The systemic challenge of global heating

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Abstract | Global heating is happening. The opportunity to prevent it has been missed. Originating in the Industrial Revolution, the ever greater use of fossil fuels impacts the entire world – especially future generations, who contribute nothing to the problem and who have no say today. The near-universal consensus is that the accumulation in the atmosphere of greenhouse gases heats the Earth's climate, that an increase above 2 °C imperils the basis of human life, and that one beyond 3 °C threatens its destruction. Global heating is the flipside of the phenomenal economic and demographic development of the past half century. Ever more people are enjoying, or pursuing, ever more comfortable and mobile lifestyles, the cumulative effect is to push the Earth beyond its carrying capacity. Recognizing these dangers, the 2015 Paris Agreement was a major achievement – but not good enough, because chances are slim that it will be realized and, even if it were, it would not suffice. Global heating is beyond individual or national remedial action. Organizing decarbonization at the proper scale and speed is the formidable global public policy challenge on which the survival of the human species depends. Can governments deliver? And what, if they can't?
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Introduction

Climate change, used here synonymously and interchangeably with global heating and global warming, is happening. To wit: 17 of the 18 warmest years on record have occurred in the twenty-first century. The past three years were the hottest since records began (World Meteorological Organization, 2018a). Distress signals are coming from all corners of the earth (Achenbach and Fritz, 2018; Samenow, 2018; Sengupta, 2018b).[1] Record temperatures and droughts afflict India, Iran, South Africa and many other countries, even England, Scotland and Sweden (Sengupta, 2018a; Yeginsu, 2018; World Weather Attribution, 2018).[2] Wildfires are causing havoc in California, Greece, Germany, Sweden and elsewhere (World Meteorological Organization, 2018b). The damage attributable to natural disasters in 2017 in the USA alone exceeded $300 billion, up from $75 billion for Hurricane Sandy in 2012 (NOAA National Centers for Environmental Information (NCEI), 2018a).

The opportunity to prevent global heating has been missed, and the task now is mitigation as well as adaptation – and limiting the political fallout. Global heating will harm, perhaps destroy, the basis of human life on earth. Unknown is the timing and extent of the damage to nature and, as a result, to societies, economies and polities. Global heating is beyond human experience and comprehension. Its origins lie in the Industrial Revolution. Its impact is global, extending far into the future and affecting mostly future generations, the poor as well as other species – those who contribute little or nothing to the problem, and who have no say in today's actions and inactions that impact them profoundly.

Politics, whether in autocracies or democracies, happens in the present. With the populist fallout from globalization, the contest over ideas, goals and resources has gradually become more parochial, transactional and short term. Choreographing multilateral cooperation is a difficult endeavor in the best of times; now it is embarked on by few and resisted by many. Advocating immediate sacrifices for uncertain future benefits is politically treacherous, no matter that the future cost of today's inaction will be steep. Because today's decision makers will not have to live with the outcomes of their choices, the "tragedy of the horizon" results, namely the short-sightedness baked into contemporary economic and political systems (Carney, 2015). Since mitigation costs are due now, yet benefits accrue in future, climate change is politically framed mainly in economic terms – how much is the current generation willing to pay – rather than as a matter of environmental preservation or risk management.

The "urgent threat of climate change" was recognized by all 180 countries that have to date ratified the 2015 Paris Agreement (Paris Agreement, Preamble). It cannot get more universal than that. Nonetheless, agreeing on a problem and setting targets for remedial action are necessary but in themselves insufficient steps.

The solution to global heating is simple: decarbonization. That means reducing to zero current carbon dioxide (CO_2) emissions into the atmosphere, and removing from the atmosphere the carbon dioxide already stored there.

Organizing decarbonization at the proper scale and speed is the formidable global public policy challenge on which the survival of the human species depends. Scientific, technical and financial solutions are available or within reach. The question is whether timely and effective policy action will be taken both individually and collectively by the largest carbon emitters, namely OECD countries plus China, India and Russia. Open, too, is if in the process the rules-based international order can be preserved; also decent, competent and democratic states where they now exist.

In normal disputes, time and compromise are the two main ingredients of successful conflict resolution. Whether in personal life or in politics, time does heal wounds and offers the space for solutions to emerge. Unfortunately, in dealing with global heating, time is not an effective tool, because we are running out of it. As one of the first scientific assessments of the relationship between carbon dioxide and global heating noted already in 1979: "A wait-and-see policy may mean waiting until it is too late" (National Academy of Sciences, 1979).

Secondly, conventional conflicts can be resolved through dialog and compromise. Not so global heating. Nature does not negotiate, nor does it compromise. Arguments within and between countries are of no concern for the Earth. It has been said that we are the first generation to feel the impact of climate change, and the last generation that can do something about it.

This paper surveys the gap between the scientific understanding of the climate challenge and the discernible policy action. It then reviews the scale of the task and concludes with questions regarding the consequences of an inadequate policy response.

Climate Change and the Genesis of a Global Public Policy Problem

Global heating is the result of too many greenhouse gases – mainly carbon dioxide (CO_2) (Le Quéré *et al*, 2017) but also methane (CH_4) (Bousquet *et al*, 2006) and other gases – in the atmosphere, about one-third of which historically contributed by deforestation, two-thirds by the burning of fossil fuels. Global heating disrupts weather patterns (Herring *et al*, 2017), accelerates desertification, leads to sea-level rise (Clark *et al*, 2016; Nauels *et al*, 2017; Mengel *et al*, 2018) destroys biodiversity (Barnosky *et al*, 2011; Crowley and North, 1988), and threatens the production of staples, such as rice, corn and wheat (Tack *et al*, 2015; Zhu *et al*, 2018). Further, it acidifies oceans, which reduces not only marine biodiversity but also their ability to function as a sink for about 25% of current CO_2 emissions. In short, pressures engendered by humans are putting the Earth system at high risk of being pushed beyond its boundaries (Rockström *et al*, 2009). Humanity's destabilization of the Earth's fundamental life-support systems has made humans the dominant geophysical force. The 11,500-year Holocene epoch, that allowed human civilization to develop and flourish, is ending (or has ended already), to be succeeded by an uncharted, unpredictable geological epoch, the Anthropocene, named after its dominant force, humans (Crutzen, 2002). This, to be sure, is a concept larger than individuals, communities, regions, nation states or international organizations. The Earth is now a single, total system undergoing world-shattering, human-induced change. Never have humans been more powerful or wealthier, and the question is if these assets can be deployed purposefully to change the way humans interact with nature and thus to safeguard humanity's survival as a species.

For hundreds of thousands of years, atmospheric levels of CO_2 were between 180 and 280 parts per million. They are now over 410 parts per million, and they keep rising. The aggregate emissions of the two centuries from 1751 to 1950 were less than those of the past 7 years. From 1945 to 2016, they increased ninefold. Today's concentrations have not been seen in at least 800,000 years and the average rate of increase in greenhouse gases in the atmosphere "over the past century exceeds any observed rate of change over the previous 20,000 years" (Ciais *et al*, 2013). The Earth has warmed 1.2 °C (2.2 °F) since the Industrial Revolution, and even if all CO_2 emissions were to stop tomorrow, warming of 1.5 °C (2.7 °F) is a done deal. Mitigation (limiting further increases) and adaptation (managing the consequences) are the tasks at hand.

Unlike steam which evaporates, carbon dioxide remains in the atmosphere for centuries. Global heating therefore is a stock as well as a flow issue, namely the result of historic and current emissions. Given the longevity of carbon dioxide, Earth will continue to heat up even if drastic remedial action is taken immediately. Conversely, the longer emissions continue unabated, the greater the effort and the higher the costs will be to deal with the consequences. Also, the risk of passing irreversible thresholds – tipping points – increases (Nolan *et al*, 2018). Warming might not proceed incrementally and allow time for adjustment. Instead, nonlinear discontinuities might "push components of the Earth system past critical states into qualitatively different modes of operation, implying large-scale impacts on human and ecological systems" (Lenton *et al*, 2018).

It is presumed that when the Earth will have warmed, compared with pre-industrial levels, by between 3 °C (5.4 °F) and 5 °C (9 °F), the western Antarctic ice sheet will collapse; deep water circulation in the North Atlantic will shut down; Amazon rainforests as well as boreal forests will give out; the West African monsoon will stop, and the thawing of permafrost will release vast quantities of methane (CH_4), thus triggering more warming in an unstoppable feedback loop (IPCC, 2014).

To avert such calamities, the 2015 Paris Agreement was a major achievement. It defined problems and outlined what needs to be done. Most countries of the world solemnly committed to holding the increase in global average temperature below 2 °C (3.6 °F) or even 1.5 °C (2.7 °F) above pre-industrial levels. Yet mapping the journey is not the same as actually moving forward.

As matters stand, what was offered and agreed in Paris has little chance to succeed. There is a probability of 99% that 1.5 °C (2.7 °F) will be exceeded this century, more than 95% that 2 °C (3.6 °F) will be exceeded, and only a small chance that the temperature rise remains below 3 °C (5.4 °F) (Raftery *et al*, 2017; UNEP, 2017). No industrialized country is on track to meet its Paris commitments. The efforts of the EU, Australia and New Zealand are rated as "insufficient;" Argentina, Canada, Chile, China and Japan, as "highly insufficient;" and Russia (that has not even ratified the Paris Agreement), Saudi Arabia, Turkey and the USA as "critically insufficient" (The Carbon Tracker, 2018).

In other words, governments have committed to something they are unable or unwilling to honor. Today's gap between ambition and action is disquieting, because it will make it even more difficult in future to enact the deeper emission cuts needed to keep global warming at 2 °C (3.6 °F). Having to operate under time pressure and in crisis conditions, possibly involving armed conflict, the current casual procrastination will strike future governments, and future generations, as reckless.

Climate Change – the Flipside of Economic Growth

While the origin of climate change goes back to the Industrial Revolution some 250 years ago, developments since then have not been linear. A significant acceleration took place during the past 60 or so years. The extraordinary growth of productivity,[3] production, consumption as well as carbon emissions, mainly in Western countries, but lately also in China, India and elsewhere, is unprecedented in human experience. No plateau has been reached yet, and further growth is projected. A few indicators:

- The world's population increased from 3 billion in 1960 to 7.5 in 2016 (The World Bank, 2018a).
- Life expectancy rose from 52 years in 1960 to 72 years in 2016 (The World Bank, 2018b).
- The world's gross domestic product increased from $1.4 trillion in 1960 (or from $470 on average for each of the then living 3 billion people) to more than $76 trillion in 2016 (over $10,000 for each of 7.5 billion people, albeit very unevenly distributed) (The World Bank, 2018c).
- The number of motor vehicles quintupled from 250 million in 1970 to 1.3 billion in 2015 (International Organization of Motor Vehicle Manufacturers, 2018); it is expected to double again by 2050.
- The number of airline passengers increased more than tenfold from 310 million in 1970 to nearly 4 billion in 2016 (The World Bank, 2018d). Its growth continues unrelentingly at a 10-year average annual rate of 5.5% (International Air Travel Association, 2017). International tourist arrivals more than doubled from 1996 (563 million) to 2016 (1235 million) (United Nations World Tourism Organization, 2018).
- Since 1960, the number of domestic ruminants (mainly cattle, sheep and goats) has increased by over 50% to 3.9 billion to accommodate the demand for meat and dairy products (Ripple *et al*, 2013; Global Livestock Methane Counter, undated but live) (https://wolfkind.neocities.org/methane/counter.html).

- A staggering 45 million metric tonnes of electronic waste were generated around the world in 2016, which corresponds to nearly 4500 Eiffel Towers. An increase of about 20% (to 52 million metric tonnes) is expected by 2021 (Balde *et al*, 2017).
- Global plastic production grew from around 1.5 million tons in 1950 to 335 million tons in 2016 (Borrelle *et al*, 2017; PlasticsEurope, 2018). Between 4 and 12 million tons are discarded annually into oceans (Jambeck *et al*, 2015).
- The global decline in vertebrate species between 1970 and 2012 is estimated at 58%. Freshwater populations have declined by 81%, terrestrial populations by 38%, and marine populations by 36% (McRae *et al*, 2017; Warren *et al*, 2018).

The past can be prolog only at our peril. Since both economic growth and population growth continue unabated, in the absence of remedial decarbonization and conservation action at the appropriate scale, the Earth's carrying capacity is being exceeded (Ripple *et al*, 2017; Motesharrei *et al*, 2016).

Climate Change and the Politics of Business as Usual

With overheating a done deal, the issue is no longer the prevention of catastrophe, but its postponement and management. It is possible, yet unlikely, that technical solutions will emerge in the coming decades to decarbonize the world economy while, at the same time, permitting the poor to become wealthy and the Earth's population to increase by another 40% or so without requiring the rich fundamentally to change their lifestyles. Relentless expansion is the logic, in fact the fetish, of today's global economy.[4] Yet infinite growth collides with the physics of a finite world. It is not only the climate change deniers who are anti-science. So, too, are the technology enthusiasts and renewable-energy optimists who entertain the fantasy that it will be possible for ten billion people to live in the style of the American or European middle class (cf. Asafu-Adjaye *et al*, 2015).

Such delusions keep global heating on the political backburner, and intellectual honesty as well as ethical responsibility muted. The facts suggest that urgent action is essential to reposition rich economies; decency requires the unavoidably radical decarbonization in the North in order to create space for the global South to escape poverty (Shue, 2018). The carbon budget – even with some uncertainty at the margins – signals a hard stop. If 2 °C (3.6 °F) is the maximum acceptable warming, the supportable amount of future CO_2 emissions is set. The International Panel on Climate Change calculates the available budget from 2011 onward – assuming a 66% likelihood of success – at 1000 billion tonnes of CO_2 (abbreviated $GtCO_2$) (IPCC, 2014). Having used about 250 $GtCO_2$ in the seven years since 2011, around 750 $GtCO_2$ remain. At current emission rates, a net-zero state must be achieved in less than 20 years to keep warming below 2 °C (3.6 °F) (The Guardian Carbon Countdown Clock, undated). It also means that of the world's estimated 2500 $GtCO_2$ coal, oil and gas resources, 68% must remain in the ground. To limit warming to 1.5 °C (2.7 °F), 85% of reserves must remain underground (Muttitt *et al*, 2016; BP, 2018a).

It is not claimed that these are hard data, yet assumed that they are reasonably plausible. This means that the big picture does not change, even if there are inexactitudes of ± a few years or ± a few $GtCO_2$. The big picture is that by 2050, annual per capita CO_2 emissions must not exceed 2 tons – and this entails a reduction of nearly 90% for the USA, 80% for Russia, 70% for the EU as well as China, and the maintenance of current levels for India. Since the population growth of 2 billion has to be factored into the per capita allocations, even steeper reductions for some developing countries are indicated.

And then, there are historical carbon dioxide emissions. The USA (29%) and the EU (27%) together have contributed well over half of the carbon dioxide stock that accrued from 1850 to 2000; Russia and China are responsible for 8% each; Japan for 4% and India for 2%. Developed countries as a group caused 77% of emissions, developing countries 23% (Baumert *et al*, 2005). Because carbon dioxide stays in the atmosphere for centuries, historical emissions, in fairness, must have a bearing on adjudicating remedial responsibilities, especially because the former high emitters are also today's. The principle of "common but differentiated responsibilities" (CBDR), unsurprisingly, is one of the battle lines in United Nations climate change negotiations. Developing countries contend that early industrialisers must carry a heavier load; developed countries stress that all need to do as much as possible. The double jeopardy is that the irreconcilability of national positions impedes global collective action, while the magnitude of the problem frustrates national initiatives.

No single country is large enough to make much of a difference in what is a global concern. Even though China accounts for nearly 30% of current emissions (the USA for 15, the EU for 10, India for 7, Russia for 5, and Japan for 3%),[5] not even it, the USA, India, or the 28 EU countries alone, can solve the problem. Only together or not at all. It is as if the enormity of the task, instead of instilling a sense of urgency, leads to various forms of denial, foot-dragging and free-riding.

China, fortunately, is somewhat different, perhaps intent on reducing pollution to deflect discontent in what is briskly becoming a middle-class society. Its authoritarian government, recognizing the environmental as well as

economic potential of renewable energy, achieved its 2020 emissions reduction target 3 years ahead of schedule, in 2017, and, in the same year, also introduced an ambitious carbon emissions' trading scheme for its electricity sector (UNFCCC, 2018; Xu and Mason, 2018; Liangyu, 2018).

But in other countries, the threat of climate change is still treated as too remote to trigger forceful remedial action. Domestic politics continue to respond to immediate concerns – those that excite the passions of the moment. Climate change is tackled incrementally at best, and the focus is on national parameters that are not contextualized globally, historically or prospectively. In many countries, the Paris goals are referenced, yet rarely the fact that they are inadequate, even if attained, which is not the case. Most governments emphasize supply and efficiency issues (e.g., the shift to renewables, cheaper batteries, decentralized grid infrastructure, electrification of transport fleets, buildings and industries), but ignore the demand of energy and the resulting emissions.

Take the case of Germany, an enlightened country widely considered a leader in environmental policies. Even though Germany is comparatively diminutive in size – it only accounts for 2% of the World's CO_2 emissions – whatever it does, or does not do, is significant mainly to the extent that it catalyzes or leverages global solutions. For instance, were Germany to invest now at scale in costly fossil-free technologies, their overall costs would drop, and investment and the fast-tracked adoption of clean technologies elsewhere would result (Frankfurt, 2018. Considering that the sun provides more energy every hour than humanity consumes in a year, the need and scope for innovation is immense (Sivaram, 2018).

It is a missed opportunity that the German government's *Climate Action Plan* deals only with national policies and contains no reference to the opportunities entailed in global decarbonization (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, 2018). Neither it nor the G-7 Charlevoix Communiqué (G-7, 2018) contain a climate change vision. They do not even mention carbon pricing, which is the most efficacious way to reduce emissions. They are also silent on fossil fuel subsidies, the perverse economic incentives that increase CO_2 emissions, which, in the G-7 countries alone, amount to over $100 billion annually (Whitley *et al*, 2018).

It is an egregious market failure that spewing carbon dioxide into the atmosphere costs nothing. Of course, there are serious costs, but they are not paid by the polluters. They are imposed on society and the planet as a whole. The United Nations World Health Organization (WHO) reports that more than 80% of people living in urban areas are exposed to poor – and dangerous – air quality (World Health Organization, 2018). To reduce carbon emissions, a price must be put on carbon, so that pollution costs real money, and that incentives are created to pollute less. Allowing the atmosphere to be treated like a free sewer must stop. Ignoring environmental damage is fairy-tale accounting, like running a business and reporting only revenues, but not the cost of raw materials. Markets do not function well when important costs are externalized; they are effective only when significant costs are included in prices.

Climate Change and the Economics of Business as Usual

Global heating, to be sure, is the result of legitimate and legal economic activities, namely the consumption of goods and services, the production of which underpins the vigor of the world economy – and that, at the same time, erodes the basis of human life on earth. It is the flipside of what is, by all accounts, a phenomenal economic success story. Precisely because it is an unprecedented triumph, changing course will be so much more difficult. The beneficiaries are happy to stay the course, no less those who aspire to join the better off – and of course also politicians, because distributional conflicts are easier to manage in a growing than in a shrinking economy.

Populist leaders have come to power in many countries as a repudiation of elites and globalization. To a man, they are hostile to the very notion of climate change which they disparage as one of the liberal fantasies – conspiracies even – they have set out to rip to shreds. They prioritize short-term national advantage over multilateral consensus-building and world order; underwriting purposeful collective efforts is not a pressing concern for them.

Multilateralism is the collateral damage of the populist backlash against globalization. Free markets, free trade, capital liberalization, lower taxes and a reduction in protectionism – the neo-liberal mantra of the 1990s – did not raise all boats. Although productivity increased and wealth exploded, both benefited mainly the rich. Globally, income and wealth disparities have soared over the past decades. For large segments of the population in Western countries, income stagnated while, at the same time, government services and protections were reduced. Governmental indifference if not collusion, the fear of an automated future and the sheer scale of international migration have prepared the ground for backward-looking, science-disdaining chauvinists. It is hard for the argument to gain traction – were it then made – that ecological and economic sustainability are not necessarily contradictory, but can be win–win, if intelligently pursued. This would mean taking stock of the consumption and emission levels, which vary greatly across an otherwise integrated world.

Per capita:	World	USA	EU	Russia	China	India	Ghana
Gross domestic product ($1000): (The World Bank, 2018e)	10	60	34	11	9	2	2
Electricity consumption (1000 kWh/year): (The World Bank, 2018f)	3	13	6	7	4	1	0.4
Emissions (tonnes of CO_2/year):[6] (Global Carbon Project, 2017)	5	17	7	11	7	2	0.5

While aggregates obscure domestic inequalities in income and wealth, they illustrate the magnitude of the decarbonization, de-growth or, in fact, growth challenges. They also show the relative energy inefficiency as well as carbon intensity of some, such as the USA and Russia, and the huge developmental backlog of countries, such as India and Ghana (the latter chosen as one of the more advanced sub-Saharan African countries). The European Union, statistically comparable to North America in economic heft – some would say in reality superior – uses per capita less than half of the electricity and emits even less CO_2. This does not mean that the EU's business model is sustainable, only that it is less extravagant than North America's.

Of note is that substantial parts of Chinese electricity consumption and CO_2 emissions are the result of OECD countries having outsourced to China much of the production of consumer goods and, therefore, the values of the US and EU should be higher, and China's lower. This topic is only flagged, since it is not the point of this paper.

In a world without natural constraints, the differences in wealth, energy use and carbon emissions would be a matter of curiosity, like who wins the hotdog eating contest. However, since humanity is overshooting the Earth's carrying capacity, it matters that the top 10% of global income earners are responsible for nearly as many greenhouse gas emissions as the bottom 90% (Motesharrei *et al*, 2016), and that about half the world's population lives on less than $3 per day. These discrepancies are neither equitable nor sustainable. Nevertheless, as if the science and the conclusions derived from it were somehow fuzzy, the remedy as broadly propagated is further growth in both developed and developing economies.

While differing in details, projections for the two decades until 2040 are grosso modo that (International Energy Agency, 2017; BP, 2018b; Shell Scenarios, 2018):

- The global economy will grow over 3% per year, which means it will double.
- The population will increase from 7.6 billion today to more than 9 billion.
- Demand for primary energy will grow by one-third.
- Fossil fuel use will increase by 20%.
- Carbon emissions will continue to increase and peak at 40 $GtCO_2$ per year.
- Renewable energy sources, while accounting for 40% of the increase in primary energy, will nevertheless only grow to 14% of total primary energy source; oil will still account for 27%, gas for 26, coal for 21, hydro for 7 and nuclear for 5%.

Climate Change and the Scale of Mitigation Requirements

To remain below the 2 °C (3.6 °F) ceiling of the Paris Agreement, a tall order of measures must be taken, such as:

- Change to low-carbon, high-efficiency energy sources.
- Carbon-pricing mechanisms to increase meaningfully the cost of CO_2 across all economies.[7]
- A tripling of the rate of electrification, with global electricity generation reaching nearly five times today's level.
- New energy sources to expand 50-fold, with primary energy from renewables eclipsing fossil fuels in the 2050s.
- Some 10,000 large carbon capture and storage facilities must be built, compared to fewer than the 50 in operation in 2020.
- Net-zero deforestation and the afforestation of an area the size of Brazil (Shell Scenarios, 2018).

Another expert group proposes, indeed demands, that in less than two years, by 2020, the following must be achieved (Mission 2020; Figueres *et al*, 2017).

- *Energy* Renewables must make up at least 30% of the world's electricity supply – up from 23.7% in 2015. No coal-fired power plants must be approved beyond 2020, and all existing ones must be retired.[8]
- *Infrastructure* Cities and states must have initiated action plans to fully decarbonize buildings and infrastructures by 2050, with funding of $300 billion annually. Cities must upgrade at least 3% of their building stock to zero- or near-zero emission structures each year.

- *Transport* Electric vehicles must make up at least 15% of new car sales globally, a major increase from the almost 1% market share that battery-powered and plug-in hybrid vehicles now claim. Also required are commitments for a doubling of mass-transit utilization in cities, a 20% increase in fuel efficiencies for heavy-duty vehicles and a 20% decrease in greenhouse-gas emissions from aviation per kilometer travelled.
- *Land* Land-use policies must be enacted that reduce forest destruction and shift to reforestation and afforestation efforts.
- *Industry* Heavy industry must develop plans to increase efficiencies, with a goal of halving emissions well before 2050. Carbon-intensive industries – such as iron and steel, cement, chemicals, and oil and gas – currently emit more than one-fifth of the world's CO_2, excluding their electricity and heat demands.
- *Finance* The financial sector must rethink how it deploys capital and mobilize at least $1 trillion a year for climate action. Most will come from the private sector. Governments, private banks and lenders, such as the World Bank, need to issue many more "green bonds" to finance climate-mitigation efforts. An annual market must emerge that, by 2020, processes more than 10 times the $81 billion of bonds issued in 2016.

While differing in some details, these studies spell out where to go, yet not how or how hard it is. They are silent on the national and international drivers and drags. In their can-do spirit, they dwell not on the kind of economic growth that is envisaged – which would be worthwhile, since not all growths are created equal (cf. Schandl *et al*, 2016). No word either on the fact that carbon capture and storage is not anywhere near ready for deployment, and may not be for quite a while (Kolbert, 2017), and that the trends in forest management are going the other way (Weisse and Dow, 2018). And, as if the prescriptions were not onerous enough already, two indispensable measures are omitted, namely phasing out carbon subsidies (Whitley *et al*, 2018) and reducing meat consumption. The latter is crucial because ruminant production is the largest source of anthropogenic methane (CH_4) emissions, and because "reductions in ruminant numbers and ruminant meat production would simultaneously benefit global food security, human health and environmental conservation" (Ripple *et al*, 2013).[9] Regardless of details or emphases, remedial action will not happen automatically, but needs to be strategically choreographed politically both nationally and internationally.

Can Politics Deliver?

There is an implicit assumption that political systems have the capacity to deliver what they must. But do they? Is there not the possibility that the reforms necessary to make the current order sustainable are politically unmanageable? Either because governments are distracted and weak, or because they embrace extreme forms of capitalist (or nationalist) ideology and, therefore, are not open to considered collective action to mitigate the risks of a heating world, even though they are clear and recognized.[10] Given the magnitude and complexity of the tasks that must be successfully undertaken by the world's major economies in the coming decade – and then scaled up – a number of questions arise with urgency:

- Can and will governments do what logic, long-term national interest and the future of humanity demand? Can or will they act before problems become too big to manage? Put differently: Is the crucial repositioning of the world's economies technically possible – and politically viable – in the short time available before the climate tips? Put more differently still: Will governments work together to ensure that the collective interests of preserving livable conditions prevail over those who, for profit, exploit the global commons?
- Are the current existing political institutions, mechanisms and tools adequate to deal with climate change? Put differently: Do existing polities, straining under multiple domestic and international pressures, have the capacity to marshal the radical responses needed to save a livable environment?
- Is it politically possible for industrialized countries to live within the ecological budget of the Earth? Can the essential, radical reforms be introduced to make the current order sustainable, or will this transformation be politically impossible to achieve? Put differently: Will, horribile dictu, those critics be proved right who contend that the unholy alliance of producers, consumers and politicians is incapable of rising to the challenge of humanity living in harmony with nature?
- What will happen to the international order when the climate shifts to 3 °C or warmer?

Notes

1 In August, the US National Oceanic and Atmospheric Administration (NOAA) – established incidentally by a Republican President, Richard Nixon – announced that July 2018 was the 403rd consecutive month of global temperatures above the 20th century average. The period between January and July was one of the warmest in the 139 years that records have been kept [cf. NOAA National Centers for Environmental Information (NCEI), 2018b].

2 India is experiencing the worst water crisis in its history, threatening millions of lives and livelihoods. Some 600 million Indians, about half the population,

face high-to-extreme water scarcity conditions (page 27), with about 200,000 dying every year from inadequate access to safe water, according to the report (page 22). By 2030, the country's demand for water is likely to be twice the available supply. Rising annual temperatures and dwindling rain and snowfall have been major factors in the crisis. 2017 was the country's fourth hottest since record-keeping began in 1901, with rainfall down by nearly 6% from 2016 (cf. Kant, 2018).

3 An engrossing illustration of how fast and far we have come is the electronic (rather than electromechanical) calculator the Japanese company Casio had perfected by 1957. Weighing 308 lb and selling for the equivalent of $11,000 in today's dollars, it could not only add and subtract but also multiply (cf. Roberts, 2018).

4 "Economic Growth is fundamental to raising living standards," so the categorical statement in the G-7 Charlevoix Communiqué of 9 June 2018 (G-7, 2018).

5 Country rankings (2016) of territorial CO_2 emissions (in million tons) and percentage share of global total (Global Carbon Project, 2017)

1. China (Mainland)	10,151 $MtCO_2$ = 28% of world total
2. USA	5,312 $MtCO_2$ = 15% of world total
3. EU	3,499 $MtCO_2$ = 10% of world total
4. India	2,431 $MtCO_2$ = 7% of world total
5. Russian Federation	1,635 $MtCO_2$ = 5% of world total
6. Japan	1,209 $MtCO_2$ = 3% of world total
7. Germany	802 $MtCO_2$ = 2% of world total
8. Iran	656 $MtCO_2$ = 2% of world total
9. Saudi Arabia	634 $MtCO_2$ = 2% of world total
10. Canada	563 $MtCO_2$ = 2% of world total
Non-OECD:	22,261 $MtCO_2$ = 62% of world total
OECD	12,550 $MtCO_2$ = 35% of world total
World	36,183 $MtCO_2$ = 100% of world total

6 The 2 °C (3.6 °F) target requires concentrations to be stabilized well below 550 ppm, which means that world average *per capita* emissions would need to decline to about two tonnes in 2050.

7 While the polluter pays principle should be self-evident, the resistance to meaningful carbon pricing is formidable. The US House of Representatives on July 19th 2018 with a nearly 100 vote majority (229–130) passed a resolution denouncing the idea of a carbon tax as detrimental to the economy. "The American Energy Alliance (AEA), the Heartland Institute, and 18 other conservative advocacy groups had urged House Speaker Paul Ryan to bring the resolution to the floor" (Lavelle, 2018).

8 Worldwide, 6,721 coal-fired power stations operate, 467 are under construction, of which 220 in China, 77 in India, 35 in Indonesia, 21 each in the Philippines and Vietnam, 11 in Japan, 7 in Pakistan, 8 in South Africa, 5 in Poland and 4 in Russia (cf. EndCoal, 2018).

9 Meat consumption is closely related to deforestation, i.e., turning forests into farmland. Livestock accounts for some 15% of global CO_2 emissions, takes up over 80% of the world's agricultural land, yet delivers under 20% of calories. A plant-based diet would reduce land-use by over 70% and the greenhouse gases and other pollution that are caused by food production by half (cf. Poore and Nemecek, 2018).

10 The World Economic Forum (2018) assesses risks in two categories: likelihood and impact. Three of the "likely" risks are related to climate change and, except nuclear war, the main four risks in terms of impact (cf. Figure IV, The Evolving Risks Landscapes 2008–2018), p. 6; http://reports.weforum.org/global-risks-2018/explore-the-survey-results/#frame/74975

Global risks in terms of likelihood 2018	
1st	Extreme weather events
2nd	Natural disasters
3rd	Cyberattacks
4th	Data fraud or theft
5th	Failure of climate-change mitigation and adaptation
Global risks in terms of impact 2018	
1st	Weapons of mass destruction
2nd	Extreme weather events
3rd	Natural disasters
4th	Failure of climate-change mitigation and adaptation
5th	Water crisis

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