Towards a cultural political economy of mitigation deterrence by Negative Emissions Technologies (NETs)

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Non-Technical Summary

In the face of limited carbon budgets, Negative Emissions Technologies (NETs) offer hopes of removing greenhouse gases from the atmosphere. It is difficult to determine whether the prospect of NETs is significantly deterring or delaying timely action to cut emissions. This paper sets out a novel theoretical perspective to this challenge, enabling analysis that accounts for interactions between technologies, society and political and economic power. The paper argues that, seen in this light, the scope of NETs to substitute for mitigation may be easily exaggerated, and thus that the risk of harm from mitigation deterrence should be taken seriously.

Technical Summary

This paper offers a new theoretical perspective on the risk that geoengineering interventions might deter or delay mitigation (previously typically described as moral hazard). Drawing on a brief review of mitigation deterrence (MD) in solar geoengineering, it suggests a novel analytical viewpoint going beyond and contrasting with the methodological individualist, managerialist and economist analyses common in the literature. Three distinct registers to assist identification and interpretation of situations and processes through which MD might arise are elaborated and compared. The paper shows that moving from a realist register via a cultural register to a cultural political economy register, makes it clearer how and why misperceived substitutability (between NETs and mitigation) and narrow climate policy goals matter for MD. We have also identified several plausible mechanisms for MD under a neoliberal political regime. The paper argues that MD cannot be overcome simply by better informing decision makers (the 'realist' response), or even by opening up the standard techno-economic framing of climate change and our responses (the 'cultural' response). The paper also concludes that the entire political regime that has evolved alongside specific economic interests is implicated in MD, and that the likelihood and significance of MD probably remain underappreciated and understudied.

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#NETs may be as susceptible as #SRM to the risk of causing moral hazard for mitigation

Keywords

Negative emissions technologies, climate geoengineering, moral hazard, mitigation deterrence, cultural political economy

1. Introduction

Mitigation of greenhouse gas (GHG) emissions, aiming to stabilise atmospheric GHG concentrations and thus control climate risk (primarily by cutting emissions, but also by enhancing natural sinks) has been the central goal of climate policy internationally, and in most countries, for decades. Mitigation practices are nonetheless expected to deliver also against socio-economic goals, not just environmental ones. For example, there is a long-standing agreement that countries bear a common but differentiated responsibility to contribute to mitigation. In practice rates of mitigation are still sub-optimal to avoid dangerous anthropogenic climate change. Scientists and analysts agree that mitigation should be intensified and accelerated, although views differ on how much is practical and how best to distribute responsibility [1,2]. In this context, it seems important to ask of any other policy option whether considering or promoting it would help *enhance or sustain* or might for any reason *deter or delay* desirable levels of mitigation [3].

For the purposes of this paper *mitigation deterrence* (MD) is broadly defined as 'the prospect of reduced or delayed mitigation resulting from the introduction or consideration of another climate intervention'. Defined this way, MD is not inherently problematic, but potentially causes several serious harms which would make it normatively undesirable. Possible harms include *elevated GHG concentrations or greater climate risk* arising from delay or failure (of the alternative intervention), and *reduced co-benefits or more serious negative side-effects*. Either harm might involve a more regressive distribution of costs and benefits. For instance, the consequences for global justice [4] and intergenerational justice [5,6] of increased climate impacts (unabated by the failed alternative intervention) would be grave. The term 'deterrence' is here used generically to include both intentional and emergent effects,[i] while the definition (as 'prospect' rather than 'outcome') also allows for the possibility of actions to avoid or reduce deterrence.

Our definition is deliberately general, intended to include a range of possible scenarios, from the common fear in the 1990s that a focus on *adaptation* might undermine mitigation, to the more contemporary concern that pursuit of *solar geoengineering* might discourage more economically costly mitigation (often described as 'moral hazard' effects). At this generic level, MD could be a product of any type of intervention. It might even arise from an intervention that is a different form of mitigation. For example, a proposal to rely on the development of novel clean-energy technologies (instead of implementing existing forms of low-carbon energy generation) might imply greater uncertainty or delay in emissions outcomes, or a different pattern of side-effects with negative consequences for justice. Such concerns with so-called 'false solutions' are widely shared amongst more radical climate NGOs.

Here we consider the potential for MD from the category of climate interventions known as Negative Emission Technologies (NETs) or Greenhouse Gas Removal (GGR). Diverse proposals for removal of greenhouse gases from the atmosphere range from large-scale soil carbon restoration to direct air capture of CO_2 using chemical sorbents [7-9]. NETs can be considered as a form of climate geoengineering (as a large-scale, intentional, technological, intervention in the climate system with the aim of reversing the processes or impacts of climate change). Insofar as the climate issue is framed as a scientific and political matter of emissions and GHG concentrations, NETs will appear a suitable response.

The significance of MD by NETs is illustrated well in the development of climate pathways under the IPCC. In the absence of adequate mitigation, pathway scenarios have incorporated increasing amounts of NETs (typically in the form of bioenergy with carbon capture and storage, BECCS). This has helped sustain high-level policy conclusions (most recently in Paris [10]) that climate targets can be met through a managed transition based on energy efficiency, low carbon energy technologies and NETs, without abrupt and (politically and economically) disruptive transformations in energy and economic systems [11,12]. In this context NETs may be triggering harmful MD, perhaps in ways similar to those hypothesized for solar geoengineering: provision of information about NETs such as BECCS appears to reduce public support for mitigation policies [13], yet the future delivery of NETs is highly uncertain [2,14,15]. Under the Paris accord, NETs are likely to receive ever more attention and interest. Yet very limited consideration has so far been given to their interactions with mitigation and the possibility of deterrence (solar geoengineering has been more intensively considered in this respect [3,16-18]). It is in this context that we seek to interpret and explain MD.

The aim of the paper is to argue for a shift to a new analytical viewpoint from which MD can better be studied. For this, we build on Markusson et al's [19] distinction between three generalised analytical registers. The registers are generalisations, and as such imperfect representations of any field, but useful to move, relatively quickly, the analytical gaze. We discuss MD briefly at each register, to illustrate what each register can accomplish and help us compare them and so justify a preference for the CPE register.

This paper first revisits studies of moral hazard in the literature on solar geoengineering as current, relevant context for studying MD from NETs, confirming why we think harm from MD may arise with NETs despite some dissimilarities with solar geoengineering, and indicating where that literature (despite being much richer than that on NETs) is deficient. Fears that solar geoengineering would undermine climate policy is a current, relevant example of a more general risk, whereby expectations or 'promises' of technical solutions [20][ii] undermine climate policy (for example see Markusson et al [19] regarding CCS).

We then argue – with reference to the existing geoengineering literature – that the likelihood and potential significance of MD by NETs has been poorly understood, and may therefore have been underestimated, by analysis frequently located at a *realist* (individualist, economistic and managerialist) register. Shifting to a *cultural* register, drawing on science and technology studies, we show how an understanding of technologies as co-produced by, and co-producing of social contexts, can reveal emergent effects and interactions that are not simply the product of individual rational decisions. However, the socially-constructivist[iii] cultural register itself remains inadequate in its treatment of materialist politics and economics. Therefore, we instead argue for a *cultural political economy* register [21,22] in which MD is mediated by material economic interests alongside framings and social imaginaries[iv]. We thus argue that shifting from the currently common realist register, via a cultural one, to a cultural political economy register puts researchers/analysts in a better place to analyse processes that might result in MD.

This paper makes several novel contributions to scholarship. Firstly, it explicates the character of the three registers in much greater detail than in [19]. Secondly, it discusses what each register can tell us about how MD could come about, what can be done about it, and the role of researchers and analysts in that process. And, thirdly, as discussed above, it argues that the CPE register is preferable.

In applying a CPE register to explore possible future forms of MD and NETs, we avoid the trap of 'speculative ethics' [23]. While speculation about the ethics associated with future technologies can help construct them in particular forms [24], from the CPE register this problem is understood as one of (unpoliticised) constructivism. CPE rather examines the emergence of the technology (and its associated ethics) in tandem with the political regime[v] and the power asymmetries within it. While it may contribute to the co-construction of the technology it is very clearly not naïve speculation, and rather than constructing a particular future, we intend it to enable the consideration and empowerment of alternative futures *in the present*.

2. Solar Geoengineering as a starting point

If we are to apply lessons from consideration of solar geoengineering, it is important to first consider how NETs may differ from solar geoengineering. We highlight three commonly suggested differences here [8,9]. (1) NETs may be more costly and slower acting. (2) They act more directly on greenhouse gas concentrations rather than temperatures. And (3) they may involve fewer attendant risks and uncertainties.

Although perceptions of solar geoengineering as cheaper might make it more susceptible to MD, NETs could also reduce costs to industry, investors and consumers from there being fewer stranded fossil assets, in comparison to mitigation. Similarly, while the relative speed of solar geoengineering may bolster arguments that climate action is premature, NETs could also enable delay by creating an expectation of recovery of carbon from the atmosphere at a future date – at costs then comparable to mitigation. Indeed, there is a *prima facie* case that the way climate pathways modellers have embraced such expectations has already helped to sustain inadequate political agreement on mitigation in the past decade [2,12,14].

Secondly, solar geoengineering acts to reduce climate risk by reducing temperatures directly (only indirectly affecting atmospheric composition). By acting (2) *directly on greenhouse gas concentrations* NETs are arguably better substitutes for mitigation, and so might again appear less likely to generate harms as a result of MD. However, removals are still imperfect substitutes, since they may be less certain in their climate effects than emissions prevented, for instance, because of the risk of leakage from carbon stores, such as through forest wildfires. Moreover, if NETs were incentivised through carbon markets, they would only be adopted as (in practice) an offset for mitigation (unless the market cap was reduced equivalently), and therefore risk crowding out actual mitigation.

With respect to (3) *risk and uncertainty*, although the specific risks arising may differ (for instance, the risk of a significant termination effect is limited to solar geoengineering, while the risk of carbon leakage from wildfires is specific to afforestation), NETs also involve significant practical uncertainties regarding their socially acceptable and sustainable deliverability at scale [25]. Moreover, the effects of NETs on ocean outgassing, and of biomass accumulation on albedo are not yet fully understood, and some integrated modelling suggests the net climate effects might be significantly smaller in the long term than implied by the absolute amounts of carbon removed [26].

Such uncertainties cast doubt on the plausibility of reliable and effective future delivery of NETs, which becomes more problematic if mitigation has already been reduced, or not accelerated, in the expectation of future negative emissions.

To sum up, whilst solar geoengineering may seem more susceptible, there is sufficient reason, and *prima facie* evidence, to think that NETs may also cause MD through similar mechanisms, and that it might be harmful. It is therefore reasonable to take the literature on MD in solar geoengineering as a starting point for discussing MD by NETs. Indeed, efforts to discursively and definitionally separate NETs from solar geoengineering [e.g. 9,27] would appear to downplay the similarities of relevance to MD, and as we shall argue later, may deliberately or unwittingly represent political shaping of the 'promise' of NETs.

3. A realist register is common in existing analyses of mitigation deterrence

In conceptualising MD, the literature on geoengineering (primarily addressing solar geoengineering) has been dominated by contributions from economics, psychology and philosophy. Scholars in this tradition have often adopted the terminology of moral hazard, following [28], and offered a range of conceptualizations, analogies and critiques. Moreover, with relatively few exceptions such scholars have adopted a realist register, tending to focus on decisions made by autonomous agents or institutions, assume that uncertainty can be known and managed, if not eliminated, by such agents, cf. [29], and thus that outcomes can be controlled, and to typically reduce phenomena to economic, financial or market dynamics, aggregated from individual choices, shorn of any power relations. Space limitations preclude more than a brief description of the main themes here (but see [3]).

Economic and individualistic framings are frequent. *Insurance* is commonly cited, see for example [16-18], as enabling rational risk-taking by autonomous actors: Lin suggests the example of flood insurance leading to more building on flood plains as a plausible parallel. Such economistically rational analyses also underlie interpretations of the problem as one of *economic substitution*, e.g. [18,30]. Here substitution of geoengineering for mitigation appears rational insofar as they are economic substitute goods meeting the same goals. Modelling of climate pathways also often includes substitution effects with near-term mitigation rates reduced in response to predicted future NETs [e.g. 31-33]. Behavioural economistic conceptualisations – including possible explanations of moral hazard arising in information asymmetries between principal and agent, perverse incentives and free-rider problems – are also frequently cited [16-18,30,34]. Although here it may be understood that actors are only boundedly rational, the framing remains economistic and primarily individualistic. Other commentators have applied economistic *game theory* [35,36], in which countries are seen as the relevant agents pursuing their specific interests.

Some scholars extend psychological insights beyond behavioural economics in a broader account of *cognitive biases* or *cultural cognition* as a root of possible MD [17,34,37-39]. The focus is less economistic, but still typically individualistic. Cognitive biases applied to perceptions of geoengineering might imply over-optimism, if geoengineering provides a misplaced sense of control regarding the climate problem [17]. Cultural cognition approaches suggest that individual reasoning on issues like climate change is distorted in line with cultural identities, in ways that could make climate denialists particularly susceptible to the attractions of geoengineering as an alternative to mitigation [17,37,40]. Psychological mechanisms also underlie conceptualisations of deterrence as *risk compensation* [16,18,34]. Again, individuals are conceived to adjust their behaviours consciously or subconsciously to a similar level of apparent risk.

Some researchers have also sought to apply approaches from *moral philosophy* [16,34,41]. These analyses typically seek to clarify the potential harm arising from MD, primarily applying consequentialist and deontological approaches rooted in the dominant liberal individualist social imaginary [29]. Such moral philosophers, even in deontological variants, tend to avoid economic reductionism, but rarely escape the other elements of the realist register. Rather, they highlight possible harms in reduced efficiency, misdirected motivations, and mal-distribution of costs and benefits. Some philosophical approaches also suggest the possibility of less individualistic forms of deterrence, a critical point, which is also highlighted by Corner and Pidgeon [38] in their categorization of moral hazard into individual and collective (social or political) forms.

The realist register has serious analytical limitations. Technologies are understood simplistically as material products of science and economic forces, independent of the socio-technical systems needed to generate them. A focus on autonomous *individuals* (either as lone but powerful human or institutional actors, or as aggregated sets) obscures the impact of collective, social phenomena like norms, institutions, narratives and, crucially, power relations, and the way they shape individuals' thoughts and actions. Understanding collective forms of MD would appear critical where there is such limited agency for individuals to understand and act on the risks of climate change and geoengineering. Relatedly, a focus on *managerial* understandings of decision making, where (at least, some, powerful) actors can know and manage risks and control the outcome of their interventions, obscures the possibility of MD being the result of distributed actions and complex, emergent processes that escape any single actor's ability to predict [42]. Markets are one collective institution that has been analysed in the relevant literature, but in an aggregative, *economistic* manner, again based on assumptions about liberal autonomous actors that largely obscure the impacts of power relations and unequal social structures. We will argue that shifting (via a cultural register) to a cultural political economy register can help overcome these limitations.

4. Key MD mechanisms, as understood at the realist register

McLaren [3] distilled from the (predominantly solar) geoengineering literature two related characteristics of situations where MD can be both likely and harmful. Firstly, the risk of harm depends on the perception of substitutability of the proposed approach for mitigation. The greater the divergence between perceived and actual substitutability the more significant the risk of harm (as then it seems both more likely that mitigation will be reduced or delayed in response, and that such reduction or delay will lead to harms). If a proposed intervention is perceived by decision makers as equally effective in reducing greenhouse gas concentrations as current options, and cheaper, quicker or politically more palatable, it is more likely to be pursued. Even if the intervention proves a good substitute in narrow climate terms (effectively reducing greenhouse gas concentrations) it may still redistribute social costs and benefits in undesirable ways. Worse, if in practice the intervention proves a poor substitute in narrow climate terms then MD might lead to more severe climate impacts, as well as other harms.

Secondly and relatedly, MD is more likely to lead to harm when climate goals are broad or more holistic (making it a poorer substitute in practice), rather than narrow. Policy makers may pursue particular policies for mitigation for a range of reasons, beyond reducing the risk of dangerous climate change. They might aim to create new economic opportunities and markets for low-carbon technologies and practices such as carbon trading, or create jobs through green Keynesianism. Cutting emissions can also reduce morbidity and mortality from air pollution, which co-benefit appears to be strongly incentivising mitigation in countries like China and India. Moreover, designers of climate policy typically aim (if often unsuccessfully) to avoid serious negative environmental or social side-effects, and through the principle of common but differentiated responsibility, global climate negotiations have sought to place greater burdens on those most able to pay, and having most benefited from the use of fossil fuels. Insofar as mitigation carries expectations of other beneficial or desirable outcomes, its substitution by alternative policies focused on greenhouse gas concentrations or climate risk alone is problematic.

Figure 1 visually summarises necessary assumptions for the two situation characteristics to be intelligible at the realist register, i.e. a realist model of MD. A pair of technologies (the bracketed technologies 1 and 2) are here compared by an individual decision maker with regards to their respective functionality – relative to assumed climate policy goals – and their mutual substitutability. The decision maker's perceptions (indicated by the eye symbol) of the technology pair may be biased and/or not perfectly informed by available evidence (which would be visible to the (notional) independent researcher/analyst).

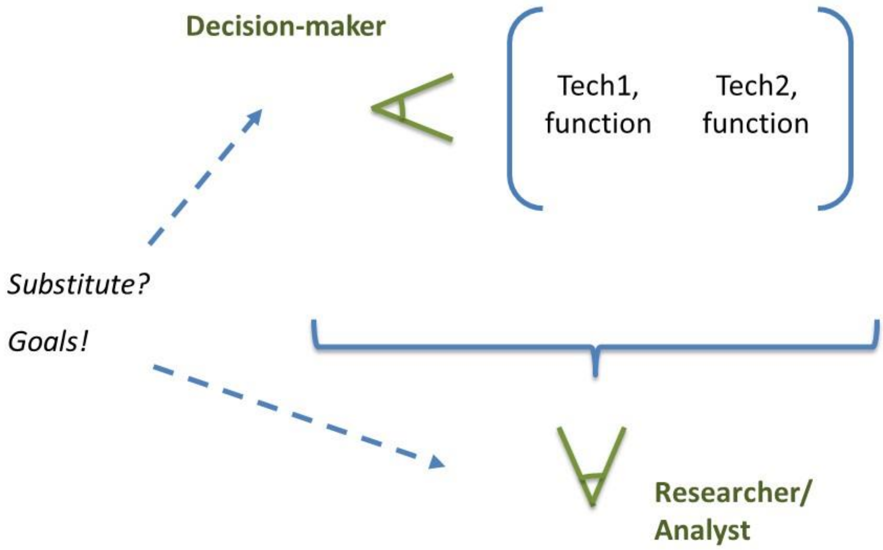

Figure 1 *A realist MD model*

At the realist register, the solution to MD problems is for the decision-maker to be better informed of the actual substitutability of the technology options. A well-informed (by 'objective' analysts) climate policy decision maker would – in the face of possible harm from MD – only deploy NETs as a supplement to (desirable levels of) mitigation rather than a substitute.

Such a response to MD suffers from multiple shortcomings: not only are there significant limits to the predictability and knowability of the impacts of future technologies, but there are complications arising from diverse 'rationalities' motivating action, and power relations that necessarily shape perceptions and decision-making [10]. Climate scientists informing policy makers that NETs should only be a supplement rather than a substitute for mitigation (given agreed policy goals) is therefore unlikely to be sufficient to avoid harm from MD.

Much scholarship at the realist register overlooks the necessary framing done by experts themselves. These framing choices are inescapably subjective, because technology substitutability – and so MD likelihood – depends on what climate policy goals are assumed. There will thus always be multiple justifiable ways of framing a given choice between technologies. The frame choice should be made explicit, and possible to reflect upon, and to contest; the apparently objective knowledge about technology option substitutability needs to be 'opened up' [43]. For this, we need to go beyond naïve realism and adopt what we can call a *cultural register*.

Note that this is not simply an argument for adopting the 'bounded rationality' of behavioural economics. Such approaches recognize cognitive biases and move away from the ideal 'rational decision maker' but maintain a commitment to objective assessment of substitutability, and in effect restate a claim that by minimising irrationality, the problem is managed. At the cultural register, there is a different relation between scientists and decision makers. Scientists are here not just truth tellers but also (epistemological) power brokers.

5. Moving to a cultural register

At the cultural register, we can analyse what kinds of rationalities, and what kinds of framings dominate. Climate policy consistently features an established standard techno-economic framing embedded in practices and institutions (and anchored in a dominant liberal administrative social imaginary, evident across contemporary systems of liberal democratic government) [29]. Users of this framing foreground the physical climate system in formulating the problem and the goals of policy, and privilege technologies as solution options, highlighting their physical effects and costs, as opposed to issues of, say, social justice and power relations [44]. Such framing draws heavily on some kinds of evidence (from physical sciences, engineering and economics) rather than others (from e.g. critical social science). The standard framing of MD is therefore, unsurprisingly, similar, excluding power relations and many justice issues.

Analysts working in the dominant social imaginary tend to construct technologies as stand-alone, isolated tools. This backgrounds how technologies are implicated in social relations and the messy political aspects of society, as well as almost all *relationships between technologies*. In the techno-economic framing of the realist register, technologies are made commensurable by focussing on narrow functionality (e.g. CO_2 emissions or reductions), and choices between them are facilitated by focussing primarily on economic costs. Not only are single technologies framed, but the relationships between them are framed too.

Insofar as MD arises in misperceived (as described above) substitutability (given broad climate policy goals), the cultural register – with its understanding of technologies as socio-technical systems – enables us to reflect on the processes in which technologies are socially constructed as being functionally substitutable, and their shares of a deployment portfolio economically optimisable. The cultural register thus helps us analyse how MD can take effect in the dominant social imaginary, and reminds us that alternative framings of the relationships between technologies are possible. Given the standard techno-economic framing, any MD mechanism that involves things other than those studied by scientists, engineers and economists is largely invisible. At the cultural register, drawing on science and technology scholarship, the antidote is to open up the restrictive framing of relationships between technologies, and expose other possible interaction effects.

Figure 2 visually summarises a model of MD at the cultural register. Here there is a range of frames through which actors may assess the substitutability of the technology options. Analysis at the cultural register, employing reflexivity and deliberation, reveals a dominant social imaginary which shapes policy goals and framings of technologies and their inter-relations. Concepts such as sociotechnical imaginaries [45] or the sociology of expectations [20, 46] helpfully 'open up' framings, revealing how tacit and powerful 'pictures' or 'promises' of desirable futures often vary, yet also profoundly shape socio-technical trajectories in unconsidered and unaccountable ways.

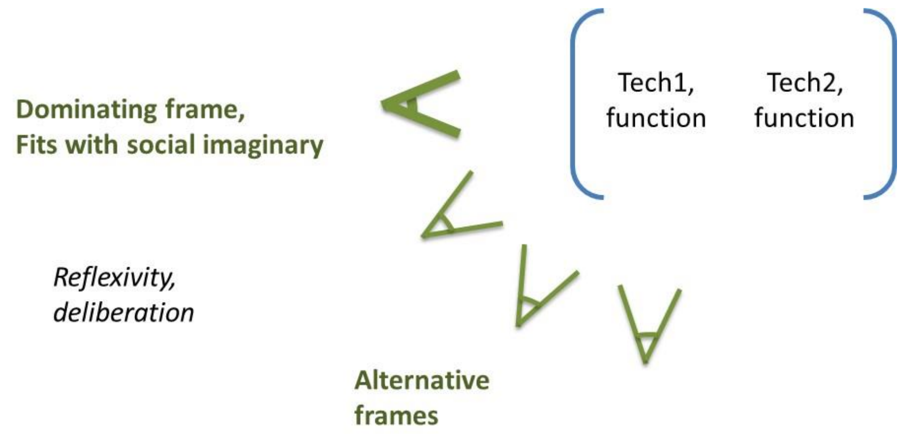

Figure 2 *A cultural MD model*

Whilst work in the dominant liberal social imaginary serves to depoliticise climate policy in favour of technocratic responses [47], the cultural register does not fully help us explain the specifics of how the dominant social imaginary and expectations of individual technologies interact. Which specific technologies get promoted as climate policy options? Under what circumstances do they succeed or fail? What power relations do they enable? Moreover, the cultural register does not help us understand the evolution of particular political economy regimes and associated social imaginaries (e.g. how is the liberal imaginary of government *dominant* in the first place?), and how envisioned technology options are implicated in that evolution, and hence the historical contingencies of the framing of technological climate policy options. For this, we need to turn to a cultural political economy (CPE) register as we outline below.

6. And from a cultural to a CPE register

At the CPE register, understanding of social relations begins from a materialist interpretation of economic interests and political regimes. For instance, we here conceptualise social relations in a Marxian tradition, recognising the need for capital to extract surplus value from labour, to sustain its economic and political domination. The ephemeral but rolling maintenance of the conditions for such exploitative profit-gathering takes the form of shifting spatio-temporal fixes [48]. These 'fix' emergent ruptures in or rejections of contested political economic conditions, '(af)fix' them in longer-lasting infrastructures and institutions and thereby secure the potential for achieving the recurrent 'fix' of profitable growth that capitalism systemically demands. But our perspective also remains essentially cultural, in that we see dominant political regimes acting through and being supported by shared and contested social imaginaries, perhaps even constructing forms of hegemony[vi]. Specifically, we adopt a non-deterministic and relational Marxian position that sees social structure as a complex system that is unstable, dynamic, in need of maintenance – both material *and* ideational – and shaped by historical contingency. This perspective incorporates strategic agency, reflexivity and resistance in the evolution of capitalist society as constitutive elements of the trajectories of social, political, cultural and techno-scientific change.

Crucially, science has become ever more important for the development of new technology, as a source of innovation. At this register, science serves to create new objects in which to invest, and from which to make a profit. Science serves to open up new capitalist frontiers, to enclose new spaces as spatio-temporal fixes for a capital that recurrently requires new avenues for profit. Science proposes technical fixes for collectively recognised problems, e.g. climate change. Spatio-temporal fixes can in this sense also be defensive, primarily, and at least initially, preserving existing investments, rather than opening up new lines of profitable enterprise [19].

Similarly as at the cultural register, *technological expectations* [20,46] here circulate amongst stakeholders as representations and perceptions of possible futures. Technological expectations also become embedded in material practices and hence can, in turn, significantly condition ongoing political economic activity. In the case of NETs, this includes pathway modelling practices, as well as technology development practices. The expectations also entail framings that foreground some things and background others, and come bundled with (more or less explicit) imaginaries of social order. Also for this reason, some technological expectations fit better with the social imaginary of the dominant political regime, and the two tend to develop in inter-active, contested parallel over time. CPE is, thus, clearly not simply a shift in 'sociological scale' to the regime level (from specific discourses at the constructivist register, or individual agents at the realist register). Rather CPE accommodates and motivates analysis at and across multiple sociological scales, transcending and incorporating the other registers. In contrast, the 'cultural' tends to be set *against* the 'realist' and vice versa.

Yet the regime level is critical to a CPE understanding. We envision that in a dynamically stable capitalist formation, mutually supportive dynamic relations subsist between science and technology, underpinning in complex cultural and material ways a hegemonic political regime, which in turn supports certain kinds of innovation (through an innovation regime favouring technologies that are seen as attractive). In other words, technology is understood as a 'politico-technical' phenomenon [49], in which the political economy is co-constructed alongside the material technology and systems thereof. In all parts of the co-evolutionary loop, there is scope for, and need of, action, to reproduce and maintain the positive feedbacks that give the loop any stability.

Of course, different reflective actors diverge in how they perceive their situation and the ongoing dynamic, and regarding what they see as desirable goals for which to aim. This also means there are multiple points of intervention and resistance around the loop, since the emergent stability is the result of multiple diverse inter-relations, not an abstract 'higher-level' reality. Intervention is here about opening up the framing of specific concrete technologies (and their relationships), but also about mobilising actors to challenge and reshape tendential trajectories of system evolution – not least through greater strategic awareness of their current positions in existing dynamics of system reproduction and transformation. Thus in the CPE model both MD, and interventions to avert it or ameliorate its harmful effects, are conceivable.

The table below summarises the contrasts between the three registers.

Table: the three registers

Register	Conception of technology	Key component	Rationality	Ontology
Realist	Techno-economic	Individuals (single or aggregated)	Objective, or boundedly rational	Realist
Cultural	Socio-technical	Social imaginary, frames	Multiple rationalities, interactive	Constructivist
CPE	Politico-technical	Political regime (economic blocs and hegemony)	Multiple rationalities, strategic	Power relational

7. The CPE-MD model

Working at the CPE register, we see MD as an outcome of the co-evolution of multiple technologies (as expectations and perhaps also as development and deployment) with political regimes, entailing both social imaginaries and economic blocs. MD is here not just about how policy goals and technologies (in isolation or in comparison) fit with a dominant social imaginary, but also how they fit with dominant material interests. And since imaginaries and interests are not perfectly aligned, the fit with the latter matters too. Therefore, at the CPE register, we need to pay attention also to who stands to make (or lose) a profit from proposed NETs, and who from mitigation, and how those things are related. This can be from NETs opening up new investment opportunities, or constituting defensive fixes to sustain the value of fossil fuel-dependent assets [19,50,51]. Whether NETs are perceived as complementary with or substitutable for mitigation may matter, but also whether they simultaneously can materially support the political regime or not. See Figure 3 (below) for a visual summary of MD at the CPE register.

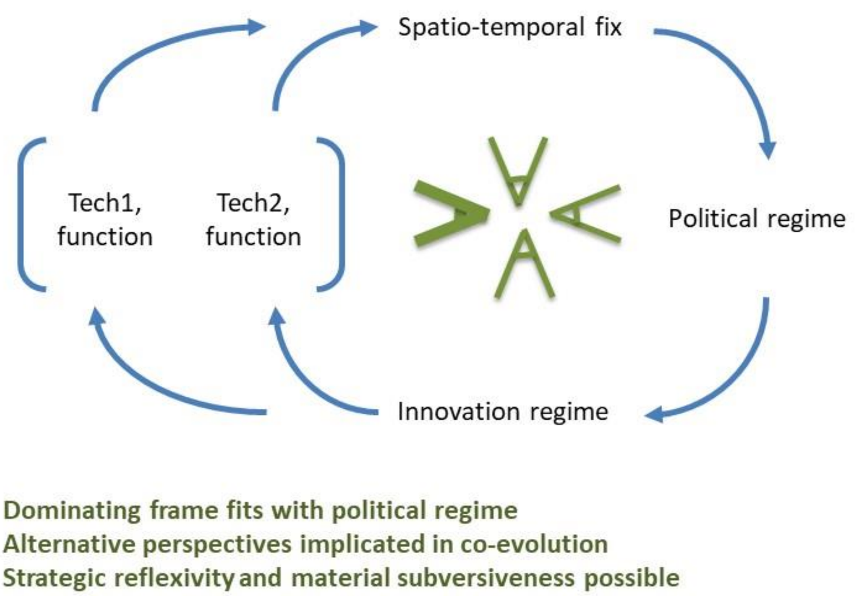

Figure 3 The CPE-MD model

Although a range of perspectives exist within a CPE approach (as on the cultural register), in Figure 3 we emphasize that all perspectives are to some extent situated *within* the hegemonic political regime (represented by their position within the regime cycle). Whilst some actors are clearly more influential than others, no one stands free from the ongoing production of power relations and framings (developed in a process described by [52] as power-knowledge). This *includes* researchers/analysts, whose only choice is to act strategically like other actors. Researchers/analysts may inform decision-makers and strategically open up aspects of reality for challenge, but to intervene against MD here may also entail advocating specific framings (closing down) and even materially supporting specific actors.

MD can be expected to emerge in specific ways in different regimes. How might MD therefore happen under the existing, specifically *neoliberal,* political economy regime? Acknowledging that the term is often disputed, here we treat 'neoliberal' as an ideological belief in the unlimited capacity of markets to solve the problems involved in governing human affairs, following [53]. Understanding neoliberalism as a hegemonic political ideology takes us beyond the idea of the social imaginary discussed at the cultural register, recognising the ideology as part of a political regime, co-evolving with a bloc of economic interests, such as oil and gas producers and financial corporations.

The neoliberal regime with its limitless belief in growth and markets has emerged alongside the expansion of seemingly endless, cheap energy supply in the form of oil and gas [50]. In this context, the prospect of NET investments suggests a possibility of cleaning up society without the need for abrupt changes to how we produce and use energy [contrast 12,54][vii]. And in analogy with the experience with CCS, this may be enough for some time to sustain the regime, and may in fact even work best (for the regime) as long as the technology remains a 'promise', rather than a costly material investment [19]. There is alternatively scope for NETs to be more directly useful to the economic bloc underpinning neoliberalism, as the captured CO_2 could be used for enhanced extraction of oil and gas [57] or diverted from storage into carbon utilisation, for example in synthetic fuels [58]. In either case, on balance less carbon is permanently withdrawn from the atmosphere. Moreover, NETs can be expected to function better as a 'promise' in this context, if they are definitionally separated from solar geoengineering, and the risks (including harm from MD) that the latter is now widely presumed to embody.

The techno-economic, depoliticising social imaginary discussed above, works well in a neoliberal political economy, supporting its market focus through tools such as carbon trading. Technologies (as opposed to changed habits and practices) are preferred solutions, because they can more easily be constructed as commensurable and fungible, i.e. their deployment (actual or prospective) can be traded on the same markets. Under neoliberalism, markets are the primary arbiters of whether and to what extent technologies are substitutable. Fungibility is easier to construct if technology functions are framed narrowly, with neatly standardised effects, cf. [59]. Poor substitutability between NETs and mitigation would thus tend to be obscured under a regime favouring market solutions, and so increase the likelihood of MD. Technology fungibility, in turn, is easier to construct if policy goals (against which technologies are assessed) are kept narrow. Expectations of fungible technological solutions thus help sustain a neoliberal political regime, with its hegemonic belief in markets. In respect of both the framing of climate policy goals and interventions to meet them, the CPE viewpoint suggests ways in which the neoliberal political hegemony might stimulate MD.

The hope of inclusion of NETs in trading and offsetting systems is part of what has driven entrepreneurship in this area. Such inclusion typically requires not only modelling of carbon flows, but the establishment of systems for measuring, monitoring, verification and accounting [59-62]. Keen entrepreneurs have started selling offsetting services ahead of such systems, potentially prompting their development.[viii] It might even be that some such commerce thrives regardless of – or even best in the absence of – such systems, as for some buyers what matters is an act of faith in having sought to offset [63]. The development of sequestration markets, and maybe even 'carbon futures', fits nicely with a neoliberal regime reliant on financial innovation and experimentation.

This analysis also makes clear – at the cost of an elaborate re-conceptualisation, complexity and much new terminology, and thus a risk of disconnection from the mainstream realist literature and policy discourse – ways in which the neoliberal regime benefits from – and co-constructs – a framing of climate change as an issue of measurable quantities of greenhouse gases, rather than a more complex nexus of cultural, social and economic constructions. Accountable, tradable quantities of carbon, convertible into useful products through carbon utilisation and enhanced oil recovery, create new markets, with the prospect of new financial instruments and derivatives. A CPE approach enables this framing to be contested, while simultaneously being capable of exposing and even challenging interests, e.g. those behind denialism, in climate policy.

One possible objection to our approach to MD might be that it appears to be 'moving the goalposts'. As leading climate engineering researcher David Keith complains of Naomi Klein, 'she attempts to solve the problems of capitalism, rather than those of the climate' [64]. But the CPE approach highlights instead that the setting of the goalposts in particular ways and in particular places by powerful interests is part of the problem of inadequate mitigation. In other words, it is not that we here ourselves introduce other, broader goals into climate policy, but that we merely highlight inter-connected issues such as economic transformation or justice and international redistribution. Hence, we are unapologetic in understanding the problems outlined here as a normative argument for moving the goalposts. Conversely, we are sympathetic to arguments that, if only for strategic reasons, climate problems must be analytically separable and capable of being addressed without first (or alongside) 'solving' capitalism (or neoliberalism more specifically, here). A CPE perspective, however, actually affords analysis that remains fundamentally aware of the inter-relations between socio-technical change (such as development of NETs) and political economic regimes *without* collapsing the former onto the latter or, therefore, arguing (explicitly or implicitly) that 'better' NETs can only be developed when problems with the latter are 'resolved'. Instead, NETs are illuminated in their broader, but irreducible, systemic context so that they can be considered with optimal strategic insight.

8. Conclusions

We have here set out a new analytical viewpoint, based on cultural political economy, for studying MD. The viewpoint offers a distinct alternative to the realist register that is common in the literature (and to constructivist challenges to it). The CPE viewpoint promises to add sensitivity to both epistemic pluralism (the presence of multiple ways of knowing) and historically contingent societal power relations. We have shown that shifting from the realist via the cultural to a cultural political economy register promises to improve our understanding of how and why poor substitutability and narrow policy goals matter for MD. We have also identified several plausible mechanisms for MD under a neoliberal political regime. The situation regarding MD now looks more complex. It is not just about insufficiently informed decision makers, or even about the problematic domination of a techno-economic framing of the climate change problem and its solutions. Rather an entire political regime is implicated in specific ways in making mitigation deterrence possible and perhaps harmful. Therefore, most existing analyses may have underestimated the likelihood and significance of MD, and we are investigating this in related work.

Conversely, however, this added complexity also means there are now more points of plausible intervention. It is no longer enough to consider messages to policy makers that NETs should not be used as substitutes for mitigation [2,12], nor to 'open up' the standard framings that make mitigation deterrence a possible outcome. At the cultural political economy register, researcher/analysts are part of the inescapably conflictual dynamic through which technologies and political regimes co-evolve. They may therefore be more overtly situated – and even engaged in *foreclosing* of debates where they are being 'opened up' in troubling new directions – and may strategize for better ways of acting in and organising society, including potentially in materially subversive ways. For this purpose, we plan in further work to develop a methodology that is capable of supporting such strategic reflection [65] and delivering empirically based findings about mechanisms of MD. It will be based on scenarios and used in stakeholder engagement, designed to produce interventions with the objective of alleviating the MD problem.

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Notes

[i] We do not deliberately echo the specialised use of 'deterrence' in the strategic military context, although the concepts may share some characteristics.

[ii] Here we follow in the tradition of science and technology studies scholars such as Mads Borup and Harro van Lente who write of a sociology of *expectations* triggered by *promises* of technological advancements.

[iii] (Social) constructivism is, simply put, the idea that reality is constituted through our perceptions of it.

[iv] A social imaginary describes the shared visions, symbols and associated feelings that people have about something.

[v] By political regime we mean the social structures and systems of power relations that enable governance over society (not necessarily in a single country).

[vi] Hegemony is the cultural dominance by a ruling group resulting in a widely shared worldview, which legitimises the group's rule.

[vii] Recent modelling studies have concluded that with radical reductions in global final energy use it may be possible to achieve 1.5°C without NETs [55] or alternatively, that even with radical behaviour change at least some NETs would still be needed [56]. In modelled futures, only pathways with substantial deployment of NETs avoid such politically and economically disruptive shifts.

[viii] See for example, Nori (online at https://nori.eco/) which is developing entrepreneurial NETs trading using blockchain technology.