak is reached.26 Consequently, it is impossible to reduce temperatures quickly by reducing CO2 emissions. If the world does start to face costly warming, the international community will therefore face strong incentives to find other ways to reduce global temperatures.

# Other stuff

#### Extinction is inevitable from future technology — nanotech, our simulation gets shut down, AI, biotech, particle accelerators, and black swans

Bruce **Sterling**, 6-1-20**18**, "When Nick Bostrom says “Bang”," WIRED, https://www.wired.com/beyond-the-beyond/2018/06/nick-bostrom-says-bang/

4.1 Deliberate misuse of nanotechnology In a mature form, molecular nanotechnology will enable the construction of bacterium-scale self-replicating mechanical robots that can feed on dirt or other organic matter [22-25]. Such replicators could eat up the biosphere or destroy it by other means such as by poisoning it, burning it, or blocking out sunlight. A person of malicious intent in possession of this technology might cause the extinction of intelligent life on Earth by releasing such nanobots into the environment.[9] The technology to produce a destructive nanobot seems considerably easier to develop than the technology to create an effective defense against such an attack (a global nanotech immune system, an “active shield” [23]). It is therefore likely that there will be a period of vulnerability during which this technology must be prevented from coming into the wrong hands. Yet the technology could prove hard to regulate, since it doesn’t require rare radioactive isotopes or large, easily identifiable manufacturing plants, as does production of nuclear weapons [23]. Even if effective defenses against a limited nanotech attack are developed before dangerous replicators are designed and acquired by suicidal regimes or terrorists, there will still be the danger of an arms race between states possessing nanotechnology. It has been argued [26] that molecular manufacturing would lead to both arms race instability and crisis instability, to a higher degree than was the case with nuclear weapons. Arms race instability means that there would be dominant incentives for each competitor to escalate its armaments, leading to a runaway arms race. Crisis instability means that there would be dominant incentives for striking first. Two roughly balanced rivals acquiring nanotechnology would, on this view, begin a massive buildup of armaments and weapons development programs that would continue until a crisis occurs and war breaks out, potentially causing global terminal destruction. That the arms race could have been predicted is no guarantee that an international security system will be created ahead of time to prevent this disaster from happening. The nuclear arms race between the US and the USSR was predicted but occurred nevertheless. 4.2 Nuclear holocaust[winter] The US and Russia still have huge stockpiles of nuclear weapons. But would an all-out nuclear war really exterminate humankind? Note that: (i) For there to be an existential risk it suffices that we can’t be sure that it wouldn’t. (ii) The climatic effects of a large nuclear war are not well known (there is the possibility of a nuclear winter). (iii) Future arms races between other nations cannot be ruled out and these could lead to even greater arsenals than those present at the height of the Cold War. The world’s supply of plutonium has been increasing steadily to about two thousand tons, some ten times as much as remains tied up in warheads ([9], p. 26). (iv) Even if some humans survive the short-term effects of a nuclear war, it could lead to the collapse of civilization. A human race living under stone-age conditions may or may not be more resilient to extinction than other animal species. 4.3 We’re living in a simulation and it gets shut down A case can be made that the hypothesis that we are living in a computer simulation should be given a significant probability [27]. The basic idea behind this so-called “Simulation argument” is that vast amounts of computing power may become available in the future (see e.g. [28,29]), and that it could be used, among other things, to run large numbers of fine-grained simulations of past human civilizations. Under some not-too-implausible assumptions, the result can be that almost all minds like ours are simulated minds, and that we should therefore assign a significant probability to being such computer-emulated minds rather than the (subjectively indistinguishable) minds of originally evolved creatures. And if we are, we suffer the risk that the simulation may be shut down at any time. A decision to terminate our simulation may be prompted by our actions or by exogenous factors. While to some it may seem frivolous to list such a radical or “philosophical” hypothesis next the concrete threat of nuclear holocaust, we must seek to base these evaluations on reasons rather than untutored intuition. Until a refutation appears of the argument presented in [27], it would intellectually dishonest to neglect to mention simulation-shutdown as a potential extinction mode. 4.4 Badly programmed superintelligence When we create the first superintelligent entity [28-34], we might make a mistake and give it goals that lead it to annihilate humankind, assuming its enormous intellectual advantage gives it the power to do so. For example, we could mistakenly elevate a subgoal to the status of a supergoal. We tell it to solve a mathematical problem, and it complies by turning all the matter in the solar system into a giant calculating device, in the process killing the person who asked the question. (For further analysis of this, see [35].) 4.5 Genetically engineered biological agent With the fabulous advances in genetic technology currently taking place, it may become possible for a tyrant, terrorist, or lunatic to create a doomsday virus, an organism that combines long latency with high virulence and mortality [36]. Dangerous viruses can even be spawned unintentionally, as Australian researchers recently demonstrated when they created a modified mousepox virus with 100% mortality while trying to design a contraceptive virus for mice for use in pest control [37]. While this particular virus doesn’t affect humans, it is suspected that an analogous alteration would increase the mortality of the human smallpox virus. What underscores the future hazard here is that the research was quickly published in the open scientific literature [38]. It is hard to see how information generated in open biotech research programs could be contained no matter how grave the potential danger that it poses; and the same holds for research in nanotechnology. Genetic medicine will also lead to better cures and vaccines, but there is no guarantee that defense will always keep pace with offense. (Even the accidentally created mousepox virus had a 50% mortality rate on vaccinated mice.) Eventually, worry about biological weapons may be put to rest through the development of nanomedicine, but while nanotechnology has enormous long-term potential for medicine [39] it carries its own hazards. 4.6 Accidental misuse of nanotechnology (“gray goo”) The possibility of accidents can never be completely ruled out. However, there are many ways of making sure, through responsible engineering practices, that species-destroying accidents do not occur. One could avoid using self-replication; one could make nanobots dependent on some rare feedstock chemical that doesn’t exist in the wild; one could confine them to sealed environments; one could design them in such a way that any mutation was overwhelmingly likely to cause a nanobot to completely cease to function [40]. Accidental misuse is therefore a smaller concern than malicious misuse [23,25,41]. However, the distinction between the accidental and the deliberate can become blurred. While “in principle” it seems possible to make terminal nanotechnological accidents extremely improbable, the actual circumstances may not permit this ideal level of security to be realized. Compare nanotechnology with nuclear technology. From an engineering perspective, it is of course perfectly possible to use nuclear technology only for peaceful purposes such as nuclear reactors, which have a zero chance of destroying the whole planet. Yet in practice it may be very hard to avoid nuclear technology also being used to build nuclear weapons, leading to an arms race. With large nuclear arsenals on hair-trigger alert, there is inevitably a significant risk of accidental war. The same can happen with nanotechnology: it may be pressed into serving military objectives in a way that carries unavoidable risks of serious accidents. In some situations it can even be strategically advantageous to deliberately make one’s technology or control systems risky, for example in order to make a “threat that leaves something to chance” [42]. 4.7 Something unforeseen We need a catch-all category. It would be foolish to be confident that we have already imagined and anticipated all significant risks. Future technological or scientific developments may very well reveal novel ways of destroying the world. Some foreseen hazards (hence not members of the current category) which have been excluded from the list of bangs on grounds that they seem too unlikely to cause a global terminal disaster are: solar flares, supernovae, black hole explosions or mergers, gamma-ray bursts, galactic center outbursts, supervolcanos, loss of biodiversity, buildup of air pollution, gradual loss of human fertility, and various religious doomsday scenarios. The hypothesis that we will one day become “illuminated” and commit collective suicide or stop reproducing, as supporters of VHEMT (The Voluntary Human Extinction Movement) hope [43], appears unlikely. If it really were better not to exist (as Silenus told king Midas in the Greek myth, and as Arthur Schopenhauer argued [44] although for reasons specific to his philosophical system he didn’t advocate suicide), then we should not count this scenario as an existential disaster. The assumption that it is not worse to be alive should be regarded as an implicit assumption in the definition of Bangs. Erroneous collective suicide is an existential risk albeit one whose probability seems extremely slight. (For more on the ethics of human extinction, see chapter 4 of [9].) 4.8 Physics disasters The Manhattan Project bomb-builders’ concern about an A-bomb-derived atmospheric conflagration has contemporary analogues. There have been speculations that future high-energy particle accelerator experiments may cause a breakdown of a metastable vacuum state that our part of the cosmos might be in, converting it into a “true” vacuum of lower energy density [45]. This would result in an expanding bubble of total destruction that would sweep through the galaxy and beyond at the speed of light, tearing all matter apart as it proceeds. Another conceivability is that accelerator experiments might produce negatively charged stable “strangelets” (a hypothetical form of nuclear matter) or create a mini black hole that would sink to the center of the Earth and start accreting the rest of the planet [46]. These outcomes seem to be impossible given our best current physical theories. But the reason we do the experiments is precisely that we don’t really know what will happen. A more reassuring argument is that the energy densities attained in present day accelerators are far lower than those that occur naturally in collisions between cosmic rays [46,47]. It’s possible, however, that factors other than energy density are relevant for these hypothetical processes, and that those factors will be brought together in novel ways in future experiments. The main reason for concern in the “physics disasters” category is the meta-level observation that discoveries of all sorts of weird physical phenomena are made all the time, so even if right now all the particular physics disasters we have conceived of were absurdly improbable or impossible, there could be other more realistic failure-modes waiting to be uncovered. The ones listed here are merely illustrations of the general case.

#### Nuclear war can’t cause extinction – We’ve nuked ourselves 2000 times – guess what happened nothing

Eken 17 (Mattias Eken - PhD student in Modern History at the University of St Andrews whose thesis focuses on “The Enola Gay Controversy and the American Encounter with Nuclear Weapons”. <MKIM> “The understandable fear of nuclear weapons doesn’t match reality”. 3/14/17. DOA: 7/17/19. https://theconversation.com/the-understandable-fear-of-nuclear-weapons-doesnt-match-reality-73563)

Nuclear weapons are unambiguously the most destructive weapons on the planet. Pound for pound, they are the most lethal weapons ever created, capable of killing millions. Millions live in fear that these weapons will be used again, with all the potential consequences. However, the destructive power of these weapons **has been vastly exaggerated**, albeit for good reasons. Public fear of nuclear weapons being used in anger, whether by terrorists or nuclear-armed nations, has risen once again in recent years. **This is** in no small part **thanks to the current political climate** between states such as the US and Russia and the various nuclear tests conducted by North Korea. But whenever we talk about nuclear weapons, it’s easy to get carried away with doomsday scenarios and apocalyptic language. As the historian Spencer Weart once argued: “**You say ‘nuclear bomb’ and everybody immediately thinks of the end of the world.**” Yet the means necessary to produce a nuclear bomb, let alone set one off, remain incredibly complex – and while the damage that would be done if someone did in fact detonate one might be very serious indeed, **the chances that it would mean “the end of the world” are vanishingly small**. In his 2013 book Command and Control, the author Eric Schlosser tried to scare us into perpetual fear of nuclear weapons by recounting stories of near misses and accidents involving nuclear weapons. One such event, the 1980 Damascus incident, saw a Titan II intercontinental ballistic missile explode at its remote Arkansas launch facility after a maintenance crew accidentally ruptured its fuel tank. Although the warhead involved in the incident didn’t detonate, Schlosser claims that “if it had, much of Arkansas would be gone”. But that’s not quite the case. The nine-megaton thermonuclear warhead on the **Titan II** missile had a blast radius of 10km, or an area of about 315km². The state of Arkansas spreads over 133,733km², meaning the weapon **would have caused destruction across 0.2% of the state.** That would naturally have been a terrible outcome, but certainly not the catastrophe that Schlosser evokes. Claims exaggerating the effects of nuclear weapons have become commonplace, especially after the September 11 terrorist attacks in 2001. In the early War on Terror years, Richard Lugar, a former US senator and chair of the Senate Foreign Relations Committee, argued that terrorists armed with nuclear weapons pose an existential threat to the Western way of life. What he failed to explain is how. It is by no means certain that a single nuclear detonation **(or even several)** would do away with our current way of life. Indeed, we’re still here despite having nuked our own planet more than 2,000 times – a tally expressed beautifully in this video by Japanese artist Isao Hashimoto). While the 1963 Limited Test Ban Treaty forced nuclear tests underground, around 500 of all the nuclear weapons detonated were unleashed in the Earth’s atmosphere. This includes the world’s largest ever nuclear detonation, the 57-megaton bomb known as **Tsar Bomba**, detonated by the Soviet Union on October 30 1961. Tsar Bomba was more than 3,000 times more powerful than the bomb dropped on Hiroshima. That is immense destructive power – but as one physicist explained, **it’s only “one-thousandth the force of an earthquake,** one-thousandth the force of a hurricane**”.** The Damascus incident proved how incredibly hard it is to set off a nuclear bomb and the limited effect that would have come from just one warhead detonating. Despite this, some scientists have controversially argued that an even limited all-out nuclear war might lead to a so-called nuclear winter, since the smoke and debris created by very large bombs could block out the sun’s rays for a considerable amount of time. To inflict such ecological societal annihilation with weapons alone, we would have to detonate hundreds if not thousands of thermonuclear devices in a short time. Even in such extreme conditions, the area actually devastated by the bombs would be limited: for example, **2,000 one-megaton explosions with a destructive radius of five miles each would directly destroy less than 5% of the territory of the US**. Of course, if the effects of nuclear weapons have been greatly exaggerated, there is a very good reason: since these weapons are indeed extremely dangerous, any posturing and exaggerating which intensifies our fear of them makes us less likely to use them. But it’s important, however, to understand why people have come to fear these weapons the way we do. After all, nuclear weapons are here to stay; they can’t be “un-invented”. If we want to live with them and mitigate the very real risks they pose, we must be honest about what those risks really are. Overegging them to frighten ourselves more than we need to keeps nobody safe.

#### 15 islands are capable of facilitating post-apocalyptic human repopulation – We’ll insert this chart

Turchin and Green 18 (Alexey Turchin – Scientist for the Foundation Science for Life Extension in Moscow, Russia, Founder of Digital Immortality Now, author of several books and articles on the topics of existential risks and life extension. Brian Patrick Green – Director of technology ethics at the Markkula Center for Applied Ethics, teaches AI ethics in the Graduate School of Engineering at Santa Clara University. <MKIM> “Islands as refuges for surviving global catastrophes”. September 2018. DOA: 7/20/19. https://www.emerald.com/insight/content/doi/10.1108/FS-04-2018-0031/full/html?fullSc=1&mbSc=1&fullSc=1)

Chart

Description automatically generated

#### Civil defense investments prevent nuclear war from causing extinction under any reasonable estimates.

Charles L. Sanders 17. Scientists for Accurate Radiation Information, PhD in radiobiology, professor in nuclear engineering at Washington State University and the Korea Advanced Institute of Science and Technology. 2017. “Radiological Weapons.” Radiobiology and Radiation Hormesis, Springer, Cham, pp. 13–44. link.springer.com, doi:10.1007/978-3-319-56372-5\_2.

2.5 Survival of Nuclear War The penetrating nature of γ-rays requires substantial shielding with denser materials in high-dose fallout regions. No lethality is expected from a radiation dose rate of 100 mGy/h. An initial dose rate from fallout of 1.0 Gy/h would not be lethal if minimum protection is taken (e.g., staying indoors). An initial dose rate of 10 Gy/h is lethal unless substantially shielded. A shelter providing a protection factor of 100 would suffice. A dose rate of 100 Gy/h would be lethal unless in the best of radiation shelters that give a protection factor of ≥500. However, the area downwind from a nuclear detonation with these high-dose rates would be limited. To protect yourself from fallout, it is essential to find shelter. The dose protection factor of a shelter is the protection afforded someone inside the shelter from radiation originating from the outside. For example, a dose protection factor of 5 means that the radiation level inside the shelter is five times less than the radiation level outside the shelter at the surface of the ground. Dose protection factors vary widely according to building construction, floor level in a multistory building, and proximity to other buildings. A dose protection factor of 5 can be assumed for most woodframe buildings. Most basements provide protection factors of about 50 in at least one area. Building a simple 6-foot trench shelter in your backyard covered with a few feet of dirt on a door would provide protection from thermal and blast effects and a protection factor of 500 from radiation fallout (Table 2.4). Provision of shelters that can withstand 100 psi blast waves, such as subway and utility tunnels, could save nearly 70% of the American urban population from a 9000-MT attack. US ICBM silos are built to withstand up to 2000 psi [60]. Americans are dreadfully ignorant on the subject of civil defense against nuclear war. Americans don’t want to talk about shelters. Most who take shelters seriously are considered on the lunatic survivalist fringe. The current US rudimentary fallout shelter system can only protect a tiny fraction of the population. There are probably less than one in a 100 Americans who would know what to do in the case of nuclear war and even fewer with any contingency plans. The civil defense system should, instead, provide stockpiles of food, water, medical supplies, radiological instruments, and shelters in addition to warning systems, emergency operation and [[TABLE 2.4 OMITTED]] communication systems, and a trained group of radiological monitors and shelter managers. There is a need for real-time radiation measurements in warning the public to seek shelter and prevent panic [61]. Shelters and a warning system providing sufficient time to go to a shelter are the most important elements of civil defense. The purpose of a shelter is to reduce the risks of injury from blast and thermal flux from nearby detonations and from nuclear fallout at distances up to hundreds of miles downwind from nuclear detonations. There are several requirements for an adequate shelter: 1. Availability—Is there space for everyone? 2. Accessibility—Can people reach the shelter in time? 3. Survivability—Can the occupants survive for several days once they are in the shelter? That is, is there adequate food, water, fresh air, sanitation, tools, clothing, blankets, and medical supplies? 4. Protection Factor—Does the shelter provide sufficient protection against radiation fallout? 5. Egress—Is it possible to leave the shelter or will rubble block you? There are several good publications that provide information for surviving nuclear war [62–64]. Two that offer good practical advice are Nuclear War Survival Skills by Kearny [65], and Life after Doomsday by Clayton [66]. Fallout is often visible in the form of ash particles. The ash can be avoided, wiped, or washed off the body or nearby areas. All internal radiation exposure from the air, food, and water can be minimized by proper ventilation and use of stored food and water. Radioactivity in food or water cannot be destroyed by burning, boiling or, using any chemical reactions. Instead it must be avoided by putting distance or mass between it and you. Radioactive ash particles will not induce radioactivity in nearby materials. If your water supply is contaminated with radioactive fallout, most of the radioactivity can be removed simply by allowing time for the ash particles to settle to the bottom and then filtering the top 80% of the water through uncontaminated clay soil which will remove most of the remaining soluble radioactivity. Provision should be made for water in a shelter: 1 quart per day or 3.5 gallons per person for a nominal 14-day shelter period. A copy of a book by Werner would be helpful for health care [67]. During the 1950s, there was firm governmental support for the construction and stocking of fallout shelters. In Eisenhower’s presidency, the National Security Council proposed a $40 billion system of shelters and other measures to protect the civilian population from nuclear war. Similar studies by the Rockefeller Foundation, the Rand Corporation, and the MIT had earlier made a strong case for shelter construction. President Kennedy expected to identify 15 million shelters, saving 50 million lives. Even at that time, there were many who felt this was a dangerous delusion giving a false sense of security. However, the summary document of Project Harbor (Publication 1237) concerning civil defense and the testimony before the 88th Congress (HR-715) both strongly supported an active civil defense program by the US government. A latter 1977 report to Congress concluded that the USA lacked a comprehensive civil defense program and that the American population was mostly confused as to what action to take in the event of nuclear war. President Carter advocated CRP (Crisis Relocation Planning) as the central tenet of a new civil defense program. President Reagan in 1981 announced a new civil defense program costing 4.2 billion dollars over a 7-year period; this program included CRP and the sheltering of basic critical industries in urban and other target areas. President Reagan believed that civil defense will reduce the possibility that the USA could be coerced in time of crisis by providing for survival of a substantial portion of her population as well as continuity for the government. Stockpile, sheltering, and education could be a relatively cheap insurance policy against Soviet attack [68]. With the fall of the U.S.S.R. came a lack of continuing interest in preparation to survive a nuclear war in subsequent administrations. The Pentagon recommended to the Reagan administration that the USA adopt a Soviet-style civil defense program, combining evacuation with fallout shelters. It was suggested that the Americans use doors wrapped in plastic to cover hastily dug trenches in their backyards. The US strategy is like poker while the Soviets’ is like chess. If we bluff and lose, we lose the game. If the Soviets bluff and lose, they only lose one piece. The Soviets have prepared for “social control” following nuclear war, while many Americans believe that all would die. Thus, a prerequisite for any substantial change in US civil defense policy requires a change in popular attitude about survival. Reagan planed for a hypothetical postwar future society in almost bizarre detail. In one additional touch worthy of Dr. Strangelove himself, it was proposed that a select group of volunteers—men and women with a carefully chosen range of skills and talents—live on the continuously moving, subterranean train and that the underground community be equipped with nuclear reactors and hydroponic gardens to sustain life in what was termed “the post-attack environment” [69]. Carl Sagan called for rejecting civil defense, appearing on television to denounce SDI military weapons [70]. Some would prefer surrender to any risk of nuclear war [71]. In 1986 the states of Oregon and Washington withdrew from an emergency drill organized by the FEMA as a protest against “planning for nuclear war.” The drill involved a hypothetical attack on these two states with 48 warheads. According to Oregon Rep. Wayne Fawbush: If you lead people to believe that a nuclear exchange can be survived, you promote the possibility of it happening. If the US was better prepared to survive a nuclear attack, then others would be less likely to launch one. Thus civil defense does not signal a willingness to wage war, but a willingness to deter war by making it less tempting to a potential aggressor. It was to the Soviets politically advantage to hyperbolically emphasize the ‘dreadful’ effects of nuclear weapons to promote American disarmament. The consequences of using nuclear weapons defy human imagination … all-out nuclear war would cause the death of more than 200 million people and 60 million more would be mutilated … Such a nuclear war would inevitably lead to global catastrophe … 80 percent of doctors would perish, 80 percent of hospital beds would be destroyed as would nearly all supplies of blood, antibiotics and other medicines … epidemics would start, radiation will remain a threat…Understand me well. We do not wish to frighten the world with these apocalyptic figures and facts. No, we wish to show the realities of a nuclear war and what needs to be done to prevent it [72]. The Federal Emergency Management Agency (FEMA) was formed in 1979, consolidating in one agency the various federal bureaucracies involved in disaster management. The 1986 FEMA plan calls for sheltering local, state, and federal officials from nuclear war, while everyone else will have to shift for themselves. Land records will be taken into shelters. The federal government denies that this is an elitist strategy but that it is rather to insure that emergency-management infrastructure survives to direct the recovery of the surviving general population. The FEMA admits that as many as half our citizens or more would be lost to the direct and indirect effects of the weapons themselves, and millions more would die in the chaos of the post-attack environment. Current FEMA strategy also calls for return to the traditions of the 1950s when school children were instructed to curl under their desks when they saw a bright flash of light. The USA is woefully unprepared for nuclear war because of radiophobia (Table 2.5). The FEMA is absent before the American public about advice. To be politically correct, the FEMA just assumes that it will never happen. To educate the public in their mind is to enhance the probability of nuclear war. A false emphasis is on prevention of nuclear war not on preparation. The National Radiological Defense Agency of the FEMA is responsible for providing radiation detection instruments, training of personnel in their use, and educating large segments of the American population about radiation hazards. A low budget and even lower public visibility have made this program largely ineffectual. The FEMA had actively promoted CRP as a method to move these more vulnerable populations prior to a war. The current goal of CRP is 80% survival of the US population following a 6559-MT attack on the USA; according to this scenario, 45 million Americans would die. During the initial phase of CRP, 150 million people would be expected to travel from 50 to 300 miles to designated low-risk areas. They will join about 75 million, totaling a shelter population of 195 million. For some the concept of CRP is flawed, unworkable, and dishonest, being in itself a [[TABLE 2.5 OMITTED]] significant threat to instigating a war since its implementation would be a sign to an enemy that we are preparing to fight a total nuclear war. To others it is common sense that we should plan for all contingencies. No one disagrees that to achieve 80% US survival will require several days to carry out evacuation and a whole lot more preparation, organization, and staffing than now exists. Richard Beal, former director for crisis management systems and planning under President Reagan, believes that “national security planning is a myth” because information uncertainty is the normal course in a crisis and that no one has devised a reliable system for tracking the implementation of presidential decisions in crises. The current White House executives have little or no experience with previous crises, making it very difficult to swiftly and accurately analyze crises using available intelligence and information. Some experts believe that civil defense will have no effect on initiation or outcome of a nuclear war. Lauriston Taylor wrote: Nobody in his right mind believes that a nuclear war can be won by anyone-civil defense or no civil defense. No worse tragedy can befall man. Unfortunately, the worst situation that can be computed today, involving a maximum mutual attack by two opponents, will not destroy man, in spite of all the nonsense that has been written to the contrary … On the basis of the worst double attack scenario that can be visualized today, it is anticipated that about 80% of the US population would die within 30 days of the attack. That means that 20% will be left in survivable condition … in varying degrees of distress, almost beyond our imagination to comprehend. Incidentally, this is almost exactly the American population just 100 years ago … Civil defense is in no sense a preparation for war. The existence or nonexistence of civil defense preparations by any party to nuclear war will have no influence on such a war coming about [73]. Paradoxically, it was Taylor who received an accidental whole-body exposure of 10 Gy and believed that 2 mGy/d (730 mGy/y) was safe while living to 102 years (Chap. 1). Nevertheless, Taylor had gotten taken up by doomsday frenzy. During the Cold War, the USA was wanting to exaggerate the effects of nuclear weapons testing to deter the U.S.S.R. from nuclear expansion and other countries from developing nuclear weapons. The U.S.S.R. did the same exaggeration when they had achieved the same capability as the USA, emphasizing that there would be no winners in a nuclear war. Their motivation was not to prevent radiation harm to its population but was political to discourage others to develop nuclear weapons. Exaggerations of the effects of nuclear war will paralyze us. We could accomplish much for so little, spending only 1% of our defense budget on civil defense. The USA has carried out little public education on how to survive nuclear war. In contrast, the U.S.S.R. had carried out an extensive educational program for all its citizens on how to survive a nuclear war. Its citizens are instructed on how to construct a simple, underground trench shelter in less than a day. The Soviets had a highly organized civil defense program, with a planned-for evacuation of cities and construction of underground shelters for some of their industries and for governmental personnel. Civil defense in the U.S.S.R. was part of everyday life as well as a propaganda tool. In peacetime, the U.S.S.R. civil defense program employed 115,000 people under military control; this could be rapidly expanded during wartime to 15,000,000. The first priority of Soviet civil defense is the survival of its political leaders. Because of this emphasis, part of the US strategy was to target Soviet leaders. The CIA predicted 25–35 million deaths in the U.S.S.R. if they had less than a week to evacuate their cities prior to total nuclear war with the USA and 100 million deaths if no warning was given [74]. Only ten million Soviets would die in total war with the USA if given 7–10 days for total evacuation and preparation [75]. In general, Europeans have in the past taken a much more serious and professional view about civil defense than do Americans. American shelters are often considered socially divisive, even though Americans are the most heavily insured people in the world. The reality is that Europeans believe with much justification that simple shelters are remarkably effective in protecting from the effects of nuclear weapons. European countries have extensive civil defense programs. Before 1990 in Switzerland, nearly two-thirds of their population had been provided shelter protection; by 1990, all their population was sheltered. Civil defense training is compulsory for all Swedes with significant support from volunteer agencies [76].

#### Nuke war won’t cause extinction---BUT, it’ll spur political will for meaningful disarmament.

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Although nuclear war is the oldest of these technogenic threats to civilization and human survival, and although important steps to restraint, particularly at the end of the Cold War, have been achieved, the nuclear world is increasingly changing in major ways, and in almost entirely dangerous directions. The third “bombs away” phase of the great debate on the nuclear-political question is more consequentially divided than in the first two phases. Even more ominously, most of the momentum lies with the forces that are pulling states toward nuclear-use, and with the radical actors bent on inflicting catastrophic damage on the leading states in the international system, particularly the United States. In contrast, the arms control project, although intellectually vibrant, is largely in retreat on the world political stage. The arms control settlement of the Cold War is unraveling, and the world public is more divided and distracted than ever. With the recent election of President Donald Trump, the United States, which has played such a dominant role in nuclear politics since its scientists invented these fiendish engines, now has an impulsive and uninformed leader, boding ill for nuclear restraint and effective crisis management. Given current trends, it is prudent to assume that sooner or later, and probably sooner, nuclear weapons will again be the used in war. But this bad news may contain a “silver lining” of good news. Unlike a general nuclear war that might have occurred during the Cold War, such a nuclear event now would probably not mark the end of civilization (or of humanity), due to the great reductions in nuclear forces achieved at the end of the Cold War. Furthermore, politics on “the day after” could have immense potential for positive change. The survivors would not be likely to envy the dead, but would surely have a greatly renewed resolution for “never again.” Such an event, completely unpredictable in its particulars, would unambiguously put the nuclear-political question back at the top of the world political agenda. It would unmistakeably remind leading states of their vulnerability It might also trigger more robust efforts to achieve the global regulation of nuclear capability. Like the bombings of Hiroshima and Nagasaki that did so much to catalyze the elevated concern for nuclear security in the early Cold War, and like the experience “at the brink” in the Cuban Missile Crisis of 1962, the now bubbling nuclear caldron holds the possibility of inaugurating a major period of institutional innovation and adjustment toward a fully “bombs away” future.

#### Industrial civilization wouldn’t recover.

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Imagine that the world as we know it ends tomorrow. There’s a global catastrophe: a pandemic virus, an asteroid strike, or perhaps a nuclear holocaust. The vast majority of the human race perishes. Our civilisation collapses. The post-apocalyptic survivors find themselves in a devastated world of decaying, deserted cities and roving gangs of bandits looting and taking by force. Bad as things sound, that’s not the end for humanity. We bounce back. Sooner or later, peace and order emerge again, just as they have time and again through history. Stable communities take shape. They begin the agonising process of rebuilding their technological base from scratch. But here’s the question: how far could such a society rebuild? Is there any chance, for instance, that a post-apocalyptic society could reboot a technological civilisation? Let’s make the basis of this thought experiment a little more specific. Today, we have already consumed the most easily drainable crude oil and, particularly in Britain, much of the shallowest, most readily mined deposits of coal. Fossil fuels are central to the organisation of modern industrial society, just as they were central to its development. Those, by the way, are distinct roles: even if we could somehow do without fossil fuels now (which we can’t, quite), it’s a different question whether we could have got to where we are without ever having had them. So, would a society starting over on a planet stripped of its fossil fuel deposits have the chance to progress through its own Industrial Revolution? Or to phrase it another way, what might have happened if, for whatever reason, the Earth had never acquired its extensive underground deposits of coal and oil in the first place? Would our progress necessarily have halted in the 18th century, in a pre-industrial state? It’s easy to underestimate our current dependence on fossil fuels. In everyday life, their most visible use is the petrol or diesel pumped into the vehicles that fill our roads, and the coal and natural gas which fire the power stations that electrify our modern lives. But we also rely on a range of different industrial materials, and in most cases, high temperatures are required to transform the stuff we dig out of the ground or harvest from the landscape into something useful. You can’t smelt metal, make glass, roast the ingredients of concrete, or synthesise artificial fertiliser without a lot of heat. It is fossil fuels – coal, gas and oil – that provide most of this thermal energy. In fact, the problem is even worse than that. Many of the chemicals required in bulk to run the modern world, from pesticides to plastics, derive from the diverse organic compounds in crude oil. Given the dwindling reserves of crude oil left in the world, it could be argued that the most wasteful use for this limited resource is to simply burn it. We should be carefully preserving what’s left for the vital repertoire of valuable organic compounds it offers. But my topic here is not what we should do now. Presumably everybody knows that we must transition to a low-carbon economy one way or another. No, I want to answer a question whose interest is (let’s hope) more theoretical. Is the emergence of a technologically advanced civilisation necessarily contingent on the easy availability of ancient energy? Is it possible to build an industrialised civilisation without fossil fuels? And the answer to that question is: maybe – but it would be extremely difficult. Let’s see how. We’ll start with a natural thought. Many of our alternative energy technologies are already highly developed. Solar panels, for example, represent a good option today, and are appearing more and more on the roofs of houses and businesses. It’s tempting to think that a rebooted society could simply pick up where we leave off. Why couldn’t our civilisation 2.0 just start with renewables? Well, it could, in a very limited way. If you find yourself among the survivors in a post-apocalyptic world, you could scavenge enough working solar panels to keep your lifestyle electrified for a good long while. Without moving parts, photovoltaic cells require little maintenance and are remarkably resilient. They do deteriorate over time, though, from moisture penetrating the casing and from sunlight itself degrading the high-purity silicon layers. The electricity generated by a solar panel declines by about 1 per cent every year so, after a few generations, all our hand-me-down solar panels will have degraded to the point of uselessness. Then what? New ones would be fiendishly difficult to create from scratch. Solar panels are made from thin slices of extremely pure silicon, and although the raw material is common sand, it must be processed and refined using complex and precise techniques – the same technological capabilities, more or less, that we need for modern semiconductor electronics components. These techniques took a long time to develop, and would presumably take a long time to recover. So photovoltaic solar power would not be within the capability of a society early in the industrialisation process. Perhaps, though, we were on the right track by starting with electrical power. Most of our renewable-energy technologies produce electricity. In our own historical development, it so happens that the core phenomena of electricity were discovered in the first half of the 1800s, well after the early development of steam engines. Heavy industry was already committed to combustion-based machinery, and electricity has largely assumed a subsidiary role in the organisation of our economies ever since. But could that sequence have run the other way? Is there some developmental requirement that thermal energy must come first? On the face of it, it’s not beyond the bounds of possibility that a progressing society could construct electrical generators and couple them to simple windmills and waterwheels, later progressing to wind turbines and hydroelectric dams. In a world without fossil fuels, one might envisage an electrified civilisation that largely bypasses combustion engines, building its transport infrastructure around electric trains and trams for long-distance and urban transport. I say ‘largely’. We couldn’t get round it all together. When it comes to generating the white heat demanded by modern industry, there are few good options but to burn stuff While the electric motor could perhaps replace the coal-burning steam engine for mechanical applications, society, as we’ve already seen, also relies upon thermal energy to drive the essential chemical and physical transformations it needs. How could an industrialising society produce crucial building materials such as iron and steel, brick, mortar, cement and glass without resorting to deposits of coal? You can of course create heat from electricity. We already use electric ovens and kilns. Modern arc furnaces are used for producing cast iron or recycling steel. The problem isn’t so much that electricity can’t be used to heat things, but that for meaningful industrial activity you’ve got to generate prodigious amounts of it, which is challenging using only renewable energy sources such as wind and water. An alternative is to generate high temperatures using solar power directly. Rather than relying on photovoltaic panels, concentrated solar thermal farms use giant mirrors to focus the sun’s rays onto a small spot. The heat concentrated in this way can be exploited to drive certain chemical or industrial processes, or else to raise steam and drive a generator. Even so, it is difficult (for example) to produce the very high temperatures inside an iron-smelting blast furnace using such a system. What’s more, it goes without saying that the effectiveness of concentrated solar power depends strongly on the local climate. No, when it comes to generating the white heat demanded by modern industry, there are few good options but to burn stuff. But that doesn’t mean the stuff we burn necessarily has to be fossil fuels. Let’s take a quick detour into the pre-history of modern industry. Long before the adoption of coal, charcoal was widely used for smelting metals. In many respects it is superior: charcoal burns hotter than coal and contains far fewer impurities. In fact, coal’s impurities were a major delaying factor on the Industrial Revolution. Released during combustion, they can taint the product being heated. During smelting, sulphur contaminants can soak into the molten iron, making the metal brittle and unsafe to use. It took a long time to work out how to treat coal to make it useful for many industrial applications. And, in the meantime, charcoal worked perfectly well. And then, well, we stopped using it. In retrospect, that’s a pity. When it comes from a sustainable source, charcoal burning is essentially carbon-neutral, because it doesn’t release any new carbon into the atmosphere – not that this would have been a consideration for the early industrialists. But charcoal-based industry didn’t die out altogether. In fact, it survived to flourish in Brazil. Because it has substantial iron deposits but few coalmines, Brazil is the largest charcoal producer in the world and the ninth biggest steel producer. We aren’t talking about a cottage industry here, and this makes Brazil a very encouraging example for our thought experiment. The trees used in Brazil’s charcoal industry are mainly fast-growing eucalyptus, cultivated specifically for the purpose. The traditional method for creating charcoal is to pile chopped staves of air-dried timber into a great dome-shaped mound and then cover it with turf or soil to restrict airflow as the wood smoulders. The Brazilian enterprise has scaled up this traditional craft to an industrial operation. Dried timber is stacked into squat, cylindrical kilns, built of brick or masonry and arranged in long lines so that they can be easily filled and unloaded in sequence. The largest sites can sport hundreds of such kilns. Once filled, their entrances are sealed and a fire is lit from the top. The skill in charcoal production is to allow just enough air into the interior of the kiln. There must be enough combustion heat to drive out moisture and volatiles and to pyrolyse the wood, but not so much that you are left with nothing but a pile of ashes. The kiln attendant monitors the state of the burn by carefully watching the smoke seeping out of the top, opening air holes or sealing with clay as necessary to regulate the process. Brazil shows how the raw materials of modern civilisation can be supplied without reliance on fossil fuels Good things come to those who wait, and this wood pyrolysis process can take up to a week of carefully controlled smouldering. The same basic method has been used for millennia. However, the ends to which the fuel is put are distinctly modern. Brazilian charcoal is trucked out of the forests to the country’s blast furnaces where it is used to transform ore into pig iron. This pig iron is the basic ingredient of modern mass-produced steel. The Brazilian product is exported to countries such as China and the US where it becomes cars and trucks, sinks, bathtubs, and kitchen appliances. Around two-thirds of Brazilian charcoal comes from sustainable plantations, and so this modern-day practice has been dubbed ‘green steel’. Sadly, the final third is supplied by the non-sustainable felling of primary forest. Even so, the Brazilian case does provide an example of how the raw materials of modern civilisation can be supplied without reliance on fossil fuels. Another, related option might be wood gasification. The use of wood to provide heat is as old as mankind, and yet simply burning timber only uses about a third of its energy. The rest is lost when gases and vapours released by the burning process blow away in the wind. Under the right conditions, even smoke is combustible. We don’t want to waste it. Better than simple burning, then, is to drive the thermal breakdown of the wood and collect the gases. You can see the basic principle at work for yourself just by lighting a match. The luminous flame isn’t actually touching the matchwood: it dances above, with a clear gap in between. The flame actually feeds on the hot gases given off as the wood breaks down in the heat, and the gases combust only once they mix with oxygen from the air. Matches are fascinating when you look at them closely. Wartime gasifier cars could achieve about 1.5 miles per kilogram. Today’s designs improve upon this To release these gases in a controlled way, bake some timber in a closed container. Oxygen is restricted so that the wood doesn’t simply catch fire. Its complex molecules decompose through a process known as pyrolysis, and then the hot carbonised lumps of charcoal at the bottom of the container react with the breakdown products to produce flammable gases such as hydrogen and carbon monoxide. The resultant ‘producer gas’ is a versatile fuel: it can be stored or piped for use in heating or street lights, and is also suitable for use in complex machinery such as the internal combustion engine. More than a million gasifier-powered cars across the world kept civilian transport running during the oil shortages of the Second World War. In occupied Denmark, 95 per cent of all tractors, trucks and fishing boats were powered by wood-gas generators. The energy content of about 3 kg of wood (depending on its dryness and density) is equivalent to a litre of petrol, and the fuel consumption of a gasifier-powered car is given in miles per kilogram of wood rather than miles per gallon. Wartime gasifier cars could achieve about 1.5 miles per kilogram. Today’s designs improve upon this. But you can do a lot more with wood gases than just keep your vehicle on the road. It turns out to be suitable for any of the manufacturing processes needing heat that we looked at before, such as kilns for lime, cement or bricks. Wood gas generator units could easily power agricultural or industrial equipment, or pumps. Sweden and Denmark are world leaders in their use of sustainable forests and agricultural waste for turning the steam turbines in power stations. And once the steam has been used in their ‘Combined Heat and Power’ (CHP) electricity plants, it is piped to the surrounding towns and industries to heat them, allowing such CHP stations to approach 90 per cent energy efficiency. Such plants suggest a marvellous vision of industry wholly weaned from its dependency on fossil fuel. Is that our solution, then? Could our rebooting society run on wood, supplemented with electricity from renewable sources? Maybe so, if the population was fairly small. But here’s the catch. These options all presuppose that our survivors are able to construct efficient steam turbines, CHP stations and internal combustion engines. We know how to do all that, of course – but in the event of a civilisational collapse, who is to say that the knowledge won’t be lost? And if it is, what are the chances that our descendants could reconstruct it? In our own history, the first successful application of steam engines was in pumping out coal mines. This was a setting in which fuel was already abundant, so it didn’t matter that the first, primitive designs were terribly inefficient. The increased output of coal from the mines was used to first smelt and then forge more iron. Iron components were used to construct further steam engines, which were in turn used to pump mines or drive the blast furnaces at iron foundries. And of course, steam engines were themselves employed at machine shops to construct yet more steam engines. It was only once steam engines were being built and operated that subsequent engineers were able to devise ways to increase their efficiency and shrink fuel demands. They found ways to reduce their size and weight, adapting them for applications in transport or factory machinery. In other words, there was a positive feedback loop at the very core of the industrial revolution: the production of coal, iron and steam engines were all mutually supportive. In a world without readily mined coal, would there ever be the opportunity to test profligate prototypes of steam engines, even if they could mature and become more efficient over time? How feasible is it that a society could attain a sufficient understanding of thermodynamics, metallurgy and mechanics to make the precisely interacting components of an internal combustion engine, without first cutting its teeth on much simpler external combustion engines – the separate boiler and cylinder-piston of steam engines? It took a lot of energy to develop our technologies to their present heights, and presumably it would take a lot of energy to do it again. Fossil fuels are out. That means our future society will need an awful lot of timber. An industrial revolution without coal would be, at a minimum, very difficult In a temperate climate such as the UK’s, an acre of broadleaf trees produces about four to five tonnes of biomass fuel every year. If you cultivated fast-growing kinds such as willow or miscanthus grass, you could quadruple that. The trick to maximising timber production is to employ coppicing – cultivating trees such as ash or willow that resprout from their own stump, becoming ready for harvest again in five to 15 years. This way you can ensure a sustained supply of timber and not face an energy crisis once you’ve deforested your surroundings. But here’s the thing: coppicing was already a well-developed technique in pre-industrial Britain. It couldn’t meet all of the energy requirements of the burgeoning society. The central problem is that woodland, even when it is well-managed, competes with other land uses, principally agriculture. The double-whammy of development is that, as a society’s population grows, it requires more farmland to provide enough food and also greater timber production for energy. The two needs compete for largely the same land areas. We know how this played out in our own past. From the mid-16th century, Britain responded to these factors by increasing the exploitation of its coal fields – essentially harvesting the energy of ancient forests beneath the ground without compromising its agricultural output. The same energy provided by one hectare of coppice for a year is provided by about five to 10 tonnes of coal, and it can be dug out of the ground an awful lot quicker than waiting for the woodland to regrow. It is this limitation in the supply of thermal energy that would pose the biggest problem to a society trying to industrialise without easy access to fossil fuels. This is true in our post-apocalyptic scenario, and it would be equally true in any counterfactual world that never developed fossil fuels for whatever reason. For a society to stand any chance of industrialising under such conditions, it would have to focus its efforts in certain, very favourable natural environments: not the coal-island of 18th-century Britain, but perhaps areas of Scandinavia or Canada that combine fast-flowing streams for hydroelectric power and large areas of forest that can be harvested sustainably for thermal energy. Even so, an industrial revolution without coal would be, at a minimum, very difficult. Today, use of fossil fuels is actually growing, which is worrying for a number of reasons too familiar to rehearse here. Steps towards a low-carbon economy are vital. But we should also recognise how pivotal those accumulated reservoirs of thermal energy were in getting us to where we are. Maybe we could have made it the hard way. A slow-burn progression through the stages of mechanisation, supported by a combination of renewable electricity and sustainably grown biomass, might be possible after all. Then again, it might not. We’d better hope we can secure the future of our own civilisation, because we might have scuppered the chances of any society to follow in our wake.