Towards a cultural political economy of mitigation deterrence by Greenhouse Gas Removal (GGR) techniques

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Non-Technical Summary

In the face of limited carbon budgets, Greenhouse Gas Removal Techniques (GGR) offer hopes of removing greenhouse gases from the atmosphere. It is difficult to determine whether the prospect of GGRs is significantly delaying or deterring 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 GGRs to substitute for mitigation may be easily exaggerated, and thus that the risk of mitigation deterrence should be taken seriously. It proposes novel participative research methods designed to better reveal, evaluate, and enable effective responses to mitigation deterrence.

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, and a new typology of the potential harms arising, it suggests a novel analytical framework going beyond and contrasting with the methodological individualist, managerialist and economist analyses that dominate that literature. Three distinct registers are elaborated to assist identification and interpretation of situations and processes through which MD might arise. In moving from a realist register via a cultural register to a cultural political economy register, it becomes clearer how and why misperceived substitutability (between GGR and mitigation) and narrow climate policy goals matter for MD. New complexities around MD are revealed, which enables improved identification and evaluation of related risks and responses. It 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 concludes that the entire political regime that has co-evolved with specific economic interests and specific technologies is implicated in MD. As a result the risk and significance of MD remain underappreciated and understudied. The paper therefore proposes and outlines new approaches to deliberative research designed not only to assist in the identification and evaluation of risks of MD, but also to generate potential interventions to reduce MD and to stimulate reflexive action by research participants, rooted in the development of phronesis (or 'practical wisdom').

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Introduction

Mitigation of climate change (aiming to stabilise atmospheric GHG concentrations and thus control climate risk) has been the central goal of climate policy internationally, and in most countries, for decades. The focus of mitigation is on the reduction of greenhouse gas emissions, although it also encompasses enhancement of natural carbon sinks. Mitigation practises are also typically expected to deliver 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, and climate policies with strongly regressive social impacts (such as crude energy taxes) are rarely adopted.[1] In practice, actual 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 (Moellendorf 2015, Larkin, Kuriakose et al. 2017). In this context, it seems important to ask of any other policy option whether considering or promoting it would help *sustain or enhance* or might for any reason *deter or delay* desirable levels of mitigation (McLaren 2016).

Defining mitigation deterrence

For the purposes of this paper *mitigation deterrence* (MD) is broadly defined as 'the prospect of reductions or delays in emissions cuts resulting from the introduction or consideration of another climate intervention'. This definition has several implications. First there are distinct descriptive and normative elements. Second it considers dynamic as well as static responses. Third it encompasses a broad range of possible scenarios and mechanisms.

On the first point, defined or described this way, MD is not necessarily 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 substitute intervention), and reduced co-benefits or more serious side-effects, either of which might involve a more regressive distribution of costs and benefits (or other forms of injustice). In other words, even if the effect of MD is such that one intervention simply replaces another (each reducing atmospheric GHG outcomes by the same amount), there can still be serious harms to particular groups. On the other hand, if MD leads to higher GHG concentrations (because emissions are allowed to grow by more than the alternative intervention reduces GHGs) we can expect this to result in both significant international injustice (poorer countries, less responsible for past emissions bear the brunt of the impacts of rising GHG concentrations), and intergenerational justice (today's youth and future generations similarly will bear greater costs). To evaluate the extent and harm of MD we therefore need to assess both how far the new intervention is likely to replace, rather than supplement, mitigation; and how likely it is to deliver its anticipated effects on the climate (and any side-effects or co-benefits). Figure 1 explores the two dimensions on which harms or benefits might arise from substitution of one climate intervention for another.

Second, in focusing on 'the prospect', or possibility of, rather than only 'an outcome' of reduced mitigation the definition allows not only for the presence of difficult-to-predict dynamic responses, but also for the possibility of intentional actions to avoid or reduce the deterrence effect. For our project, this is critical, as we hope to identify and enhance such actions.

[1] Many national and regional climate policies, such as the EU emissions trading scheme, are nonetheless somewhat socially regressive due to the political influence of industrial interests and the challenges of imposing costs on internationally traded sectors.

Table 1: The dimensions of mitigation substitution and deterrence

	Better side effects	**Side effects identical**	**Worse side effects**
GHG outcomes enhanced	**Synergies**: new intervention delivers more mitigation with fewer side-effects: win-win outcomes for climate, economy and society	**Enhancement**: new intervention achieves more mitigation with same costs/side effects	**Pro-climate trade-offs**: intervention delivers lower GHG concentrations but at higher social, economic or environmental cost (note 1)
GHG outcomes identical	**Beneficial substitution:** equal net mitigation, side effects reduced.	**Plain substitution:** Equal net mitigation, side effects no worse, no less fairly distributed (note 2)	**Harmful substitution:** Equal net mitigation, side effects worse or less fairly distributed
GHG outcomes worse	**Anti-climate trade-offs**: higher GHG concentrations but lower social, economic or other environmental cost	**Deterrence**: Reduced net mitigation, side effects no worse, no less fairly distributed	**Exacerbated deterrence**: reduced net mitigation, side effects worse or less fairly distributed

Notes to table 1:

1. This situation could arise where fear of worse side effects/higher costs triggers more emissions reduction (the 'galvanisation' effect found in a mild form for SRM in one empirical study (Merk, Pönitzsch et al. 2016)).

2. Here we talk of substitutes in relation to the primary purpose of mitigation (reducing GHG concentrations). In the economic sense of the word, the perfect substitute would have the same functionality (with no worse side-effects) (the central cell in Table 1).

And third, 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). This allows us to learn from history of climate policy and other policy issues. 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 ones, even if economically costly) might imply greater uncertainty or delay in emissions outcomes, or a different pattern of side-effects with negative consequences for justice. If a focus on nuclear power or CCS deterred renewable energy or behaviour change, this

could redistribute costs – e.g. of waste management - unfairly, or result in higher emissions should the technological promises prove unfulfilled (such concerns with so-called 'false solutions' are widely shared amongst more radical climate NGOs). Arguably, under a broad definition of mitigation (including both emissions reduction and enhancement of sinks), at least some GGR is also a form of mitigation. Nonetheless, the concept of MD remains valid, and – we believe – helpful in understanding the risks and dynamics involved. Here we use the term mitigation as broadly synonymous with emissions reduction, and the more general term 'climate abatement' to include sinks (and GGR) although we recognize that both terms are ambiguous in usage.

The typology set out in Table 1 is an effort to describe outcomes across the two dimensions of possible harm, to highlight the different possible outcomes and the relative desirability of them. The figure shows the dynamic outcomes of the interaction between the two interventions. Even where the new intervention aims to reduce concentrations by the same amount, at a system level there may be other effects which shift outcomes up or down (or indeed left or right) in the table. In general it might be assumed that in considering alternative interventions, policy makers would aim to move to the top left of the diagram. However, there are various pressures that may act (intentionally or emergently) to push outcomes towards the bottom right. Such pressures include desires to minimise financial costs, but also optimism biases which lead to overly positive assessments of the likely impacts of adopting alternatives whose effectiveness (at reducing GHG concentrations) or side-effects are uncertain or unknown and may not be knowable for several decades at least. Here it is important to acknowledge that the expected (or intended), and likely effects of new interventions are not simply objectively predictable, and unintended emergent effects may undermine or even overturn expected outcomes.

The diversity of possible outcomes allows us to conceptualise the existence of a 'hierarchy', not only of different forms of climate response, but also of different forms of mitigation. In encompassing both climate goals and side-effects, the figure reminds us that the effectiveness and desirability of particular policies are conditioned by a range of factors. Waste management suggests an analogue, where the idea of a policy hierarchy as a useful guiding heuristic is more developed. While the weight and relevance of the factors considered remains contestable, there is a broadly accepted preference for waste reuse over recycling, and both are seen as preferable to energy recovery through incineration, which in turn is better than landfilling. This hierarchy reflects factors such as economic benefits, health implications, toxic pollution, waste generation and citizen responsibility, not just the efficiency with which waste is removed and 'disposed of'. For climate actions the hierarchy is less well defined yet few would prefer the development of nuclear power to renewable energy, and fewer still to energy efficiency and demand management, for example. Many argue that to deliver broad sustainability, interventions that trigger behaviour change, especially amongst rich consumers, are preferable to novel technologies eg (Klein 2014).

Of course, such a hierarchy is a heuristic device and does not eliminate political debate and influence. Nonetheless, this analogy with the waste hierarchy suggests a hierarchy could be useful in helping consider how climate policy might mix adaptation, mitigation and GGR options, and in understanding where substitution and deterrence effects between policy options are normatively undesirable. In this context the analogy raises at least three issues. First, that marginal shifts up the hierarchy may not be the optimum response: replacing landfill with incineration is much less environmentally and socially beneficial than introducing recycling, especially if the shift 'locks in' incineration in the form of long-lived industrial scale plant. Second, that hierarchies cannot always simply be applied sequentially in practice. It may appear rational to suggest that the hierarchy directs us to do all the waste reduction possible, then recycle as much of the residue, etc etc. But at any given time the best that can be done practically is to estimate each of these possibilities as part

of a mix, and reshape the system as well as possible toward delivering such an outcome, with simultaneous interventions across the different options. Third, that using such a hierarchy reduces the relative weight put on cost, and helps shape financial incentives, rather than leaving financial measures to determine the hierarchy of treatment options (as arguably occurs in carbon markets). We do not seek to develop a detailed hierarchy here, but rather recognise that such rankings are implicit in policy formulation and selection.

MD from Greenhouse Gas Removal

In this working paper we consider the potential for MD from the category of climate interventions known variously as Carbon Dioxide Removal (CDR), Negative Emission Technologies (NETs), Greenhouse Gas Removal (GGR), or carbon geoengineering. 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 (Royal Society 2009, McLaren 2012, National Academy of Sciences 2015). GGRs 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).

The significance of MD by GGR is well illustrated in the development of climate pathways under the IPCC. In the absence of adequate mitigation, pathway scenarios have incorporated increasing amounts of GGRs (typically in the form of bioenergy with carbon capture and storage, BECCS) thus helping to sustain high-level policy conclusions that climate targets can be met without radical transformations in energy and economic systems (Fuss, Canadell et al. 2014, Anderson 2015). But the delivery of such GGRs is highly uncertain (Larkin, Kuriakose et al. 2017), and provision of information about GGRs such as BECCS appears to reduce public support for mitigation policies (Campbell-Arvai, Hart et al. 2017). It seems therefore that GGRs are likely to trigger MD, in ways similar to those hypothesized for solar geoengineering which has to date been more intensively considered in this respect (Hale 2012, Lin 2013, Reynolds 2014, McLaren 2016). Under the Paris accord, GGR seems 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. It is in this context that we seek to interpret and explain MD.

In the same way that one form of mitigation can deter another in ways that can lead to harm through higher net GHG concentrations or from more serious side effects, so might GGR substitute for, or deter other actions that enhance carbon sinks as well as those that reduce emissions, leading to higher GHG concentrations, or to more serious side effects.[2] For example GGR through BECCS, relying on plantation forestry, might have more harmful side effects on biodiversity or indigenous peoples than forms of habitat protection, or might lead to net increases in GHG concentrations through diversion of captured CO_2 to enhanced oil recovery. More generally, modelling work consistently suggests at least a marginal shift between GGR and emissions reductions, when GGR is included in some form, with significant delays in emissions peaking as a result, eg. (Azar, Lindgren et

[2] Mitigation as defined by the IPCC includes sink enhancement (and thus certain forms of GGR), rather than only constituting emissions reduction. But this does not invalidate a concern about deterrence of preferable forms of mitigation – particularly emissions reductions (or indeed of other desirable practices, such as adaptation). Neither would it help to substitute 'abatement' for mitigation. 'Abatement' is not synonymous with emissions reduction either: one can speak of emissions abatement, or climate abatement, and MAC curves (which include sinks) describe marginal abatement costs. We therefore use the term mitigation to indicate desirable interventions that might be deterred, typically as a shorthand for emissions cuts (and in some cases where it seems particularly significant, we specify 'emissions reduction').

al. 2010, van Vuuren, Deetman et al. 2013), resulting from 'rational' economic substitution of future GGR for some current mitigation.

Our definition of MD does not, however, specify the processes through which other climate interventions may result in a delay or reduction of mitigation. This paper aims to develop an analytical framework through which this can be studied. To do so, we draw on Markusson et al (Markusson, Dahl Gjefsen et al. 2017) to distinguish between three generalised analytical registers. We first argue that the likelihood and potential significance of MD by GGRs has been poorly understood, and probably underestimated, by analysis at purely 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 cultural register itself remains incomplete in its treatment of materialist politics and economics. Therefore, we instead argue for a *cultural political economy* register (Tyfield 2012, Sum and Jessop 2013) in which MD is mediated by material economic interests as well as by the framings and social imaginaries of the cultural register. We thus argue that shifting from the currently dominant realist register, via a cultural one, to a cultural political economy register puts researchers in a better place to analyse processes that might result in MD. We offer some initial suggestions of how researchers might explore MD from a CPE perspective, with particular reference to the practice of *phronesis*, and the development of phronetic forms of knowledge. First, however we revisit the literature on solar geoengineering to set the context for studying MD from GGRs.

Solar Geoengineering as a starting point

If we are to apply lessons from consideration of solar geoengineering, it is important to first consider whether GGRs differ significantly from solar geoengineering. We highlight three commonly suggested differences here (broadly following the learned societies' reviews of CDR technologies ((Royal Society 2009, National Academy of Sciences 2015). (1) GGRs 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, GGRs 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, GGRs could also psychologically enable delay by promising 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 such promises have been mobilised in climate pathways modelling has already helped to sustain inadequate political agreement on mitigation in the past decade (Anderson 2015, Larkin, Kuriakose et al. 2017).

Moreover, cost is also critical to distributional and corrective justice. International climate policy rests on a presumption that the costs of mitigation should primarily be borne by historically high emitting states. This has positive distributional implications in that it reflects ability to pay. It also has positive corrective implications as it imposes higher costs on those more responsible for the problem. Low(er) cost solar geoengineering deployed as a substitute for mitigation would effectively redistribute resources spatially from the global South to the global North. Although – contrary to claims about solar geoengineering - GGRs appear to have higher direct financial costs, the construction of promises of future GGR implies that these costs would be displaced over time from

the present (culpable) generation to future people. Such future people may be the inheritors of the benefits of fossil fuel use, but they would also be the inheritors of more severe climate impacts. Moreover, the indirect costs of GGRs' elevated demands for land for biomass production would appear likely to be concentrated on the global poor (McLaren 2012). In such respects, GGR might be seen as not only a 'spatial fix' for fossil capitalism (Sapinski 2016), but also a 'temporal fix'.

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* GGRs are arguably better substitutes for mitigation, and so might again appear less likely to generate harms as a result of MD. However, removals may be less certain in their climate effects than emissions prevented, because of the risk of leakage from carbon stores, such as through forest wildfires, and are therefore still imperfect substitutes. Moreover, if GGRs were incentivised through carbon markets, they would only be adopted as a formal 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), GGR techniques also involves significant practical uncertainties regarding their socially acceptable and sustainable deliverability at scale (Boysen, Lucht et al. 2017). Moreover, the effects of GGR 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 much smaller than implied by the absolute amounts of carbon removed (Keller, Feng et al. 2014). Such uncertainties cast doubt on the plausibility of reliable and effective future delivery of GGRs, 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 GGR may also threaten harmful MD through similar mechanisms. It is therefore reasonable to take the literature on MD in solar geoengineering as a starting point for discussing MD by GGR. Indeed, efforts to discursively and definitionally separate GGR from solar geoengineering, eg (Heyward 2013, National Academy of Sciences 2015), would appear to downplay the similarities of relevance to MD, and as we shall argue later, may actually represent and bolster – whether deliberately or unintentionally - political or commercial interests in the 'promise' of GGR.

Re-visiting the literature on mitigation deterrence

McLaren (McLaren 2016) distilled from the geoengineering literature two related characteristics of situations where MD can be particularly 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. If a proposed intervention is perceived by those able to implement it as a good substitute for mitigation (eg equally effective in reducing greenhouse gas concentrations, and cheaper, quicker or politically more palatable), it is more likely to be pursued. If the intervention is a good substitute in narrow climate terms it would not impact negatively on greenhouse gas concentrations; although still possibly redistributing social costs and benefits in undesirable ways. On the other hand, with a poor substitute then MD might lead to more severe climate impacts, as well as redistributing costs and benefits.

Secondly and relatedly, MD is more likely to lead to harm with an intervention that responds to narrow climate goals rather than broader or more holistic ones (also making it a poorer substitute). Particular policies for mitigation may be pursued for a range of reasons, beyond reducing the risk of dangerous climate change. They can create new economic opportunities and markets for low-carbon

technologies and practices such as carbon trading, or create jobs through green Keynesianism. Moreover, designers of climate policy typically aim to avoid serious environmental or social side-effects, and international climate policy aspires to redistribution, placing 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. On the other hand, if the climate interventions replaced by NETs are less redistributive than the aspirations, the harm from MD is less. At present there is no governance for NETs that would constrain their deployment towards redistributive effects, and strong *prima facie* reasons to anticipate regressive impacts, for instance as a result of demands for productive land.

In conceptualising MD, the literature on geoengineering (primarily addressing solar geoengineering), has been dominated by contributions from economics, psychology and philosophy. It has mainly adopted the terminology of moral hazard, following (Keith 2000), and offered a range of conceptualizations and analogies. But almost without exception it employs a realist register, tending towards being individualistic (focussed on decisions made by autonomous, atomistic individuals or institutions), managerial (assuming that uncertainty can be known and managed by such individuals or institutions, cf. (Groves 2014), and so outcomes controlled) and economistic (reducing phenomena to financial or market dynamics, aggregated from individual choices, shorn of any power relations).[3] Space limitations preclude more than a brief description of the main themes here (but see (McLaren 2016)).

Economic and individualistic framings predominate. *Insurance* is commonly cited, see for example (Hale 2012, Lin 2013, Reynolds 2014), 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*, eg (Reynolds 2014, Moreno-Cruz 2015). 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 GGRs, eg (Azar, Lindgren et al. 2006, Azar, Lindgren et al. 2010, van Vuuren, Deetman et al. 2013). 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 (Hale 2009, Lin 2013, Morrow 2014, Reynolds 2014, Moreno-Cruz 2015). 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* (Manoussi and Xepapadeas 2013, Manoussi and Xepapadeas 2014) 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 (Kahan, Jenkins-Smith et al. 2013, Lin 2013, Corner and Pidgeon 2014, Morrow 2014, Merk, Pönitzsch et al. 2016). The focus is less economistic, but still predominantly individualistic. Cognitive biases applied to perceptions of geoengineering might imply over-optimism, if geoengineering provides a misplaced sense of control regarding the climate problem (Lin 2013). 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

[3] The moral philosophy literature offers a notable exception to this third characteristic, but rarely escapes the other elements of the realist register.

to mitigation (Kahan, Jenkins-Smith et al. 2013, Lin 2013, Morton 2015). Psychological mechanisms also underlie conceptualisations of deterrence as *risk compensation* (Hale 2012, Morrow 2014, Reynolds 2014). 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* (Hale 2012, Morrow 2014, Baatz 2016). Such 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 (Groves 2014). They highlight possible harms in reduced efficiency, misdirected motivations, and mal-distribution of costs and benefits. However, some philosophical approaches also suggest the possibility of less individualistic forms of deterrence, a critical point, which is also highlighted by (Corner and Pidgeon 2014) in their categorization of moral hazard into individual and collective (social or political) forms. Understanding collective forms would appear critical where there is such limited agency for individuals to understand and act on the risks of climate change and geoengineering.

The realist register has serious analytical limitations. 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. 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 individual's ability to predict (Stirling 2014). 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.

We believe that the pair of situation characteristics (misperceived substitutability and narrow policy goals) distilled by (McLaren 2016) from the solar geoengineering literature transfers well to GGRs. But the way these situation characteristics matter and develop varies depending on the register of our analysis, as explored in the following sections, starting with the default realist register of the existing literature.

A note on technology

In this paper, we have so far talked about technologies, going along – perhaps too far – with the dominating techno-economic framing, but climate policy options are all socio-technical – both apparently technological ones and apparently behaviour-based ones – although the proportion/emphasis varies. Options that can be presented as technologies (in contrast to behavioural change, for example) are arguably more attractive to policy makers (and modellers), since they are (seen as) standardised, more easily quantifiable, scalable etc., as compared to messy, idiosyncratic, bottom up (apparently) social initiatives (Lohmann 2005). Mitigation clearly involves both apparently technological options, e.g. solar power, and apparently social, behavioural ones, say reduced showering frequency. GGRs have typically been described as thoroughly technological in character, and this holds for techniques such as BECCS and direct air capture, but here also it is possible to imagine socially-dominated options, like local experiments in living with climates (Buck 2012, Olson 2012, Martindale 2015). Unfortunately, space limitations preclude any more detailed discussion of the different approaches to GGR and their diverse uncertainties and side-effects.

However, initial public opinion research suggests that the more 'technological' options are more vulnerable to mitigation deterrence (Campbell-Arvai, Hart et al. 2017).

From the realist register to a cultural one

The preceding sections have illustrated the ways in which the literature on GGRs (and other forms of geoengineering), even when identifying a possible mitigation deterrence effect, has been predominantly rooted in a realist register of analysis. Here we seek to shift from the realist to a cultural register.

Figure 1 visually summarises necessary assumptions for the pair of situation characteristics identified above 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 analyst).

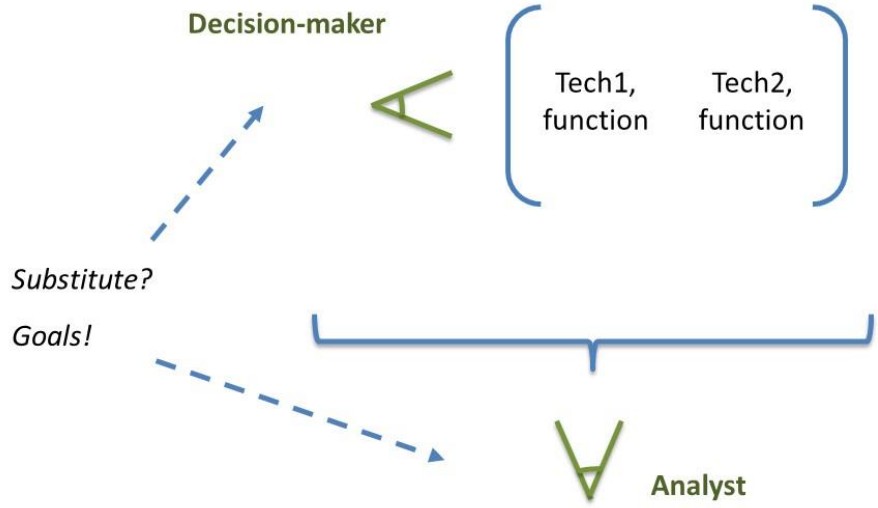

Figure 1 A realist MD model

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. Well-informed (by 'objective' analysts), a climate policy decision maker would – in the face of likely harm from MD – only deploy GGRs as a supplement to 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 (Geden 2016). For climate scientists to inform policy makers that GGRs must be a supplement rather than a substitute for mitigation (a common-place statement in the literature) is therefore unlikely to be sufficient to avoid MD.

Work at the realist register tends to assume a single, universal rationality, and ignore the necessary framing done by experts themselves. These framing choices are inescapably subjective, because

technology substitutability – and so MD risk – 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 (Stirling 2008). 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 recognising and 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.

At the cultural register, we recognise the diversity of rationalities and framings that can exist, and can ask 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) (Groves 2014). This framing foregrounds the physical climate system in formulating the problem and the goals of policy, and privileges technologies as solution options, highlighting their physical effects and costs, as opposed to issues of, say, social justice and power relations (Castree, Adams et al. 2014). The standard 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.

In the dominant social imaginary technologies are typically constructed as stand-alone, isolated tools. How technologies are implicated in social relations and the messy political aspects of society is backgrounded, and so are almost all the relations between technologies. Studies at the cultural register reveal and examine the ways in which technologies are co-produced as socio-technical systems. 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. Insofar as MD arises in misperceived substitutability (given particular climate policy goals), the cultural register enables us to reflect on the processes in which technologies are constructed and framed as being functionally substitutable, and their shares of a deployment portfolio economically optimisable. Not only are single technologies framed, but the relationships between them are framed too. And, again, the cultural register illuminates how MD can take effect in the dominant social imaginary, and helps to remind us that alternative framings of the relationship 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. (These and other contrasts between the registers are summarised later in Table 2)

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 (Jasanoff 2015) or the sociology of expectations (Borup, Brown et al. 2006), (Hansson 2012) 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.

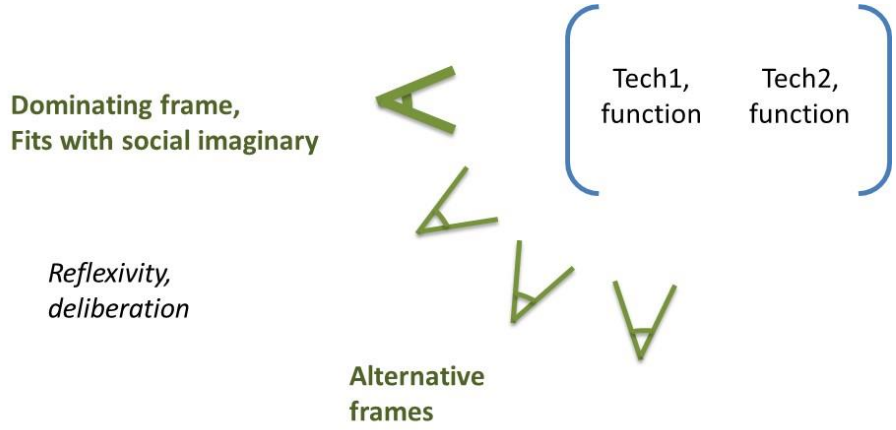

Figure 2 A cultural MD model

Whilst the dominant liberal social imaginary serves to depoliticise climate policy in favour of technocratic responses (McLaren 2016), the cultural register does not fully explain the specifics of how the dominant social imaginary and individual technology promises interact. Which specific technologies get promoted as climate policy options? Under what circumstances do they succeed or fail? What power relations do they enable, and enable them in turn? Moreover, the cultural register does not help us understand the evolution of particular political economy regimes and associated social imaginaries, 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.

And from a cultural to a CPE register

The CPE register transcends the realist-constructivist dualism of the two previous registers, by exploring the necessary conditions of possibility of the forms of knowledge to be deployed by 'decision-makers' regarding socio-technical issues such as GGR (or MD). This move involves, in particular, both attention to the systemic material-cum-ideational contexts or preconditions of such knowledge claims and their deployment, and the constitutive and relational nature of power in these processes. It thus not only understands the evolution of technology as influenced by the dominant social imaginary *and* associated political economic regime, but also understands both of *these* as, likewise, co-produced with technology, especially through iterative cycles of technological 'fixes' for political crises. In other words, we cannot talk of either knowledge, nor technology, abstracted from power; nor, vice versa, of power independent of knowledge or technology (hence described by (Foucault 1981) as power-knowledge). As we consider further below, this raises some fundamental challenges for research, including of MD/GGRs: how can we 'know' and even somehow foresee these dynamic system worlds, and what does 'knowing' mean when the analyst is also *within* those unfolding power/knowledge trajectories?

Previous CPE style analysis of the co-evolution of promises of CCS with the neoliberal political regime (Markusson, Dahl Gjefsen et al. 2017), has already shed some light on a form of MD. Here we use this case as a starting point for a discussion of the CPE register. Note that 'neoliberal' is here understood as a fundamentalist belief in the capacity of markets to solve the problems involved in governing human affairs (Mirowski 2013). Understanding neoliberalism as a hegemonic political (economic) ideology takes us beyond the idea of the social imaginary discussed at the cultural register, recognising the ideology as an explicit part of a political economic regime, co-evolving with a bloc of economic interests, such as oil and gas producers and financial corporations. But it does not collapse us back to a 'realist' interpretation of technologies simply reflecting the demands of political or economic power. It reveals a more complex picture in which the space for explicit and implicit forms of MD is substantial.

(Markusson, Dahl Gjefsen et al. 2017) show how the promise of CCS proved useful to build policy support for a climate policy regime in the mid-2000s that was heavily reliant on market instruments (Narita 2012), crucially emissions trading, thus reinforcing wider neoliberal politics. But, this promise was effective only as long as the technology remained unimplemented, due to the emissions trading system being weak and non-disruptive to fossil-dependent industry (and until the continually deferred promise eventually got worn, and the climate crisis got deeper). That is, CCS worked well as a promise to support the neoliberal regime, but not as implemented practice, which would have required a more interventionist policy. As the CCS promise started to wear thin, fresh justificatory power emerged in promises of GGRs, notably BECCS. The promise of CCS not only helped sustain the dominance of toothless neoliberal climate policy, it helped sustain a political regime that is crucially dependent on fossil fuel use, and which legitimises that use through a promise to govern its ecological and social impacts effectively and non-disruptively through market-based policy instruments.

This dynamic fits our definition of MD. It was a process where a proposed climate intervention (the promise of CCS) appears to have led to an outcome of reduced or delayed mitigation. CCS appeared a better substitute for other forms of mitigation than it has yet proven in practice. This is clearly not a process discernible at the realist register. There is no key actor making that crucial decision, and predicting and controlling its outcome (though the US government had a key role, and likely hoped to minimise economic impacts). Rather, the actions undertaken were aligned with – and co-produced with – a hegemonic belief in market solutions and a standard techno-economic framing. But, crucially, it happened under a neoliberal regime. In a different era, e.g. the socio-liberal post-war era, it may have played out differently, as there was then a widespread belief in the limitations of markets and a corresponding legitimacy for intervention (through regulation, nationalisation etc.). Arguably, CCS would likely be more feasible under a social-liberal political regime, supported by a different dominating political economic constituency, taking a stricter regulatory approach. This shows that we need to discuss the specifics of how technologies (and promises of them) co-evolve with political economic regimes, a process that the cultural register cannot perceive.

At the cultural political economy register, in other words, MD is seen to be mediated, not just by a social imaginary, but by a historically contingent (if perhaps more 'sedimented', whether in terms of manifest and enduring materialities or deeply institutionalized power/knowledge relations) political economic regime, evolving alongside specific political economic positionalities. Deep accelerated mitigation does not just threaten a cultural viewpoint (the techno-economic framing), however well embedded, but also powerful – and specific, historically situated – vested interests. This analysis illustrates how CPE type analysis can help in *identifying* MD effects. Next we turn to the potential of CPE as a new analytical framework for *analysing* them.

The CPE register

Our understanding of contemporary social relations begins from a Marxian analysis of the need for capital to extract surplus value, and of powerful economic actors underpinning dominant political regimes. The ephemeral but rolling maintenance of the conditions for such exploitative profit-gathering takes the form of shifting spatio-temporal fixes (Harvey 2003, Jessop 2004). 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 thoroughly cultural, in that we see dominant political regimes acting through and being supported by shared yet potentially (un)contested social imaginaries, at times even constructing forms of hegemony. 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 profit. Science opens up new capitalist frontiers, acting to enclose new spaces as spatio-temporal fixes for a capital that recurrently requires new avenues for profit. Science also produces promises of technical fixes to collectively recognised problems, e.g. climate change. Spatio-temporal fixes can in this sense also be defensive fixes, primarily preserving existing investments, rather than opening up new lines of profitable enterprise (Markusson, Dahl Gjefsen et al. 2017). GGR might constitute a spatio-temporal fix as a means by which carbon can be commodified and a new industrial sector stimulated to manufacture equipment for carbon capture (ideas that form part of contemporary discourses of ecological modernisation (McLaren 2016)). But it might also act as a fix in the form of a promise which allows fossil fuel use to continue on the basis that the carbon can be recovered from the atmosphere later.

As at the cultural register, for CPE *technological promises* (Borup, Brown et al. 2006, Hansson 2012) circulate as representations and perceptions of possible futures. Technological promises also become embedded in material practices and hence can, in turn, significantly condition ongoing political economic activity. In the case of GGRs, this includes pathway modelling, as well as technology development practices. The promises 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 promises 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. Rather CPE accommodates and motivates analysis at multiple 'sociological scales', thus 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). For example, although far from hegemonic, political ideas of a green industrial economy, with a price on carbon, appear to be co-evolving with GGR research (McLaren 2016). In other words at the CPE register, technology is understood as a 'politico-technical' phenomenon

(Eveland 2016), in which the political economy is co-constructed alongside the material technology. 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. Thus in the CPE model both MD, and interventions to avert it or ameliorate its effects – and, indeed, even interventions in GGR deployment that might enable *positive* synergies (see table 1 above) are conceivable. The three registers thus map onto table 1 in different ways. The realist register sees primarily the predicted outcomes, and therefore perhaps tends to expect outcomes towards the upper left. The cultural register sees the possibility of alternative framings, and a full range of outcomes (intended or emergent) across the table. And the CPE register sees also the co-produced regime interests alongside the framings, and (in the current situation) expects outcomes pushed towards the bottom right, while simultaneously revealing new targets and opportunites for reflexive interventions trying to redirect outcomes back to the upper left.

The CPE-MD model

MD is, at the CPE register, an outcome of the co-evolution of multiple technologies (as promises and perhaps also as development and deployment) with political economic 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 material interests, albeit dynamic ones. 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 GGRs, and who from mitigation, and how those things are related. This can be from GGRs opening up new investment opportunities, or from constituting defensive fixes to sustain the value of fossil fuel-dependent assets (Mitchell 2011, Malm 2015, Markusson, Dahl Gjefsen et al. 2017). Whether GGRs are perceived as complementary with or substitutable for mitigation may matter, but also whether they simultaneously can materially support the political regime or not. Finally, here it is also recognised that although a range of viewpoints exist (as revealed at the cultural register), they are all to some extent embedded *within* the hegemonic political regime. Thus, to some extent the viewpoint of any given observer can be conditioned or shaped by the regime, and CPE analyses not only the diversity of viewpoints but the ways they are conditioned and (potentially) privileged. For instance, debates over how diverse identities may be morally recognised, expressed and empowered within a political system (Ingram 2006, McNay 2008, McLaren 2017) are helpfully illuminated at this register.

Figure 3 gives a visual summary of MD at the CPE register.

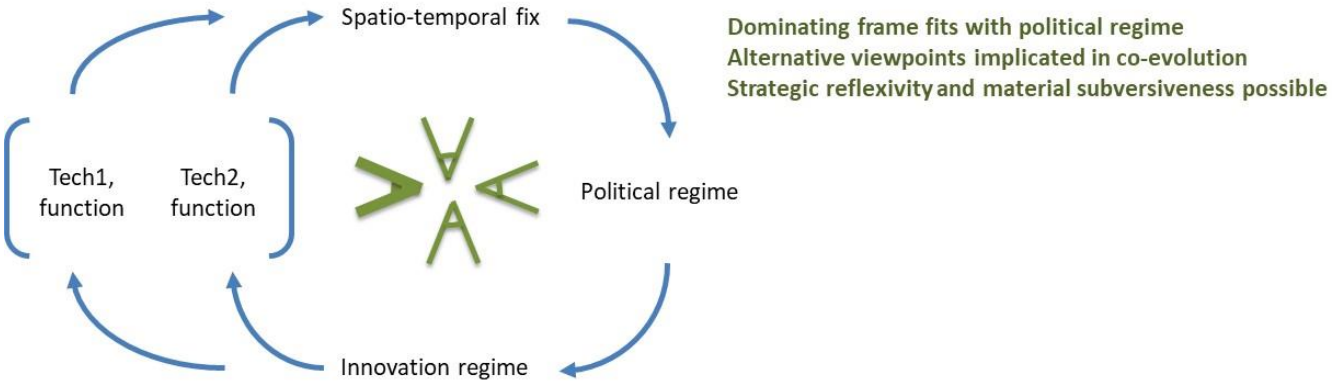

Figure 3 The CPE-MD model

The table below summarises the contrasts between the three registers.

Table 2: The three registers

Register	Conception of technology	Key component	Rationality	Understanding of risk	Ontology	Prescriptions
Realist	Techno-economic	Individuals (single or aggregated)	Objective, or boundedly rational	Managerial, quantifiable	Realist	Improved knowledge
Cultural	Socio-technical	Social imaginary, frames	Multiple rationalities, interactive	Multiple forms of uncertainty & unknowability	Constructivist	Opening up perspectives and framings
CPE	Politico-technical	Political regime (economic blocs and hegemony)	Multiple rationalities, strategic	Uncertainties as powerful agents, (potentially constructed).	Relational Marxian	Situated capacities / practical wisdom

Mitigation deterrence is an inherently uncertain phenomenon, arising in situated fashion as a result of diverse possible mechanisms. It is therefore important to elaborate on the ways in which the different registers treat risk and uncertainty if we are to understand what the 'risk of MD' might mean, and why the prescriptions to overcome MD vary depending on the register of analysis.

In work at the realist register risk is rarely explicitly defined, but portrayed as a probabilistic, quantifiable and manageable phenomenon. Research is often justified as helping reduce risks by increasing knowledge. In the cultural register this is understood as only one construction of risk, and indeed one that perhaps increases the likelihood of unexpected outcomes, by failing to distinguish quantifiable risk from unquantifiable uncertainties or unknowable states of ignorance (Funtowicz and Ravetz 1993, Stirling 2007). At the cultural register much human activity can be understood as a means of trying to reduce or domesticate uncertainty about the future and the ways this action reflects specific frames and imaginaries can be revealed (Groves 2014). At the CPE register, uncertainties retain these multiple forms, but are also understood both as emergent framings and potentially actively manufactured or coopted by interests in the regime, and moreover constituting powerful agents in themselves, shaping human activities and co-producing political regimes.

Neoliberalism typically co-constructs uncertainties in ways that enable them to be commodified (through investment risk management), and this has extended to carbon markets (Lohmann 2012). But uncertainty can be mobilised in other ways too. Climate denialism is an example of how uncertainties are converted into political agents sustaining market freedoms in a neoliberal political regime underpinned by fossil energy (Oreskes and Conway 2010, Malm 2016). The next section explores more fully how MD might emerge in the neoliberal regime.

MD in the neoliberal political economy

MD is not a product of only one particular political regime, but can be expected to emerge in specific ways in different regimes. How might MD therefore happen under the existing, specifically *neoliberal,* political economy regime? Note that 'neoliberal' is here understood as an ideological belief in the unlimited capacity of markets to solve the problems involved in governing human affairs (albeit an ideological belief which is combined with an apparently contradictory but pragmatic level of control exerted by a strong, and militarised state) (Mirowski 2013). 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 an explicit 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 (Mitchell 2011). In this context, GGR investments provide a promise of cleaning up society without the need for major change to how we energise it. And in analogy with CCS, this promise 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 (Markusson, Dahl Gjefsen et al. 2017). There is alternatively scope for GGRs 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 (Endres, Cozen et al. 2016) or diverted from storage into carbon utilisation in synthetic fuels, plastics or building materials. In either case, on balance less carbon is permanently withdrawn from the atmosphere. Moreover, if GGRs are to function as a 'promise' in this context, it is also clearly in the interests of the regime that they are definitionally separated from solar geoengineering, and the risks (including MD) that the latter is 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. (Lohmann 2005). Poor substitutability between GGRs and mitigation would thus tend to be obscured under a regime favouring market solutions, and so lead to risks of MD. Technology fungibility, in turn, is easier to construct if policy goals (against which technologies are assessed) are kept narrow. Promises of fungible technological solutions thus, in turn, help sustain a neoliberal political regime, with its hegemonic belief in markets. Both in respect of the framing of climate policy goals and interventions to meet them, the CPE framework suggests ways in which the neoliberal political hegemony might stimulate MD.

As noted above GGR also offers a fix for neoliberal capitalism in the creation of new industries and new domains for profit. Through this lens it is perhaps unsurprising that leading capitalist

entrepreneurs have established initiatives such as the Virgin Earth Challenge (a prize for a scaleable, sustainable and commercial carbon removal technique) and the Carbon Utilisation X-Prize (Virgin , X-Prize). Nor is it surprising that such initiatives have been slow to come to fruition as the sector requires not only technological innovation, but developments in carbon accounting, system modelling and governance that could establish profitable markets for such new technologies. Such initiatives nonetheless exemplify the ways in which neoliberalism presents technocratic, administrative, depoliticised capitalism as a (the) solution to problems such as climate change, yet simultaneously positions a market ideology alongside strong pragmatic state intervention (a model perhaps most clearly seen in military procurement, in which economically unproductive technologies are converted into highly profitable business). Such approaches risk MD in the ways that carbon is repositioned as a 'resource' for utilisation (in plastics, chemicals, building materials, synthetic fuels and more) (Elkington 2017, Holmes 2017, Eisenberger Undated) In comparison to geological storage, such uses would result in relatively short-term retention of carbon before its return to the atmosphere. The promise of carbon removal is transmuted into (at best) a direct substitute for mitigation rather than a supplement. They also constitute a mechanism for economic rebound from the development of GGRs, a second form of MD, as - in a still far from decarbonised economy – this makes the problem of greenhouse gas emissions harder to deal with, rather than easier. A third way in which GGRs risk MD in the neoliberal regime is through systematically over-inflated promises which are incentivised in early stage innovation where venture capital demands high projected profitability and an early 'exit strategy' (ideally through a stock market flotation). For GGR this could incentivise exaggerated claims about the scale, rate and cost of removal, raising the likelihood that reductions to mitigation resulting from such promises of GGR will be greater than the future amounts actually removed.

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 (Lohmann 2005, Lohmann 2012, Narita 2012). Keen entrepreneurs have started selling offsetting services ahead of such systems, potentially prompting their development.[4] 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 (Factor 2015). 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 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 and promise new financial instruments and derivatives. 'Realist' climate science has supported such a framing in part from a fear that the alternative empowers political climate denialism. A CPE approach enables this framing to be contested, while simultaneously exposing and challenging the hand of denialism in the neoliberal political regime.

In the neoliberal regime a further possible source of MD arises in the attitudes of the system to risk, particularly with respect to uncertainty about the future. Neoliberalism tries to tame such uncertainty in two distinctive ways. First it seeks to reduce it to quantifiable risk and commodify it.

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

This is a mechanism (highly simplified) that has contributed to problems like financial bubbles and crashes, exacerbated by the incentives on actors to displace risk onto others, in which a classic 'moral hazard' parallel to MD can be seen. Second it seeks to discursively make risk normal and even desirable ('we have to be risk-takers'), but tends to do so in ways that impose that rhetoric on the precarious and vulnerable, rather than the well-off. The result here parallels our earlier discussion (figure 1) of the ways in which harms might arise from MD, through a new distribution of side-effects.

Before moving on to the methodological implications of a CPE approach, we need to deal with one possible objection to our approach, that in highlighting the role of the political regime or system it might appear to be 'moving the goalposts', and shifting focus away from climate change. 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' (Keith 2013). 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 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. A CPE perspective, however, actually affords analysis that remains fundamentally aware of the inter-relations between socio-technical change (such as development of GGRs) and political economic regimes *without* collapsing the former onto the latter or, therefore, arguing (explicitly or implicitly) that 'better' GGRs can only be developed when the problem of neo-liberal capitalism are 'resolved'. Instead, GGRs are illuminated in their broader, but irreducible, systemic context so that they can be considered with optimal strategic insight. In the next section we turn to the practical challenges of such research, acknowledging that, as researchers, we are inevitably embedded within the regime/imaginary.

Implications of CPE for methodology, epistemology and ontology

The foregoing has argued for a shift in register to permit us to observe and identify a broader range of potential sources of MD. In this section we discuss how one might *study and evaluate* MD from a CPE perspective.

Above we introduced key elements of this perspective, in terms of the substantive issues and concepts of CPE vis-à-vis a dominant individualist/ realist/ managerialist perspective and a subordinate but still familiar (or dominant in much academic literature) 'cultural'/ constructivist/ narrative approach.

When we turn to the key issue of *how* to do CPE analysis, however, the most important aspect, and our starting place, concerns the situation and relation of the researcher to the issue of study. This is intimated above (see diagrams), in that we are ourselves, from a CPE perspective, always and irreducibly *within* the system we are studying and hence, at least in part, productive and constitutive of it – both before, during and following the research itself – as are those agents whom we observe, question and work with in the research process. It may seem clear that this entails asking a different set of substantive questions in our (predominately qualitative) research, and probably applying different methodologies too. Indeed it does. But to start here is still to feed the misapprehension that a CPE approach simply implies the addition of a further level of substantive considerations to a

research process that is largely unchanged. While we must, of course, return to the issues of substantive questions, methodologies and specific methods, then, to explore the issue of how to do CPE analysis, but diving straight into these issues is both too incremental and piecemeal, and, as such, likely to reflect and cement an incomplete understanding of the CPE approach.

Instead, we must start by reckoning with a deeper challenge from the CPE admission that we are always within our field or issue or system of study; namely that this also entails a changed *goal* of research, which then feeds back to resituate and illuminate further the methodological and substantive theoretical questions in turn. In short, before we can turn to the latter questions, we must first take a *qualitative* step so as actually to inhabit an entirely different and transformed positioning, implicit in the CPE approach. This amounts to a paradigm shift, a turnabout in fundamental orientation, regarding issues of epistemology – but also ethics and ontology; that is, the full gamut of philosophical commitments underpinning research. This shift in perspective may be summarized under the label of 'phronesis', or situated practical wisdom. In what follows in the next section, however, we flag in advance that we will seemingly depart quite considerably from the matter at hand – namely MD and how to study it. But this is not in fact the case. To the contrary, we argue that what follows constitutes a reorientation in our relations to knowledge that is absolutely crucial for a productive engagement with the complex, uncertain and yet hugely consequential issues of GGRs and MD.

Phronesis was long ago identified by Aristotle as the third and fundamental form of knowledge, underlying and presupposed by *techne* and *episteme*. It transcends and underpins 'pure' knowledge as end-in-itself (episteme) and 'applied' knowledge as means (techne) and conceives of knowledge as inherently relational and processual. Yet it has been systematically neglected, if not denigrated, since the dawn of modern Western thought as part of the broader rejection of Aristotelianism, identified with Scholasticism. More recently however, phronesis has returned to the scene amidst growing intellectual (and practical) dissatisfaction with (post-)Enlightenment binary thought. But it is also now given a post-critical (i.e. post-Kantian) twist in the work of Flyvbjerg (Flyvbjerg, Landmann et al. 2013), following Foucault. This adds a power-awareness to the 'situated practical' aspects of phronesis, consisting of three overlapping points:

- that knowledge practices are not only always irreducibly situated but also practices of strategic manoeuvring, conditioned by and transforming (differential) positions of enablement, empowerment and constraint, hence always practices of *power/knowledge*, where neither side of this duality may be reduced into the other nor entirely separated from it;
- that the 'power' implicit in this acknowledgement and formulation of power as conjoined twin of knowledge can be productive, relational, dispersed, strategic/tactical, normatively ambiguous, not – as is generally understood - coercive, possessed, unitary, definitive and presumptively bad (respectively); and
- that power/knowledge is thus *constitutive* of dynamic strategic relational systems, including the very individual subjectivities that deploy and develop 'knowledge'.

Phronesis thus works from these fundamental redefinitions of knowledge, as an ongoing practice of knowledge making that is not only irreducibly situated, relational and practical, working with the concrete complexity of actual issues as they present themselves and learning therefrom; but also one that self-consciously acknowledges this process to be constituted as and concerned with (the illumination of) changing systems of power/knowledge relations and technologies. Most fundamentally, however, this *systems* perspective and the situatedness of knowledge inescapably *within* it, ineluctably challenges and transforms our very concept of 'means' and 'ends' (including of

knowledge) itself. Instead of this binary common-sense, therefore, and other cognate fundamental dualisms – such as fact-value, truth-power, object-subject etc… – that frame our understanding of research as knowledge production, a phronetic approach is framed in terms of a rolling, engaged *practice* and deepening *capacity* for skilful judgement respectively, where these are simply different and inter-related moments or aspects of the one, single process.

Phronesis is thus an epistemic paradigm shift. Its aim is not improved, objective and authoritative 'knowledge' (the goal of science at the 'realist register), *then* supposedly to be used by enlightened policy, which presumes an impossible, and thence politically culpable, observational outsiderness. Nor is it the maximal airing of diverse voices towards a hoped-for 'legitimate' consensus, which presumes an implausible abstraction and seclusion of such participatory research processes from materialised, institutionalized and constitutive power/knowledge relations. The former keeps 'knowledge' and 'power' too separate, reducing knowledge to 'means'; the latter elevates knowledge to end(-in-itself) somehow 'speaking truth to power' through deliberative openness (yet effectively collapsing knowledge and power into each other, and failing to reassess power and how knowledge engages with, and co-produces it). Instead, the 'goal' of phronetic research is to be a *practice* that itself cultivates an ever-deepen*ing capacity* for skilful judgement in the world, including the skilful deployment of familiar power/knowledge technologies of *episteme* and *techne* alike. It thus transcends the means-end binary, with an understanding of their co-evolution.

Simultaneously phronesis implies an ethical shift, as a *virtue practice*, again going beyond and subsuming the familiar choice between deontology and consequentialism that precisely maps onto the means-end binary.[5] As a virtue practice it acknowledges ethics as situated and constructed, yet provides tools to help us decide which ethical framework(s) are appropriate in which circumstances. And, finally, phronesis is an ontological turn, away from a world of 'free' subjective agents amidst fixed, given objects (or 'free' cultural agents capable of collective voluntarism in shaping *future* cultures), to one of constitutively relational and strategic systems of inter-active 'selves' and 'things', humans and non-humans. Needless to say, this approach is also, therefore, intrinsically better attuned to working with complex socio-technical systems and their open, uncertain evolution – as in the case of anthropogenic climate change, GGRs and (possibly) MD.

The aspiration, if not 'goal', of phronetic aspiration is thus simply to be an *enlightening moment*, in an ongoing, never-ending and constantly diversely-contested process through which dynamically

[5] Indeed, as such, phronesis productively resituates both consequentialism and deontological ethics. The former is reframed in acknowledgement not only of a more complex, processual ontology of cause/effect, but also one in which ethical action is *itself always already* a factor. Against utilitarianism, say, ethics cannot thus be identified as that which is identified at/as the *conclusion* of a consequentialist analysis conducted purely in terms of what 'will' be the case – i.e. an approach that precisely tends to the simplistic causal ontologies of the first issue. Meanwhile, deontology is resituated in that, vice versa, there never is a purely (hence complete, static, permanent) 'ethical' moment that can be meaningfully abstracted from the open, uncertain process of ethical development of actual, imperfect, vulnerable and interdependent beings – or the situated, complex and specific concreteness of actuality, where ethical decisions must actually be made. As such the ethical predicament is simply misdescribed by deontological approaches: not to be 'resolved' in *knowing* what one *has* to do (and self-willing it) but 'lived through' and 'learnt from' in actually *doing* it, attending to where a particular course of action may lead, and (not just or primarily) in terms of 'effects' but in terms of ethical e-ducation (or 'leading out'), of oneself and interdependent others. In other words, the ethical question is, "who and what world is processually cultivated by a particular course of action?" This approach is also thus particularly germane to issues of MD, not least because it opens up the possibility of understanding what may be *intrinsically* disastrous *consequences* (re deontology and consequentialism respectively) of purely consequentialist or deontological approaches alike to complex, wicked problems, especially when writ large at the level of planetary environment.

constituted systems of power/knowledge relations and technologies are constantly being reproduced and transformed; and for as many and diverse participants and stakeholders in the issue at hand as possible, *including* the researcher herself. By 'moment' we do not mean a single 'once and for all' event, but a productive, even *momentous*, interruption of reflective and reflexive discontinuity – a practice of collective social mindfulness. Moreover, no pretence is any longer maintained here that the knowledge thereby produced is *a*political or politically neutral or abstracted from political/power/strategic effect. To the contrary, the knowledge produced is 'enlightening' precisely to the extent that it is enlightening *of* strategic and ethical action (i.e. in the world, *after* the research) for as many as possible of the diverse stakeholders and engaged participants of the research. Hence these participants are themselves conceived by the phronetic research methodology as strategic, ethical situated agents (albeit always imperfectly so, on both counts) and are encouraged, as a key element and product of the research, to see *themselves* as such. In contrast to work at the cultural register, which might reveal and provide some form of voice to excluded or disempowered groups, phronesis seeks to strategically and relationally empower such groups to act for themselves.

In short, therefore, by admitting the inseparably twinned yet irreducible distinctness of power/knowledge, not only the researched but also the researcher (and indeed the subsequent users of the research) must not only be explicitly brought into the self-conception of the research process, and recognized as productive, creative actors within the 'real world' problem field under investigation; but then, as such, each of these *themselves* must also be explicitly conceptualized as the products and outputs of the research – perhaps even the *primary* ones. Yet, of course, for this to be plausible, we must in turn admit that the 'research' itself cannot ever claim authoritative and sole authorship of the 'research outputs'. They are a co-production of actor and output. At best, the research has merely shaped, redirected and illuminated such 'actor/outputs' *for themselves* through exertion of their own creativity and reflectiveness. Explicitly *populating* research, and acknowledging the dynamic, contested power/knowledge relations amongst and constitutive of them, we can also now conceive of a research process that changes *us*, not just our 'knowledge' of given, fixed 'facts' while also presuming 'we' are thereby *unchanged* – and yet, somehow, the uncertain, as-yet-unformed future world is/can be changed and improved around us!

Doing phronetic research thus starts with the (grounded, evidenced) presumption that, on the one hand, both researcher and researched human agents have an educated, if still developing, embodied sensibility and capacity for skilful judgement that can be, and must be, improved; and, on the other, that the issues at hand are simply too complex, specific, uncertain and open to be informatively 'captured' in tidy, abstractly expressible (let alone universalizable) lessons that enable the identification and thence execution of 'correct' ways forward. Nonetheless a phronetic research process can aspire to identify and possibly execute 'better' ways forward, acknowledging the inevitable gap between intention and action. Like 'non-ideal ethics', the best is not allowed to be the enemy of the good, and moreover, the prospect of continued improvement (and system-self evolution) is opened up. A helpful example might be seen in the practice of care ethics: as described by scholars such as Held and Tronto (Tronto 1993, Held 2006) care is intensely relational and situated, yet it doesn't preclude other ethical guidance nor collapse into relativism, rather it frames how and when other ethical guidance should be applied.

To reiterate, then, the aspiration of phronetic research is to assist in the construction of skilled (i.e. ethical and strategic) *human agents* who are now *better capable* – given the research, its outputs and its process – to govern and constitute the issue at hand, in an ongoing process that works ever more skilfully with the relentless uncertainty, contingency, complexity, contestedness and dynamism

of these complex, relational systems. In short, precisely to cultivate phronetic citizens, experts and decision-makers and, thence, phronetic societies.

Firmly situated, thus, in this qualitatively different understanding of the role and nature of research itself, we may now return to the core issue at hand of CPE methodology, both in itself and specifically regarding analysis of MD. The key issue here is not only 'how to investigate MD from a CPE perspective', but also, more specifically, 'how informatively to investigate possible MD *futures*… and what role does CPE play in this process?'

CPE highlights how the complex 'social' issues of research such as this, including on issues of technoscience and socio-natural relations, entail a comprehensive 'trans'-disciplinary approach regarding complex systems. Moreover 'cultural political economy' itself is given a deeper and richer valence regarding its *practice*, in terms of (i) the essential *creativity* it aims to bring to bear – hence precisely a *cultural*, cultur*ating* and cult*ivating* activity[6] – and (ii) in connection with the irreducibly situated strategic, power/knowledge-attentive 'home'-making it enacts – i.e. precisely a productive, constitutive *doing*, not just the study, of *political œco-nomy*. Hence, to be more concrete still, a phronetic CPE approach regarding MD would explore and develop scenarios in which trajectories of the co-produced development of dominant political economic regimes and GGR have co-evolved, starting *from* the neoliberal present. In other words, the question for these scenarios becomes "what future dominant CPE regimes could co-evolve with GGR, leading to what possible forms of MD in each case?"

Phronetic research and deliberation

This section does not seek to set out a fully developed methodology or research plan. Rather it outlines initial thinking on how deliberative research can incorporate a CPE approach, and reflect the understanding of different registers discussed in this working paper.

Deliberative forms of participation can be deployed at any register. Researchers might use focus groups to identify and assess the strength of public concerns regarding a technology (treated as an objective given). These could include concerns about the ways in which the technology might be co-opted by, and certainly shaped by, existing powerful interests. Alternatively researchers might use deliberative techniques to intentionally open up discussion of alternative constructions of the technology. All these purposes are valid, and with a CPE perspective, they might be supplemented by deliberate discussion of the ways in which the technologies might reconstruct political regimes and social imaginaries. But in a phronetically-inspired focus group, expectations and intentions would also extend to the ways in which the process could re-construct opinions, values and practices of both the participants and the researchers involved. In this respect our proposed deliberations reflect a co-productionist approach (Chilvers and Kearnes 2016) in which publics are understood to be mediated and emergent, part of and engaged in diverse socio-material collectives, and participation is constitutive of science and democracy, involving processes of contestation and negotiation that are 'collective experimental practices in the making'.

Such groups might differ from established forms in several respects, not simply in respect of the questions posed and topics discussed (digging in to the power/knowledges involved) but most importantly also in the forms of subjectivity constructed and the sorts of outputs generated. Our aim is to enable politically empowered, strategically acting, citizens who generate practical, situated plans of action. We also anticipate differences therefore in terms of who might participate; how participants would be selected and prepared; what sort of materials and introductions might be

[6] A process that helps participants become more 'cultured', in terms of being more skilful and ethical, and more aware of how their society works.

provided; how the roles of facilitators, participants and others (eg issue experts) would be defined; how proceedings and other outputs might be captured and analysed; and what feedback might be sought from, and follow-up provided to, participants. This section outlines our proposals for deliberative workshops and describes how such events might differ from conventional focus groups, citizen's juries and scenario workshops, even though our methodology draws aspects and learning from all three.

In contrast to a realist register 'focus group' in which the facilitator avoids both contestation and consensus, constituting the participants as independent individuals whose views and opinions are all equally valid (Soneryd and Szerszynski Undated); a phronetic deliberative workshop would encourage disagreement, debate and the emergence of areas of agreement and consensus, treating participants as a potential collective, as strategic, relational and reasoning beings, rather than the idealised autonomous consuming individuals of the (neo)liberal social imaginary, where the mode of deliberation constructs a liberal consumer subjectivity for participants. Moreover, in contrast to the selection of a 'representative group' either through selection of participants with a shared characteristic, or more abstractly as a cross-section of the population, which process enables the convenors of a realist focus group to assert that the findings represent public opinion (or that of a subsection of it); the selection of participants for a phronetic deliberative workshop intentionally brings together diversity and a mix of relevant power/knowledges to enable generative debate.

Nor would a phronetic deliberative group closely resemble a citizen's jury. In the latter model of deliberation, although selected to be diversely representative of the general public, participants are expected to set aside their situated life experiences, their strategic reasoning, and don a cloak of objective impartial evaluation of the evidence presented to them by selected expert witnesses. In other words the model constructs a liberal *political or citizen* subjectivity for participants (Soneryd and Szerszynski Undated). The processes of questioning and dialogue between jurors and witnesses, and subsequently between jurors might be similar in practice to those in a phronetic group, but distinguished by the artificial separation of experts and public, and by the demands of objective evaluation. In a phronetic group, expert and lay participants will be mixed, and their power/knowledges enabled and challenged and in both collaboration and contestation.

Our proposed approach more closely resembles the scenario or futures workshop. In this model diverse members of the public as convened to discuss scenarios or pathways to alternate futures, bringing their situated and distintctive power/knowledges to the table, with the aim of constructing an action plan. However, Soneryd and Szerszynski (Undated) note that in many instances such workshops further adopt a liberal model of 'consensus achievable through public reasoning'. They, and we, believe that such a consensus model demands an unrealistic approach to difference, and that a genuinely political deliberative setting would not demand consensus (but debate and negotiation based in understanding and recognition of difference). Our groups would use similar techniques, but deployed to enable political deliberation over the public good in the issue at hand, support the groups to construct their own collective identities, and suggest their own future plans and interventions. Moreover they would be embedded in a model which seeks to support and enable continuing strategic action by participants.

In keeping with the 'non-ideal' understanding of phronesis, decisions on participants, mechanisms and facilitation would also be influenced by practical circumstances. A diversity of participants would be essential. Diverse participants would be expected to bring their diverse identities and life experiences into the discussion. In the same way as women-only groups often reveal different perspectives (Burgess, Stirling et al. 2007), it may prove helpful to separate experts from ordinary 'citizens' and seek to facilitate reflections by the latter on the opinions and interests of the former,

before (re)combining the groups. More generally, the participant selection should not simply target those with the power and capacity to reshape a discourse, but also those unheard or unempowered voices that could disrupt a discourse, and would bring practical experience of inequality and exclusion into the room. Here, ideally, we would seek to recognize currently unheard groups, and enable their voices to be heard in ways that help identify, acknowledge and transform existing regimes and power relations (Ingram 2006, McLaren 2017). Yet we will still have to start with the willing, those already engaged with the topic to at least a basic degree, and if possible, those with existing capacity or agency to be influential in redefining or reframing the concerns to hand.

Our design for deliberative workshops would use the ideas of the CPE register to move a conversation on, stepwise, from a realist register discussing (for example) potential 'failures' of GGRs, to discuss the political economy of the topic, and the cultural/constructivist imaginaries and framings, before bringing these together in a CPE approach. We plan to use scenarios (as in scenarios/futures workshops) of future development of specific GGR technologies, with illustrative developments based on learning from analogues elsewhere in climate and other policy areas where interventions appear to have worsened the problems they were intended to solve. These will be sketched out as stimulus for participants, perhaps in a multi-stage process with a series of 'future news items', sequentially shifting the register of analysis. Ideally, these scenarios will include both institutional/structural and personalized illustrations of the changes and processes involved, and will illustrate possible synergies as well as deterrence effects.

The scenarios only need to be 'plausible' (not 'probable' or 'preferable') (Wilkinson, Kupers et al. 2013), to enable debate, reflection and possibly policy formulation. In the deliberative events, they will be evaluated by participants, and used as a springboard for creative discussion of the ways in which MD might arise, and of interventions that could reduce the risks of MD, and maximise synergies (including but not limited to risks and synergies suggested in the scenarios). The stimulus scenarios will be themselves developed phronetically by the research team with reference to project advisors, and utilising inputs from interviews with relevant experts and stakeholders on the GGR technologies involved, and on the analogous cases as well as material sourced from literature review of analogues and possible mechanisms that illuminate the power/knowledge dynamics involved. This "testing" stage with a sub-set of stakeholders would ensure practical relevance, and accuracy/coherence regarding current developments in knowledge and policy. In this respect the research team brings to the scenario development process an alertness to issues of the dynamic coproduction of regimes and technoscientific interventions/ innovations/ attempted 'fixes.' Hence the scenarios will seek to imaginatively and iteratively trace potential, 'plausible' trajectories around the 'cycle' of coproduction of technology and regime; and to use such coproduction as a productive 'disciplining' framework to imagine how GGR could develop (beyond the extrapolation of potentially superficial current headline trends. They will provide a foundation (yet with openness and flexibility) for participants to explore the future worlds that might be co-produced by GGR, and to deliberate on the dominant imaginaries of key actors and how those in turn might co-evolve with the promises and materialities of GGR, following Macnagten and Szerszynski (2013).

To help move discussions to a CPE register, recognising the potential for deliberative processes to construct, constitute, re-construct, and re-constitute publics and interests around particular technologies (Chilvers and Kearnes 2016, Bellamy and Lezaun 2017), and for participation itself to be co-constructed in multiple sites (Chilvers and Longhurst 2016) our groups will be challenged to reflect on the implications of our research process in assembling such an interest group.[7] In other

[7] Of course, deliberative processes are only one way in which interests might emerge, and groups constituted in this way may have limited agency to further influence discourses and material outcomes.

words participants will be asked to use their personal circumstances to reflect on the extent to which framing matters and how it relates to publics and interests. They will also be stimulated to use that as a platform to consider what other framing processes, and interventions (such as national and international policy processes, professional associations' and learned societies' engagements, innovation prizes etc) act to constitute and legitimise technologies and publics/interests around them, and how these processes might be differently constructed to minimise risks of MD. This should enrich discussions of the likelihood and potential causes of MD, in the light of the development of socio-technical and politico-technical systems around co-produced GGR technologies.

In contrast with most deliberative processes, our sessions will aim less at constructing an abstract objectivity, but rather will seek to surface the interests and differences in knowledge and framing that are at play in the group, and explore how these arise as a result of cultural, political and economic factors, including identity factors such as gender, (and what interests or contexts are missing from the group). In the sessions we will seek to reveal and unsettle established relationships of power and authority (perhaps with an icebreaker exercise designed to reveal existing interests and values), and the expose preconceptions that participants might be bringing to the topic. We seek to generate reflexivity and humility amongst participants, expert and lay alike. In this context the roles that facilitators take will also be distinctive. While they will be asked to provide a neutral stance, they will also be briefed to conduct probing questioning to surface values, interests, viewpoints and preconceptions.

While the primary use of the scenarios will be to inform the focus group discussions we also anticipate using those discussions as inputs for further iterative updating and amendment of the scenarios, enabling them to be published for broader public / policy maker audiences and *their* phronetic 'education' on this particular issue. In addition, to inform these subsequent phases, we will deploy follow up interviews seeking to investigate how opinions and responses have developed with exposure to different framings and participants. Critically, we will ask: what are you going to do next/differently, and for researchers, has it/how has it changed the ways you conceive and conduct your research; and has it/ how has it changed how you plan to communicate your research? We would use standard feedback forms for all participants, and select a subset for interview, including some who did not complete the forms. Such interviews would serve the dual purpose of discussing and reflecting on possible responses to MD, and of stimulating further action by participants.

This subsection has set out several suggestions for a phronetic approach to deliberation. Taken together these definitively enable a step beyond the limited mindset of rationally 'controlling' and 'engineering' both the planetary atmosphere and, with it, socio-technical change. As we have argued above, this rational 'realist' perspective is not only the one within which most GGR research and development is being pursued, but also that that from which the risks of MD are in fact *most likely* to arise. Escaping this perspective, and illuminating it might be achieved from a constructivist analysis and in deliberation that reframes the issue, but to generate more productive responses to, and more skilful government of, GGR (and other complex technoscientific interventions), we argue that the CPE approach is essential.

Conclusions

We have here set out a new analytical framework based on cultural political economy that promises to offer a new perspective on MD effects. The framework offers a distinct alternative to the realist

register that dominates the literature, and promises to add sensitivity to both epistemic pluralism and historically contingent societal power relations.

We have elaborated three registers on which processes that may result in MD can be understood. As we shifted from realist via cultural to a cultural political economy register, our understanding of how and why poor substitutability and narrow policy goals matter for MD also changed, and – we have argued – improved. The situation regarding MD now looks more complex. It is not just about insufficiently informed decision makers, or even about the standard techno-economic framing of the climate change problem and its solutions, but an entire political regime that has evolved alongside specific economic interests is implicated in the mitigation deterrence that appears to have contributed to the ongoing inadequacies of climate policy. It also looks likely, therefore, that existing analyses have underestimated the risk and significance of MD, but this needs further investigation.

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 GGRs should not be used as substitutes for mitigation (Anderson 2015, Larkin, Kuriakose et al. 2017), nor to 'open up' the standard framings that make mitigation deterrence more likely. At the cultural political economy register, analysts are part of the inescapably conflictual dynamic through which technologies and political regimes co-evolve, and may therefore be more overtly partisan and engaged in closing down of debates in new directions, and strategizing for better ways of acting in and organising society in materially subversive ways.

For this purpose, we outline a series of modifications to deliberative research methods designed to make them more capable of supporting such strategic reflection (Flyvbjerg, Landmann et al. 2013). Our proposed methodology is based on scenarios, deliberated on in stakeholder engagement, seeking to identify and shape interventions with the objective of alleviating the MD problem. Critically, it suggests that deliberative participants are understood as co-producing research and its potential impacts and products (notably including new constructions and framings of the GGR technologies under consideration) alongside the convenors of the process, in the production of phronetic wisdom.

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