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Limits to climate action - Narratives of bioenergy with carbon capture and storage

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ABSTRACT

In recent years, bio-energy with carbon capture and storage (BECCS) has been awarded a key role in climate mitigation scenarios explored by integrated assessment models and referenced in reports by the Intergovernmental Panel on Climate Change. Because a majority of scenarios limiting global warming to 2 °C or 1,5 °C include vast deployment of BECCS, a critical discussion has emerged among experts about the moral implications of thus introducing an unproven technology into the policy realm.

In this paper, we analyse this discussion as it has played out between 2013 and 2019, with a focus on how expert narratives are constructed in the mass media about the possibilities for decarbonisation within the current political-economic order. We find there are almost no narratives that support massive deployment of BECCS, and that all narratives presuppose limits to decarbonisation imposed by the current political-economic system. The perception of such limits lead some to argue, through deterministic and apolitical narratives, for the necessity of negative emissions technologies, while others argue instead that "degrowth" is the only solution. Thus, there is a distinct lack of positive narratives about how capitalism can bring about decarbonisation.

1. Introduction

When the IPCC released the synthesis of its fifth assessment report (AR5) in 2014 (IPCC, 2014), critical words had already been voiced about the fact that the climate mitigation scenarios produced by working group 3 relied extensively on a technology called bioenergy with carbon capture and storage, or BECCS, to reach stringent climate targets. Since the release of the report, the Paris Agreement[1] (UNFCCC, 2015) struck in 2015 and the IPCC special report on the 1,5° target (IPCC, 2018) have further entrenched the view that so called negative emissions, among which BECCS is held to be the most cost-efficient alternative, will be needed to limit global warming to within 2° in the long term.

Yet, BECCS remains a largely unexplored technology, at least in integrated, large-scale systems. Currently, there are only five facilities operating around the world, none of which generate power, according to the Global CCS Institute (Consoli, 2019). While there are some larger BECCS power plants in the pipeline, the massive deployment levels of BECCS that figure in climate mitigation scenarios referenced by the IPCC remain a fiction. But what kind of fiction? Given the gigaton-scale upon which it is imagined to generate net negative emissions in climate mitigation scenarios,[2] it could be construed as a call for ambitious state investment programs into green technology. At the same time, some critics have instead seen BECCS as a way of deferring political responsibility for decarbonisation by promise of future "technofixes" (e.g. Carton, 2020; McLaren & Markusson, 2020; Smolker, 2019). In a time when conventional wisdom about the political-economic order and possibilities for system change are challenged (Lent, 2020; Stiglitz, 2019), when an influential business paper like the Financial Times - rarely associated with appeals for more government - has its leading

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[1] While the agreement makes no explicit mention of negative emissions, the phrasing about achieving a balance between sources and sinks, and the fact that most scenarios compatible with limiting warming to below 2° include large-scale BECCS, is widely acknowledged to legitimate BECCS as a mitigation technology (e.g. Beck & Mahony, 2017; Evans & Yeo, 2015).

[2] The extent to which climate scenarios deploy BECCS vary according to assumptions. The general pattern is for scenarios that limit warming to 1,5 °C or 2 °C to rely on large amounts of negative emissions, of which BECCS forms the major part, with emissions reductions occurring earlier in scenarios using the lower temperature target (Evans & Hausfather, 2018; Rogelj et al., 2015). Depending on model assumptions, the lower warming target is still possible to achieve with only limited amounts of carbon dioxide removal (Van Vuuren et al., 2018) and without BECCS (Grubler et al., 2018).

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economics commentator argue for a "global systems transition [through] large-scale policy interventions" (Wolf, 2020) a deeper exploration of the role BECCS occupy in the public expert imaginary is warranted.

In this paper, we seek to understand the ideational setting where BECCS is made intelligible by climate experts in the public news media debate. We seek to identify different ways of imagining limits and possibilities for decarbonisation provided by nature and society - how understandings of biophysical realities intersect with understandings of the political-economic order to define visions of possible futures. The IPCC argue that "unprecedented" changes to global energy and land use systems are required to limit global warming to 1,5° (IPCC, 2018). Here, we will investigate experts' views of the role of BECCS in such a transformation, as represented in public news media discourse.

The scientific process that has identified BECCS and other negative emissions technologies as potentially important measures to make low climate warming targets – 1,5 or 2 degrees of warming in the industrial era – attainable is called integrated assessment modelling. In this paper, we focus on the outcome of these models, and more specifically the scenarios that include large-scale BECCS deployment. However, rather than adding to the substantial literature that analyse either the assumptions from which such scenarios are derived, or the political setting in which they are built, we seek to investigate how scenarios are transposed into public, expert discourse, and thus contribute to the less explored research field of scenario reception (see Haikola, Hansson, & Anshelm, 2019; Lahn et al., 2020). By focusing on how BECCS is debated in news media by experts, we can shed light on how the heretofore most important driver of so-called negative emissions in climate scenarios is made intelligible for a lay public. Thus, we do not aim to give an accurate representation of the climate policy debate about carbon dioxide removal in general, but rather to explore one important process of scenario translation. To facilitate this endeavour, we use a narrative reading that focus our attention specifically on the relation between views on BECCS as a possible mitigation technology and ideas about what, if any, changes to the wider political-economic system is required for a low temperature target to be achievable. We ask: How are expert views on integrated assessment modelling results including large-scale BECCS represented in the public news media? What views on the role of BECCS in energy system transformation are present in the discourse? How are the views on BECCS connected to wider ideas about political-economic change on a system level?

In the following, we will set up the empirical analysis with a background section (2), in which we first explain our methodological approach (2.1), and then provide some reflections on the study of climate narratives (2.2) in relation to research on the IPCC and integrated assessment modelling (2.3). Then, in section 3, we present our narrative analysis of the BECCS debate. Finally, in section 4, we discuss our findings in terms of visions of political-economic change and BECCS role thererin (4.1–4.2), before we conclude (4.3) with some implications of our investigation for integrated assesment models.

2. Background

2.1. Method

We have previously analysed the public expert debate about BECCS and described the main positions that evolved from 2008 to 2018 (Haikola, Hansson, & Anshelm, 2019). For the present paper, we have returned to the same empirical material and updated with new material published in the subsequent period. The previous paper covered approximately 800 feature articles, editorials, and opinion pieces published in English, German, Swedish, Danish, and Norwegian in larger (e.g. BBC, The Washington Post, The Guardian, and Der Spiegel) and smaller (e.g. MSN South Africa and Slate Magazine) news media and in the debate sections of scientific media such as Nature and Science, as well as reports in popular science media such as Science Daily. From these, we cited around 120 as representative samples of wider discursive patterns. We used the Retriever database, and employed variations on the search terms "BECCS"/"Negative emissions technologies"/"Carbon dioxide removal" together with terms like "COP21" and "climate policy". To complement this previous analysis with more recent material, we have read through a further 200 texts using the same database and similar search terms. Together, the two sets of texts thus compose over 1000 texts, and span from the time period 2008 to late summer 2019. We have re-analysed the old material (of around 800 texts) together with the new. In this process, our previous analysis has informed our understanding of the main features and developments of the debate. However, our research questions and analytical lens in the current investigation differs significantly from the previous one. While the former investigation served the more descriptive purpose of surveying the main positions in the debate, the current paper is specifically attuned to the ideological underpinnings of the debate, and concretely to how interpretations of large-scale BECCS scenarios are framed in narratives of political-economic system change.

The Retriever database has a global coverage of over 12 000 newspapers. Even so, the vast majority of texts about BECCS have been published in Western Europe and the US. In selecting texts for citation, we have not considered place of origin but rather sought texts that are representative of the narratives we identify.

By focusing exclusively on the expert debate of BECCS in news media, the present investigation does not delve into the more nuanced or extensive analyses of possible climate actions expressed in other media (often by the same people cited in the news media reports referenced in this paper). Had it done so different narratives might well have been possible to identify. Given the importance of news media in making climate science accessible for a lay public, however, we believe the choice of empirical focus is warranted. After all, our concern here is not to understand how experts "actually" understand integrated assessment model results, if such insight is even possible to attain scientifically, but the way such results are rendered accessible to a lay public through news media. While it might well be that media misrepresents certain views of climate scientists, our concern here is to analyse media narratives as they actually appear, not regarding how well they reflect the underlying science.

The focus on BECCS also means that other parts of the public, expert debate on carbon dioxide removal is only included to the extent that they appear in our empirical material, i.e. indirectly and only in relation to BECCS. We make no pretence to analyse the influence of integrated assessment models on the debate of carbon dioxide removal more generally. However, the point of the investigation is precisely to trace connections between the specific technology BECCS, given its significance in low climate warming scenarios, and broader understandings of the political-economic system.

The potential futures that emerge from integrated assessment model "runs" of different climate scenarios form an important basis of IPCC reports, but they are little more than mere numbers, devoid of socio-political analysis. It is only when transposed into the realm of common discourse, "translated" through the discussions of experts, that these scenarios are made intelligible to a wider audience. The concept of narrative is used here to analyse the way such translation work entails connecting the raw numbers of model output - or rather the notion of a specific technology that has emerged from those numbers - to ideas about how energy-systems transformation can and should be enforced through or beyond the current political-economic system.[3] Using a narrative lens, we thus investigate how the model output that include

[3] The narratives we identify in the present paper should not be confused with narratives developed by researchers from different modelling groups to explain and inform the so called Shared Socioeconomic Pathways, baselines for socio-economic development trajectories used for the upcoming sixth assessment report of the IPCC.

large-scale BECCS is incorporated into or excluded from visions of the future by discourse construction. In this context, it should be noted that we use the term "scenario" simply to connote model output, and specifically the technologies and measures by which an integrated assessment model achieves a certain climate warming target. This is slightly different from the way the term is used in the integrated assessment modelling discourse itself.

The analytical act of linking statements into coherent narratives focuses our attention on the central message in texts. That is, we identify how arguments are bound together to form visions of the world that have a significant degree of internal logic, rather than analyse internal contradictions. In the actual debate, narratives are not as clear cut as they are presented here. Individual actors might "jump" from one narrative to the other, and statements might often be difficult to pin down as belonging to one or the other narrative. The categories we present here should thus be understood as generalised patterns of thought that we find in the debate, not as explicitly stated visions (even though such may occur). Often, the assumptions and norms that underpin and make up the narratives are unspoken, and we must construct them through a critical reading of what is implicitly taken for granted (Wickström, 2015).

In presenting the debate, we distinguish between four main narratives, identifiable as such based on their attitude to climate scenarios including large-scale BECCS. This means that they are identifiable as separate narratives in this regard only. Had our analytical approach to the same empirical material been different, say about identifying environmental narratives, it is likely that the categorisation would be different. This also motivates the ordering of the narratives – from 1 being the most positive of BECCS to 4 being the most critical. We have arrived at these narratives through an inductive process. In the first instance, we have only noted the lines of argumentation adopted, as we have sought the main patterns of thought constituting the discourse. Only as a subsequent reflection have we noted if a certain narrative is dominated by a specific type of actor group or represent a certain kind of interest.

The material encompasses a range of voices, including mainly researchers engaging in the public climate policy debate, environmental organisations, policymakers and journalists. Together, they form what we in the present paper call the "public expert debate". Thus, we use the term "expert" inclusively, as connoting a person claiming a certain expertise within a field of relevance for BECCS, such as climate policy, energy systems transition, or soil science. Any person partaking in this debate do so on the basis of some claim to expertise within their specific domain, be it climate journalism or engineering. However, their competence as experts is of no relevance for our purposes (nor would we able to accurately judge it), as we are only interested in their role as interpreters of climate scenarios.

Before we move on, two terms merit clarification. First, we make a distinction between "large-scale" BECCS and BECCS deployed on lower levels. By this, we do not refer to an exact magnitude but intend to distinguish between the multi-gigaton per year-levels that are commonly deployed in integrated assessment models, and the more modest deployment levels envisioned by some experts partaking in the debate. Secondly, as the vast majority of media texts cited are published in the West, the political-economic system to which we refer in the concluding discussion can be loosely defined as a liberal, capitalistic market economy.

2.2. Disruption and lock-in through narratives

In this paper, we use the concept of narrative for the different ways BECCS is understood within the debate. We take narrative to signify a coherent story about the way the world functions, i.e. the explicit and - more often - tacit understandings groups of people share about causal relationships and structures in nature as well as in society (e.g Bruner, 1986). Departing from the philosophical perspective that phenomena are always made socially intelligible through language and, thus, through the stories we tell about the world, we operationalise narrative to signify the specific set of assumptions and norms that link statements about BECCS into a more or less coherent perspective of its role within the current and future climate policy and energy systems. Narratives both draw upon and constitute the common political imaginary that form the ideational setting for BECCS, the boundaries of which is contested and reinforced to different degrees by different narratives.

Narratives connect accounts of the past and present to the future by positing possible futures. This premise underpins the wide-ranging scholarly interest in how narratives and ways of imagining the future determine possibilities for socio-technical change (Anshelm & Hansson, 2014; Berkhout, 2006; Brown & Kraft, 2006; Daniels, 2011; Haikola & Anshelm, 2018; Jasanoff & Kim, 2009; van der Horst, 2014). Within the field of environmental humanities, for example, researchers have studied how climate futures are explored through fictional and non-fictional narratives, and how scientific accounts of climate change and climate mitigation are mediated through culture and shared imaginaries (Alberro, 2019; Daniels & Endfield, 2009; Hulme, 2015; Luke, 2015; Mann & Wainwright, 2018; Nikoleris et al., 2017; Skrimshire, 2010; Tyszczuk & Smith, 2018; van der Leeuw, 2019). Similarly, sociological studies of technology have long looked into the reinforcing and legitimising role that discourse and accounts of the future influence the trajectory of technological development (Cretí & Joëts, 2017; Levidow & Papaioannou, 2013; WED, 2019), often with specific focus on environmental policy (Hajer, 1995; Scrase & Ockwell, 2010; Unruh, 2000).

As narratives bridge past and future, they possess an inherent tendency towards system preservation. Equally important, however, is their ability to create new possibilities by imagining historical discontinuity rather than continuity (Bushman & Oels, 2019). This double function of narratives becomes ever more acute within the modern system of financial capitalism, characterised, as it is, simultaneously by deep path dependence in its large infrastructural systems and visions of technological disruption as one of the main driving forces in social change. As noted already by Schumpeter (1983), speculation about future technological possibilities is a primary driving force in modern capitalistic societies, as it frees socio-political imaginaries to stake claims on future resources. However, as is continuously evidenced by our inability to act on climate change, capitalism has not dispensed with path dependency, and capital has retained its tendency towards stability and fixity, in infrastructure as well as institutions (Harvey, 2007).

Scenarios of future energy and climate pathways promoted through the IPCC are caught between these countervailing forces of path dependency and system disruption (e.g. Aykut, 2019). On the one hand predicated on a logic of system preservation, they also need to explore radically different kinds of futures that could be seen as scientifically legitimate visions of low-carbon societies. In recent years, BECCS – or bioenergy with carbon capture and storage - has appeared not only as illustrative, but even emblematic for the speculative dilemma in climate mitigation scenarios. Climate modellers struggle to detach mitigation scenarios from real-world constraints while retaining their "policy--relevance", by shifting conceptual focus from "predictions" to hypothetical "what if?"-explorations (Haikola, Hansson, & Fridahl, 2019). Commentators, meanwhile, debate whether BECCS constitutes a necessary part of ambitious climate policy or a purely speculative "gamble", rooted in inability or unwillingness to challenge the status quo (Haikola, Hansson, & Anshelm, 2019).

To understand what is at stake within this debate about how socio-economic climate modelling informs policy, we need to highlight the tension that resides within the IPCC and within the socio-economic models that inform IPCC reports.

2.3. Conservatism and disruption - the tension within the IPCC and integrated assessment modelling

Since its inception, the Intergovernmental Panel on Climate Change

(IPCC) has been criticised for favouring economics among the social sciences and, by doing so, tending towards conservatism in its estimations of required societal transformations (Bjurström & Polk, 2010; Hulme & Mahony, 2010; Yearley, 2009; see also; Brysse et al., 2013). In trying to reconcile widely divergent interests, the IPCC has adopted a non-confrontational stance towards established industries that stand to lose from disruptive energy systems transitions (Agrawala, 1999; Aykut & Castro, 2017; Hulme, 2011). Spokesmen for the Panel, on their part, have made it their standard response that they should never stray from the objective function of representing and assessing the available science by venturing into the terrain of concrete political advice (e.g. Azar et al., 2019; Livingston, 2018).

The apolitical character of the IPCC has, however, been increasingly difficult to reconcile with the fact it bears a message of revolutionary societal change. The latest assessment report AR5 (IPCC, 2014), and the special report on 1,5 °C (IPCC, 2018) both clearly stress the need for drastic, immediate measures if global warming is to be limited to within 1,5 or even 2 degrees of warming. A similar tension is evident within the integrated assessment models (IAMs) that are used to explore how such measures may come to materialise. IAMs are a form of speculative devices that explore different possible development trajectories by integrating projected energy use and climatic change with social and economic factors through advanced computer modelling (Anderson & Peters, 2016a; Beck & Krueger, 2016; Low & Schäfer, 2019; Schneider, 1997). They have formed an important basis for IPCC assessments for a long time, and are, in the professed mission statement of the modellers themselves, not to be seen as tools for prognosis but rather a purely hypothetical exploration of different possible futures (Haikola, Hansson, & Fridahl, 2019). Because such models are highly sensitive to assumptions, their use for climate policy purposes has been the subject of critique (Carton, 2020; Ellenbeck & Lilliestam, 2019; Heymann & Dahan Dalmedico, 2019; Pindyck, 2013; Schneider, 1997).

While these models are nowadays often set to achieve stringent climate warming targets, they retain a neoclassical economic core that presuppose an optimal current state of the global economy. They are thus inherently conservative. They make assumptions about cost-effective technological development derived from economic theories that largely disregard the complex dynamics through which large-scale system transformations are likely to occur, and how innovation drives technological change in advanced capitalistic economies (e.g. Faran & Olsson, 2018; Grubb & Wieners, 2020; Kaya et al., 2017; Köberle, 2019; Mercure et al., 2019). Rather than attempt to calculate the complex dynamics of innovation and technological learning, the models choose technologies for their supposed potential to keep mitigation costs down (Köberle, 2019; Mercure et al., 2019). Since the economy is assumed to be operating at full potential, any investment is assumed to detract from welfare in the present, leading to a static vision of technological development (Semieniuk et al., 2018). Meanwhile, many IAMs impose limits on the extent to which current energy technologies may be substituted with new, cleaner ones, adding to the conservative bias (Kaya et al., 2017; cf.; Mercure et al., 2018).

BECCS enters into the models on the assumption it necessitates relatively little in the way of socio-economic disruption (see for example Sluisveld et al., 2018). It is a so-called negative emissions technology, i.e. a technology that aim for carbon dioxide removal from the atmosphere.[4] Its theoretical strength lies in the combination of power generation with carbon removal: biomass stores carbon through photosynthesis and is replaced with new biomass when removed for combustion, while CO2 released from power plants is buried underground. In models, the application of capture and storage technology to biomass-based electricity generation can appear extremely potent, because it allows power to be generated while CO2 levels in the atmosphere are reduced (Köberle, 2019). IAMs therefore tend to favour BECCS as a cost-effective mitigation technology that allows for a period of relatively higher emissions trajectories – a so called "overshoot" of the carbon budget - and smoother phase-out paths (Azar et al., 2013; Bauer et al., 2018; Carton, 2020).

Like other negative emissions technologies, however - such as the anthropogenic acceleration of natural weathering processes (Beerling et al., 2018), or the removal of carbon dioxide directly from ambient air (Fasihi et al., 2018) - BECCS remains far from being commercially realised on a significant scale. Besides technical uncertainties, its large-scale deployment is premised on the availability of underground storage and, most significantly, vast quantities of biomass that could necessitate massive land-use changes (Fuss et al., 2014). Therefore, its adoption as a standard mitigation technology in IAMs has brought on criticism of scientifically illegitimate speculation in the availability of future resources (e.g. Anderson & Peters, 2016; Asayama & Hulme, 2019; Geden, 2015). Carton (2019) has stressed the political dimensions inherent to such "mortgaging", arguing it portrays some forms of mitigation as economically irresponsible or impossible in favour of speculative negative emissions technologies (see also Hansson et al., 2021).

Such critique strikes at the heart of tensions that reside within the IPCC and within IAMs, because it is simply impossible to envision a decarbonisation of the global economy without at least implicitly stipulating the need for political-economic change. BECCS, of course, is no different: it may be a conservative fantasy, but one that would have immense societal consequences if materialised on the levels assumed by many climate scenarios. While representatives of the IPCC and the integrated assessment modelling community assert that what they do is not meant to be policy prescriptive, it would make little sense to argue that they do not partake in shaping the conditions of possibility for discourses of socio-technical and environmental change. Not only does the IPCC hold a uniquely authoritative position as the pre-eminent voice of climate science but, furthermore, the IPCC-aligned modelling community has for decades worked with an explicit ambition to be policy relevant, that is to say precisely to partake in forming the political imaginary (Heymann & Dahan Dalmedico, 2019). Tyszczuk and Smith (2018), for example, regard such climate mitigation scenarios as forming a "rehearsal space" for possible mitigation actions, while Nikoleris et al. (2017) construe of them as "thought experiments" that allow more robust policies to be developed from exploration of fictions (p.308; see further Nilsson et al., 2017). Heymann & Dahan Dalmedico (2019), Hulme (2011) and Rindzevičiūtė (2015) all further highlight the specific politico-ideological context in which climate modelling is embedded and invite reflection on how model results derived from a specific, institutionalised way of looking upon the world resonate with other public imaginaries. In the following, we embark on such an investigation.

3. The BECCS debate

In the following presentation, narratives are numbered for their general attitude towards BECCS, where 1 is the most positive and 4 the most negative. The way narrative appears in the analysis is dictated by the logic of the presentation, which is semi-chronological, with thematic expansions where so is needed for explanatory purposes.

3.1. The narratives are drawn up

In 2013, the main contours of today's public expert debate about BECCS were drawn. BECCS became a topic of debate in response to media reports that took note of new research about so called negative emissions. While this early period saw some highly optimistic descriptions of the technology, as being, for example, the "climate's saviour" (e.g. Hood, 2015; Rueter, 2014), these were mixed with

[4] Negative emissions technologies are contrasted to technologies like carbon capture and storage (CCS), which remove fossil carbon from point sources. The latter might theoretically allow for carbon neutrality, but unlike negative emissions technologies they cannot remove more CO2 than the process adds.

warnings that no undue attention should be awarded speculative technologies that risked drawing attention away from the imperative to decarbonise immediately (Ahmed, 2014; Doyle, 2014a, 2014b; Lukacs, 2014; McGrath, 2014; Rincon, 2014; Ritter, 2014; Spencer, 2014; Vergano, 2014; "What is …", 2014).

Here already, two distinct narratives are visible - one extremely positive towards BECCS, and one critical. In the following analysis, these will be designated narrative 1 and narrative 4 respectively, ordered so in relation to their enthusiasm for BECCS. The former has been firmly entrenched in the Norwegian debate where the forest industry, energy agencies, energy and economy researchers and politicians, together with the ENGO Bellona, were quick to join forces in support of what they perceived to be the key to unlocking the supposed opposition between economic and environmental sustainability (Benjaminsen, 2016; Helseth, 2011, 2012; Hohle, 2014, 2016; Jansen, 2015; Lindeberg, 2013; Moe, 2016; Slettemark, 2016; Solbakken, 2014). Bellona, identifying a "magical combination" (Helseth, 2014) in BECCS of power generation and climate mitigation, called for "massive roll-out" (Benjaminsen, 2016; Carstens, 2015) of the technology globally, thus envisioning a world of vast, interconnected global BECCS networks in which biomass was exported for combustion and, post-capture, CO2 for ultimate storage. Forestry actors in Norway, however, were careful to delimit their visions to a national context, thus side-stepping the issue of whether BECCS could be expected to deliver negative emissions on a global scale (Bjørdal, 2015; Frøvoll, 2015; Helseth, 2012, 2014; Kløvstad, 2014, 2016; Lahnstein, 2015a, 2015b, Lahnstein, 2016, 2015b; Løken, 2015; Rødland, 2015; Sellæg, 2015a,b).

Whether a strategic omission or due to national myopia, leaving out the global context of BECCS meant avoiding the issues at the centre of the opposed narrative, number 4, which was established by ENGOs like Greenpeace and Biofuelwatch in 2013 and 2014. Focusing on the catastrophic impacts that a massive roll-out of BECCS would entail for agricultural systems in vulnerable regions, they concluded that the dystopic visions of vast biomass plantations in the global south, producing the raw material for energy in the north, was a recipe for disaster, whether put in practice or proving a "dangerous distraction" that would allow for continued "business as usual" (Ahmed, 2014; Lukacs, 2014; McGrath, 2014; Spencer, 2014; also Collins, 2017; Fuhr, 2014; Smolker, 2018a, 2018b). A sad irony, noted by a group of twenty African movements on the UN climate meeting in Bonn in 2016, was that the imperative for BECCS probably originated in pressures from representatives of poorer nations at climate negotiations for more ambitious climate targets, and that its introduction as a mitigation alternative risked "sacrificing the global south in the name of the global south" (Currie, 2018; Hickel, 2017a; Mahnke, 2017; Moshood, 2016).

Having been established by ENGOs in the early days of the debate, the BECCS-critical narrative would be strengthened and nuanced as academic experts added to it in the years following the Paris climate summit in 2015. At the same time, the highly BECCS-positive narrative would fail to gain discursive ground. It was carried further primarily by commercial companies, such as the Drax Company and the Energy Technologies Institute in the UK, with a direct economic interest in promoting the technology (Cuddihy, 2018; Morningstar, 2018; Woodroof, 2018). While it has been unusual for scientists to explicitly back up the more optimistic BECCS scenarios, there are some statements, for example by researchers from Berkely and IIASA, that refer to BECCS as one of the most promising and cost effective technologies in reaching net negative emissions (Clickgreen, 2015; Pearce, 2016a; Profeta, 2016; Spectrum Online, 2015).

Between these two narratives, two middle-of-the-road alternatives emerged in which BECCS or some other forms of negative emissions technologies appeared as uncertain but necessary measures to limit global warming to within 2 or 1,5°. Also established in the early days of the debate (e.g. Arup, 2014; Carstens, 2015; Clickgreen, 2014, 2015; Gunn, 2015; Hagemann, 2014; Kløvstad, 2014; Koch, 2014; Kristoferson, 2014; Miller & Arup, 2014; Milman, 2016; Morales & Nicola, 2014; Nielsen, 2014; Pearce, 2014; Rincon, 2014; Solbakken, 2014; Steen Nielsen, 2014; Vedeld, 2014; "What is …", 2014; cf.; Biello, 2015a), these two narratives relied heavily upon the carbon budget calculations used in integrated assessment modelling to argue that the math simply did not add up for ambitious warming targets without relying on carbon removal through technology. As time went on, this deterministic view would come to gain significant ground in the debate, challenging both the narrative (nr.1) that retained faith in the huge amounts of BECCS deployed in many climate mitigation scenarios, and the BECCS-critical narrative (nr.4).

3.2. *Contestation of BECCS*

The latter was ascendant in the years following the climate summit in Paris in 2015. As it became obvious that the IPCC fifth assessment report (AR5; IPCC, 2014) and, by inference, the Paris Agreement, relied heavily on climate mitigation scenarios deploying huge amounts of BECCS, the debate around its implications for politics and resource use intensified. Critical scientists added to the arguments first voiced by ENGOs when negative emissions were originally made a topic of debate in 2013, often focusing on the geo- and biophysical limits that made mitigation scenarios with huge amounts of BECCS appear unrealistic. In 2015, a paper in Nature Climate Change received widespread media attention, arguing that the ecological footprint of BECCS would be completely unacceptable (Mooney, 2015a). Similarly, a group of German scientists calculated that the amounts of BECCS suggested by climate mitigation scenarios referenced by the IPCC would demand 75% of arable land globally (Nestler, 2015; Speicher, 2015). Besides the immediate displacement of food production (Anderson & Peters, 2016a; Harvey, 2016; Seidler, 2015), others pointed to wider ecological-systemic repercussions from large-scale BECCS, highlighting that a more comprehensive systems analysis would yield completely different results for BECCS (Biello, 2015b; Hamilon, 2016; Lavelle, 2016; "Outside the …", 2016). Vera Heck, of the Potsdam Institute for Climate Impact Research, for example, argued in Nature that irrigation and fertilizers for the vast BECCS-plantations imagined by climate mitigation scenarios would lead to ecological disaster (Heck et al., 2018). Phil Williamson, researcher at the Natural Environment Research Council in the UK, also publishing in Nature, similarly dismissed the notion of large-scale BECCS for reasons of biodiversity, arguing it would never have been promoted in the first place if the IPCC had awarded equal importance to ecologists as it did physicists and modelers (Williamson, 2016; see also; Appelt & Bossen, 2017; Collins, 2017; Currie, 2018; Mahnke, 2017; McGrath, 2017a, 2017b; Unmüßig, 2017; Wetzel, 2017). The critique was further strengthened by the release of a report by the European Academies' Science Advisory Council (EASAC, 2018) which urged for more "realistic" appraisals of BECCS' potential. Perhaps the weightiest contribution to this biophysically grounded critique (see further Carrington, 2018a, 2018b; Heck, 2018), however, came from inside the IPCC itself, when its special report on climate change and land was released in 2019 (IPCC, 2019). Called by some commentators the most political IPCC report ever, it substantiated claims that large-scale BECCS would seriously jeopardise global food supply and ecosystems, and that land use availability put severe limits on BECCS' potential as a mitigation technology (Gerretsen, 2019; Meyer, 2019; Sauer & Farand, 2019; Stokstad, 2019; Walsh, 2019).

Thus, central to the critical narrative as it evolved after 2015, was the notion that BECCS was in fact not an important mitigation technology as construed by the IPCC, but rather an environmental threat. According to this narrative, the very notion of large-scale BECCS was a product both of a dysfunctional economic system, and of a dysfunctional perspective on nature. For critics who built on this narrative in a system-critical direction, BECCS appeared as a damning indictment of late, colonial capitalism. If this was a vision for the future that the climate science establishment considered legitimate, it meant the whole endeavour of the IPCC must be refocused. Environmental journalist Fred Pearce,

writing for the ENGO Fern in 2016, described BECCS as a "recipe for the industrialisation of environmentalism with vast swathes of the world's most diverse forest ecosystems turned into, at best, factory hands. A new approach is required. One based not on creating a vast new industry for sucking carbon from the air, but on […] natural regeneration" (Pearce, 2016b). Following this line of argumentation, several critics went on to posit "natural" technologies for carbon removal as alternatives to the technocratic, colonial and industrial approach they perceived BECCS to represent (Ahmed, 2014; Collins, 2017; Fuhr, 2014; Moshood, 2016; Schneider, 2018; Smolker, 2018a, 2018b).

In 2018, Greenpeace, Oxfam, Actionaid and Global Forest Coalition, co-published a report titled Missing Pathways to 1,5 °C, which claimed that the IPCC had understated the potential of natural carbon sinks in favour of technocratic solutions like BECCS (Dooley et al., 2018). Commenting favourably on the report, Biofuelwatch (Smolker, 2018a) and other ENGOs argued that large-scale BECCS would not only be unnecessary if the forests' natural potential was utilised, but that it would in fact severely threaten this potential by competing for land and water (Catanoso, 2018; Globalnyt, 2018; Green, 2018; Gupta, 2018; Heinrich Böll Stiftung, 2018; Lang, 2018). Later the same year, a broad coalition of environmentalists – both such traditionally in favour of corporate environmentalism and explicitly anti-capitalistic movements – called for natural solutions to the climate threat. The Climate Action Network, gathering more than 1200 NGOs, together with Actionaid and Friends of the Earth, all argued that IPCC's focus on BECCS threatened the livelihood and traditions of the vulnerable populations for whose benefit the 1,5° target was proposed in the first place (ActionAid USA, 2018; CAN international, 2018; Envirotec Magazine, 2018; Stone, 2018). Similarly, a group of 200 organisations, scientists and elected officials called for a strengthened focus on natural solutions through a platform called Stand4Forests.

The political dimensions of BECCS - mostly hinted at through the aforementioned critique - were further elaborated by others. For outspoken critics like Kevin Anderson, professor of Energy and Climate Change and deputy director of the Tyndall Centre for Climate Change Research, BECCS modelling amounted to pure "gambling … on the appearance in a puff of smoke of a carbon-sucking fairy godmother" (Anderson, 2015a; c.f.; Hamilton, 2016). Other critical researchers echoed Anderson's sentiments. Tim Krüger and Steve Rayner of the Oxford Geoengineering Programme, together with Oliver Geden, head of the EU division at the German Institute for International and Security Affairs, dismissed BECCS as "science fiction" (Krüger et al., 2016). Researchers, environmental journalists and ENGOs all contributed to thus highlighting the speculative nature of the technology now supposedly being proposed by the IPCC as "the holy Grail" of climate mitigation (Fuhr, 2014; Hickel, 2017b; Pearce, 2016b), with BECCS being described as "something between a godsend and voodoo" (Mooney, 2015b), a "Cinderella technology" (McGrath, 2014) emanating from "magical thinking" (Krüger et al., 2016; Mooney, 2015b; see also; Mahnke & Staude, 2017; McGrath, 2017b; Paterson, 2017).

This speculation was not, however, innocent in any sense, but rather an "unjust and high-stakes gamble", according to Anderson and Glen Peters, senior researcher at Center for International Climate and Environmental Research in Oslo (Anderson & Peters, 2016a; see also; Anderson & Peters, 2016b; Lackner et al., 2016). Those who stood to lose the most if – or rather when – large-scale BECCS failed to materialise were the most vulnerable populations (Anderson, 2015b; Smolker, 2018a, 2018b). By sanctioning speculative mitigation scenarios including BECCS, IPCC was thus seen, in this narrative, to surrender to political pressures (Anderson, 2015a; Geden, 2015a, 2015b; Jotzo & Stern, 2015; Krüger et al., 2016; Speicher, 2015; c.f.; Carbon Brief, 2015; Climate News Network, 2015; Nestler, 2015; Tarantola, 2014) and disregard the fact that drastic decarbonisation in the affluent world would render large-scale BECCS unnecessary (Anderson, 2015b). According to the ENGO the ETC group, BECCS was a way of displacing political reality, by burying carbon dioxide "out of sight and out of mind" (Dano, 2015; Dano & Mooney, 2015; see also; Moshood, 2016).

To some scientists, journalists and ENGOs, science stated a clear imperative for systems change, with Anderson arguing that climate scientists were unwilling to accept and communicate "the revolutionary implications" of their scientific results (Anderson, 2015b), and economic anthropologist Jason Hickel arguing for "degrowth" (Hickel, 2017a, 2017b, 2017b) or "downscaling" (Hickel, 2017b) of the world economy (see also Ahmed, 2018; Danielsson et al., 2016; Heinberg, 2018; Mahnke & Staude, 2017; McGrath, 2017b). In another comment, Anderson explicated his view on how the current system precluded anything but status quo:

> But rather than rely on post-2050 BECCS, deciding to pursue this alternative approach would have begged profound political, economic and social questions. Questions that undermine a decade of mathematically nebulous green-growth and win–win rhetoric, and questions that the politicians have decided cannot be asked.
> Move away from the cosy tenets of contemporary economics and a suite of alternative measures comes into focus. Technologies, behaviours and habits that feed energy demand are all amenable to significant and rapid change. Combine this with an understanding that just 10% of the population is responsible for 50% of emissions, and the rate and scope of what is possible becomes evident.
> The allying of deep and early reductions in energy demand with rapid substitution of fossil fuels by zero-carbon alternatives frames a 2 °C agenda that does not rely on negative emissions. So why was this real opportunity muscled out by the economic bouncers in Paris? No doubt there are many elaborate and nuanced explanations — but the headline reason is simple. In true Orwellian style, the political and economic dogma that has come to pervade all facets of society must not be questioned. For many years green-growth oratory has quashed any voice with the audacity to suggest that the carbon budges associated with 2 °C cannot be reconciled with the mantra of economic growth (Anderson, 2015a).

In this radical version of the BECCS-critical narrative, the question was raised why an alternative to the current system of economic growth and capitalistic resource exploitation was so impossible to contemplate in the public discourse (Ahmed, 2018; Friends of the Earth, 2018; Hickel, 2017b, 2018; Pearce, 2019; Corlet Walker, 2019; Woroniecki, 2019).

3.3. … and normalisation

While the BECCS critical narrative (nr.4) was prominent in the years following the climate summit in Paris, it would subsequently be challenged by two narratives that argued for some deployment of negative emissions technologies – be it BECCS or something else – as simply necessary to keep within the carbon budget for the more ambitious warming targets. These two middle-of-the-road narratives, number 2 and 3 in our categorisation, thus share the same assumption about the necessity of some "techno-fix", and differ from each other only with regards to whether BECCS could be assumed to deliver negative emissions on a significant scale, or whether other carbon removal technologies like direct air capture, or even geo-engineering solutions like solar radiation management, would be necessary.

In 2016, in response to a paper in Science by Anderson and Peters, 45 signatories led by the physicist Klaus Lackner, director of Center for Negative Carbon Emissions, published a commentary arguing that the portrayal of technologies for carbon removal as "gambles" was unwarranted, and that no proof existed for their mitigation-deterrent effect (Lackner et al., 2016). Lackner himself, however, shared the critique of BECCS' detrimental land use effects and thus argued instead for other options (Mooney, 2016a, 2016b; Sneed, 2016). Key to this line of reasoning, which forms the core of narrative 3, was the notion that technology must step in where climate policy had failed to deliver

decarbonisation. Such fatalistic determinism underpinned also the argumentation of those who argued for a limited deployment of BECCS, who, beginning in 2017, began shifting the emphasis of the debate towards a cautious acceptance of BECCS' necessity. Several commentators, some of whom had previously explicitly criticised the inclusion of BECCS in the mitigation portfolio, now argued that policy and research plans must be prepared for a limited introduction of BECCS, as dictated both by carbon emissions trajectories and by the need for feasibility assessment of the technology (Peters, 2017a, 2017b, 2017c; Dehmer, 2017; Goering, 2017; Harvey, 2017; McGrath, 2017b; Peters & Geden, 2017). Often, BECCS was thus promoted together with fossil CCS, with Glen Peters, for example, stating bluntly that "love it or hate it, we need carbon capture and storage to keep below 2 C" (Peters, 2017b). From 2017 onwards, this moderately BECCS-positive narrative, number 2, has been pronounced in the debate. Its proponents, including influential climate scientists like Johan Rockström, Hans-Joachim Schellnhuber and Corinne Le Quéré, are quick to point out problems with BECCS, and regard climate mitigation scenarios including huge amounts of BECCS with suspicion, yet they retain a belief that mathematics simply make it "probably essential to take us to zero emissions" (Goering, 2017; see also; Dehmer, 2017; Harvey, 2017; Häusler, 2018; Mahnke, 2017; McGrath, 2017b; Peters, 2017a, 2017b; Rosen, 2018).

4. Discussion

Throughout the debate, we have identified four main narratives in terms of how they relate to the notion of BECCS and numbered them with 1 being the most BECCS-positive, and 4 the most BECCS-critical (see Table 1). While all these narratives play out on a discursive space determined by the notional goal of limiting global warming to 1,5 or 2°, they differ as to how they understand the possibility of achieving decarbonisation within the current political-economic system. In this concluding discussion, we will first specify and then reflect upon these differences.

4.1. Politicising decarbonisation

Narrative 1 is the only narrative that puts faith in the scenarios that include large-scale BECCS. This requires treating the world as little more than a resource base, presupposing biomass may be produced in one place, shipped across the globe for combustion and then transported again to be stored in underground facilities in a third country, to achieve a massive, net carbon removal effect. It thus requires a vision of the world without biophysical and geopolitical boundaries. Given that its supporters are primarily actors with a direct commercial interest in BECCS, it must be regarded as an outlier within the context of the debate.

Narratives 2 and 3 fuse an apocalyptic understanding of the climate threat with a sense of technological determinism, often stating as unequivocal, mathematical truth that a certain amount of carbon removal through BECCS and/or other negative emissions technologies will be necessary to compensate for emissions that are lingering in the atmosphere and society is unable to dispense of. For both narratives, the huge amounts of BECCS that many mitigation scenarios envision are unrealistic as well as undesirable for moral and environmental reasons. At the same time, BECCS and other negative emissions technologies become necessary because societies are unlikely to be able to decarbonise at the rate and within the timeframe that is necessary.

Here, then, resides a tension within both these narratives, in that they stress a paramount need for profound societal change, yet remain committed to achieving it within the frames of a political-economic system they deem resistant to decarbonisation. These narratives are dictated by assumed pragmatism and notions of cost-effectiveness, and they focus on where integrated assessment models agree, namely on a significant gap between a low warming target and what are deemed feasible trajectories for decarbonisation through conventional means. Both discuss the possibilities and limitations to a range of different negative emissions technologies and reiterate that no single technology is likely to be a "silver bullet". They can thus be seen as attempts to rationalise and translate integrated assessment model results to a wider audience, by conferring a sense of negative emissions technologies as an abstract rather than a literal concept. While both welcome, either explicitly or implicitly, at the very least a restructuring of the global economy to facilitate low-carbon technologies, they are predominantly apolitical in their reluctance to envision profound societal change.

Narrative 4 instead serves to concretise and politicise the issue of decarbonisation. It does so, first, by stressing the concrete environmental and social effects that a global BECCS system would have if implemented on the levels assumed by climate models. More than that, however, it explicitly connects the very idea of BECCS to a specific political-economic order and its associated ways of understanding nature, justice and societal transformation.

Narrative 4 should, in fact, be differentiated as three separate subnarratives (termed 4.1–4.3), each distinguished by the degree to which they relate the critique of BECCS to a wider critique of the current capitalistic system. Narrative 4.1 is focused on what is perceived as transgression, by integrated assessment models, of social, ecological and biophysical boundaries. Especially, it stresses how such models erase land-use conflicts and complex ecosystem interdependencies from view in the construction of BECCS-intensive climate mitigation scenarios. In this sense, 4.1 is a primarily "deconstructive" narrative grounded in the natural sciences that, by revealing and criticising certain key assumptions behind modelling of BECCS, implicitly politicise the debate without engaging in explicitly political analysis.

Narrative 4.2 is constructed mainly by environmental, non-governmental organisations such as CLARA. It also departs from an understanding of BECCS as a speculative move that serves to hide political-geographical realities but extends the critique by explicitly describing these realities in terms of colonial and geopolitical power relations. Here, modelling of BECCS appears not merely as flawed science, as in 4.1, but rather as a deeply political manoeuvre that displaces the burden of decarbonisation from its rightful place in time and space, and thus constitutes a "spatiotemporal fix" typical of capitalism (Harvey, 2007; Jessop, 2001). BECCS, in this view, is therefore symptomatic of a technocratic logic intricately linked to colonial capitalism. Narrative 4.2 presents, as a positive counter-narrative, the vision of "natural" alternatives for carbon dioxide removal that would make the 1,5° target attainable without resort to speculative technofixes. It conjures a positive alternative to what it perceives as a technocratic dystopia but maintains it must be sought through radical changes to the current political-economic order. It requires political decentralisation and the empowering of indigenous communities, a restructuring of the global system of production and a geopolitical shift away from the global north. In its implications, and by excluding factors such as innovation and technological development from its argumentation, the narrative is decidedly anti-capitalistic. However, it is a narrative of bottom-up change and thus the theoretical, system-level implications of its suggested measures are never spelled out.

In contrast, narrative 4.3 departs from analysis informed by political-geographic theory, from which it derives its understanding of what kinds of future a climate policy based on speculative BECCS scenarios would bring into being. Like 4.2, it construes large-scale BECCS as a spatiotemporal fix, but whereas the former focuses on the spatial and concretely geographical aspects of an imaginary global BECCS system, 4.3 focuses the temporal dimension. It understands BECCS as postponement of action, a political fiction with the role of burying, as it were, the reality of carbon emissions in the theoretical underground storage provided by abstract computer models. To proponents of narrative 4.3, the move whereby negative emissions facilitates continued business as usual is designed to save capitalism from its inherent contradictions, and temporally postpone the inevitable conclusion that capitalistic accumulation and ecological sustainability

Table 1
Overview of the narratives within the BECCS debate.

	Attitude to large-scale BECCS	Attitude to moderate level BECCS	Attitude to moderate level NETs	Main features	Main argument
Narrative 1	Positive	–	–	Deterministic, national in scope (mainly Norway, UK)	Large-scale BECCS is the only proven technology that allows for an economically sustainable climate transition
Narrative 2	Critical	Positive	Positive	Deterministic, apolitical (but acknowledges the need for unprecedented socio-economic change)	Negative emissions necessary to achieve stringent climate targets, BECCS and CCS among the most likely ones to materialise
Narrative 3	Critical	Critical	Positive	Deterministic, apolitical (but acknowledges the need for unprecedented socio-economic change)	Negative emissions necessary to achieve stringent climate targets, but BECCS unlikely to materialise at scale
Narrative 4.1	Critical	Critical	Critical, but should be researched (including BECCS)	Deconstructive, critical, grounded in natural sciences	Large-scale BECCS is only feasible within abstract climate models
Narrative 4.2	Critical	Critical	Critical, but should be researched (including BECCS)	Critical, decolonial, politicising, anti-capitalistic, bottom-up	Large-scale BECCS is symptomatic of a failure of capitalistic imagination, only "natural" carbon dioxide removal is needed
Narrative 4.3	Critical	Critical	Critical, but should be researched (including BECCS)	Critical, politicising, anti-capitalistic, informed by political-geographic theory	Large-scale BECCS is symptomatic of a failure of capitalistic imagination, revolutionary "degrowth" is needed

are ultimately irreconcilable. As in narrative 4.2, the alternative vision is proposed as a positive counternarrative, but in this case one that explicitly requires a radical reordering of the current political-economic system.

4.2. Limits to action within capitalism

Therefore, narrative 4.3 is the only narrative in the BECCS debate that explicitly argues that decarbonisation requires fundamental systems change. Narrative 4.2 indicate critique of a similar kind, but its bottom-up approach precludes a macro-scale analysis that would spell out the implications in a more systematised manner. The debate offers ample space for critique of BECCS as a specific technology, but little in the way of grander societal visions or discussion about how political and economic institutions need to change in order to foster an historically unprecedented level of energy systems transformation. We illustrate the positions of the different narratives below, in Fig. 1.

As Mann and Wainwright (2019) have recently argued, *all* mitigation scenarios regarded by mainstream climate science today as compatible with stringent climate targets preclude a business-as-usual thinking. They all require more or less drastic market interventions by the state (or its complete dismantling into anarchy). The 1990s debate (e.g. Goulder & Mathai, 2000; Grubb, 1997; Grubb et al., 1995; Nordhaus, 1991; Wigley et al., 1996) about whether decarbonisation should be postponed for the sake of cost-effectiveness, has been effectively banished within mainstream climate science through the imposition of stringent warming targets (cf. Carton, 2019). It's worth asking, then, why so few of the narratives in the BECCS debate venture into discussion about whether energy systems change also warrants political-economic systems change.

First, it must be acknowledged that the news medium imposes certain restrictions on the kind of analysis that might be expressed. When experts give their view of BECCS in this specific context, it may be that they try to deliver easily grasped, short messages, rather than deliver a verdict on political-economic structures. Furthermore, however, it is worth considering again

how BECCS come to be construed as a significant mitigation technology in the first place. When integrated assessment models calculate cost-effectiveness, they do so on the premise that decarbonisation and mitigation must occur at the lowest possible cost, from the perspective of a single agent that is taken to represent society. This version of cost-efficiency stems from a neoclassical paradigm that defines economic processes as the allocation of scarce resources. Climate modelling based on such assumptions necessarily implies trade-offs between economic gain (for the benefit of a unitary agent) and decarbonisation.

Obviously, this version of an economy bears little resemblance to the fragmented and sectorial processes of modern-day financial capitalism. When integrated assessment modelling of climate scenarios is transposed into a public expert debate, we therefore find they have no resonance as concrete roadmaps for the future. No one is inclined to embrace a narrative of such forms of governmental interventions that would be required for BECCS to materialise on levels often assumed in the modelling results (thus leaving the bottom left corner of Fig. 1 unoccupied).

However, the premise that decarbonisation and economic growth must necessarily be understood as a matter of trade-offs remains. In narrative 2 and 3, it is expressed through ambivalence towards the possibility for deep societal transformation, which results in a deterministic belief in BECCS or other negative emissions technologies simply as mathematical necessities rather than societal choices. Thus, they are not so much optimistic "green growth" narratives, as narratives of technological fatalism: not premised on profound belief in the transformative nature of a dynamic capitalism but rather disillusioned commitment to a limited concept of economic growth derived from economic models. BECCS and other technologies for carbon removal are therefore construed as necessary compensatory mechanisms for the

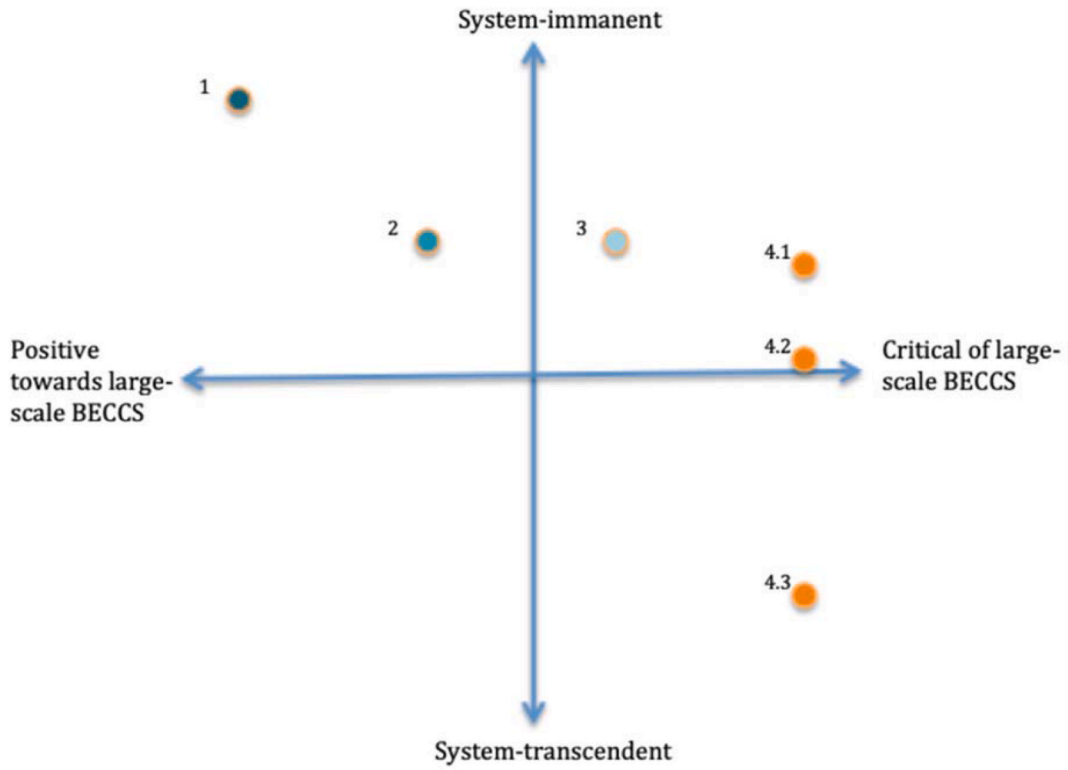

Fig. 1. Positioning of the narratives in relation to the idea of large-scale BECCS (x-axis) and political-economic system change as necessitated by low climate warming targets (y-axis).

expected failure of prevailing political-economic structures to maintain economic growth while reducing carbon emissions enough to keep within a tight carbon budget.

The advocates of moderate levels of BECCS in narrative 2 face a specific dilemma, that those who argue for other negative emissions technologies, in narrative 3, do not. A technology like Direct Air Capture can, theoretically, be envisioned as sustainable on a massive scale. It is therefore logically possible, at least superficially, to argue for giving its engineers free reins in the dynamic setting of the capitalist market (cf. Malm & Carton, 2021). As Malm and Carton argue, it fits well with the combination of "boundless technological voluntarism with bottomless resignation to political fate" that is typical of bourgeois modernity (Malm & Carton, 2021, p. 17). BECCS does not, however, given both its obvious environmental impacts and lack of a useable product. Its proponents in narrative 2 are therefore left with only the resignation, as they struggle to envision a capitalist, free-market rationale to deploy a technology within strict limits.

Narrative 4 inverts the order of argumentation. Instead of deducing the need for negative emissions technologies from perceived mitigation gaps, it focuses on how proven measures and technologies – among which its proponents do not count BECCS or other negative emissions technologies - may deliver decarbonisation. While 4.1 remains agnostic as to what implications these measures would have for capitalism as a social order, narratives 4.2 and 4.3 argue for its incompatibility with decarbonisation, the latter by explicitly arguing for "degrowth" without specifying its meaning in any precise terms.

With the exception of narrative 1, then, the positions in the debate range from ambivalence towards capitalism's ability to deliver decarbonisation, to explicitly anti-capitalist, "degrowth" narratives. It should be noted that narratives 2, 3, 4.2 and 4.3 share the assumption of an opposition between economic growth and decarbonisation that is proposed by integrated assessment models, but that they differ in how to interpret the model results. In narrative 2 and 3, the vast amount of carbon dioxide removal in integrated assessment model results is interpreted figuratively, as an approximation of the total amount of carbon dioxide removal that will be necessary to deliver by technological means. Thus, scenarios are construed rather as informed guesses about limits to decarbonisation. For narrative 4.2 and 4.3, the fact that such an amount of carbon dioxide removal is even contemplated to be achieved through "technological fixes" is taken to indicate a failure of capitalist imagination to envision and grapple with its own limits. Since the concept of economic growth in itself is rarely articulated nor debated, narratives 4.2 and 4.3 tend to equate capitalism with emissions-driven growth along the same logic as the less critical narratives 1–3. Therefore, their politicising thrust is couched in explicitly anti-capitalist terms.

4.3. Conclusion

Meckling and Allan (2020) have recently identified a shift in the climate policy debate since 2008, by which climate action has come to be seen more as driving than, as previously, inhibiting economic growth. Key to this shift, argue Meckling and Allen, is that neoliberal doctrine about the primacy of the market has been questioned, and the state has been "rediscovered […] in economic and technological change" (Meckling & Allan, 2020, p. 437). All the while, however, optimism surrounding the win-win possibilities of climate action has been tempered by a persistent 'limits to growth'-perspective that understands the very concept of "green growth" as an oxymoron (Meckling & Allan, 2020; see also; Tobin, 2020). In this context, van Beek et al.'s (2020) historiography of socio-economic, climate change modelling provides a useful reminder that today's climate IAMs are rooted in a 'limits-to-growth'-tradition, originating with Meadows et al.'s seminal study with that title in 1972.

These broader traditions and shifts in the political-economic and climate modelling discourses can be usefully connected to the present investigation, which sheds some new light on how results from integrated assessment models are received in a public, expert imaginary.

Critics have often accused integrated assessment models of climate change of promoting "business as usual" by deploying fantastical levels of BECCS as compensation for continued emissions. However, our analysis shows that commitment to business as usual is not the predominant feature of the BECCS media debate. All narratives welcome state action to enforce immediate and drastic emisisons reductions in ways that go well beyond the neoliberal adherence to carbon taxes that used to prevail in climate policy debates.

Instead, the idea of large-scale BECCS conditions the debate through a strong determinism, as evidenced by narratives interpreting model results - albeit from differing viewpoints - as illustrations of limits to how much decarbonisation can be achieved within systems of capitalist, economic growth. Because large-scale BECCS is derived from the neoclassical conception of fossil-fueled economic growth, the discourse is limited to positions of resigned belief in negative emissions technologies as necessary to keep capitalism going, and what amounts to their simple antitheses: the need to abolish capitalism.

To conclude, therefore, we argue that the public, expert debate of large-scale BECCS reveals a key dilemma for the integrated assessment modelling community and, by extension, the IPCC who rely on IAM scenarios for its reports. In achieving low warming targets while assuming that economic growth can only be achieved in a certain way and be opposed to decarbonisation, integrated assessment models produce scenarios that have little resonance in the public, expert imaginary. While the IAM community is careful to stress that scenarios are not projections, it must arguably be considered a problem if almost all narratives deem the vast majority of scenarios that achieve 1,5 degrees of warming to be neither possible nor desirable.

Thus, on the basis of this evidence, both in the way scenarios are construed as unrealistic by almost all narratives in the debate, as well as in the way the debate is discursively limited to a conception of economic growth ill-suited for profound energy-systems change, the scenarios produced by integrated assessment models fail in the stated intent of opening radically different futures (e.g. Vaughan et al., 2018). Given the significance of BECCS in low temperature IAM scenarios, and in turn their significance in IPCC reports, we believe this points to a danger in placing much emphasis on models that seem designed to close rather than broaden horizons of expectations for political-economic change and energy systems transitions (see also Carton, 2020; Gambhir, 2019).

Declaration of competing interest

We have no conflicts of interest to declare for the paper.

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