



# Boundary Work and Interpretations in the IPCC Review Process of the Role of Bioenergy With Carbon Capture and Storage (BECCS) in Limiting Global Warming to 1.5°C

Anders Hansson<sup>1\*</sup>, Jonas Anshelm<sup>2</sup>, Mathias Fridahl<sup>1</sup> and Simon Haikola<sup>3</sup>

<sup>1</sup> Unit of Environmental Change, Department of Thematic Studies, Centre for Climate Science and Policy Research, Linköping University, Linköping, Sweden, <sup>2</sup> Unit of Technology and Social Change, Department of Thematic Studies, Linköping University, Linköping, Sweden, <sup>3</sup> Unit of Technology and Social Change, Department of Thematic Studies, Centre for Climate Science and Policy Research, Linköping University, Linköping, Sweden

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### \*Correspondence:

Anders Hansson  
anders.n.hansson@liu.se

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Paris Agreement-compatible emissions pathways produced by integrated assessment models (IAMs) often rely on large amounts of carbon dioxide removals, especially afforestation and bioenergy with carbon capture and storage (BECCS). These pathways feature prominently in the work of the Intergovernmental Panel on Climate Change (IPCC), to the extent that the IAMs have been granted an interpretative privilege at the interface between climate science, economics, and policymaking. The privilege extends to and influences climate governance, including governance of BECCS. This paper contributes to recent debates about the role of the IPCC, and its framing of BECCS, at the science-policy interface. By analyzing all BECCS-related expert review comments and author responses on the IPCC Special Report on Global Warming of 1.5°C, the paper shows that boundary work influences the representation of BECCS by authors referring to: (1) a limited scope or capacity; (2) a restrictive mandate; (3) what constitutes legitimate science, and; (4) relativizing uncertainties. The responses to the review comments indicate a significant degree of compliance on behalf of the authors. Yet, the revisions do not seem to go to the heart of the unease that runs through many of the reviewer comments, i.e., that BECCS seems to be presented as a viable CDR technology at grand scale. While several revisions serve to clarify uncertainties surrounding BECCS, some fundamental aspects of the critique are deflected, through the boundary work identified. What the analysis reveals, beyond a dissatisfaction among many reviewers with the focus on integrated assessment modeling, the associated pathway literature, and analysis of BECCS, is a disagreement about how model results should be interpreted and communicated. While acknowledging the herculean task of the IPCC and the efforts to improve the pathway literature that the SR1.5 triggered within the IAM communities, we

argue that the identified boundary work also risks entrenching rather than problematize dominant framings of the feasibility of BECCS. Such entrenchment can counteract the ambition of opening up the scientific work of the IPCC to include more diversity in the process of drafting reports, and arguably also influence the governance of CDR.

**Keywords: the Intergovernmental Panel on Climate Change, 1.5°C warming, bioenergy with carbon capture and storage, carbon dioxide removal, boundary work, integrated assessment models, BECCS, IAM**

## INTRODUCTION

Integrated assessment models (IAM) and their associated climate mitigation scenarios were key features in the Intergovernmental Panel on Climate Change's (IPCC) second assessment report, published in 1995, and their importance has increased in later years (Beck and Mahony, 2018; Gambhir et al., 2019; Hilaire et al., 2019; van Beek et al., 2020). As of 2015, the IAM community has responded to the UN Framework Convention on Climate Change's (UNFCCC) Paris Agreement by forcing their models to resolve pathways capable of holding global warming well below 2 or 1.5°C. This includes the massive deployment of negative emissions technologies (NETs) and, in particular, bioenergy with carbon capture and storage (BECCS) (on average 5–20 GtCO<sub>2</sub>/yr by mid century) (e.g., Fuhrman et al., 2019; Rogelj et al., 2019). Thus, the unprecedented rate of climate mitigation scenarios intended to resolve stringent temperature targets can be understood in light of the UNFCCC's invitation to the IPCC *special report* on the impacts of *global warming of 1.5°C* above pre-industrial levels and related global greenhouse gas emission pathways (IPCC, 2016: 21§, decision 1/CP.21) and IA modelers who strive to be policy relevant. The IPCC accepted this invitation despite the fact that very few IAM-derived climate mitigation scenarios at that point in time depicted the goal as achievable (Livingston, 2018), and begun its work on what was to become its Special Report on Global Warming of 1.5°C (SR1.5), finalized in October 2018 as part of its sixth assessment cycle.

Guided by scenario estimates from SR1.5, carbon dioxide removals (CDR), achieved through deliberate deployment of negative emissions technologies (NETs), would sum to between 260 and 1,080 gigatons in the period 2020 to 2100 (IPCC, 2018). In the scenarios, BECCS would, on average, withdraw 550 gigatons accumulated over the latter half of the century, despite the method being merely in a demonstration phase (Mander, 2018). There is no scientific support for the upper ends of the range being realistic and possible to reconcile with other sustainability goals (e.g. EASAC, 2018; Carton, 2019; Haikola et al., 2019; Hu et al., 2020; Workman et al., 2020). There are currently no methods for CDRs, besides forest management and reforestation, that even approach the volumes needed to contribute to climate mitigation in any meaningful way, (Fuhrman et al., 2019). Carton et al. (2020) conclude, based on a literature review, that the forest-based CDRs are not proven at scale, and argue that the history of carbon removal, including afforestation, challenges the very idea of forest-based NETs.

The IAMs are called integrated since they combine input from many scientific disciplines to consider interlinkages between

climate-, economic-, energy-, and land use systems, which perform a form of multi-criteria assessment of the economic value of various options to mitigate climate change. The nature of IAMs makes them particularly relevant for the IPCC report chapters that deal with mitigation and have a policy- or solution-oriented approach. Thus, these IAMs have an interpretative privilege at the interface between climate science, economics, and policymaking (Livingston, 2018; Haikola et al., 2019; Livingston and Rummukainen, 2020; Low and Schäfer, 2020), and have also gained an aligning role in the negotiation between science and policy (van Beek et al., 2020). van Beek's et al. (2020) review of IAMs in the science and policy interface since the 1970s show that modelers have not only been reactive to societal demands and formulated responses, but have also anticipated and helped policy makers to formulate new goals, most prominently the 1.5°C aspirational goal.

Critique has been put forth that the current generation of IAMs are black boxed or unfit for policymaking since scientific uncertainties are resolved based on arbitrary or culturally-biased assumptions, they use unrealistic input data, normativity and bias are not disclosed or dealt with, and ethical consequences are neglected (Ellenbeck and Lilliestam, 2019; Haikola et al., 2019; Low and Schäfer, 2020; Workman et al., 2020). The critique has reached beyond the role of IAMs, and extends to the scope of the IPCC, its neutrality, scientific rigor, and integrity. Another strand of criticism focuses on the possibly performative, mitigation-detering role of IAMs that depict net negative emissions as feasible through so called overshoot scenarios, where near-term emissions reductions are postponed or even canceled because they are perceived as costly (e.g., Geden, 2015; Markusson et al., 2018; Asayama and Hulme, 2019; Carton, 2019; Ellenbeck and Lilliestam, 2019; Workman et al., 2020).

As a response to the critique, the IPCC's ambition with the SR1.5 was already from the onset to be more transparent and more interdisciplinary than previous reports. As the SR1.5 is scientifically more diverse and also more influenced by political demands and requests to be policy relevant, it has arguably become more difficult to maintain distinctions between science and policy. However, the new ideals potentially also open up for a re-negotiation of the hierarchy or traditional boundaries between different sciences and perspectives and, potentially, for leaving the more traditional and quantitative practices of the past (Livingston, 2018, see also; Sundqvist et al., 2018; Workman et al., 2020).

The aim of this paper is to contribute to recent debates about the role of the IPCC at the science-policy interface and the governance implications of how the IPCC frames and

communicates the potential role of CDR in global responses to climate change (e.g., Beck and Mahony, 2018; Livingston, 2018; Haikola et al., 2019; Carton, 2020; Low and Schäfer, 2020; Workman et al., 2020). Empirically, the paper investigates the critical review comments to the second order draft of the SR1.5, related to BECCS, and the author responses. Through the lens of the concept boundary work (the rhetoric to distinguish one thing from another thing, e.g., Gieryn, 1983), and in particular in relation to IAMs and BECCS, we will first briefly summarize the critical comments put forth by the reviewers and then analyze how the SR1.5 authors responded by delimiting relevant and accurate science. Finally, we conclude with a discussion of responses to the general critique of IAMs put forth both within and beyond the IAM communities, and what challenges we can see from having the type of boundary work observed influence the IPCC review processes. Thus, by investigating scientific discussions on BECCS in climate mitigation scenarios and in relation to IAMs and how the forwarded critique is dealt with in the IPCC's review process, insights can also be gained into how the increased ambitions for interdisciplinarity play out (i.e., Callaghan et al., 2020). Even though all review comments and IPCC author responses are publicly available already, the sheer amount of comments arguably makes the central conversations difficult to comprehend and assess for a reader. Thus, by the summary this paper also contributes to the transparency of the review process.

## BACKGROUND: THE IPCC'S MANDATE AND INTEGRATED ASSESSMENT MODELS

The IPCC is governed by principles that specify its mandate, procedures, and organization (IPCC, 2013), including its specific mandate: “to assess on a comprehensive, objective, open and transparent basis the scientific, technical, and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation” (6§). Importantly, the IPCC reports should be “neutral with respect to policy” (6§) but are allowed to “deal objectively with scientific, technical and socio-economic factors relevant to the application of particular policies” (6§). This, for short, has been termed the principle of providing policy-relevant yet policy-neutral assessments. Sundqvist et al. (2018) and Thoni and Livingston (2021) make clear that the consensus approach and tight coupling of science and policy often lead to the marginalization of alternatives, and that the often-narrow definitions of science in the IPCC contexts lead to a scientific reductionism.

If first constrained by a specific climate objective or other types of assumptions, the IAMs can be run to generate least cost pathways for transitioning the world in a manner that is compatible with the model constraints. This has resulted in a prioritization of BECCS among the NETs in the IAM-derived scenarios aimed at the most stringent targets (RCP1.9), and only 0.1% of these scenarios represent NETs other than BECCS,

afforestation, or reforestation (Workman et al., 2020)<sup>1</sup>. As noted by Gambhir et al. (2019), BECCS has made “some of the most stringent mitigation targets achievable in the framework of the IAMs” (p. 2). While BECCS was originally proposed as a backstop technology to manage risks (Obersteiner et al., 2001) and later featured in a minority of IAMs to resolve more stringent targets during the IPCC's fourth review cycle (Tavoni and Socolow, 2013), it has now become vital as an equation solver for the Paris Agreement's temperature goal (Fuss et al., 2014; Minx et al., 2017; Gambhir et al., 2019).

Livingston and Rummukainen (2020) argue that the science-policy interactions of the SR1.5 are unusual, in addition to the fact that this was the first IPCC report to include all three working groups, in the sense that science and policy were even more blurred regarding both institutional set up and processes than was the case for previous reports. They conclude that the consideration of the 1.5°C aspirations made climate change as an object of governance more complicated, subjective, and multiple, not the least because of a lack of agreement from both a scientific and a political perspective on the suitability of actually including 1.5°C in the Paris Agreement in 2015. Their interviews with IPCC authors reveal that the unexpected and unusual request from the UNFCCC to the scientific community, to investigate the novel more stringent targets, confirm the observation that these targets were considered unrealistic by many scientists (see also van Beek et al., 2020). This may illustrate an inverted process compared to first settling the science and then opening up for political deliberations. Thus, the UNFCCC aspirational goal to limit global warming to 1.5°C, and how it was scientifically assessed, challenged the traditional norms of the IPCC.

## METHODOLOGY

### Boundary Work and the IPCC Review Process

IPCC reports must balance scientific validity with policy relevance, and that relation is produced and reproduced discursively (Huiteima and Turnhout, 2009). Like Low and Schäfer's (2020) interview study of the contested authority of IAMs and the feasibility of BECCS, our paper departs from boundary work as an analytical framework. Boundary work entails rhetorical strategies—applied intentionally as well as unintentionally—to distinguish one thing from another thing, for example to distinguish relevant science and knowledge and to structure language between the positive and negative and between what is included and excluded (Gieryn, 1983; Friman, 2010). Boundary work also entails distinguishing boundaries between science and politics and also distinguishing the objective from the subjective, and that kind of boundary work has arguably recently become more salient in the recent debates on the IPCC's work processes (see also Frickel, 2004; van der Sluijs, 2005; Livingston, 2018). The procedural structure and work that takes place during revisions of an IPCC report indicate the frame for the boundary work, as they instruct the types of texts to

<sup>1</sup>The number 0.1% was assessed from the IIASA 1.5 scenario explorer in May 2019 by Workman et al. (2020).

include or exclude, what terminology to use, and how to define the overarching scope and aim of the report. Nonetheless, the instructions are interpreted by the IPCC authors and reviewers, and are also often referred to, implicitly or explicitly, by the actors in their boundary work. We will investigate how boundary work took place in the drafting of the SR1.5 report by looking at how critical comments are taken care of in general, and more importantly also the arguments presented in the cases when assessed as not being a basis for modifying the draft text or being possible to integrate.

The initial step in drafting an IPCC report is taken at a closed scoping meeting at which experts draft a report outline. The experts are selected by the relevant WG bureau from a list of nominees solicited from governments, observer organizations, and IPCC bureau members (IPCC, 2013). After the scoping meeting, the bureaux of the WGs and Task Force selects authors to be engaged in drafting the report(s). Criteria such as mix of expertise, gender balance, geographical origin, and previous experience in IPCC work are to be considered when selecting scoping meeting experts as well as authors. The authors then proceed to assess the scientific literature on issues within its mandate and the scope of the report. At the first lead author meeting, the authors also receive instructions on appropriate IPCC procedures, the type of sources that may or may not be included in the assessments, and how to calibrate uncertainty language (Mastrandrea et al., 2011; IPCC, 2013).

The review process is generally done in three steps: an expert review of the first order draft of the longer report(s), government and expert review of the second order draft(s), and government review of the summaries for policymakers (SPMs) and overview chapters and/or the synthesis report of the longer underlying reports prepared by each WG. Expert reviewers self-nominate and are then selected by the IPCC on the basis of expertise. The technical support units of the IPCC's WGs may also identify people with relevant expertise and directly invite them to nominate themselves as reviewers (IPCC, 2013). Every chapter is designated review editors, who attend lead author meetings and raise issues and concerns during the two review rounds. The review editors have continuous contact with the lead author teams regarding responses to review comments. The review editors also publish a final report for each chapter in order to describe the review process, describe the main areas of concern arising from the review comments, and confirm that contentious and controversial issues have been addressed and how they have been handled (IPCC, 2013, 2017, 2019a).

From 541 nominations, 91 coordinating lead authors, lead authors, and review editors from 44 countries were singled out for the SR1.5<sup>2</sup>. In addition, 133 contributing authors were invited by the chapter teams to provide specific input. As the comprehensive amount of review comments—40 001 in total, contributed by 796 individual reviewers and 65 governments—and author responses are very well-documented (IPCC, 2019b,c,d), and the authors clearly and systematically motivate their responses to all comments, this material constitutes exemplary material to scrutinize the boundary work

at the interface of science and policy and in-between various sciences and perspectives.

## Method and Analysis

The empirical focus in this paper is limited to a qualitative analysis of the critical reviewer comments and author responses to three chapters of the second draft, and not the final versions, however we include the authors' claims on how the texts were revised in the final versions, but we do not assess whether those revisions were undertaken or not. The material is publicly available, and the IPCC editors have presented all review comments and author responses in a transparent and accessible way (IPCC, 2019b,c,d). The dialogue between reviewers and authors is of primary analytical relevance for the analysis, and we have no reason to believe that the stated revisions were not undertaken.

The three chapters were selected due to their reliance on IAMs and the relatively high share of the acronym BECCS of the total word content: Summary for Policymakers, Chapter 2, and Chapter 4 (see **Table 1** below for an overview of the chapters and comments). All comments ( $n = 717$ ) including BECCS were read (The term "Bioenergy with carbon capture" did not appear in isolation from BECCS in the documents). Recurring themes and topics in the second reading were identified and ordered into categories applying a bottom-up approach, i.e., critique of bias in favor of BECCS; critique of how BECCS ecological, social, political, and economic consequences are described and analyzed; BECCS feasibility; BECCS and IAMs; land-use; and BECCS in relation to natural CDRs. The themes in the third reading were reduced to "reviewers' critique of biased framings," "lack of realism," "criticism of assumptions," and "neglect of alternatives." The themes overlap somewhat and are not mutually exclusive and single comment, especially the longer comments, can be ordered into several categories. Minor comments on e.g., language, missing space, and punctuations or inconsistencies and lack of clarity that are easily addressed are omitted from the analysis. An overall impression of the critical comments including BECCS is that they often convey a coherent questioning of not only the prominent position BECCS received in the draft but also bring attention to crucial issues concerning the meaning of feasibility, framings and interpretations of the main message the report presents, the role of assumptions and methodology, as well as boundary settings. The analysis was inter-coded by two of the article authors, and a third author cross-checked a larger sample of references at a later stage.

The author comments have been ordered into four categories that can be seen as illustrations of boundary work. Also the reviewers perform boundary work, but the present study is analytically limited to the authors' boundary work because authors must respond explicitly to all review comments (which enables a more transparent analysis) and also make the final decisions on how to revise the report, i.e., draw the boundaries. The strength of the inductive approach is that it allows for sensitivity to how the authors responded to critical comments, in contrast to defining and applying boundary work categories already identified in previous research. Boundary work is context dependent and previous research suggests that the

<sup>2</sup>List of authors and editors: <https://www.ipcc.ch/sr15/authors>.

**TABLE 1** | The share of the acronym BECCS of the total content of the review comments and responses to the first order draft of the Summary for Policymakers and individual chapters of the second order draft of the full report.

Chapter	Comments with references to BECCS	BECCS share of the total word content [% <sup>a</sup> ]	Review comments <sup>a</sup> (total/of substance) <sup>b</sup>
<b>Summary for Policymakers<sup>c</sup></b>	<b>133</b>	<b>0.3</b>	<b>NA</b>
Chapter 1: Framing and context	33	0.1	11 074/NA
<b>Chapter 2: Mitigation pathways compatible with 1.5°C in the context of sustainable development</b>	<b>350</b>	<b>0.6</b>	<b>3 724/2 088</b>
Chapter 3: Impacts of 1.5°C of global warming on natural and human systems	41	0.1	4 209/3 874
<b>Chapter 4: Strengthening and implementing the global response</b>	<b>234</b>	<b>0.3</b>	<b>4 409/NA</b>
Chapter 5: Sustainable development, poverty eradication and reducing inequalities	45	0.1	2 299/NA

<sup>a</sup>IPCC, 2019b,c,d.

<sup>b</sup>IPCC (2019a). Review comments that are not of substantive nature are, for example, editorial in nature, pertain to references, or relate to the use of uncertainty language.

<sup>c</sup>Chapters marked in bold are those that have been selected for analysis.

**TABLE 2** | The four boundary work modes.

Boundary work mode	Examples of rhetoric and coding
1) Remitting or referring to a limited scope or capacity.	Selection of literature argued to be not in line with the scope of the chapter; impacts on a certain SDG are outside the scope of the report or chapter; the issue is too complex for the authors; space restrictions.
2) Claiming to be beyond the mandate: subjective and policy prescriptive.	Land-use issues are within the mandate of another forthcoming IPCC report; excluding BECCS from the analysis is policy prescriptive/subjective; the mandate is to reflect assessments in the scientific literature only.
3) Restricting and defining what is legitimate science.	A certain field of literature (i.e., the pathway literature) defines what is relevant to include, cannot conduct an analysis beyond what is already conducted in the relevant literature; the reviewer's suggested literature does not meet scientific criteria.
4) Relativizing uncertainties.	A specific problem/challenge/obstacle is also valid, or worse, for another alternative; a global energy transition will involve a large land footprint regardless of whether BECCS is implemented or not; most CDRs are untested.

work procedures of the IPCC, contentious topics and views on uncertainty and policymaking change over time (e.g., Livingston and Rummukainen, 2020), thus the inductive approach opens up for a more open-minded exploration of boundary work not already discussed in the literature. We inductively constructed four boundary work modes (see **Table 2**), and as will be elaborated on in the Discussion (chapter 5), they are not mutually exclusive and some modes often interact or overlap. The boundary work modes were constructed by reading the authors' rebuttals or partial rebuttals of critical comments, but the complying responses were not analyzed. Taken together the four modes hopefully convey most rhetorical means that were deployed. One can argue that a fifth mode could have been added—neglecting a comment—but instead we decided to merely mention when that occurred. The table above (**Table 2**) shows the four boundary work modes and exemplifies how they were coded and identified.

## ANALYSIS AND RESULTS

This chapter exclusively summarizes content of the comments and responses. The first sub-section (The reviewers' critique of

BECCS) presents the reviewer comments and the second sub-section (The authors' responses) thematically structures salient and recurring themes derived from the review comments and author responses in the three analyzed chapters<sup>3</sup>. The latter section, based on the author responses, also discusses the material but in relation to four inductively-derived boundary work modes: (1) remitting or referring to a limited scope or capacity, (2) claiming to be beyond the mandate: subjective and policy prescriptive, (3) restricting and defining what is legitimate science, and (4) relativizing uncertainties. **Table A1** shows the 15 reviewers that submitted the largest number of critical comments.

### The Reviewers' Critique of BECCS

A central line of the critique raised by reviewers is that the second order draft of SR1.5 is strongly biased in favor of BECCS, and that the report underplays fundamental uncertainties related to technical, socio-political, and ecological aspects. Some reviewers

<sup>3</sup>References to review comments and responses follow the unique numbering assigned by the IPCC review editors with prefix letters added to facilitate the identification of the context in which the comments have been given: "A" denotes a reviewer or author comment to the SPM (IPCC, 2019b), "B" denotes chapter 2 (IPCC, 2019c), and "C" denotes chapter 4 (IPCC, 2019d). The list of references is illustrative and not exhaustive.

have even gone so far as to claim that the unwarranted focus on BECCS in the draft conflicts with the IPCC's intention to present comprehensive and unbiased assessments<sup>4</sup>. This, however, is framed in somewhat different terms in the chapters analyzed in the present paper. Comments to chapter 2 are the most technically oriented, while they also highlight perceived problems with how BECCS is represented in IAMs. Similarly, comments to the SPM also aim to incorporate caveats and limitations in IAMs and is concerned with the overall impression given by that chapter, which, according to some reviewers, gives a dangerously favorable impression of the real potential of BECCS that is not substantiated by the science. Comments to chapter 4 more often tend to focus critically on the feasibility aspect of BECCS and draw more attention to issues of policy and governance<sup>5</sup>.

Many reviewers argue that portrayal of BECCS as necessary for achieving the 1.5°C target is unfounded and over-emphasized, or that the report itself does not support the heavy reliance on BECCS in the pathways. Several comments stress that BECCS is not proven at scale and conclude that should be clearer communicated. Additional comments state that it is irresponsible or even unethical, to let scenarios compatible with 1.5°C rely so heavily on BECCS and afforestation as the only CDR methods without explaining this single-minded focus<sup>6</sup>. The reason for the bias is occasionally claimed to be the IAMs' internal logic, which according to reviewers privilege large-scale techno-fixes and foster technological determinism or results in systematic neglect of alternatives<sup>7</sup>. The draft report is also criticized for cherry-picking or highlighting scenarios that rely heavily on BECCS, even though scenarios without BECCS or with only small proportions of BECCS and other NETs are available. Some reviewers argue for re-phrasing or removing wording that suggests all scenarios need BECCS in order to reach 1.5°C<sup>8</sup>.

A wide array of what is argued to be less speculative CDR alternatives to BECCS is put forth in comments by reviewers. These methods sometimes described as more natural, include land-use management, changed agricultural practices, and restoration of ecosystems including forests, and are seldom or never included in the IAMs. Several reviewers argue that the so called natural CDRs are more ecologically sustainable, tested at larger scale, less expensive, involve fewer risks, and may enhance food and water supply security<sup>9</sup>. Also other CDR methods, such as direct air carbon capture and storage (DACCS), afforestation and regenerative agriculture, are suggested in one comment to be “preferable” but insufficiently covered in the IAMs in spite of being, they argue, more feasible, desirable and ethical than BECCS at scale<sup>10</sup>. Other—more mature, less costly and far less speculative—mitigation options and paths to decarbonization are claimed by reviewers to be unwarrantedly ignored, such

as improved solar and wind power, scaling down of agri-food systems, forest restoration, methane and nitrification inhibition, reduced energy demand, and nuclear power<sup>11</sup>. An important problem with the draft, as identified by reviewers, is that its reliance on integrated pathways literature, and bias or neglect of options in the IAMs underpinning the mitigation pathways, means many mitigation methods are not analyzed<sup>12</sup>.

Some reviewers also criticize what they perceive as the presentation, in the draft, of afforestation and BECCS as equally feasible. This, they claim, is misleading as the former has already been implemented at scale and provides several co-benefits. The future cost of BECCS is understood by some reviewers to be inherently impossible to estimate, while afforestation, in contrast, is argued to be possible to cost-efficiently scale-up<sup>13</sup>. Both methods entail land-use problems, the reviewers argue, and some suggest that claims that BECCS is better than afforestation should firmly be avoided<sup>14</sup>.

Several reviewers criticize what they perceive as a lack of transparency in general, or regarding how the range of scenarios were selected. Many call for more transparent discussion about the strength and weaknesses of IAMs and crucial model assumptions<sup>15</sup>, including discount rates, natural sinks, land-use effects and land-use trade-offs<sup>16</sup>, hydrological and water aspects and nutrient loss from soils<sup>17</sup>, biomass productivity rates and crop yields<sup>18</sup>, and technological learning and economies of scale<sup>19</sup>. For some, the extremely high levels of BECCS deployment in reviewed scenarios depend on calculations that are either untraceable, unrealistic, or rest on flawed assumptions. Some of these comments forward that if these calculations and assumptions are not dealt with in a scientifically robust manner, together with the general limitations, biases and strengths of IAMs<sup>20</sup>, the narrative of a BECCS-dominated path to 1.5°C is either not trustworthy or comprehensible<sup>21</sup>.

According to some comments to chapter 4, where the most colorful remarks are to be found, the draft text is suffused with magical thinking because it treats model results as reality, or does not explain how the apparent contradiction between what is feasible in the models and feasible in reality should be interpreted<sup>22</sup>. According to several reviewers, the lack of transparency around climate scenarios and their underlying assumptions results in a potentially deceptive impression of the maturity and feasibility of BECCS. Because of the draft report's reliance on IAMs, some argue, BECCS is represented as feasible

<sup>4</sup>e.g., A19436, B51036, B53970, B55468, B55478.

<sup>5</sup>e.g., C13342, C31658, C60780.

<sup>6</sup>A42862, A42912, A43810, A43858, A43738, A50414, A51160, B51038, cf. B53260, B53492.

<sup>7</sup>A19360, A19362, B51036, B55478, C51048.

<sup>8</sup>A19436, A56512, A62906, C19708, C19756, C24386, C53268, C55700.

<sup>9</sup>A19002, A29556, A50036, A51072, A51074, A51166, B19614, B19628, B51038, B53970, B54512, B55480.

<sup>10</sup>A43858, A43810.

<sup>11</sup>B2072, B3198, B19614, B19628, B51038, B53970, B54512, B55468, B59926, C52072.

<sup>12</sup>A19436, B11824, B19614, B51038, B59926, B55478, B55468.

<sup>13</sup>A29182, A30100, B53260, B59998, C18618, C39300, C53264, C53266, C56052.

<sup>14</sup>C18618, C51522, C53266, cf. C62786.

<sup>15</sup>B11708.

<sup>16</sup>B11700, B11708, B11800, B19310, B19624, B27962, B51036, B51148, B56872.

<sup>17</sup>B13924, B15730, B53262.

<sup>18</sup>B18110, B37376.

<sup>19</sup>B2072, C37212.

<sup>20</sup>A19360, A19362, B51036, B51038, C51044, C51196, C53248, B55468.

<sup>21</sup>A49532, A56506, A59256, B11700, B37398, B55468, C51044, C53250, C53258.

<sup>22</sup>C51044, C53246, C53258, C53264, C53268, see also A19362, B11700, B18010, B37398.

at an unrealistic scale or in a way that is contradicted even by findings reported on elsewhere in the SR1.5 draft<sup>23</sup>.

If, some reviewers argue, the conclusion is that the 1.5°C target is only possible to achieve with large scale BECCS deployment, the risks related to relying on an unproven method with low feasibility should be clearly spelled out<sup>24</sup>. Several reviewers call for explicit accounts of the lack of scientific support for anything but very limited or slow implementation of BECCS<sup>25</sup>. A few reviewers comment on what they see as a neglect and underestimation of severe limitations to BECCS deployment, as well as questionable statements that BECCS would entail positive side-effects (e.g., lower food prices)<sup>26</sup>.

The availability of land is another frequently raised concern. Several reviewers observe as remarkable the assumption made for some pathways, e.g., that 25–46% of the available arable land will be included in future BECCS systems. Such land use would, they note, significantly impact the potential to achieve other SDGs or result in forest degradation, social tensions, biodiversity losses, or reduced food security, conflicts many reviewers argue need to be explained in more detail<sup>27</sup>. In chapter 4, one reviewer, the director at the NGO “The Partnership for Policy Integrity,” argues that some pathways entail land areas for biomass production that “would strike most people as insane,” but that the report treats these numbers as unproblematic<sup>28</sup>.

The scenarios’ heavy reliance on bioenergy use is a point of concern for reviewers, not only for what this reliance implies in terms of land use change, but also for the wider energy system repercussions when limited bioenergy resources are devoted to BECCS. This would supposedly make fossil phase-out more difficult if it means less bioenergy available to substitute for fossil fuels in other sectors. This is one additional factor that reviewers identify as a risk for fossil lock-in due to an overreliance on BECCS, besides the neglect of alternative ways for decarbonization<sup>29</sup>. In addition to impacts on food security and biodiversity, the land-use associated with biomass production for large-scale BECCS is occasionally suggested to imply substantial governance challenges, including potentially negative economic and political consequences<sup>30</sup>.

All these comments are often summed up in the frequently recurring message that massive implementation of BECCS has been envisioned as achievable only because extensive problems associated with its implementation have not been taken into account. Several reviewers emphasize that detrimental land-use effects, economic costs, and other systemic risks associated with large-scale BECCS are of such a magnitude that BECCS must be rejected as an option for removing CO<sub>2</sub> at scale. Instead some argue that alternative CDRs, that pose lower risks, are more

readily available. Thus, the option to cope with only low levels of CDR, or without CDR entirely, should, according to some comments, be presented as preferable<sup>31</sup>.

The harsh, comprehensive, and intense criticism that several reviewers articulate is obviously an expression of fundamental disagreements, even though they are for the most part conveyed in a restrained manner. However, some voices diverge (two university professors and two NGO representatives) from this pattern by use of a more contentious rhetoric. Among these voices, accusations that the report does not at all rest on scientific objectivity, rationality, and policy neutrality are recurrent. On the contrary, the draft is said to be permeated with irrational and unfounded beliefs. A few reviewers maintain that the report’s reliance on BECCS resembles the belief in “fairy dust”<sup>32</sup> or “magical thinking” and “is frankly absurd”<sup>33</sup>, or being “practically a fantasy”<sup>34</sup>, and another understands this reliance on BECCS as a result of a “teleological determinism”<sup>35</sup> in the IAMs, and that singling out BECCS as the main option for negative emissions “makes no sense”<sup>36</sup>. The two latter reviewers also claim that the IAMs relied upon in the draft include “insane” assumptions<sup>37</sup> or present “crazy numbers”<sup>38</sup>. In a similar manner, another reviewer argues that the narratives and messages concerning BECCS and negative carbon systems appear to be “a house of cards”<sup>39</sup>.

The polemical tone and the provocative statements of some reviewers bear witness to the contentiousness of BECCS in the review process and to the importance that was attributed to the draft’s analysis of BECCS. It was partly against this backdrop of harsh criticism, sometimes couched in polemical language, that boundary work guided the revised version of the report toward scientific rigor and objectivity as well as policy neutrality.

## The Authors’ Responses

The reviewer comments are generally met with at least some degree of compliance by the authors, who in most cases clearly acknowledge the validity of the comment in question. In many instances, authors also claim to have responded accordingly by making the required revisions to the text. This is true for the many comments that point to the need to further highlight the fact that BECCS remains unproven at scale, while the feasibility claims are nuanced by insertion of caveats and clarifications that certain results rest on pathway literature, or by authors highlighting that BECCS is more uncertain and harder to assess than for example low-energy scenarios<sup>40</sup>. In chapter 4, especially, authors claim to have developed or clarified the feasibility

<sup>23</sup> A19436, A19360, A49532, B30878, B30880, B53492, B55468, A56506, A59256, C12292, C30976, C51044, C51196, C53246, C53248, C57876.

<sup>24</sup> C22774, C57876.

<sup>25</sup> C28472, C51044, C51196, C53248, C57876, C60780.

<sup>26</sup> B28054, B 53978, B55646, C18612, C37470, C61014.

<sup>27</sup> A4450, A32624, A54764, B10286, B28002, B37376, B37382, B51134, C18612, C39232, C51196, C51516, C53154, C53250, C54732, C57864, C57876.

<sup>28</sup> C53250.

<sup>29</sup> B11844, C51516, C60678, C63270.

<sup>30</sup> B37382.

<sup>31</sup> A43858, A43810, A51138, A51158, A51160, A51166, B51036, B51038, B51134, B53970, B53978.

<sup>32</sup> A19362.

<sup>33</sup> C53266.

<sup>34</sup> C53264, C53268.

<sup>35</sup> C51048.

<sup>36</sup> C51048.

<sup>37</sup> C53250.

<sup>38</sup> C51044.

<sup>39</sup> B37398.

<sup>40</sup> A51166, B3198, B18010, B18006, B19614, B27998, B51036, B51038, B53260, C53264, B53970, B53978, B54512, B55478.

discussions and scaling issues substantially<sup>41</sup>, and further state they have assessed the literature about side-effects or long term storage<sup>42</sup>. On several occasions in chapter 4, the authors briefly confirm that suggested re-formulations and literature have been taken into account and revised accordingly<sup>43</sup>, while a few rebuttals or partial rebuttals are made due to limited space in the report<sup>44</sup>.

Authors further acknowledge a mistake in unwittingly presenting BECCS and afforestation as equally feasible and revise potentially misleading formulations accordingly. Additional clarifications of the differences and similarities between the two methods have been added by the authors, explicitly including statements of the methods being at different maturity levels, with BECCS merely in the demonstration phase<sup>45</sup>.

The frequently voiced critique of a BECCS bias in the report is never explicitly addressed by the authors. Instead, they respond to the comments calling for inclusion of a broader variety of CDRs, and those criticizing a perceived neglect of non-CDR scenarios, by explaining that the draft has been revised to state that most but not all pathways include BECCS<sup>46</sup>. The heavy reliance on BECCS and afforestation is also claimed to be balanced with explanations that several mitigation options not included in the climate mitigation models are in fact available and that a broad variety of mitigation options actually are preferable, despite the clear prioritization of BECCS in the integrated pathway literature. The heavy reliance on integrated pathway literature in chapter 2 is also claimed to be in line with the scope of that chapter<sup>47</sup>.

Authors additionally respond to critique on certain figures downplaying BECCS' negative impacts on the environment and food security by revising or removing them. A more general rephrasing is conducted throughout the three chapters, as nuances are added about the environmental consequences of BECCS and bioenergy in general. Comments about relations between land-use and BECCS in IAMs, as well as the relation between bioenergy and BECCS in 1.5°C pathways, have also led to the addition of a discussion and an explanatory box<sup>48</sup>. Additional comments have also been inserted explaining that many of the impacts associated with BECCS are in fact also valid, or even worse, for several of the alternatives that the reviewers present<sup>49</sup>.

The general pattern of the authors' responses is thus an addition to the text rather than subtraction, and to clarify where reviewers call for it. Even the more critical comments in chapter 4 are met with acknowledgment and often result in revisions. However, the deeply critical verdicts of that chapter, which question the scientific rigor and fundamentals of crucial

assumptions and methods without pinpointing specific figures, numbers, or calculations that can be easily amended, are sometimes passed over without remark.

Nevertheless, despite the consistently appealing tone, some fundamental points of the critique are deferred through the boundary work we presented in the introduction of this chapter, i.e., (1), remitting or referring to a limited scope or capacity, (2) claiming to be beyond the mandate: subjective and policy prescriptive, (3) restricting and defining what is legitimate science, and (4) relativizing uncertainties. While acknowledging that BECCS would have an impact on the fulfillment of a number of SDG and deleting statements to the contrary, the authors' general response is to claim that SDG conflicts, land-use competition and assessment of technological assumptions are outside the scope of the report, too complex for the author teams to engage with, or simply impossible to address due to space restrictions (boundary work mode 1: remitting or referring to a limited scope or capacity). When such critique appears in comments to chapter 2, on the other hand, it is commonly argued by the authors that sustainability aspects will be dealt with exclusively in other chapters (while briefly referred to also in chapter 2)<sup>50</sup>. Another recurring argument is that the pathway literature defines which options to include, and that an in-depth analysis beyond what is already conducted in the referred literature falls outside the scope (boundary work mode 3: restricting and defining what is legitimate science)<sup>51</sup>. The overall impression is that the four boundary work modes were equally common.

Boundary work mode 1 is also seen in response to calls for clarifications about land-use-related trade-offs resulting from large-scale BECCS. This discussion is acknowledged by authors as important but outside the scope of SR1.5 and, while certain minor revisions are made, they commonly, refer land-use issues to the forthcoming IPCC Land-use Report due in 2019, 1 year after the SR1.5<sup>52</sup>. When critique is rebutted in this manner, it is not always clear whether it is a matter of boundary work mode 1 (limited scope/capacity) or a matter of restricted mandate (subjective and policy prescriptive), i.e., boundary work mode 2, since both aspects are sometimes implied. So, for example, the request to exclude massive implementation of BECCS from the report due to infeasibility is met with the argument that doing so would not only require complex but also subjective assessments<sup>53</sup>. In response to this and similar requests, the authors point out that, in line with the mandate of the IPCC, the report is not to provide policy prescriptions or feasibility judgements, but instead only to reflect assessments in the scientific literature<sup>54</sup>.

Similarly, boundary work modes 2 and 3 are often used in conjunction with each other. This is especially the case concerning comments about land-use and bioenergy issues in chapter 2 and the request to broaden the literature scope, which

<sup>41</sup>C51516, C53248, C56062.

<sup>42</sup>C18618, C28546, C51196, C57876.

<sup>43</sup>C1644, C18616, C31556, C51516, C53248, C53254, C54068, C56052, C58184.

<sup>44</sup>A19360, C39244, C51522, C53252.

<sup>45</sup>A51072, C39300, C51048, C51522, B53260, C53264, C53266, C56052.

<sup>46</sup>A19436, A51158, A51160, A56512, A62906, B51148, B53492, C19756, C24386, A43738, C55700.

<sup>47</sup>B51038, B55468, B55478, B56872, B59904.

<sup>48</sup>B11700, B18118, B56036.

<sup>49</sup>A49528, A50036, A53876, B53260, B59998.

<sup>50</sup>B10286, B11824, B19628, B53970, B53978, B59938.

<sup>51</sup>B51036, B51038.

<sup>52</sup>A29556, B11788.

<sup>53</sup>B51134.

<sup>54</sup>B53980, C28472, C51516, see also A43810.

the authors in general are slightly more reluctant to respond to favorably. The critique of land-use-related sustainability issues—when these are not argued by authors to have already been included elsewhere in the report or addressed with clearly expressed caveats—is rebutted with the argument that the report exclusively rests on scientific, peer-reviewed results. Review comments on this topic are thus often dismissed either because they are deemed to be based on literature that does not meet scientific criteria, or because the referenced papers are judged to not deal explicitly with these issues, and therefore, the authors would move beyond their mandate if they drew broader conclusions based on these studies<sup>55</sup>. The authors claim to be restricted to making solidly scientific and objective assessments without favoring any specific options or technologies or prescribing specific policies. When called upon to sharpen a formulation about constraints to large-scale BECCS, for example, the authors respond that doing so would be policy prescriptive, since it lacks wide support in the reviewed scientific literature: “Reject. Qualifying the constraints would be perceived as policy prescriptive and judgmental, and is not supported by the width of the literature.”<sup>56</sup>

Boundary work mode 3 is also used to justify the lack of comparison with natural CDRs. Authors of chapter 2 refer to—and regret—that the investigated literature does not assess alternative CDRs, which disqualifies several methods from inclusion in the chapter. More specifically, the authors agree that it is a flaw that only BECCS, afforestation, and DACCS are included among the NETs. However, they emphasize that the selection in chapter 2, was made since these are the only NETs available in the reviewed “integrated pathways literature” or that the other options do not feature strongly<sup>57</sup>. However, boundary work mode 1 is sometimes also used to clarify why natural CDR options and land management are excluded, as the authors argue that those methods instead fall under the scope of the forthcoming special report on Climate Change and Land Use, to be published in the autumn of 2019<sup>58</sup>.

Furthermore, critical comments about the relation of BECCS to other CDRs, as well as its relation to bioenergy usage without CCS, is also deferred by authors, who resort to boundary work mode 4, i.e., relativizing uncertainties. In the SPM, for example, requests to compare BECCS to other, natural and according to reviewers ecologically less risky and more proven CDRs are often met with acknowledgment and revisions, but the responses are sometimes followed by a comment that natural CDRs demand equal or even larger land areas than BECCS and have other constraints of importance. Similar arguments are used in a more general defense of the way that the SPM is written. Authors, while acknowledging the need to further clarify potential environmental risks from large-scale BECCS, add that all forms of bio-energy use are associated with the same fundamental land-use problems. In the SPM, comments to the effect that large-scale BECCS will entail land competition with

other land uses and CDRs, are responded to with the claim that a global energy transition will involve a large land footprint regardless of whether BECCS is implemented or not<sup>59</sup>. This boundary work mode is also evident in chapter 4. Responding to a request to clarify that BECCS is untested at scale, the authors reply that while this is true, the same applies to many CDR technologies<sup>60</sup>.

## DISCUSSION

The responses to the critical reviewer comments indicate a significant degree of compliance on behalf of the author team. Comments are often met with acknowledgment of their relevance, and a large number of revisions are made. Yet, such revisions do not seem to go to the heart of the unease that runs through many of the comments, i.e., that BECCS is presented as a viable, or feasible, CDR technology at a gigaton-scale in the future. While several revisions are made to further clarify uncertainties surrounding BECCS, many of the more fundamental aspects of the critique are deflected rather than incorporated, through the boundary work described in the previous sections.

There are two key junctures at which the boundary work operates to deflect fundamental criticism of the way that BECCS is represented in the draft IPCC report. The modes of boundary work in play arbitrate, first, arguments over *what constitutes relevant science* in relation to the report, and second, arguments over *what constitutes an accurate representation of science*. At both these junctures, review comments aim to broaden the scope of the text while the authors deploy different boundary work modes to hold in place what they define as the boundaries for their role as scientific interpreters. In this concluding discussion, we will highlight how boundary work by the authors sometimes tends toward abstract and reductionistic treatment of BECCS, and, finally, what challenges we can see from permitting this type of boundary work to influence the outcome of the review process. The discussion-section ends with a reflection on the key challenges of communicating the IPCC report’s scientific results in a “policy-relevant yet policy-neutral” manner and the role of IAMs in IPCC assessments.

### What Constitutes Relevant Science?

The report authors of chapter 2 explicitly assert that the integrated pathway literature should be given most weight without clearly stating whether this is due to issues of scientific validity and relevance or if it is due to time limits. This strict limitation to a certain type of literature, that rely on IAMs, cannot be fully explained by the draft outline decided at the scoping meeting, which in vague terms calls for considering “[t]echnological, environmental, institutional, and socio-economic opportunities and challenges related to 1.5°C pathways” (IPCC, 2016, p. 19). The scoping meeting decision also instructs authors to consider the recommended focus as “indicative” (IPCC, 2016: Decision IPCC/XLIV-4, §4), which

<sup>55</sup> B33578, B55468.

<sup>56</sup> C28472.

<sup>57</sup> B51038, B55468, see also B2072, B18010, B55478.

<sup>58</sup> A29556, B11788, B18110.

<sup>59</sup> A11372, A11376, A49528, A50036, A53876, A56028, B53260.

<sup>60</sup> C22774, see also C53264.

provides flexibility for the authors to decide what literature they consider relevant for which chapters.

As illustrated in the section “The authors’ responses,” sometimes authors respond to requests for broadening the scope of the literature review by claiming that only peer-reviewed papers are to be included in the review, while comments indicate the existence of peer-reviewed, relevant literature that casts doubt on several of the assumptions made in the pathway and IAM literature preferred by the authors. Thus, the boundary work modes 1 (scope and capacity) and 3 (legitimate science) blend, as authors sometimes point to the limited scope of the report or chapter being discussed as reason for not including certain suggestions, while the reference to the peer-review criterion sometimes implies this to be the motive for excluding certain suggestions.

The demarcation between assertions of limited scope and relevance is further blurred by the way authors sometimes motivate excluding certain statements about alternative CDRs or mitigation options, land-use impacts, or conflicts with SDGs. In addition to omitting certain critique based on assertions of the limited scope of the report, the capacity of the author team due to the complexity of the request and the lack of relevant literature, the authors also relativize the uncertainties and risks associated with BECCS (boundary work mode 4). Requests for analyses of how other biomass-based mitigation options are related to and could conflict with a deployment of BECCS on a gigaton-scale are often responded to with the assertion that their land-use effects would be equally or even more severe than those of BECCS. Thus, it is implied that while the focus on BECCS in the literature is unfortunate, avoiding BECCS or referring to a broader palette of alternatives would not make a substantial difference to the report’s conclusions, since doing so entails equally troublesome or even worse consequences for agriculture, land-use, and forestry.

## What Constitutes an Accurate Representation of Science?

The same tendency to avoid delving into some of the specifics of BECCS is evident also in discussions between authors and reviewers about the proper way to represent the science that is assessed by the IPCC. Critical commenters often urge that BECCS be reframed as a highly speculative technology. The critics call for a much sharper distinction between the real-world potential for BECCS deployment and the levels depicted in the imaginary climate mitigation scenarios. This includes elaborating a nomenclature that clarifies the meaning of the term feasibility when used in connection to integrated assessment modeling as opposed to real-world deployment potentials (see also Low and Schäfer, 2020). While acknowledging the speculative nature of BECCS and making some linguistic adjustments, the IPCC authors tend to respond to such requests by referring to boundary work mode 2, i.e., they are restricted by their mandate to assess existing literature while being “neutral with respect to policy” (IPCC, 2013, §2). Following this logic, the literature would be used in a restricted sense for its conclusions about theoretical possibilities or feasibility rather than as a base

for “policy prescriptive” judgements about how feasible these deployment levels are. However, the boundary between what constitutes unwarranted policy prescription and what constitutes a legitimate scientific review is apparently not clearly defined.

Our analysis reveals certain ambiguities and inconsistencies in how report authors respond to reviewers that can partly be explained as a consequence of recent changes of the IPCC work processes and attempts to be more inclusive, as described by Gambhir et al. (2019), Thoni and Livingston (2021), and Workman et al. (2020). The IPCC has a reductionistic tendency deeply rooted in its history as an institution that favors quantitative models and data and results from the natural or economic sciences over less quantitative methods and perspectives (Bjurström and Polk, 2011; Hulme, 2011; Fløttum et al., 2016; Haikola et al., 2019; Low and Schäfer, 2020; Thoni and Livingston, 2021). The SR1.5, meanwhile, was set-up to be the most transparent, inclusive, and interdisciplinary of all IPCC reports, and many IPCC actors welcomed the increased plurality. However, the practical drafting of an IPCC special report must deal with conflicting ontological and epistemological demands at the interfaces of different scientific disciplines as well as between science and policy. This would force a tradeoff between embracing complexity and the reductionism that is often required by the conventional methodologies favored by the IPCC and its consensus ideal (IPCC, 2013: §10; see also Livingston, 2018; Thoni and Livingston, 2021). The boundary work studied in the present paper could be seen as a response to being torn between strengthened ideals of openness concerning the IPCC work processes and the institutional path dependency that regulates the work of the IPCC. These new ideals for more inclusive scientific assessments and less reductionist tendencies seem to invite the type of critical arguments for embracing uncertainty and complexity, which the IPCC historically had a culturally ingrained tendency to reduce<sup>61</sup>.

It could well be that this review process has lived up to being billed as the most open IPCC report to date. There are, nevertheless, some challenges attached to the type of boundary work that operates in managing some of the more critical review comments. BECCS goes through a two-step abstraction because the relativization of BECCS at scale coincides with the treatment of pathway literature in the reductionist tradition identified by Hulme (2011) and Thoni and Livingston (2021). The treatment of the IAM literature as a detached, separately existing body of scientific work to be assessed as objective science is especially problematic since the modeling communities that produce this literature are also encouraged by the IPCC to produce these same scenarios/pathways and optimize them toward politically pre-set targets (see Livingston, 2018; Carton et al., 2020; Workman et al., 2020, see also van Beek et al., 2020).

By thus detaching the 1.5°C pathway literature from the institutional and political contexts in which it is embedded, and from the contested assumptions it departs from, the authors’ boundary work risks normalizing what is in fact a highly speculative option in the portfolio of mitigation and CDR

<sup>61</sup> See Haikola et al. (2019) for guidance on literature on the historic role of models and IAMs in relation to climate science.

alternatives (see also e.g., Geden, 2015; Faran and Olsson, 2018; Carton, 2019; Ellenbeck and Lilliestam, 2019; Haikola et al., 2019). If SR1.5 is regarded as merely one type of statement, intended to be viewed in a context of a series of reports, as indeed is suggested by authors in the review process, the chosen approach appears perfectly sound. However, to do so would assume a very high level of awareness and knowledge about scientific uncertainties, the nature of IAMs, and the concept of feasibility, among the many actor groups that use and rely on the findings of IPCC assessment reports.

## Concluding Reflections

Communicating uncertainty to non-specialized audiences while maintaining the “policy-relevant yet policy-neutral” stance of the IPCC has become a key challenge for the organization (Hollin and Pearce, 2015). The readability of the SPMs has proven to be poor (Barkemeyer et al., 2015), and the standardized nomenclature used by the IPCC to communicate probability and uncertainties is prone to misinterpretation and differing interpretations (Budescu et al., 2014; Low and Schäfer, 2020). Fløttum et al. (2016) also show that the standardized probability language reinforces natural science framings in all of the IPCC working groups, at the expense of social science framings and perspectives that include critical remarks on the governance implications of global BECCS deployment at large scale (see also Carton et al., 2020). The emphasis on policy-relevance in the sixth assessment cycle would also seem difficult to reconcile with a strengthening of uncertainty communication and the concurrent requests for inclusion of a plurality of scientific perspectives.

The communication challenge is made even more difficult by the IPCC’s heavy reliance on IAMs in their narration of assessment reports, as IAMs have long been criticized precisely for their tendency toward reductionism and lack of transparency. The IAM communities have reacted to such critique and the SR1.5 arguably acted as a trigger, and the main response has been to conclude that it is not fruitful to abandon IAMs since they have been proven to be useful tools and are highly demanded by policy-makers and other actors concerned with the transformation, distribution, costs, and use of energy resources. Instead, the IAM communities’ recommendations seem to favor supplementing the IAMs with additional analytical models and methods, e.g., improve representation of behavioral and lifestyle changes, and include additional CDRs or minimize the use of BECCS (see e.g., Grubler et al., 2018; van Vuuren et al., 2018; van Beek et al., 2020).

Thus, incremental changes are favored from within the IAM communities: by aiming at including more scientific perspectives and connecting qualitative evidence to quantitative in a more systematic way (e.g., Gambhir et al., 2019; Hilaire et al., 2019; van den Berg et al., 2019; De Cian et al., 2020), initiating model inter-comparison projects (e.g., Rickels et al., 2019), and by including a broader span of NETs, technological diffusion dynamics, political constraints, and socio-cultural changes in the models (Fuhrman et al., 2019; Workman et al., 2020). Currently self-reflection and meta-studies to improve the understanding of mitigation pathways and enhance the models’ utility and credibility are

underway (Fuhrman et al., 2019; Gambhir et al., 2019; Hilaire et al., 2019; Rickels et al., 2019).

What our analysis reveals, beyond a dissatisfaction among many reviewers with the focus on integrated assessment modeling, the associated pathway literature, and the analysis of BECCS, is a disagreement about how model results should be interpreted and communicated. Perhaps, however, there is a limit to how well-uncertainty in highly complex computer models can be communicated to anyone beyond experts on models. While the review process itself is obviously open to a highly critical examination of BECCS and its theoretical presuppositions, the scientific foundation on which central chapters of SR1.5 rests, i.e., primarily the integrated pathway literature, as well as interpretations of the IPCC’s scope, tend to partly filter out this highly critical discussion through boundary work.

Therefore, in addition to initiating a more comprehensive analysis of BECCS within the pathway and IAM literature, the review process might also have the opposite effect to what was intended. It may also risk entrenching, rather than problematize, a contested representation of the potential of BECCS (see also e.g., Beck and Mahony, 2018; Carton, 2019; Ellenbeck and Lilliestam, 2019; Workman et al., 2020). We see a challenge related to the type of boundary work observed in this paper influencing the outcome of the IPCC assessment processes, as it does little to mitigate the problems associated with such a heavy reliance on IAM literature that easily tend to include the massive deployment of BECCS. Doing so decreases the total modeled cost of the transition necessary to limit global warming. This can be misinterpreted and have implications for governance and policy making since it risks legitimizing a more relaxed fossil decarbonization in the near term by building belief in speculative future CDR. This moral hazard, while not empirically verified, could obscure the critical need for increased ambition in the near-term global response to climate change (Hilaire et al., 2019; see also Asayama and Hulme, 2019; Carton et al., 2020).

A more optimistic interpretation of the role of IAMs, in line with van Beek et al. (2020) argumentation, is that the IAM community has been able to adapt to new demands at the science-policy interface by remaining up-to-date and developing its provision of policy relevant knowledge while also anticipating, or even help shaping, the demands of policy makers. Since the IAM communities are populated by a relatively small group of researchers there is a risk attached to letting this group not only define the boundaries of relevant science but also influence how that science should be interpreted and translated to policies (see also Hughes and Paterson, 2017). A critique of IAMs is their lack of ability to conceive of more radical societal transformations, which is suggested by van Beek et al. (2020) to be solved by a closer engagement with social sciences and humanities for example by conceptualizing human behavior in the IAMs beyond the rational choice model. However, what we have revealed in the review of the interaction between critical reviewers and IPCC authors is that the critique very seldom is about lack of social sciences or humanities in the pathway literature or the IPCC assessment reports, but instead a questioning of what is considered unrealistic input data for IAMs, representations of technologies and basic assumptions about

resource availability. Thus, the critique is not predominantly formulated from social scientific or humanities perspectives, but instead from perspectives asking for more realistic assumptions and for natural complexities to be taken more seriously, often accompanied by a questioning of the privileged position of the IAM literature in the assessment processes. Perhaps the responses to the critique formulated within the IAM community are misguided—at least they do not respond to the request from many reviewers: to balance the privileged status of IAMs in IPCC assessments with a profoundly more diverse representation of potential climate transition pathways. A true pluralization of perspectives in the IPCC assessment report series would therefore not entail merely adding perspectives as complements to the IAM core. Rather, it would mean creating space for alternative perspectives (cf. Markusson et al., 2020)—not at all necessarily only from within the social sciences and humanities but from within the natural and engineering sciences as well—to make claims about future mitigation paths without having to relate them to IAMs.

## DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found at: <https://www.ipcc.ch/site/assets/uploads/>

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## AUTHOR CONTRIBUTIONS

AH is the lead author and coordinator and designed the research. AH and JA analyzed the data. MF performed the cross-checking. AH, MF, and SH contributed to the contextualization, background, and discussion chapters. All authors made a substantial and intellectual contribution to the text and approved the submitted version.

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## APPENDIX

**TABLE A1** | List of the reviewers with the largest number of reviewer comments coded as critical.

Reviewer	Affiliation/position	No. of comments
Mary Booth, United States of America	Director at The Partnership for Policy Integrity (PFPi)	22
Doreen Stabinsky, United States of America	Professor of Global Environmental Politics at the College of the Atlantic in Bar Harbor, USA/Uppsala University, Sweden	20
Jennifer Morgan, Netherlands	Executive Director, Greenpeace International	16
Linda Schneider, Germany	Senior Programme Officer for International Climate Policy at the Heinrich Böll Foundation's head office in Berlin	13
United States of America	N/A	10
Andy Reisinger, New Zealand	Vice chair IPCC, and Deputy Director of the New Zealand Agricultural Greenhouse Gas Research Centre	10
United Kingdom (of Great Britain and Northern Ireland)	N/A	9
Andrea Tilche, Belgium	European Commission, Head of Unit DG R&I, Brussels, Belgium	9
Peter Carter, Canada	The Climate Emergency Institute	7
Helmut Haberl, Austria	Professor and director of the Institute of Social Ecology Vienna, Alpen-Adria Universität, Austria	7
Elenita Daño, Philippines	Co-Executive Director, ETC-Group	6
Kate Dooley, Australia	PhD, University of Melbourne	6
Germany	N/A	5
Eleanor Johnston, United States of America	Climate Interactive, Washington, DC, United States of America	3
Simon Bullock, United Kingdom (of Great Britain and Northern Ireland)	Tyndall Centre for Climate Change Research	3