Three Decades of Climate Mitigation: Why Haven't We Bent the Global Emissions Curve?

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Three Decades of Climate Mitigation: Why Haven't We Bent the Global Emissions Curve?

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Abstract

Despite three decades of political efforts and a wealth of research on the causes and catastrophic impacts of climate change, global carbon dioxide emissions have continued to rise and are 60% higher today than they were in 1990. Exploring this rise through nine thematic lenses—covering issues of climate governance, the fossil fuel industry, geopolitics, economics, mitigation modeling, energy systems, inequity, lifestyles, and social imaginaries—draws out multifaceted reasons for our collective failure to bend the global emissions curve. However, a common thread that emerges across the reviewed literature is the central role of power, manifest in many forms, from a dogmatic political-economic hegemony and influential vested interests to narrow techno-economic mindsets and ideologies of control. Synthesizing the various impediments to mitigation reveals how delivering on the commitments enshrined in the Paris Agreement now requires an urgent and unprecedented transformation away from today's carbon- and energy-intensive development paradigm.

Contents

1. INTRODUCTION: THREE DECADES OF INSUFFICIENT CLIMATE ACTION

Drawing on an already long-standing and growing body of research, the first assessment report of the Intergovernmental Panel on Climate Change (IPCC) was published in 1990. Scientifically informed warnings of the potentially catastrophic impacts of climate change have since sparked a myriad of political responses to the challenges posed by rising emissions. At the international level, the key landmarks have been the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, followed by the Kyoto Protocol and the Paris Agreement in 1997 and 2015, respectively. Add to this hundreds of formal decisions, countless frameworks, action plans and work programs, the establishment of international financing mechanisms (such as the Global Environment Facility and Green Climate Fund), a near continuous round of international meetings, and a proliferation of efforts at the regional, national, and local levels, and one would have expected to see significant levels of progress. Yet global carbon dioxide (CO_2) emissions[1] have been steadily rising over the past three decades and are now 60% higher than they were in 1990[2] (see **Figure 1*a***). Considering the unprecedented risks of projected levels of warming, what are possible explanations for this continued rise in global emissions and the ongoing failure to bend the curve? This article aims to address this challenging question in the hope that it may lend important insights to ongoing climate mitigation efforts while elucidating key questions for future research and action on climate change.

IPCC: Intergovernmental Panel on Climate Change

UNFCCC: United Nations Framework Convention on Climate Change

Kyoto Protocol: international treaty that included legally binding requirements for industrialized nations to limit or reduce their greenhouse gas emissions

Paris Agreement: international treaty in which 191 countries have committed to limit global average temperature rise to well below 2°C and pursue 1.5°C through voluntary, nationally determined contributions

Carbon dioxide (CO_2): the greenhouse gas contributing to the majority of historical and ongoing anthropogenic warming

GHGs: greenhouse gases (e.g., CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6)

1.1. Emissions 1990–2020: An Overview

The article focuses primarily on the past three decades, but in developing the review and analysis it has, on occasions, been necessary to consider more deep-seated factors extending further back in history. Although any analysis will be partial and selective, some headline numbers and a breakdown of emissions trends can begin to reveal important dynamics behind the continued rise in emissions. While historically most emissions have been released in today's wealthy, industrialized countries (hereafter referred to as developed countries, following UN terminology), approximately half of the cumulative CO_2 emissions over the past 30 years have been released within so-called developing countries (**Figure 1*b***). However, considering the large proportion of the world's population within this group [79% in 1990 and 84% in 2018 (1)], the per capita emissions in these countries have, on average, been more than four times lower than in developed

[1]The persistent and long-term warming effects of CO_2 and its dominant role as a greenhouse gas (GHG) stemming from the burning of fossil fuels make it central to our analysis, notwithstanding the importance of other GHGs, notably from agriculture, forestry, and other land use.
[2]The only notable, although short-lived, exceptions to this relentless rise in emissions have been the consequences of two global economic recessions: the first in 2008 accompanying the global financial crisis and the second in 2020 following the coronavirus disease 2019 (COVID-19) pandemic.

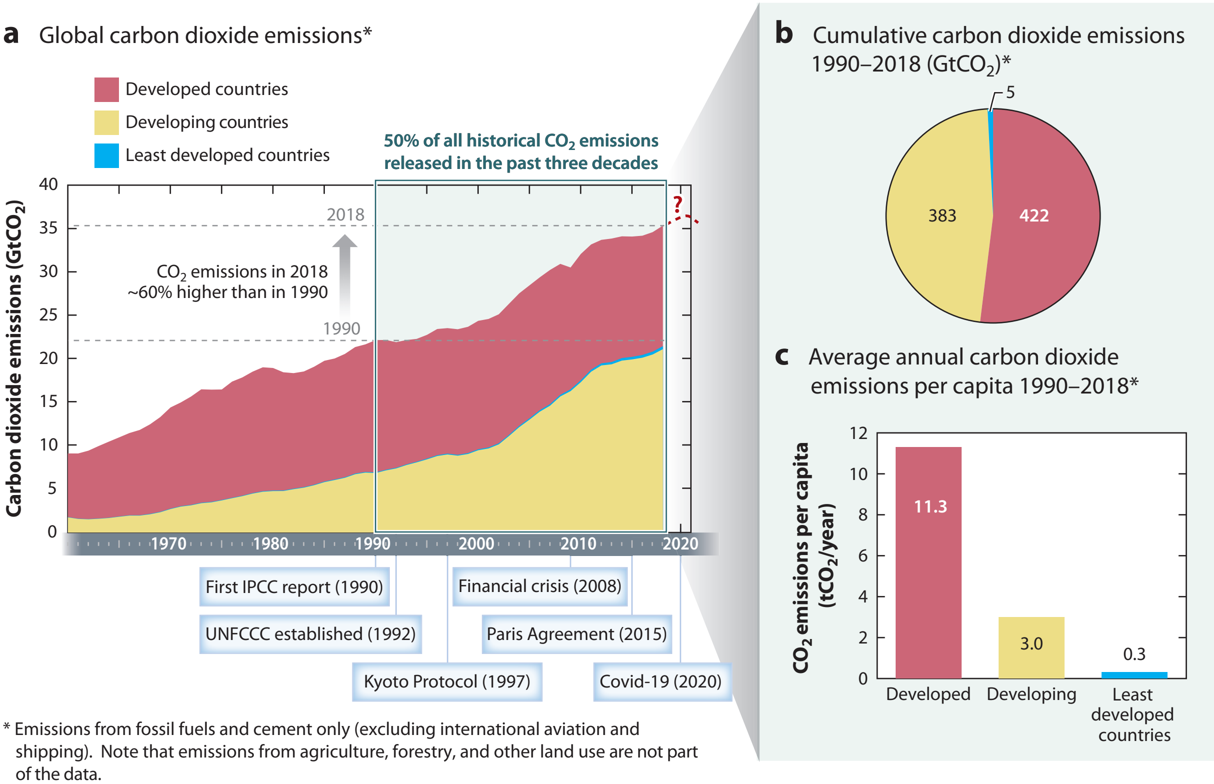

Figure 1

Territorial carbon dioxide (CO_2) emissions of so-called developed, developing, and least developed countries (LDCs) (*a*) over time, (*b*) cumulatively 1990–2018, and (*c*) per capita. The categorization of countries follows the United Nations Framework Convention on Climate Change (UNFCCC) terminology of Annex I (developed) and non-Annex I (includes both developing and LDCs). Countries not party to the UNFCCC were categorized following Anderson et al. (10), who also propose a revised classification of all countries based on their gross domestic product per capita and Human Development Index. Emissions data are from the Global Carbon Project (7), and population data are from the World Bank (1). Additional abbreviations: COVID-19, coronavirus disease 2019; IPCC, Intergovernmental Panel on Climate Change.

countries over this time period (**Figure 1*c***), but with great variations within each group. This is not to underplay the significant contributions that the rise in emissions in large and rapidly industrializing countries such as China and, to a lesser extent, India have made to the global emissions curve, but rather to put them into perspective. The average per capita emissions in the so-called least developed countries (LDCs) have been 10 times lower than in other developing countries and close to 40 times lower than in developed countries. These numbers expose the highly unequitable nature of climate change, not least since LDCs are among those already suffering the worst consequences of a rapidly changing climate. Combining consumption-based emissions accounting (i.e., fully accounting for emissions resulting from a particular lifestyle) with data on global and national income inequality reveals an even starker reality about the carbon inequality of our world. Recent research suggests that globally, the wealthiest 10% have been responsible for as much as half of the cumulative emissions since 1990 and the richest 1% for more than twice the emissions of the poorest 50% (2).

A GLOBAL CARBON BUDGET AND THE PARIS AGREEMENT

The concept of a carbon budget captures the cumulative nature of CO_2 emissions and quantifies the total amount of emissions that can be released to stay below a certain rise in global average temperatures. Combining the carbon budgets, as calculated by the IPCC, with the temperature commitments enshrined in the Paris Agreement brings attention to the urgent need for unprecedented levels of climate mitigation. Without a belief in the successful deployment of planetary-scale negative emission technologies (NETs), and recognizing the principles of equity underpinning the Paris Agreement, double-digit annual mitigation rates are now required by wealthy, industrialized countries (10).

1.2. Implications of the Failure to Bend the Global Emissions Curve

Historical accounts suggest that there was a shared understanding among influential industrialists, scientists, and politicians as early as the late 1980s that anthropogenic climate change was a real concern and that action was needed (3, 4). Indeed, the topic was addressed in the UN General Assembly in 1988, and the IPCC was established in the same year. Public recognition of the issue started spreading around the world in the 1990s, even if understanding was limited (5, 6). Had concerted and decisive action been taken at the time, moderate emissions reductions and an incremental transition away from fossil fuels could have averted much of the climate change that now has been locked in. Instead, and in just three decades, more fossil CO_2 has been emitted than previously throughout history (804 $GtCO_2$ in the 240 years 1750–1990 and 872 $GtCO_2$ in the three decades 1990–2019) (7). The cumulative nature of CO_2 emissions has accelerated the rate and depth at which fundamental, system-level change has become necessary if societal development pathways are to be reconciled with the political commitments in the Paris Agreement (8, 9). For wealthier, industrialized countries, delivering on the Paris temperature commitments and the principles of equity enshrined in the agreement now requires rates of territorial mitigation above 10% per annum (10; see also the sidebar titled A Global Carbon Budget and the Paris Agreement).

However difficult or unlikely such an unprecedented and rapid transformation of industrialized societies may seem, failing to do so will further exacerbate the intra- and intergenerational suffering that already has been locked in. Challenging levels of adaptation and irreversible loss and damage (i.e., harms to human livelihoods and ecosystems resulting from sudden-onset events or slow-onset processes from climate change, which cannot be mitigated or adapted to) are now present-day realities facing communities around the world. One increasingly common way to relate to this predicament, across disciplinary domains, is through the lens of the Anthropocene. The Anthropocene is a grand story of humanity's long-lasting imprint on this planet (11). It is a concept that draws attention to the magnitude and consequences of a warming world and highlights that the irreversible damage already done to vulnerable ecosystems and people will extend across many millennia. In contrast to the past 12,000 years of relative climate stability, known to geologists as the Holocene, the Anthropocene has been described as an unpredictable and dangerous era in planetary history when humanity has become a major force of nature that is changing the dynamics and functioning of Earth itself (12, 13). Even if there is considerable disagreement about the meaning, implications, and appropriateness of the term (e.g., see 14 for a critique), the Anthropocene has prompted new ways of thinking about our relationship to the natural world, to ourselves, and to our collective existence (15). In a time of melting ice caps, rising sea levels, extreme weather, and mass species extinction, many conventional systems of knowledge and institutional practice are challenged and may need to be radically rethought.

2. REVIEWING THREE DECADES OF CLIMATE MITIGATION THROUGH NINE THEMATIC LENSES

Social imaginaries: collective images of how we might live

In reviewing possible reasons as to why the global emissions curve continues upwards, the first two authors of this article (Stoddard and Anderson) formulated nine thematic lenses to structure the process. They cover issues of international climate governance (Section 3.1), the vested interests of the fossil fuel industry (Section 3.2), geopolitics and militarism (Section 3.3), economics and financialization (Section 4.1), mitigation modeling (Section 4.2), energy supply systems (Section 4.3), inequity (Section 5.1), high-carbon lifestyles (Section 5.2) and social imaginaries (Section 5.3). These lenses were chosen to complement other recent reviews on, for example, carbon lock-ins (16), discourses of climate delay (17), and interdisciplinary research agendas (18, 19).

For each thematic lens, a pair of additional coauthors were then invited to conduct expert reviews.[3] As no single discipline can explain the sheer scale of the failure to effectively tackle climate change, the lenses drew on broad sets of literature from across the natural sciences, social sciences, and humanities. To ensure some breadth and diversity within each lens, and as a form of internal peer-review, the author pairs were selected, in part, for their different engagement with, and interpretation of, the relevant research. In line with calls for more critical research agendas (see, e.g., 20), authors with a distinct ability to critique orthodoxy and provide perspectives drawing on more heterodox schools of thought were prioritized.

The process of writing this article has been iterative and humbling. The nine lenses provided key insights into the apparently inexorable rise in emissions, but with each insight came new questions and the prospect of still other lenses. As the article coalesced, it became increasingly evident that any attempt to distil a single clear narrative was misguided. Surveying the lenses from a distance, however, suggested several common threads around which they might be clustered, but as with all clustering different threads emerged with each scan. It was only when these alternatives were considered in the context of the article's core rationale that a stronger sense of direction became apparent, and power emerged as a particularly important thread to emphasize.

On the face of it, a focus on power offers little different than many other analyses but, nevertheless, emerged as a recurrent and important motif in all of the reviews. Reflecting on how power wove through the different lenses opened up important distinctions in how it was both conceived and played out. Ultimately, a first cluster of lenses was seen as embedding deep-seated and largely unchallenged forms of power. Such power has come to shape debates, control institutions, and describe the boundary of the paradigm within which most societies implicitly operate. It is within this rarefied world that questions of global governance (Section 3.1), geopolitics and militarism (Section 3.3) and, arguably, vested interests of the fossil fuel industry (Section 3.2) can be said to reside, caricatured in this article as the Davos cluster.[4]

Within a second cluster of lenses are forms of power that can more appropriately be described as instrumental, whereby ostensibly "objective" analysis operates within—and thereby reinforces—the deeply subjective boundaries decreed by the powers of the Davos cluster. Here, the image is of a legitimizing collaborator, the Enabler cluster, whereby responses to all issues (including climate change) can be addressed within the contemporary socioeconomic paradigm.

[3]The Author Contributions statement at the end of the article indicates which authors covered each thematic lens.

[4]Davos is a Swiss ski resort and home to the annual, invitation-only, World Economic Forum, which engages "the foremost political, business, cultural and other leaders of society to shape global, regional and industry agendas" (**https://www.weforum.org/about/world-economic-forum**).

Whether it's the unchallenged dominance of mainstream economics and finance (Section 4.1), the narrow techno-economic rationality underpinning global mitigation models (Section 4.2), or the self-reinforcing technological determinism of centralized and large-scale energy supply (Section 4.3), all see the future as a simple extension of today. Yet, and despite their existing and tacit allegiance to the Davos cluster, it is within this "expert" realm that the power to both legitimize and undermine the status quo resides. In that regard, it has the potential of being highly influential and a facilitator of rapid change.

A final cluster gathers lenses that explore phenomena that are arguably more elastic and with the potential to both indirectly maintain and explicitly reject and reshape existing norms. Many of the topics addressed here can be appropriately characterized as bottom-up, with strong and highly diverse cultural foundations. Although they are influenced by global and regional social norms, the expert framing of institutions, and the constraints of physical infrastructure (from housing to transport networks), they are also domains of experimentation, new norms, and cultural change. Building on this potential for either resisting or catalyzing change, the caricature chosen here is one of avian metaphor and myth: the Ostrich and Phoenix cluster. Ostrich-like behavior—keeping heads comfortably hidden in the sand—is evident in different ways across the lenses of inequity (Section 5.1), high-carbon lifestyles (Section 5.2), and social imaginaries (Section 5.3), which make up this cluster. Yet, these lenses also point to the power of ideas, to how people can thrive beyond dominant norms, and to the possibility of rapid cultural change in societies—all forms of transformation reminiscent of the mythological phoenix born from the ashes of its predecessor. It is conceivable that this cluster could begin to redefine the boundaries of analysis that inform the Enabler cluster, which in turn has the potential to erode the legitimacy of the Davos cluster. The very early signs of such disruption are evident in some of the following sections and are subsequently elaborated upon in the latter part of the discussion.

3. GOVERNANCE, GEOPOLITICS, AND VESTED INTERESTS (THE DAVOS CLUSTER)

The Davos cluster engages the three lenses of international climate governance (Section 3.1), the vested interests of the fossil fuel industry (Section 3.2), and the entrenched nature of geopolitics and militarism (Section 3.3) to explore how effective mitigation has been, and continues to be, obstructed.

3.1. International Climate Governance

At the international level, a key response to climate change has been to develop a regime—a form of governance centered on a legal treaty that enables cooperation and negotiation between sovereign states, based on agreed principles, norms, rules and decision-making procedures (21, 22). The climate change regime, founded on the basis of the 1992 UNFCCC, has fulfilled some of its expected functions. It has raised awareness, promoted learning, established reporting and monitoring systems, galvanized large sections of civil society, and achieved some convergence of norms, notably rhetorical acceptance of the 2°C and 1.5°C temperature targets. The regime has impacted policymaking, with key events—entry into force of the 1997 Kyoto Protocol, the 2009 Copenhagen Conference, adoption of the 2015 Paris Agreement—triggering an expansion of domestic climate change legislation (23). There has been full legal compliance with the Kyoto Protocol's specific emission commitments (24), yet, the commitments have never been commensurate with the unprecedented and escalating scale of the challenge. The reasons for this are complex and interconnected, and they include the highly intractable nature of climate change itself and the hegemony of an international political-economic system that is based largely on state sovereignty and competition (see Sections 3.3 and 4.1), neither of which the climate change regime has provided sufficient incentives to overcome. Here, attention is turned toward two other factors: the climate regime's institutional design and deliberate political strategy.

CBDR&RC: common but differentiated responsibilities and respective capabilities

Different concerns about institutional design have been raised over the past 30 years, often set in the context of heated political debates. Of particular importance has been the differentiation of countries under the 1992 UNFCCC into Annex I (43 developed countries) and, by exclusion, non-Annex I (mostly developing countries), with each group taking on different responsibilities in accordance with the principle of common but differentiated responsibilities and respective capabilities (CBDR&RC). Annex I countries were required to "take the lead" in "combating climate change" (Article 3.1) (25, p. 4) and "modifying longer term trends in . . . emissions" [Article 4.2(a)] (25, p. 6), with a subset of wealthier nations (Annex II Parties[5]) also required to provide financial and technological assistance to developing countries (25). This division was subsequently applied to the Kyoto Protocol, in which most Annex I Parties took on legally binding emission targets.

Without an automatic graduation mechanism, this division has been charged by some as being inflexible, failing to reflect diverse and changing national circumstances, entrenching a political divide, and enabling emerging economies to delay assuming commitments commensurate with their rising emissions (see, e.g., 26, 27). The categorization is, however, more nuanced and responsive to differing national circumstances than is commonly recognized,[6] and the UNFCCC also included clear pathways for reviewing the annexes and amending the country categories. The alleged inflexibility of the regime was therefore always much more of a political issue than one of institutional design. The Paris Agreement eventually abandoned the UNFCCC's annex-based structure, with both developed and developing countries expected to take on voluntary nationally determined contributions. This flattening of the regime structure involved a clear weakening of commitments for the developed countries.

Whereas some critiques of institutional design have focused on differentiation, others have pointed to the regime's limited success in building mechanisms to operationalize its principles and commitments, notably in relation to inadequate funding and technology transfer for developing countries (28). Donor countries have faced criticism for persistent reneging on financial promises and foot-dragging on financial reporting, including double counting (see, e.g., 29). Arguably, multilateral development banks have also been slow to move from funding high- to low-carbon development projects.

Decision-making through consensus, because of the absence of agreed rules of procedure, is another candidate for criticism, on the grounds that it generates lowest common denominator outcomes and inflates the leverage of small groups of countries (30). More generally, there are varying views in the literature on the relative merits of different types of institutional approaches, including legally binding targets combined with emissions trading for developed countries (as used in the Kyoto Protocol) versus the universal and voluntary policy pledges (as used in the Paris Agreement) (27, 31). Neither of these two approaches has thus far sufficiently impacted the global emissions curve (although it is too early to assess the full impacts of the Paris Agreement). At a more fundamental level, some claim that the problems with the climate change regime run much deeper; a global negotiation process involving nearly 200 countries and thousands of participants

[5]Annex I Parties that were also members of the Organization for Economic Co-operation and Development in 1992.

[6]For example, special concessions are granted to LDCs, a certain degree of flexibility is allowed for transition economies, and special circumstances of individual countries are recognized in various articles (Articles 4.8 and 4.10) (25) and conference of the parties decisions (e.g., Turkey, decision 26/CP.7).

is by nature cumbersome, subject to high transaction costs, and compromised by political grandstanding and wider geopolitical game-playing (see Section 3.3).

A further issue hindering progress has arisen from the deliberate political strategies of interest groups, notably the fossil fuel industry and related sectors (see Section 3.2) and their lobbying to maintain laggard positions in countries such as Australia and the United States and to mute leadership in others, such as Germany. Obstructionism has come from fossil fuel–exporting countries, stalling negotiations, exacerbating political tensions, and avoiding any reference to fossil fuels as the main cause of climate change (see, e.g., 32).

The nation most significantly undermining the call to action has been the United States. Even during more engaged Democratic presidencies, US participation has remained directed toward the flattening of differentiated commitments between developed and developing countries. US exceptionalism has dominated the regime in part because of the lack of more positive, sustained leadership from others—and indeed the willingness of some high-emitting developed countries to support its laggard stance. The European Union (EU) has long positioned itself as leader in the regime (33), based on its relatively stronger domestic and regional policies. However, its leadership claims are marred by erratic delivery on financial promises, delayed ratification of the Kyoto Protocol's second commitment period, inconsistent domestic policies among its members (e.g., continued coal subsidies in Germany, obstruction to strong action by Poland), and ultimately, its participation in weakening the regime for developed countries. China has taken some action domestically but has proved reluctant to assume a leadership role commensurate with its prominent economic and emitter status, while continuing domestic and foreign investment in fossil fuels (e.g., via its Belt and Road Initiative).

Critiques of various institutional design features of the climate governance regime have some explanatory value in accounting for the failure to bend the global emissions curve over the past 30 years. However, these critiques appear overshadowed by the effects of deliberate political strategy, unequal power, and the absence of leadership. Despite relative progress in some countries, the wealthy, developed nations have failed to decisively lead in addressing climate change, both in achieving significant emission cuts (9) and providing adequate and predictable finance (28, 29), which could have built trust and impetus for a "race to the top." This failure to lead in accordance with the principles of the UNFCCC has sowed mistrust and created little incentive for developing countries to act. Such mistrust has provided ample flanks for powerful and vested interests within these developing countries to maintain business-as-usual approaches, thus prolonging and further embedding high-carbon development rather than low-carbon alternatives.

3.2. The Vested Interests of the Fossil Fuel Industry

The rapid reduction in emissions necessary to check ongoing climate change poses a real threat to the near- and medium-term business models of incumbent fossil fuel companies and associated vested interests (34). A growing body of literature has outlined how powerful vested interests have developed strategies to both directly discredit the science on climate change and more subtly to delay the need to reduce reliance on fossil fuels (35, 36). Alongside programs of misinformation by hydrocarbon companies (37, 38), such strategies have notably been used by think tanks in the United States, Australia, the United Kingdom, Canada, and Europe—all with close ties to this industry (39, 40).

Denouncing climate change as a hoax, scam, or swindle is an old phenomenon, laid bare in the United States from at least 1989 onwards (35). The links between denial of climate change, fossil fuel interests, and conservative think tanks have been revealed in an array of studies over several years (e.g., 39). Organized denial has grown stronger in the United States over the past two decades (35) and was a major theme in Trump's successful 2016 presidential campaign, with the changing of rules and regulations in favor of the fossil fuel industry during the subsequent presidency (41).

Negative emission technologies (NETs): technologically focused approaches for carbon dioxide removal (e.g., direct air capture, bioenergy with carbon capture and storage)

Most studies have, so far, focused on a particular nation and/or set of actors with little comparative work extending across cases. One important exception (42) demonstrates how political debates in Australia and Canada have been heavily influenced by global narratives doubting climate change that originated primarily in the United States. Some antipathy to climate action stems from a realization that addressing climate change often can involve significant levels of government intervention and as such may conflict with particular worldviews and political values. In terms of lobbying by various vested interests, approaches are tailored to align with the worldviews of those being lobbied, such as industrial/breadwinner masculinities in Sweden (43) and denial as a form of nationalism in China (44). In the case of Norway, both of these narratives are found to intersect (45). Importantly, denial claims are frequently created, recreated, and recycled, in order to challenge the latest claims of climate science and thus the need for policy action (46). Of late, the organized denial and contrarian positions so prevalent in the United States have found a receptive and growing audience among right-wing nationalist parties within other English-speaking countries and much of Europe (47).

Political action to mitigate climate change has also been slowed at the regional, national, and international levels through direct lobbying by fossil fuel companies and through the funding of political actors. Regions that rely on fossil fuels for jobs and revenues find it particularly difficult to withstand such lobbying attempts (34). Research by InfluenceMap (**https://influencemap.org**) shows how fossil fuel companies have lobbied to weaken climate policies around the world and have continued to do so while claiming to support the Paris Agreement.

Political lobbying by fossil fuel interests also explains why the Paris Agreement makes no explicit mention of decarbonization or the reduction of fossil fuel use, despite the scientific evidence that holding to 1.5–2°C of warming requires most fossil fuels to remain in the ground (48). To avoid such undue influence, civil society organizations have long argued that fossil fuel companies should be kept out of the UN climate change negotiations (49). However, curtailing fossil fuel interests at the negotiations is complicated by the fact that state-owned companies would still have a seat at the table. Countries rich in fossil fuel reserves, such as Saudi Arabia, the United States, Kuwait, and Russia, have been particularly notable for obstructing the negotiations and disputing the science on climate change (50; see also Section 3.1).

Vested interests can thus be both private and public. What they have in common is that they view climate change as a significant business risk, although they have adopted slightly different strategies to deal with this risk (51). Those opposing decarbonization are increasingly abandoning outright climate denial in favor of hedging strategies, such as diversifying operations to mitigate risks (36) and insistently promoting gas as a transition fuel. The Oil and Gas Climate Initiative, for instance, brings together some of the largest oil and gas companies to try to devise strategies to lower their climate impacts (51). Moreover, companies such as Repsol SA, Shell, BP, and Lundin Petroleum have recently set themselves net-zero emissions targets to be achieved in the coming decades. However, unpacking the accompanying scenarios reveals that the plans typically see significant and ongoing use of oil, and particularly gas (as well as renewable energy, biofuels, nuclear energy, and/or hydrogen), with high levels of emissions compensated through future carbon capture, use and storage, offsets [including afforestation (AF)], and other speculative negative emission technologies (NETs) (see Section 4.2). As it stands, such scenarios stretch credulity and most fall short of Paris-compliant carbon budgets. Nevertheless, it is telling that powerful vested interests can shift their positions if they come under sufficient pressure from investors, regulators, and the public.

3.3. Geopolitics and Militarism

Although research on mitigation extends across most disciplines and domains, the importance and role of geopolitics remain, with few exceptions (52), oddly underaddressed in climate policy debates. This source of obstruction lies in interconnections between global power structures and the militarism that sustains these, and is manifest in global extractivism, geopolitical competition over energy resources, and ideologies of control that frame dominant responses to climate change.

Extractivism: the exploitation, control, and export of raw materials, mainly from the developing "South" to fuel the industrial development of the "North"

Of initial relevance here is the intense globalization of the economy that accompanied the post-1940s Great Acceleration (12). Shaped, in part, by prevailing global military orders, this form of globalization was built on an architecture of exchange based on export-led growth strategies and trade liberalization. The internationalization of production relied on fossil fuel–intensive modes of transport, energy use, and industrial agriculture. As such, it reinforced entrenched patterns of ecologically uneven exchange (53) premised on historical and contemporary colonial forms of extractivism and the export of waste and displacement of negative impacts to poorer regions of the world.

Layered upon this economic globalization is geopolitical competition to gain spheres of influence through control of resources such as oil and gas, often backed by military force to secure the infrastructures that enable their extraction (54). Also increasingly important in this are land grabs, through which wealthier states seek to acquire territory from poorer ones in order to meet their own domestic energy, food, and water needs, and green grabs where climate mitigation and other environmental justifications are used to legitimize such actions (55). Geopolitical shifts have seen the increasing prominence of the so-called rising powers of China, India, Brazil, Russia, and South Africa—each pursuing carbon-intensive pathways. A notable feature of this reconfiguration of power is that traditionally wealthier centers such as the United States and Europe have outsourced the more carbon-intensive parts of the production chain to countries such as China and India (56). Despite claims to the contrary, this merely displaces emissions, rather than reducing them.

A second issue is that—despite the prevalence of war rhetoric in climate change resistance (57)—militaries have for a long time had a direct, yet relatively neglected, role in causing climate change. Everyday military operations directly generate vast emissions of GHGs (58). Recent research found the US military to be the world's largest institutional consumer of petroleum and emitting more GHGs than most medium-sized countries (59). If the US military were a country, it would be the 55th largest emitter of GHGs in the world, sitting above Portugal, Sweden, and Denmark (59).

From the burning of oil wells in the Gulf Wars to mass deforestation in the Vietnam War, environmental devastation has also long been a potent instrument of conflict. Even while formally downplaying climate change, major military powers have been actively positioning for advantage in an anticipated radically warming world (60)—for instance, in the growing competition of the United States and Russia over the Arctic (61). Climate change itself is widely recognized to be a major factor in the pressuring of future wars (62), often described (sometimes problematically) as a threat multiplier (63). Taken together, all this makes it hard to envisage deep decarbonization strategies that, at a system level, do not challenge the mindsets and practices currently embedded in global military institutions.

A third set of obstructions to mitigation relate to how military focused mindsets facilitate wider ideologies of control, which form an important part of the inertia against zero-carbon transformations. The globalizing formations of industrial modernity that have propelled climate devastation over recent centuries are, arguably most distinctively driven by an array of fallacies, fictions, and fantasies of control. These, in turn, rest in analogies with machines but extend historically across nature by science, societies by bureaucracies, labor by capital, territories by coloniality—with a new proclaimed Anthropocene epoch increasingly expanding this to the "control variables" of the Earth itself (64). The effect in elite political discourse, financial markets, and popular imaginations alike is to exercise a strong bias in favor of control over concentrated energy sources and technologies, in contrast to more distributed infrastructures and practices (65). In this regard, few applications rival military technologies in their needs for intense concentrations of energy—for instance, in explosives, combat aviation, orbital platforms, naval propulsion, and (increasingly) directed energy weapons and new forms of battlefield power provision (66). Beyond this, the dedicated military antecedents to many key geoengineering technologies make military interests some of the strongest drivers behind this burgeoning planetary control ideology (67, 68).

Acknowledging how narratives of planetary control influence the debate on climate change raises a further issue. This lies in the significant entangling of fossil fuel and nuclear infrastructures. At first sight this may seem counterintuitive. Nuclear technologies are often presented as a means to escape carbon lock-in (69). But when attended to more closely, a set of dynamics emerge in which the effect is also reinforcing. One lies in debates over what are often the surprisingly significant CO_2 emissions from nuclear infrastructures. An arguably more important factor lies in the now large and growing disparity between the cost-effectiveness and wider strategic merits of nuclear-based strategies for CO_2 emissions abatement, when compared with alternative zero-carbon pathways (70). Recent analysis of existing national energy mixes suggests a negative association between the intensity of national nuclear commitments and the efficacy of climate change mitigation strategies (71). It is also evident that for some the most significant driver of continuing nuclear commitments is the allure of nuclear weapons (72). The use of climate change arguments to cloak motivations around military supremacy not only risks slowing down zero-carbon transformations but also severely compromises their efficacy. There is a real risk that nuclear infrastructures may serve more to reinforce than to challenge the culture of control that also sustains global fossil fuel infrastructures (73).

On this broader canvas, transformations toward most alternative visions of a zero-carbon world rest on deeper considerations than mere substitution of particular technologies or infrastructures. Without radically reconfiguring long-run sociocultural and political-economic norms and institutions, fossil fuel dependencies can simply be expected to reproduce themselves (74). It is perhaps in this regard that the geopolitical entrenchment of global militarism that has long been so distinctive of modernity can be seen as one of the most crucial impediments to further progress toward a decarbonized future. That the struggle against these wider and incumbent military interests and imaginations is so neglected in international climate change discourse is perhaps one of the most important problems in this field.

4. ECONOMICS, MITIGATION MODELING, AND ENERGY (THE ENABLER CLUSTER)

The three different lenses captured within the Enabler cluster explore ways in which orthodox schools of economics and financialization (Section 4.1), dominant forms of mitigation modeling (Section 4.2), and energy supply systems (Section 4.3) have contributed to the failure to bend the global emissions curve.

4.1. Economics and Financialization

Economics is a diverse discipline combining a wide range of heterodox schools of thought (e.g., ecological, feminist, institutional, Marxist, post-Keynesian) but dominated by a neoclassical orthodoxy, reliant on theories of equilibrium created using deductive mathematical formalism. In contrast, heterodox schools emphasize an absence of such equilibrium, with a focus instead on dynamic change, strong uncertainty, power relations, and social and economic structure beyond aggregated individual agency. These concepts combine to create a descriptively realist theory of political economy that includes ethics, equities, and justice. However, economic schools, whether orthodox or heterodox, have generally failed to incorporate biophysical reality (i.e., the nonhuman world, ecosystems, natural resources, pollutants, etc.) (75). One notable exception is ecological economics with its explicit inclusion of physics, energy, material flows, and ecosystems (76).

Integrated assessment models (IAMs): generally categorized as either process- and energy-based models (see Section 4.2) or cost-benefit-based models (see Section 4.1)

Over recent decades, mainstream neoclassical economics has become increasingly allied to neoliberalism, where government regulates to the benefit of particular business interests and the economy is equated with market capitalism (77). Within this framing, the function of macroeconomics is to sustain capital accumulating economic growth, while microeconomics claims to deliver optimal (cost-efficient) resource allocation through prices created by actors in unregulated markets (i.e., price-making markets). Consequently, the market orthodoxy reinforces a perpetual growth economy driven by market exchange without any explicit sources of, or sinks for, energy and materials.

This ideological notion of free-market economics, together with a simplified physical climate model, forms the core of cost-benefit integrated assessment models (IAMs) (for a discussion on the more complex, process-based IAMs, see Section 4.2). These influential models, often key in framing mitigation policy, rely on two principle variables: global mean temperatures linked by a damage function to monetary losses [translated to consumption possibilities forgone and measured in gross domestic product (GDP)] and reductions in GHG emissions (mitigation) linked to a cost function. A series of contested assumptions then allow equating diverse damages and trading-off the benefits of avoiding these damages against the costs of mitigation (78).

Employing money as the sole measure of value means everything is made comparable and therefore tradable. Thus, harm is equated to good and creating more harm (e.g., pollution) can be compensated by more good (e.g., consumption). Calamitous and irreversible damages become specified as GDP consumption losses and highly uncertain, or even unknowable, futures are translated into probabilistic risks (78). Ongoing debates on the "correct" price of time (i.e., discount rates) assume continued economic growth making consumption today more valuable than in the future (78). The consequence of this framing is that it favors policy recommendations that prioritize consumption possibilities over loss of life, rich over poor, and current over future generations (78, 79). Thus, mainstream economists, such as Stern (80) and Nordhaus (81), are able to recommend "optimal levels of climate change" that correspond with a serious risk of extreme and irreversible changes to the conditions for life on Earth (82).

Within this neat mathematical characterization of the world, climate economists claim that they can use cost-benefit analysis to "get the prices right" by translating potential damages (externalities) into monetary values (social costs) that can be internalized using permits and taxes to have markets correct "market failures" (78, 83). Yet this understanding of markets ignores several facts. Markets are politically regulated institutional processes far removed from idealized, perfect competition, and prices are negotiated between small numbers of powerful brokers (84) involving hidden subsidies, e.g., for infrastructure (see Section 4.3) and military technologies (see Section 3.3). Governments provide safety nets and corporate bailouts in times of crisis, offering a form of public insurance to facilitate private profit (85). Thus, as a major source of emissions, airlines have been able to expand massively as providers of jobs and economic growth. At the same time, their kerosene fuel is typically tax exempt, and public road and rail connections to airports are cross-subsidized.

A primary reason for the ongoing failure to respond to climate change is that markets are predominantly oligopolistic in nature (i.e., dominated by a small number of suppliers). This enables prices to be controlled, in effect divorcing them from resource costs and economic efficiency. In addition, competition in markets incentivizes pushing costs on to others. In this sense, climate change is not the result of a market failure but rather the outcome of a fully functioning capital accumulating economy working hard to shift costs on to others (85), and especially those who lack voice or power (such as the poor, future generations, children, and nonhumans) (see Section 5.1). Within such market structures, straightforward direct regulation of economic production and consumption behavior would be an "effective" means of controlling pollution, but that is not the main goal.

Carbon markets: made up of emission credits (offsets) that can be traded through emission trading schemes, also known as cap and trade

Exacerbating the failure of lightly regulated markets is the promotion of carbon markets as cost-efficient. These include the selling of offsets, now increasingly referred to as a form of nature-based solutions, and emissions trading schemes (ETS), also known as cap and trade. Offsets were introduced under the Kyoto Protocol's clean development mechanism as "certified emission reduction" credits (Article 12), allowing developed countries to count mitigation projects in developing countries against their own emission targets. Offsets suffer from dubious assumptions concerning equivalences, such as the burning of coal (i.e., permanent emission release) with the planting of trees (i.e., only temporary sequestration). Similarly, additionality—such as assuming trees would not have been planted otherwise—is incalculable for most projects (86). The Kyoto Protocol also led to the establishment of the EU's ETS, the first international GHG market. Such schemes have suffered from absence of a real cap, extreme price volatility, speculators, and fraud (87, 88) and have failed to drive any significant emission reductions (89). Despite this, carbon markets remain heavily promoted. ETS have appeared in California and China and the EU ETS is expanding under the European Commission's Green Deal. New international carbon offset markets include those for civil aviation emissions and the Sustainable Development Mechanism currently being negotiated under the Paris Agreement.

Carbon markets are part of a growing financialization of the environment that is being magnified by initiatives such as the EU's sustainable finance agenda (90). Such financializaton increasingly uses cost-benefit analyses as a means of reducing climate policy choices to abstract monetary values, postponing ambitious mitigation to "when the price is right" and sidelining distributional issues. Despite the dubious history of efforts to financialize the environment, a new environmental asset class is now being created that includes so-called green securitizations of carbon offsets and natural disaster insurance—catastrophe, or cat, bonds (91). Cat bonds are a type of insurance policy and encourage risk taking because, in theory, once the premium is paid a catastrophic event is insured against. They do not encourage mitigation and are part of adaptation policies, as they address effects rather than the causes of climate change (91). As with carbon markets, cat bonds have thus far failed to live up to their promises of providing protection and raise major ethical concerns, such as exacerbating the severe and already unequal distribution of climate impacts (90).

Across the policy landscape, mainstream economists have been active participants in the advocacy of markets for almost everything (83). Three decades on, the scale of policy failure suggests that an effective strategy for delivering on Paris will inevitably involve a paradigmatic challenge to the hegemony and dogmas of economic growth, price-making markets, and the financialization of the environment (92).

4.2. Mitigation Modeling

As evident from Section 4.1, the extent to which particular epistemologies (i.e., philosophies of knowledge) and research approaches may have impeded mitigation responses over recent decades is a key question to explore. Here, the use of IAMs is considered in more detail. Apart from the "simple" cost-benefit models mentioned above (Section 4.1), a second category of IAMs exists that is commonly used to explore different emission pathways. As coupled socioeconomic and biogeophysical climate models, these "complex" IAMs have become an influential feature of the global assessments that inform the IPCC and are used extensively across the climate change mitigation literature. They grew out of the scenario-based energy analyses pioneered by oil and gas companies in the 1960s and 1970s and the early energy modeling work carried out at the International Institute for Applied Systems Analysis in the late 1970s and early 1980s. Today's global climate IAMs have grown in complexity from their predecessors but remain structurally connected to their energy, economic, and land-use modeling heritage. The role and influence of IAMs in climate policy have long been critically debated and calls for complementary approaches that better reflect uncertainty and incorporate qualitative dimensions have been around for many decades (93, 94). As the models continue to grow in complexity and, arguably, influence, so the assumptions and inherent uncertainties underpinning current IAM scenarios have received renewed scrutiny (95–97).

CCS: carbon capture and storage

Carbon dioxide removal (CDR): an umbrella term for techniques that sequester and store carbon dioxide from the atmosphere by technical or ecological means

BECCS: bioenergy with carbon capture and storage

One of the main concerns with IAMs revolves around the kind of futures they end up representing and foregrounding. Grounded in neoclassical economic theory, IAMs employ a linear and reductionist understanding of societal change that is ultimately constrained by the cost-optimizing nature of the model and its inbuilt objective to avoid mitigation actions that would be financially disruptive (see Section 4.1). IAMs tend to prioritize large-scale, simple technological and market-based solutions and generally fall short at capturing factors that are less easy to model or quantify. Systemic, uncertain, or contested aspects—often relating to social, political, and ethical issues and trade-offs between different mitigation measures—are more likely to be excluded (95). Hence, although model outputs are intended to be exploratory rather than prescriptive, they tend to emphasize a narrow suite of technological options for reducing emissions, with typically limited representation of demand-side options or more far-reaching changes to socioeconomic structures (98, 99).

As political calls for more ambitious mitigation have intensified over the past decades, a number of technologically focused responses have grown in influence, as can be seen through the example of carbon capture and storage (CCS). Model comparison studies have highlighted a central role for significant levels of CCS in mitigation scenarios (100), despite the considerably limited adoption of the technology. Since the fourth IPCC assessment report, IAMs have become heavily reliant on large-scale carbon dioxide removal (CDR), or negative emissions. To date, IAMs have included two forms of CDR: afforestation (AF) and bioenergy with carbon capture and storage (BECCS), with work ongoing to include other approaches (such as direct air capture and storage). BECCS and AF are both associated with high levels of uncertainty. BECCS has yet to be deployed at commercial scales and, at the very large scales represented in modeled pathways, both approaches raise considerable concerns in terms of feasibility, effectiveness, and potentially far-reaching negative consequences (101, 102).

This recent inclusion of large-scale CDR technologies has reignited a lively discussion about the extent to which IAM outputs are setting the terms for the mitigation debate and are influencing the kinds of mitigation deemed politically possible, as well as those that are not (103). Modeling, critics maintain, inevitably involves numerous value judgments and assumptions, embedding model outputs with political and economic choices that remain hidden behind a seemingly objective methodology (96). Given their central role in informing mitigation policy, IAMs are actively shaping the future by making implicit choices about the kind of policies and technologies that are necessary to meet climate targets (104). Recent attempts to attend to such concerns have sought to broaden the range of mitigation options explored in IAMs, for example through the development of scenarios that exclude BECCS or explore reductions in energy demand (105, 106). Nonetheless, the subjective nature of model assumptions continues to call attention to who is involved in modeling practices and who is not. Integrated assessment modeling is decidedly dominated by research groups from the Global North, raising questions about whose assumptions and interests are being represented in models (107).

There are widespread concerns about the effects that hypothetical and highly improbable technological promises might have on climate ambitions. The future option of large-scale CDR provides a justification for incremental business-as-usual climate policies, thus averting a political reckoning of the historical failure to bend emissions curves, and thereby precluding any change in policy direction (108). By allowing an overshoot of the carbon budget, CDR promises to reduce the urgency of eliminating emissions, therein exposing a moral hazard or a form of "mitigation deterrence" (109). Whereas this effect is clearly observed in model results, its presence in policy outcomes remains contested. Nevertheless, there are obvious political and economic incentives for using carbon removal as an alternative to more stringent near-term reductions, and one can find numerous precedents for this in how vested interests have in the past projected and pursued technological promises (such as CCS) to justify continued fossil fuel use (110). However, the use of CDR may be a defensible strategy in the context of hard-to-abate emissions in, for example, the agricultural sector. These concerns take on a concrete form in the recent net-zero framing, which both creates a need for future CDR and is conceivable because of CDR. The ambiguity arises from net climate goals introducing a risk of problematic substitution of near-term for future reductions in emissions. Yet, with strict agreed limits on the scale and scope of CDR, net-zero could help unify efforts to reduce emissions as close to zero as possible.

Overall, the reliance on large-scale CDR in IAMs is part of a broader culture of technological optimism and a limited techno-economic rationality that has underpinned policy development over the past 30 years (111). This has created a convenient discourse validating existing climate policy approaches, while marginalizing a range of proposed alternatives. As the scale and urgency of climate change action accelerate and global carbon budgets become tighter, the pressure to rely on approaches such as CDR may further increase. To mitigate the risk that CDR is misused as a forceful and effective delaying tactic, it is more critical than ever that the use of IAMs be accompanied by a diverse array of approaches and perspectives. These may extend from deliberative participatory methods (see 95) to alternative economic models (see Section 4.1) to very different interpretations of possible and desirable futures (see Section 5.3). A better, more inclusive, understanding of the possibilities and limitations of proposed climate solutions is urgently needed to promote an honest, pluralistic, and more informed choice about the realities of our future climate.

4.3. Energy Supply Systems

Throughout human history, the principal sources of energy powering societies were humans, animals, and biomass (112). Only in the past 200 years has this significantly changed, with the global energy system increasingly dominated by energy-dense fossil fuels: first coal, then oil, and finally gas (**Figure 2*a***). At the global level, the progression through the different fossil fuels has not been a story of substitution, but rather one of addition, leading to a rapid growth in total energy use. Various nonfossil energy sources have added to this growth, from hydropower to nuclear energy and more recently, renewable energy sources based on solar and wind. Despite the emergence of low-carbon technologies, energy supply continues to be dominated by fossil sources (**Figure 2*b***). In recent years, the contribution of modern renewables to global energy use has grown rapidly, but nevertheless remains much smaller than the dominant fossil sources and, importantly, has thus far primarily added to the total energy supply, rather than providing any absolute displacement of fossil fuels.

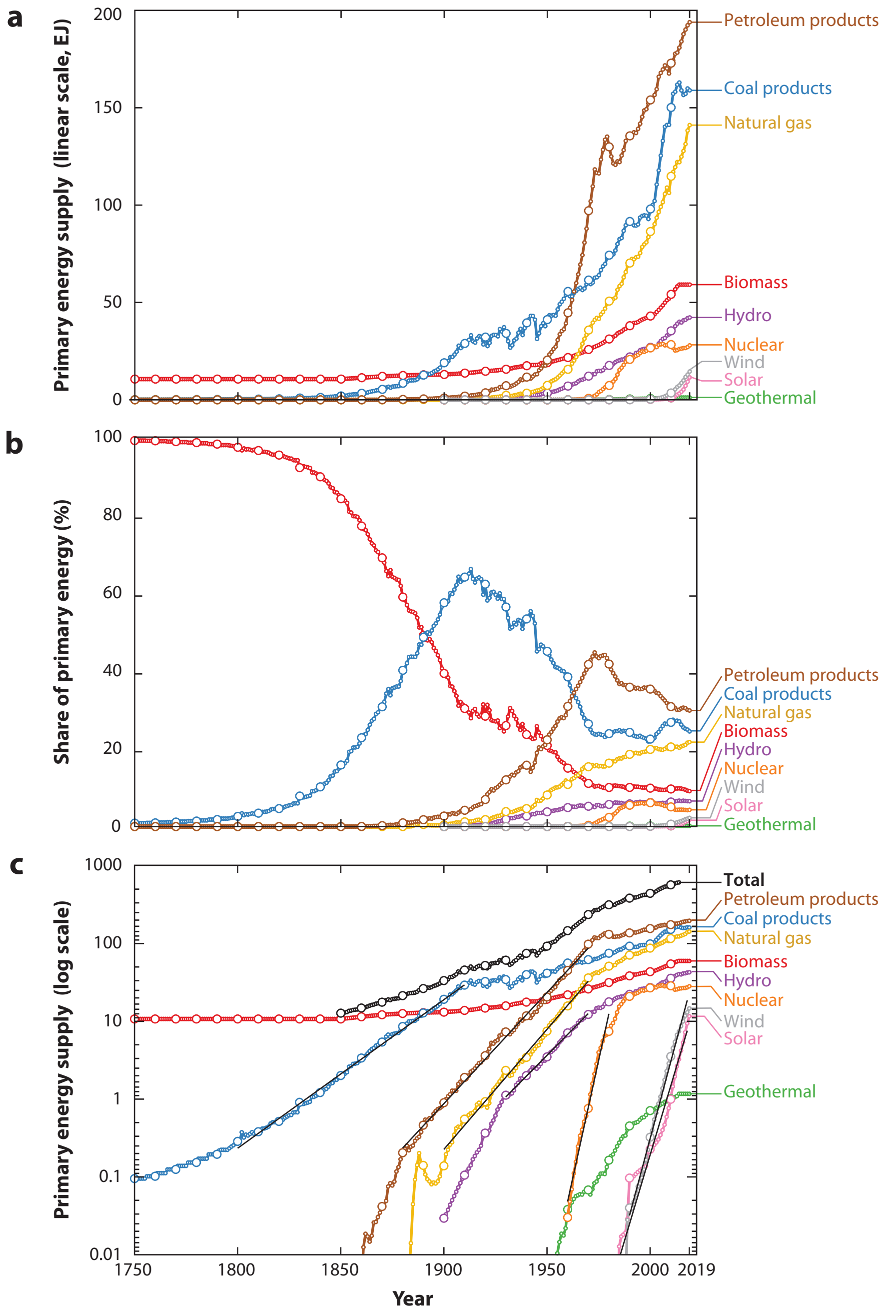

Figure 2

The global energy system from 1750 to today showing (*a*) absolute primary energy supply, (*b*) share of primary energy supply, and (*c*) the log of primary energy supply. The data are from the International Institute for Applied Systems Analysis's Primary, Final and Useful Energy Database from 1900 to 2015 (188), extended forward to 2019 using the British Petroleum Statistical Review of World Energy (189), and back in time for bioenergy (190) and fossil fuels assuming constant implied emission factors applied to the Global Carbon Project dataset (191). To complete the dataset, it was assumed bioenergy was constant before 1850, and bioenergy and geothermal energy were constant after 2015. Human power was not included before 1900 where it could have had a relatively important effect.

Recognizing that there has not yet been a commercialized energy source that has clearly peaked and then declined in favor of another source is key to understanding why emissions have remained stubbornly high. Despite its inefficiency and local health consequences, traditional biomass has remained almost constant over the past two centuries and is still widely used in poor parts of the world where alternatives are costly (113). There is some evidence that coal use could be nearing a global peak, as modern renewables become cost-competitive and have less local pollution and the push for a cleaner energy system builds momentum (114). Nuclear energy had a rapid initial growth, but growth has since waned as public opposition and costs have made the technology less attractive. Oil use continues to grow, and without major policy intervention may not peak until the 2030s (114). Gas use is showing signs of accelerated growth in recent years (115) and looks set to continue growing without policy intervention, particularly if coal is replaced with gas. The COVID-19 pandemic led to dramatic changes in the global energy system in 2020, but in the absence of an explicit policy agenda to build on such changes, it is unlikely to fundamentally alter any of the pre-COVID trends (114).

History has shown that the early growth of new energy supply technologies is near exponential, before moving to either more linear growth or slower exponential growth (**Figure 2*c***). This gives the perception that energy systems are slow to change (116) and that new energy sources will be limited or slow in their ability to substitute for fossil fuels (112). Historically, most technical transitions have been a process whereby a new technology emerges and, at varying rates, displaces an older redundant technology (98). The energy supply system stands, to a degree, in contrast to this as it has continued to grow as new energy supply technologies have emerged and slowly diffused into the system. These historical observations, however, provide limited insights into the possibilities of an energy transition that is explicitly accelerated by robust policy intervention and that catalyzes subsequent feedbacks in behavioral change and technology development.

It is clear that many technologies have the capacity to grow fast, such as nuclear in the 1970s and 1980s, coal in China during the 2000s, or solar and wind in the 2010s. These rapid expansions have added to existing supply, thereby facilitating new and additional energy demand. If policy intervention drives greater energy efficiency and the early retirement of high-carbon energy sources, then new technologies could diffuse into the energy system at a much higher rate and assume a larger share of the total energy supply (114, 117, 118). Importantly, many global energy and mitigation scenarios have been deeply conservative on the deployment of renewables (119), reinforcing the potential of ambitious mitigation policies to drive a rapid deployment of low-carbon supply at rates well beyond those suggested by current models. As it is, climate mitigation scenarios typically require a significant retirement of old energy systems, particularly coal (120). Indeed, many studies show that simply allowing existing fossil facilities to run until their expected end of life would be sufficient to transgress the carbon budget necessary to keep emissions below both 1.5°C and 2°C (114, 121, 122). Thus, early retirement or repurposing of energy infrastructure is necessary to meet Paris commitments, even in the presence of large-scale and debatable CDR (123). Without successful development and deployment of large-scale CDR, the rate and scale of fossil fuel phase-out required to deliver on the Paris Agreement increases significantly (124).

To date, most energy system models have not emphasized the necessary level of infrastructure retirement and have simultaneously failed to fully capture the cost declines of renewable energy (119). Similarly, models have often excluded the granular dynamics of the electricity system, unduly limiting how fast energy systems can transform (125). Exacerbating such constraints, many models have favored pathways high in retrofitted and new CCS and CDR technologies, effectively limiting the level of retirements (123, 126). There remains a lack of systematic analyses of scenarios assuming low deployment of such technologies (105, 106, 127), with inevitable implications for retirement rates. As such retirement dynamics remain little more than a tertiary focus of many studies, the scale of retirements developed in models is seldom reported or detailed in accompanying papers.

Understanding the scale of proposed CCS, CDR, net energy efficiency improvements, and energy infrastructure retirements is key when considering future energy supply scenarios. Such factors can either prolong the lock-in to fossil fuels or enhance a low-carbon energy transition. Historical dynamics suggest that each new energy source adds to the other, leading to projections of continued high fossil fuel use and a relatively slow deployment of renewable energy (116). IAMs, despite weaknesses (see Section 4.2), show that a policy-driven energy transition aligned with the Paris Agreement requires the early retirement of existing high-carbon energy sources. The rate of such retirement depends on assumptions of the relative costs and weighting of retirement versus alternatives (retrofits or CDR) and on the levels and make-up of energy demand. Historical precedence shows, and again depending on the levels and make-up of energy demand, that nonfossil energy sources have the real potential to grow much faster than typically assumed (128). Although there will likely be limits to the speed of an energy transition, these limits have yet to be observed.

5. EQUITY, LIFESTYLES, AND IMAGINARIES (THE OSTRICH AND PHOENIX CLUSTER)

The final grouping of three distinct lenses forms the Ostrich and Phoenix cluster, which reflects on the underlying dynamics of inequity (Section 5.1), the psychology and social practices of high-carbon lifestyles (Section 5.2), and social imaginaries for post-carbon futures (Section 5.3). These expose barriers to—as well as possible openings for—achieving the deep-seated transformation of societies needed to limit climate disruption and bend the global emissions curve.

5.1. Inequity

The magnitude of the disparities between those most responsible for causing climate change and those most vulnerable to its impacts is vast, to the point of being difficult to fathom. The wealthiest 1% of the world's population are responsible for twice the emissions of the poorest half (2). Their carbon footprints are more than 100 times larger, matching their greater consumption, wealth, and political influence (2). These major inequities are mirrored at the national level (129) and are structurally linked to dominant forms of political decision-making and economic allocation. Poor and marginalized communities—both globally and within nations—lack the basic capacities needed to adapt to current levels of warming. Moreover, the marginalization of these communities has typically been tied to the very processes that cause climate change, including colonialism, expropriation of resources (often while degrading the ecological resources that support local livelihoods), and fossil fuel–driven capital accumulation (130, 131).

A vast literature has emerged around climate (in)equity, much of it centered on the UNFCCC and its foundational principles of equity and CBDR&RC (132–134). However, despite persistent pressure led primarily by those in the Global South, the UNFCCC has not enabled a regime capable of reckoning with the depth of climate-related injustices (see Section 3.1). As but one example, the Global Stocktake under the Paris Agreement is mandated to be undertaken "in the light of equity" (135, Article 14, pp. 18–19), but the prospects for this exercise are hamstrung by the fact that any assessment is of "collective progress" (135, p. 18), rather than the progress of individual countries.

While discussions of equity in the global climate regime will necessarily continue, inequity can also be seen as a driver that systemically undermines climate action. With support in the reviewed literature, three mutually reinforcing mechanisms are identified: first, that inequity decouples the vulnerable from the powerful, second, that inequity erodes social trust required for collective action and, third, that inequity reinforces the preference of elites for a status quo hostile to climate action. Each is discussed briefly below.

With regard to the first mechanism, internationally, the spatial and economic disjuncture between those who have largely caused and those who are most vulnerable to climate change has undermined the perceived need for global action. The accumulation of harm in the least well-off countries with the least international negotiating power has allowed business as usual to continue in wealthy, high-emitting countries (136). Continued societal tolerance for the unequal harms of the fossil fuel economy has also facilitated domestic inaction on climate change. To date, these harms have been borne disproportionately by low-income people, people of color, and indigenous people, whereas those who are wealthy, typically white, and more closely connected to government and corporate power have been able to avoid costs, while appropriating benefits. This entwined incidence of harm and avoidance is only possible due to continued political and social segregation (137). That powerful and affluent groups may opt for personal protections, rather than joint responses that secure communal benefit, has already been seen in concerns about exclusive adaptation that protect the privileged at the cost of those who are most vulnerable (138).

The capacity for inequality to concentrate life-threatening harm in marginalized communities appears to have played a central role in social upheaval, including the 2008 financial crisis (139), as well as in societal collapses (140). Extreme inequity can also enable those with economic and political power to insulate themselves from the negative consequences of their decisions and actions, even as they harm the majority. This decoupling of the powerful from the vulnerable interrupts communication mechanisms that otherwise could signal the need for an effective response, thus further delaying action.

Reducing social trust for cooperative action is a second mechanism by which inequity undermines climate action. Numerous studies have demonstrated the centrality of rules that provide some bounds to inequity and strengthen social trust for successfully navigating challenges related to the commons (141). Some level of fairness is widely understood as an essential component of politically feasible domestic policy (142). Internationally, there has been widespread recognition that countries will not commit to an agreement they do not perceive as "fair enough" (143, 144). At all scales, attention to inequity becomes a political necessity for enabling effective and timely climate mitigation.

Finally, a third mechanism describes how inequities in economic and political power have allowed those who benefit from the status quo to protect their interests. As discussed above (see Section 3.2), this can take overtly obstructionist forms, such as corporations entangled in the fossil fuel economy funding think tanks to mislead the public (145), engaging in policy to impede climate action (146), or shaping legal and regulatory systems to maintain disproportionate power over national policy directions (147). More subtle, but equally insidious, blocking occurs through a myriad of pathways to protect disproportionate appropriation of planetary resources. Internationally this dynamic is evident in the persistent assumption, manifest in the Kyoto Protocol, the Copenhagen Accord, and the Paris Agreement, that any discussion of emission reductions is based on a percentage of reduction below current emissions. This presumption establishes deviation from the status quo as the burden to be divided rather than the burdens of the status quo themselves (148). Similarly, among global and national elites, a high-carbon lifestyle has become an entitlement protected through normalization (149). Consequently, regressive climate policy options—such as a universally applied carbon tax—receive much more attention than more progressive ones, such as disincentives for flying frequently, driving SUVs, building large homes, or owning multiple cars (not to mention owning mansions and private jets). Such patterns are evident even in the actions of those of us working on climate change itself, explicitly or implicitly justified through, e.g., reliance on business as usual and existing entitlements embedded in comparative baselines, the use of high discount rates, and assumptions that privilege technical mitigation over personal lifestyle and behavioral changes, or market-based solutions over redistributive solutions (see Sections 4.1 and 5.2).

An unwillingness by the powerful to imagine a world where their/our high-carbon lifestyles and other "privileges" are no longer upheld has steadily undermined climate action and is only possible due to the depth of inequity underpinning the climate crisis. The preference of powerful groups for a profoundly inequitable status quo over a stable climate was amply illustrated when President Obama's Special Envoy for Climate Change, Todd Stern, issued an ultimatum to his negotiating partners in the lead-up to the Paris Agreement: "If equity's in, we're out" (150).

5.2. High-Carbon Lifestyles

Despite widespread public awareness about climate change (151), high-carbon lifestyles persist, particularly among influential groups within industrialized nations and increasingly among wealthier communities in low-income countries (2). Inadequate responses from societies can partially be attributed to psychological factors such as the limited capacity to apprehend and formulate responses to climate change (see also Section 5.3) but also to the routinized nature of consumption and the complex relationship between individual action and sociotechnical systems.

Fundamental features of human psychology can constrain the perceived personal relevance and importance of climate change, limiting both action and internalization of the problem. Cognitive shortcuts developed over millennia make us ill-suited in many ways to perceiving and responding to climate change (152), including a tendency to place less emphasis on time-delayed and physically remote risks and to selectively downplay information that is at odds with our identity or worldview (153). Risk perception relies on intuition and direct perceptual signals (e.g., an immediate, tangible threat), whereas for most high-emitting households in the Global North, climate change does not present itself in these terms, except in the case of local experiences of extreme weather events. Where strong concern does exist, this tends to be linked to care for others (154) combined with knowledge about the causes and possible consequences of climate change (155).

Behavioral perspectives position emissions as the outcome of actions of many individuals through the consumption of products and resources. From this standpoint, personal actions of relevance to climate mitigation are determined by psychological (e.g., proenvironmental values and identity), contextual (e.g., cultural norms), and structural factors (e.g., built environment) (154). But despite a recognition of these factors in the academic literature and policy sphere, attempts to influence people's behavior have had limited success and have rarely been scaled up to the level needed to curb emissions (156). Although individuals may recognize the relevance of personal action and seek to act on good intentions, attempts to be climate-friendly typically show little association with more objective measures of environmental impact. Even those who are concerned about climate change may fail to translate this into meaningful lifestyle changes (157). A general lack of attention to more impactful personal actions has been underpinned by a long-standing public discourse that normalizes and emphasizes relatively trivial behaviors (e.g., switching off lights and washing at 30°C) (157, 158).

Many high-carbon activities are also highly routinized. From a psychological perspective, this bears the hallmarks of habitual behavior, in that environmentally significant actions are often stable, persistent, and an automatic response to particular contexts (159), e.g., commuting by car repeatedly over many months or years. Theories of social practice offer a contrasting account in which routines coevolve with infrastructures, competencies, conventions, and expectations (160).

For example, developments in urban infrastructure, everyday routines, and the shifting social significance of private transport have culminated in the car becoming a dominant mode of mobility (161). Elsewhere, coordinated developments across spheres of production and consumption have led to the freezer becoming regarded as a domestic necessity (162), and changing patterns of domestic labor and shifts toward sedentary recreation have contributed to the rise in indoor temperature control (163). Although such assemblages shift over time, policy and action intended to reduce emissions have been ineffective in coordinating changes throughout these social and material configurations. As a consequence, routinized, commonplace, and largely unconscious behaviors remain mostly unaffected, with many high-carbon activities even growing and expanding (e.g., frequent flying).

A social practice perspective draws attention to routines and sociotechnical systems that give rise to and sustain high-carbon lifestyles, e.g., through interlocking practices of leisure and work and visions of a good life associated with features such as convenience and comfort. Social practice theories propose that in focusing mainly on technological substitution and behavioral change, inadequate attention has been paid to complex and distributed factors that normalize and expand high-carbon lifestyles (164). This critique has also been directed to identify alternative targets for intervention (165), positioning decarbonization as a question of how to unsettle high-carbon routines and normalize low-carbon alternatives, or how to grow low-carbon practices (e.g., practices of sharing and active, nonmotorized travel) while simultaneously shrinking those associated with high levels of emissions (e.g., practices associated with fast fashion and automobility).

For low-carbon practices to grow and displace high-carbon ones, integrated action across disparate spaces and coordination between many different actors are necessary (161). For example, mobility scholars (166) highlight the extent of reconfiguration required to disassociate academia from high-carbon travel, including altered institutional cultures, funding practices, and student recruitment to support virtual ways of working. Although novel low-carbon practices may emerge, policy must ensure these stabilize and become prevalent, as well as impeding the circulation of high-carbon practices.

Ultimately, high-carbon lifestyles arise from both individual actions and systemic conditions of everyday life. Perspectives that emphasize lifestyles and consumption help to foreground the fundamental inequalities and injustices in the drivers of climate change (see Section 5.1). There are large variations in emissions between different lifestyles even within similar social groups and geographic regions (not least those with high income versus those without) (2, 129)—and yet, there has so far been a pervasive failure to direct mitigation efforts toward high emitters and emission-intensive practices (156, 158, 162). Confronting such variation and inequality requires demand management practices that target high-carbon lifestyles without disproportionately impacting more vulnerable communities. Such tailored approaches could lead to more effective mitigation policies by focusing on high-emission practices (e.g., frequent flying by wealthier groups). Furthermore, participatory and practice-oriented policy processes, where these involve citizens questioning how to bring about more system-wide change, can engender critique of the very power dynamics and patterns of influence that facilitate unsustainable lifestyles.

5.3. Social Imaginaries

Critical to historical and ongoing carbon lock-in has been the pervasive failure in industrial, modern societies to imagine desirable ways of living that are neither wedded to the carbon economy nor dependent on narratives of progress reliant on perpetual economic growth (see Section 4.1). This scarcity of plausible imaginaries underpins many of the factors discussed in this article and persists for a number of interconnected reasons.

First, social imaginaries (collective images of how we might live) tend to be "put together out of already existing representations" (167, p. 24). As the emerging field of energy humanities (168) is beginning to show, the traditions, cultures, and beliefs of contemporary, industrial societies are deeply entangled with fossil fuels in what have been called petrocultures and carbonscapes (169). Future visions are dominated by such constrained social imaginaries (170), and hence rarely offer a "radical departure from the past" (171, p. 138).

Second, with technocratic forms of modeling, cost-benefit analysis, and forecasting at the core of most governmental and industrial imaginaries (see Sections 4.1 and 4.2), the future continues to be framed as open to exploitation. Although these approaches are essentially speculative in character (172), they are highly influential and can easily substitute transparent choices about the characteristics of proposed futures for hidden "expert" judgments played out in the algorithms and assumptions of black box models. Such imaginaries—even when premised upon models that emphasize social dynamics—therefore struggle to fully emancipate themselves from modernist imaginaries of energy use (173). Typically, they transfer energy consumption from fossil fuels to other energy sources, are subject to political tropes (such as interpreting energy as a national security concern; see also Section 3.3), and frame the future as a focus for cost-benefit analysis and rational decision-making (174).

Third, the production of social imaginaries is a site of political contestation in which certain visions of the future are actively marginalized and different groups' capacity to imagine better futures systematically eroded (175). Historically, energy- and carbon-intensive actors have dominated mainstream public and media exploration of post-carbon futures (3). Where alternatives to fossil fuel–based cultures are being conceived, these are often, and necessarily, subject to (partial) democratic debate and subsequently do not offer a simple alternative trajectory (176). Indeed, issues of climate justice, racial justice, and gender equality have, until recently, too rarely been considered together and at times have been seen as competing (e.g., in relation to labor rights). This fragmentation, in a world that looks for simple stories, also drives a mistaken belief in many circles that no alternative social imaginaries are plausible or achievable.

Contemporary educational establishments offer limited help in addressing this poverty of social imaginaries. Universities have systematically excluded or sidelined many knowledge traditions not associated with industrial modernity. Furthermore, a neoliberal agenda is increasingly pervading the very purpose of many universities, skewing research funding and eroding academic integrity (177). Within such a marketized and competitive structure, new social imaginaries of decarbonized futures are much less likely to emerge. In filling this vacuum, consultancies and carbon-intensive incumbents promote parochial futures with limited academic critique. Similarly, schools provide few resources to support students to interrogate and critically reflect upon the underlying narratives that shape industrial modernity; indeed, they may be better understood as active sites of their production. Attempts to disrupt this, such as critical pedagogy and Education for Sustainable Development, have been marginalized (178). As a result, young people graduate from formal education typically with little capacity to support critical analysis of dominant narratives of the future or to enable them to begin to construct new social imaginaries (179). Given the constraints above, it can be argued that the psychological, social, and emotional capacity of individuals and groups to understand, explore, and create different social imaginaries has been steadily weakened.

The creative imagination of plausible and desirable futures not wedded to fossil fuels may in many cases require efforts to critique and dismantle the sociopolitical mindsets of industrial modernity and the knowledge infrastructures that support it (180). In other words, the scarcity of social imaginaries capable of conceiving plausible forms of living without dependence on fossil fuels is not just a climate change problem (181). Rather, it is intimately tied to an "epistemological monoculture" that has impoverished the collective global capacity to imagine and realize forms of living not dependent upon exploitation of people and natural "resources" (182). Yet in many communities around the world, locally rooted worldviews and endogenous interpretations of development have persisted and never been fully or even partially subjugated to increasingly globalized Western modernity (183). These in confluence with many sites of long-standing resistance and emerging counterpoint perspectives to modernization offer openings toward an enriched social imagination.

In the political sphere, the building of common causes across social movements and intersectional interests, linking climate justice with, for example, gender justice and racial justice, and learning from the experiences and knowledge of indigenous communities, is intensifying and building on long traditions of imagining alternative futures. Participatory democracy and citizens' assemblies hold some potential for negotiating and developing post-carbon imaginaries across social divides. Political theory focused on the role of conflict and the future of democracy has been calling attention to the need to develop new ways of dealing with hostile disagreement and trauma beyond the search for simple consensus (184). A profound examination of inherited assumptions and desires as well as artistic, speculative, and imaginative tools are necessary elements of any political processes seeking to go beyond a simple and incremental reinterpretation of today's carbonscape and its accompanying mindsets (185).

In the educational and epistemological arena, indigenous and decolonial traditions of thought are already providing a powerful critique of education's role in reproducing and defending the status quo. Critical futures studies, anticipation studies, and analysis unpicking deeply colonial framings of histories, social practices, and beliefs are all challenging the over-reliance on modeling in generating accounts of the future. At the same time, attention to the emotional, embodied, and empathetic aspects of education around fossil-free imaginaries is also growing. Aligning such studies and processes can help to address the profound cognitive and emotional challenges involved in conceiving social imaginaries that interpret the future as far richer than a simple extrapolation of the present (186).

6. DISCUSSION

Studying climate mitigation—or the lack thereof—through a series of thematic lenses allows us to sketch the contours of a highly multidimensional problem, arguably rooted in many different realms—from the political to the cultural, the material to the epistemological. The lenses offer different views that at times are complementary, overlapping, contrasting, and occasionally contradictory. Nonetheless, this exercise reveals a series of insights as to why we have failed to bend the global emissions curve, as well as critical questions for further research and action on climate change.

The clustering of the nine lenses provided a simple heuristic from which one particularly prominent feature of historical and ongoing lock-in to high-carbon development pathways stood out, namely power. Multiple forms of power and its expressions are evident across the nine lenses, including the entrenched, institutional power featured strongly in the Davos cluster, the instrumental forms of power emphasized by the Enabler cluster, and the power of ideas as foregrounded by the Ostrich and Phoenix cluster. Building from this base, Section 6.1 seeks to elicit more nuanced reasons underpinning the resilience of current emission trends to change.

6.1. Why Haven't We Bent the Global Emissions Curve?

Three decades of carefully crafted political statements, rumors of significant decoupling, and promises of technical breakthroughs have barely dented the apparently inexorable rise in emissions. Key to reversing this legacy of failure is understanding why, despite the clear science and international commitments, CO_2 emissions are now some 60% higher than they were in 1990. Certainly, the causes and impacts of climate change are multiple, diffuse, and distributed unequally across space and time. High emitters (whether countries, organizations, or individuals) are often the least vulnerable, weakening direct incentives for action, while those least responsible for emissions often suffer the worst impacts. Combustion of fossil fuels and large-scale land-use change have underpinned economic development over more than two centuries, creating deep path dependencies (not only economic but also material, social, cultural, and psychological). Dominant economic and political interests are invested in the status quo and work hard against change. Causes are also deeply embedded in wider economic and geopolitical divisions, including the historical backdrop of colonialism, imperialism, and other systemic injustices.

What is strongly evident across the reviews and analysis in this article is how redirecting the rising trajectory of emissions toward Paris-compliant rates of decarbonization brings to the fore questions highly challenging to the dominant paradigm of "progress." The almost uncritical pursuit of economic growth, piecemeal politics, and a narrow, techno-economic rationality are fundamental characteristics of this paradigm. Furthermore, worldviews and perspectives that offer alternatives to this highly constricted development pathway have (thus far) tended to be marginalized, undermined, or otherwise ignored.

Vested interests, from the individual to the geopolitical level, stand out as key impediments to dismantling carbon- and energy-intensive incumbencies, which in turn are underpinned by wider ideologies of control. However, these vested interests extend well beyond the usual suspects such as the fossil fuel industry, cascading down through tiers of power and influence. As several of this article's lenses show, the earlier and direct language of climate denial has partly morphed into something much more pervasive and insidious. Whether it is the ostensibly low-carbon energy scenarios from BP, Shell and Equinor, or the many IAM scenarios that dominate IPCC mitigation reports (WGIII), oil and gas continue to fuel unconstrained economic growth far beyond the middle of the century. This smooth maintenance of the status quo was and continues to be facilitated through the speculative potential of planetary-scale NETs to substitute for rapid and deep mitigation today. At the very time the Paris Agreement's inclusion of "pursuing . . . 1.5°C" tightened the global ambition, the adoption of NETs, manifest in the guise of "net-zero" targets, was spearheaded by "progressive" nations and organizations. In many respects, this is exactly what the reviews and analysis in this article have warned of. Whether concern is over the dominant model of economic growth, the lock-in of existing fossil-fueled technologies, the marginalization of alternative social imaginaries, or the maintenance of prevailing inequalities (both within communities and internationally), the failure to bend the global emissions curve stems from the strength of the existing paradigm of "progress" to resist change.

6.2. Looking Ahead

In 2021, there is increasing agreement that urgent and unprecedented action is required to bring emissions down in line with the commitments enshrined in the Paris Agreement. From the pages of UN reports (8, 9) to the 2030 Agenda and the UN Secretary General's announcement of a "Decade of Action," calls for transforming our world are widespread. Some argue that humanity now needs to harness all its existing social, economic, and technological powers to manage and gain control of the climate crisis and safely navigate the Anthropocene (13, 187). Often implicit in such proposals is that there is no time (or need) to question many of the core tenets of modern, industrialized societies. The literature reviewed for this article, however, collectively suggests that a key impediment to successful climate mitigation over the past three decades is the pervasive failure to do just that.

The thematic lenses, in their different ways, help to resituate climate mitigation within a more systemic landscape, where the scale and rate of ongoing climate change is not simply a problem to be fixed but rather a symptom of a "functioning," yet highly unsustainable, global political economy. This is not to imply that there is no meaningful scope or time for more reform-based strategies. However, it does mean that the dynamics that continue to lock in high-carbon pathways and marginalize alternatives urgently—and continuously—need to be challenged.

In this, we coauthors have not necessarily been neutral observers of others' failings. As members of societies and communities that have failed to respond adequately to the climate crisis, we are all entwined in business as usual—and need to recognize this in developing insights and understanding. This can involve further problematizing orthodox schools of knowledge production (including highly constrained forms of modeling) and bringing attention to underaddressed issues, such as the influence of militarism or the role of media (not touched upon in this article). More broadly, concerted efforts to actively reconfigure the knowledge systems and institutions (including their funding) that keep reproducing the very problems driving climate change are urgently needed. An important corollary lies in the need to bring plurality and more divergent thinking into a range of research fields and educational contexts. Similarly, it is key, when highlighting the very real and high stakes involved in failing to address climate change, to understand it as one of a suite of interwoven sustainability emergencies.

When it comes to policymaking and broader issues of governance, several of the thematic lenses suggest that there are significant, yet underutilized, opportunities for effective climate mitigation within current governance systems, if the political will can be mobilized.[7] Coherent and thoughtful leadership aligned with the scale and urgency of climate change (in lieu of political grandstanding within the UNFCCC climate regime and other international bodies), the stringent regulation of corporations, and the phased dismantling of heavily emitting industries all offer potential. Demand management approaches targeting consumption and high emitters could be particularly effective considering the very large share of global emissions that can be attributed to a small proportion of the world's population.[8] Identifying new targets for intervention that are also attentive to the complex and distributed factors that expand and sustain high-carbon lifestyles may further help to drive emissions reductions. While a politics of urgency and equity is required to rapidly bend the global emissions curve, climate change and the broader ecological crisis more profoundly call for a politics of humility, where we resituate ourselves as participants in a larger living system rather than as abstract from it.

7. CONCLUSION

This article has demonstrated that, while the reasons for 30 years of failure to bend the global emissions curve are multifaceted, a common and strong thread is woven through them all. In various guises and to differing degrees, the centralization of power and the privileges that accompany it have coalesced around a particular worldview. Through recent decades, the central tenets of

[7]The financial crisis of 2008 and COVID-19 in 2020 are two revealing examples where vast amounts of financial, technological, institutional, and political capital were mobilized as soon as they were interpreted as crises.

[8]The potential effectiveness of such approaches from a mitigation perspective—globally as well as domestically—is deftly illustrated by the fact that if the top 10% of global emitters decreased their emissions to the average level within the EU, global CO_2 emissions would drop by 30%.

this worldview have evolved into a wider global Zeitgeist whereby development and progress are reduced to economic growth and defined by increasingly narrow financial metrics and indices. Coincident with this financial reductionism and economic characterization of nations and societies has been a growing recognition that the "system" externalities are set to undermine the very tenets of the system. Thus far, however, the power and inertia of the existing system have been sufficient to give the impression of ongoing control. The challenges are "recognized" and "internalized," and through promised technical futures that are carefully costed in elaborate models, the existing power structures remain unchallenged.

However, even if people can, at least temporarily, be steered to ignore physical reality, the same is not true of the natural systems on which human societies ultimately depend. In 2021, there are early signs that elements within society are beginning to ask fundamental questions about the appropriateness of the dominant development paradigm, including its response to the climate crisis. There is some emergent coming together of critically minded expertise that typically resides within the Enabler cluster with more bottom-up questioning from the Ostrich and Phoenix cluster, including the many and varied social movements with the potential to become increasingly interconnected across geographies and issues. The escalating stresses on the climate system are such that they are beginning to exceed the ability of the status quo to either absorb or hide them.

So, while this article set out to shed some light on why we have failed to bend the global emissions curve, what has become apparent is that the very stability of the current Zeitgeist, with its deep reliance on escalating and centralized energy use, looks set to be its downfall. The changes locked into Earth's natural systems, and the scale and rapidity of change now required of human societies, can no longer be reconciled with a massaged form of the status quo. In a real sense, a critical tipping point has emerged. Whatever direction is chosen, the future will be a radical departure from the present. Societies may decide to instigate rapid and radical changes in their emissions at rates and in ways incompatible with the Zeitgeist, or climate change will impose sufficiently chaotic impacts that are also beyond the stability of the Zeitgeist. Within both of these futures, the existing power structures and paradigm associated with the Davos cluster are simply unfit for purpose.

SUMMARY POINTS

1. Despite three decades of political efforts and scientifically informed warnings of the likely catastrophic effects of climate change, CO_2 emissions have continued to rise globally and are 60% higher today than they were in 1990.
2. Since the first IPCC report was published in 1990, more anthropogenic fossil CO_2 has been released into the atmosphere than previously throughout all of human history.
3. The failure of leadership, particularly from within high-emitting countries, sectors, corporations, and individuals, has locked in intra- and intergenerational suffering and long-term existential threats to livelihoods and ecosystems.
4. Entrenched geopolitical, industrial, and military power and associated mindsets are fundamental barriers to effective mitigation.
5. Orthodox schools of thought and research traditions (including highly constrained forms of modeling), particularly in the fields of economics, energy, and climate mitigation, need to be challenged and replaced with, or complemented by, more heterodox approaches.

6. Three decades of choosing to fail on mitigation have shifted the climate challenge from a technocratic adjustment to business as usual to requiring a rapid, system-level change within both industrialized and industrializing societies.
7. Transformations toward more sustainable and just futures require a radical reconfiguration of long-run sociocultural and political-economic norms and institutions currently reproducing the very problems driving climate change.
8. Attention to equity, high-carbon lifestyles, and conditions for enabling new social imaginaries has the potential to disrupt dominant, high-carbon development pathways.

FUTURE ISSUES

1. How could geopolitical competition over energy resources and ideologies of control that frame dominant responses to climate change be challenged and overcome?
2. How have mainstream economics and neoliberal responses to climate change (e.g., carbon markets and a broader financialization of the environment) become so pervasive, and what opportunities are there for alternative or complementary approaches?
3. How can research approaches currently dominating advice and underpinning climate mitigation policy (such as integrated assessment modeling) be complemented with a more varied array of approaches and perspectives?
4. How could approaches that rapidly reduce energy-related emissions be realized (e.g., actively displacing and disassembling fossil fuel–based energy systems, and energy demand management practices)?
5. How can the large asymmetry in responsibility for emissions within, as well as between, nations be addressed in climate policy and governance?
6. How can fossil fuel–based, high-carbon lifestyles, practices, and visions of incremental mitigation be rapidly replaced by sustainable alternatives and profound system change, informed by a timely response to the Paris temperature and equity commitments?
7. How can knowledge systems and institutions currently reproducing the very problems driving climate change be transformed?
8. How can existing and new social movements mobilize popular power and social imaginaries in a way that effectively challenges the status quo and helps drive structural change at the scale and pace required?

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AUTHOR CONTRIBUTIONS

Isak Stoddard and Kevin Anderson conceived the overall framing, invited coauthors, and further contributed variously to the nine thematic lenses and as main authors of all other sections of the article. The nine thematic lenses were primarily covered and written by Joanna Depledge and Matthew Stilwell (Section 3.1), Martin Hultman and Naghmeh Nasiritousi (Section 3.2), Andy Stirling and Peter Newell (Section 3.3), Clive L. Spash and Frederic Hache (Section 4.1), Clair Gough and Wim Carton (Section 4.2), Glen P. Peters (Section 4.3), Sonja Klinsky and Sivan Kartha (Section 5.1), Stuart Capstick and Claire Hoolohan (Section 5.2), and Magdalena Kuchler and Keri Facer (Section 5.3). Niclas Hällström, Youba Sokona, Mariama Williams, and Eva Lövbrand contributed to the writing and editing of the article as a whole.

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