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ADVANCED REVIEW

Contested framings of greenhouse gas removal and its feasibility: Social and political dimensions

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Abstract

Prospective approaches for large-scale greenhouse gas removal (GGR) are now central to the post-2020 international commitment to pursue efforts to limit the global temperature increase to 1.5°C. However, the feasibility of large-scale GGR has been repeatedly questioned. Most systematic analyses focus only on the physical, technical, and economic challenges of deploying it at scale. However, social and political dimensions will be just as important, if not more so, to how possible futures play out. We conduct one of the first reviews of the international peer-reviewed literature pertaining to the social and political dimensions of large-scale GGR, with a specific focus on two predominant approaches: Biomass energy with carbon capture and storage (BECCS) and afforestation/reforestation (AR). Our analysis of 78 studies proposes two important insights. First, it shows how six key social and political dimensions of GGR feasibility–namely economics and incentives; innovation; societal engagement; governance; complexity and uncertainty; and ethics, equity, and justice–are identifiable and are emphasized to varying degrees in the literature. Second, there are three contested ways in which BECCS and AR and their feasibility are being framed in the literature: (a) a *techno-economic* framing; (b) a social and political *acceptability* framing; and (c) a *responsible development* framing. We suggest this third frame will, and indeed should, become increasingly pertinent to the assessment, innovation, and governance of climate futures.

This article is categorized under:

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KEYWORDS

afforestation, biomass energy with carbon capture and storage, feasibility, framing, greenhouse gas removal, social and political dimensions

1 | INTRODUCTION

Following the adoption of the 2015 Paris Agreement, the development of approaches for large-scale greenhouse gas removal (GGR)[1] have become central to scientific and political debates about limiting global temperature rise to well below 2°C. As the remaining carbon budget for staying within 1.5°C of warming rapidly decreases, proposals for capturing and storing greenhouse gases at scale have raised the prospect of a near-term budget "overshoot". This overshoot would subsequently be compensated by "negative emissions" projected to accrue in the second half of the 21st century (Masson-Delmotte et al., 2018). GGR is also central to the achievement of the no net emissions (net-zero) policy target in the Paris Agreement, given hard-to-abate sectors such as shipping, aviation, and agriculture. However, many GGR methods are only in the nascent stages of research and development and proposals for their future deployment at scale remain highly speculative. Indeed, some global assessments have raised serious questions about their physical, technical, and economic feasibility (Courvoisier et al., 2018; Smith et al., 2016). To date, only two large-scale GGR approaches have been included in the global emission scenarios used to explore the opportunities for reaching the carbon budgets associated with the Paris Agreement: Biomass energy with carbon capture and storage (BECCS) and afforestation (AR) (IPCC, 2018).

In this article, we present one of the first reviews to survey the international peer-reviewed literature pertaining to the social and political dimensions of BECCS and AR, taking a comparative focus on the two approaches.[2] In contrast to a range of systematic reviews that have been conducted on negative emissions technologies (NETs) (McLaren, 2012a, 2012b; Minx et al., 2018) and geoengineering (Oldham et al., 2014), this review is neither a synthesis of the existing evidence-base nor an assessment of the overall feasibility of GGR for delivering net-zero emissions scenarios. Instead, it aims to: (a) map the key social and political dimensions raised in existing studies of GGR; and (b) identify the dominant framings of large-scale GGR and related contestations over the feasibility (or infeasibility) of integrating BECCS and scaling-up AR in 1.5°C mitigation pathways.

Early proposals for large-scale GGR developed within what may be regarded as a geoengineering problem-framing (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 1992), emphasizing the urgency of technological solutions to address perceived political failures to effectively mitigate anthropogenic emissions. Assessments of the feasibility of GGR approaches have broadly centered around IPCC integrated assessment modeling (IAM) and the comparison of cost-effective pathways to scenarios based on temperature targets. Some commentators suggest that the urgency of current debates about the technical feasibility of large-scale GGR can be seen as the corollary of a consensus about what is otherwise deemed politically "infeasible" within current mitigation policy (Anderson & Peters, 2016; Larkin, Kuriakose, Sharmina, & Anderson, 2018). For others, GGR represents an attempt to reframe policy debates about achieving net-zero emissions pathways away from geoengineering discourses that have often been represented in opposition to piecemeal mitigation approaches (Lomax et al., 2015). Such debates suggest that physical, technical, and economic assessments of GGR feasibility often rely on simplified, and potentially over-optimistic, assumptions about social and political realities.

Our review concentrates on BECCS and AR; two approaches that are predominant in integrated assessment modeling and policy debates. Other approaches, such as direct air carbon capture and storage (DACCS) are gaining attention but are not included in the majority of IPCC modeled emission pathways (IPCC, 2018). Both BECCS and AR are likely to require significant land-use change (both direct and indirect) for biomass plantation, setting them apart from other GGR approaches.[3] However, BECCS and AR will start from very different places in innovation processes aiming to scale these as GGR "technologies," and therefore provide a point of comparison for analyzing social and political dynamics of GGR.[4] Around this focus, this article aims to make two central contributions to the literature. First, to identify some of the key social and political dimensions highlighted in the social science literature when considering the feasibility of GGR. Second, through a more interpretive analysis, we draw attention to different framings of GGR and its feasibility, as seen through the examples of BECCS and AR.

This article proceeds as follows. In the next section, we outline the review methodology employed and provide an overview of the corpus of literature considered. We then report on the main social and political dimensions identified in the literature important to the feasibility of BECCS and AR. In the following analysis, we explore the three main ways in which these GGR approaches and their feasibility are being framed in the literature. In conclusion, we consider prospects for the responsible development of GGR in relation to alternative climate futures.

2 | REVIEW METHOD

This review analyzed 78 peer-reviewed articles addressing social and political dimensions of large-scale GGR. The initial literature search applied identical queries to both Web of Science and Scopus, removing duplicates. The queries (search strings included in the Appendix) were structured to distinguish between three distinct, but related, bodies of literature: (a) Literatures on GGR, with partial focus on BECCS and/or AR,[5] (b) Research on BECCS and/or AR, with explicit reference to GGR,[6] and (c) Research on bioenergy, carbon capture and storage (CCS) and AR, with no explicit reference to GGR. Query strings were therefore constructed to filter for research on public debates about GGR and governance issues, with the exception of BECCS due to the comparatively low overall volume of research published to date (see Appendix 1). Regarding the third body of literature, the volume of existing research on bioenergy, CCS, and AR is very high. We included these literatures because they are likely to contain empirical studies relevant to the social and political dimensions of GGR. We justify this on the basis that while there are relatively strict criteria that demarcate GGR from non-GGR research in policy and technical assessment literatures, such boundaries are often less clear cut in empirical studies focused on discourse and practice. Our literature searches returned an overall pool of 1,061 articles (after removing duplication) spanning these three domains. Two authors read the abstracts for each article, independently compiling two long-lists of 100 articles relevant to questions about the feasibility of GGR. These were merged into a final long-list of 162 articles which was then screened against two criteria to arrive at the final corpus: (a) Did the abstract foreground social or political dimensions of GGR? (b) Did the abstract describe findings or promise substantive evidence on the feasibility of BECCS or AR (or components thereof)? The final corpus of 78 articles was purposively selected to reflect a diversity of disciplinary and methodological stances across the three aforementioned bodies of literature. The (approximate) percentage breakdown of the final corpus is as follows: a = 50% (n = 38), b = 20% (n = 15), and c =30% (n = 25).

In initial attempts to design structured queries, it became clear that BECCS literatures were relatively straightforward to demarcate, in large part due to the novelty of BECCS as an object of scientific research and policy analysis.[7] In contrast, AR literatures relevant to questions of large-scale GGR were much more difficult to query for: It was notable that literatures about “negative emissions” and “carbon dioxide removal” contain little, if any, detailed discussion about AR. While much BECCS literature arguably adopts an off-the-shelf geoengineering problem-framing, representing large-scale GGR as distinctive from ongoing mitigation activity, such a distinction appears much less clear cut in the case of AR. In collecting a corpus on AR relevant to GGR concerns, we therefore used proxy terms principally relating to the Paris Agreement and to the REDD+ policy framework that has provided the main focus for large-scale afforestation (and avoided deforestation) to date.[8] We justify this on the basis that, in mitigation policy, reducing deforestation has to date taken priority over large-scale afforestation. Although not considered in this review, a query that included Land Use Land-Use Change and Forestry (LULUCF) or Agriculture, Forestry and Other Land Use (AFOLU) would broaden this focus (e.g., to include political topics like “land grabbing”).

In analyzing the framings of GGR through BECCS and AR in the selected literature we followed an iterative qualitative coding approach. In the first stage, we tested the corpus against a coding scheme generated from a short workshop involving the authors (which included the following initial codes: competence; costs; impacts; incentives; leadership; legislation and policy; international relations; security; social acceptance; trust; place attachment; competing resource use; alternative solutions; moral hazard; equity and justice; framing; sociotechnical imaginaries; who controls/governs; heterogeneity). Three authors individually applied codes generated from this workshop to a sample of the corpus (with no limit on the number of codes per article) and compared results. Some revisions were made to the code lists to reflect significant initial omissions, themes emerging from the literature, redundant codes, or codes that could be merged. Repeating the process, the revised code lists were then applied by two authors across the full corpus, with inter-coder reliability established through comparison of codes applied to a sample of articles. The restructured coding scheme provides the basis for the analysis of key social and political dimensions raised in the literature and the three framings of GGR approaches presented below.

3 | WHAT ARE THE SOCIO-POLITICAL DIMENSIONS OF BECCS AND AR?

In this section, we describe six key social and political dimensions evident in the selected literature pertaining to BECCS and AR, and their relevance to debates about the feasibility of large-scale GGR. While there is overlap evident between the six dimensions, we suggest that this reflects the nuances and, at times, ambiguities that characterize much of the literature. Dimensions that recur more frequently in the literature reviewed, such as governance, receive correspondingly more attention here. We begin with dimensions that tend to feature more in interdisciplinary studies, before outlining more distinctive dimensions evident in the more discipline-specific social scientific articles.

3.1 | Economics and economic incentives

Studies across the corpus suggest the importance of appealing to the economic interests of key stakeholders to secure long-term, large-scale investment in BECCS and AR. Much of the literature either advocates explicitly, or is premised on the notion, that carbon pricing must become significantly more ambitious in order to enhance the incentives for GGR adoption. In principle, this could occur through market-based instruments of various kinds (Lockley & Coffman, 2018)—see dedicated discussion below. A carbon price of around 100 USD/tCO_2 assumed in most IPCC's Fifth Assessment Report scenarios is widely considered a precondition for delivering BECCS at a global scale, although future costs are hugely uncertain (Kemper, 2015).

Given that increased availability of biomass could significantly reduce costs for BECCS, economies of scale in projects are likely to be central to their economic viability. To be commercially attractive, the literature highlights that BECCS power plants need to operate at a high load factor and high rates of CO_2 capture (Kemper, 2015). They could produce carbon-free electricity *and* negative emissions permits, potentially offering a double incentive to would-be investors, given a conducive policy instrument framework (see below).

Some studies identify how demonstrable socioeconomic benefits are key to successful deployment of AR (Schirmer & Bull, 2014) and bioenergy-based policies more broadly (Nikodinoska, Mattivi, Notaro, & Paletto, 2015). Where private landowners are the decision-makers, afforestation is most likely to be practiced on marginal land, and where there are environmental co-benefits (Schirmer & Bull, 2014). However, where users of forest resources seek to satisfy immediate needs, rather than prioritizing longer-term effective carbon storage, a "temporal mismatch" of incentives may occur (Buck, 2016, citing Unruh, 2011).

3.2 | Innovation

The prospect of deliberate innovation focused on developing the techniques and technologies associated with GGR is an explicit focus of a variety of papers in the corpus. This may relate to various stages of development, including early R&D or modeling efforts through which the feasibility of effective GGR at scale is determined. Typically, these stages are classified in (rather linear, stylised) terms of "technology-push" and "demand pull" drivers (the former reducing costs of innovation through, for example, research, the latter increasing the pay-offs, for example, by increasing the demand for new technologies in the market place). Analysis by Nemet et al. (2018) has highlighted how broadly GGR-focused innovations literature is mostly focused on the R&D phase and the "supply-side" of innovation, while BECCS literature is more balanced in this regard. The language used by innovation-oriented literature tends to reflect a supply-side focus: NETs are typically discussed as being "deployed" rather than "adopted".

The literature (e.g., Kemper, 2015; Nemet et al., 2018) highlights the limited number of on-going BECCS projects, and the relatively nascent stage of innovation they reflect. Around 20 BECCS projects, in various stages ranging from evaluation, operation to cancellation, have been identified globally (Kemper, 2015). It also highlights a wariness, particularly among non-governmental actors, to prioritize investment in developing BECCS in anticipation of the opposition it will likely face, particularly in certain regions (Fridahl & Lehtveer, 2018). From a governance perspective, the scale-up of BECCS appears likely to be an "uphill struggle" (Bellamy & Healey, 2018).

A number of papers investigate why CCS has failed to take off from socioeconomic perspectives (see e.g., Haszeldine, 2016; Kemper, 2015), one highlighting uneven political support as a critical factor (Bui et al., 2018). From more sociological and cultural perspectives, Markusson, Ishii, and Stephens (2011) highlight the complexities of learning and importance of organizational dimensions in CCS projects (e.g., private-public partnerships) to their broader political reception. In highlighting how disparate component elements must be made to work not only technically but also organizationally, this literature is instructive for those seeking to demonstrate, then develop, an even more disparate system, namely BECCS (Russell, Markusson, & Scott, 2012).

In principle, innovation activity could be evaluated not just in terms of the likelihood of developing effective technologies, but also of the desirability of societal ends and values that are being furthered by following a particular pathway compared to alternatives (Bellamy, Chilvers, Vaughan, & Lenton, 2013). In practice, the literature in our corpus is dominated by the former, that is, narrower, conceptualization.

3.3 | Societal engagement

Societal engagement is a theme that often arises when the real-world feasibility of GGR approaches is debated in academic, practitioner, and policy communities. The literature reviewed exhibits significant variation: At one end of the spectrum are analyses premised on an instrumental, normative concern to secure public acceptance, in order to preempt a possible backlash that might prevent BECCS or AR implementation at scale. This is especially evident in literature examining the lessons from, and prospects for, attempts to deploy CCS (e.g., Duetschke, Schumann, Pietzner, Wohlfarth, & Höller, 2014; L'Orange Seigo, Dohle, & Siegrist, 2014). On BECCS specifically, Cummings, Lin, and Trump (2017) and Dowd, Rodriguez, and Jeanneret (2015) review literatures on public perceptions, warning of widespread lack of public awareness that risks undermining the nascent industry's "social license to operate". However, acknowledgment of the importance of public perceptions is much less evident in the literature when it comes to AR. Local perceptions of impacts are found to be influential, however, in shaping current and future behavior (Malkamäki et al., 2018). A survey of tree planting in Australia by Schirmer and Bull (2014) finds that land-owners' willingness to undertake large-scale afforestation, especially on agricultural land, is influenced by, among other things, their views about its social acceptability and how they believe others in the community view the prospect.

Questions about societal engagement also extend to consideration of the importance of lay knowledge and value disagreements, and how these may inform the development of GGR-related policies, plans, and programs. Trust in institutional procedures emerges as an important factor in more sophisticated understandings of "public perception," in which social license or socio-political legitimacy is viewed in dynamic terms (Gough, Cunningham, & Mander, 2018; Mabon, Shackley, Blackford, Stahl, & Miller, 2015). Perceived "naturalness" of BECCS technologies is found to increase public acceptability (Thomas, Pidgeon, & Roberts, 2018). Gamborg, Anker, and Sandøe (2014) highlight the importance of managing value disagreements and governance implications relating to bioenergy production. For some authors, the adequacy of societal engagement can be judged according to criteria of procedural justice (McLaren, Parkhill, Corner, Vaughan, & Pidgeon, 2016).

3.4 | Governance

Governance was a focus across almost all papers in the corpus, encompassing discussions of the adequacy of provisions made by the UN climate regime, national legislation, particular policy instruments (and mixes thereof), and the importance of NGOs/interest group involvement in their design.

In general, much of the literature either acknowledges explicitly, or does not take issue with, international-level agreement as a sine qua non for effective large-scale GGR. Absence of such agreement constrains national-level policymaking, allows short-term planning horizons of public and private sector organizations to remain the norm (Meadowcroft, 2013), and allows low expectations of social acceptance to deter ambition regarding GGR development (Fridahl & Lehtveer, 2018). Co-benefits are often less obvious for GGR approaches than they are for conventional mitigation, where positive impacts (e.g., on health, employment, energy security, etc.) have allowed solutions to be framed in attractive ways to win widespread support (Honegger & Reiner, 2018). A means of reliably accounting for carbon removal also needs international-level agreement; the important political dynamics affecting this seemingly administrative matter are widely noted in the literature. Long-standing debates about the inclusion and management of biological sinks in GHG accounting procedures reveal that political contestations over the feasibility of BECCS and AR often take shape through expert practices as much as the representations of government actors (Dooley & Gupta, 2017; Krug, 2018). For BECCS, carbon accounting appears particularly significant in relation to the inclusion of the land sector in new market mechanisms envisaged in the Paris Agreement, and which are required to mobilize international financial flows on a sufficiently large scale (Honegger & Reiner, 2018). In contrast, policy instruments promoting the scale-up of AR at international level are rather different: REDD+ can perform as a global policy framework in part precisely because it does not imply strict GHG accounting rules and is sufficiently malleable to cope with diverse views (Ehrenstein, 2018).

National-level policy instruments for promoting GGR may be slow to develop despite international-level agreement (Moe & Røttereng, 2018). Even among supposed climate policy leaders, for example, the EU, concerted promotion of BECCS fits uneasily with established, strongly pro-mitigation policy paradigms (Geden, Scott, & Palmer, 2018). Experience with bioenergy regulation reveals how multiple cross-cutting interconnections and their uncertain effects may present acute policy and governance challenges (Gamborg et al., 2014). National-level policymakers may also be deterred from regulating by the risk of provoking international trade disputes over non-tariff barriers: The EU's experience with sustainability criteria for biomass production is commonly cited (Gamborg et al., 2014). AR is more commonly a major focus of national action, although interest in REDD+ has become less consistent than originally hoped (Hein, Guarin, Frommé, & Pauw, 2018; Moe & Røttereng, 2018), and governments (particularly in an era of fiscal austerity) spend little on domestic forestry (Nabuurs et al., 2017).

A significant number of studies are explicitly normative, that is, make recommendations for reforms (at national or global level) to promote the deployment of BECCS (Buck, 2016; Honegger & Reiner, 2018; Peters & Geden, 2017; Torvanger, 2019; Zakkour, Kemper, & Dixon, 2014), or AR (Nabuurs et al., 2017). Many attempt to draw lessons from the checkered experience of policies promoting CCS and biofuels separately, particularly in a European context (Buck, 2016; Geden et al., 2018; Thornley & Cooper, 2008). Here, stronger policies, and smarter policy and instrument mixes to ensure an effective global carbon price, and direct government expenditure on research and development, are widely recognized as incentives, with broad potential applications to GGR (Bellamy & Healey, 2018; Meadowcroft, 2013; Möllersten, Yan, & Moreira, 2003; Nabuurs et al., 2017).

The degree to which BECCS and AR can and should be incentivized through existing market-based instruments promoting mitigation, or whether they would threaten to undermine these, is increasingly discussed. The unequal treatment of BECCS and fossil CCS in accounting rules and the challenge of integrating bioenegy into existing carbon markets is frequently highlighted (Zakkour et al., 2014), with some warning that inclusion in cap-and-trade systems would lead to BECCS being treated simply as an offsetting device (Geden et al., 2018; Kemper, 2015; McLaren, 2012b), sustaining a neo-liberal political economy (Markusson, Dahl Gjefsen, Stephens, & Tyfield, 2017). Other assessments acknowledge the advantages of more adaptive governance approaches. For example, these may facilitate gradual and modest deployment, allowing “careful assessment of difficulties, adjustment to regulatory frameworks, and time for societal debate about the implications of different choices to mature” (Meadowcroft, 2013) rather than being premised on a necessary desirability of GGR (Bellamy & Healey, 2018; Meadowcroft, 2013).

3.5 | Complexity and uncertainty

A range of complexities and areas of uncertainty associated with possible pathways for the development of GGR were articulated in the literature. Various studies highlighted that uncertainties associated with particular pathways are often hard to represent in integrated assessment models (IAMs)—in particular assumptions relating to social processes and the interactions between different physical, technical, and environmental processes (e.g., Merk, Pönitzsch, & Rehdanz, 2019; Otto, Frame, Otto, & Allen, 2015). Overestimates of the potential of BECCS and AR to deliver CO_2 removals may have consequences for mitigation policy and mask the wider implications of pursuing very ambitious GGR. Particular pathways may entail certain consequences (foreseen or unforeseen) which detract from the attainment of either GGR-related goals or related policy priorities, such as ambitious emissions reduction, biodiversity conservation, food security, and sustainable development goals more widely. When these consequences become visible, societal, and political support for GGR is likely to be undermined.

The consequences undermining near-term mitigation action could occur during implementation of GGR—or even before. Recent experiences with bio-energy are cited in many analyses, to illustrate the danger that poorly implemented BECCS strategies could in fact increase GHG emissions through indirect land use changes (e.g., forest clearances) (Mohr & Raman, 2013; Vaughan & Gough, 2016). Even prior to implementation, “conceptual use” of BECCS by policy makers allows tougher mitigation choices to be avoided (Geden et al., 2018; Markusson et al., 2017; see also ethics below). Such a concern is less evident in AR-specific literature reviewed.

Consequences that compromise other sustainable development goals (including protection of biodiversity and water resources) are also discussed in the literature. Dooley and Kartha (2018), for example, draw a comparison between BECCS and AR via land-based risks. Others find that BECCS may pose a threat to energy security (given the necessary trade-off between energy produced and amount of carbon removed; Fajardy & MacDowell, 2018). However, the potential for synergies (rather than trade-offs) between land-based GGR and the achievement of sustainable development goals remains under-explored (Dooley & Kartha, 2018). Some more conceptual discussions of uncertainty problematise the precise interpretation of sustainability, and the implications for governance: Gamborg, Anker & Sandøe (2014, p. 327), for example (referring to bio-energy, but with wider relevance), note how "[a]s long as there is disagreement over what the critical issues are—in relation to deciding how to achieve a higher degree of sustainability, and indeed what sustainability actually is—it will remain difficult to separate good from bad bioenergy, and consequently there will be no easy way to separate the right method of steering from the wrong".

3.6 | Ethics, equity, and justice

A smaller number of papers in the corpus devote attention to issues relating to equity and justice implications of the principle of GGR in the context of global carbon budgets over time and the impact BECCS and AR may have on these. Such considerations have been introduced as abstract analytical frameworks (McLaren, 2012b; Preston, 2013, 2015), while in other studies (e.g., McLaren et al., 2016) they reflect concerns emerging from empirical research where concepts like "justice" hold real-world significance. Cross-cutting considerations relevant to both BECCS and AR include land-use conflicts, impact on communities, the wider-scale effects from the "food versus fuel" trade-off that follow from re-designating agricultural land (see above), and also issues of inter-generational justice. In a limited number of papers, equity is seen a matter of "effort-sharing" between countries or individuals in the international context of the estimated carbon budget (Geden et al., 2018; McKinnon, 2015), sometimes analyzed through modeling (Tavoni, Chakravarty, & Socolow, 2012).

The literature highlights how ethical challenges may vary across different stages, from research to deployment and beyond (McLaren, 2012b; Preston, 2013). Prominent among these challenges is "moral hazard", relating to risks imposed on current or future generations as a result of unanticipated consequences, over-estimating potential effectiveness or delays in climate change mitigation (McLaren et al., 2016; Merk et al., 2019; Preston, 2013).

Yet, distinctions between ethical and political concerns are often less clear in empirical research on afforestation and BECCS. For instance, questions about who benefits from changes in forest ownership and forest access in afforestation projects may be difficult to disentangle from the ways forests are valued by governments (Buck, 2016; Ehrenstein, 2018). People with communal or unclear land tenure may be displaced if governments launch forest carbon sequestration efforts (Malkamäki et al., 2018). The experience with REDD+ shows how social safeguards, even if set through, for example, certification schemes may not always be met. Some equity-oriented discussion in the literature also draws conclusions for governance: Proceeding towards a greater economic valuation of carbon will not work without institutions that support livelihoods, good governance, and land tenure security in developing countries. It is suggested that development aid dedicated to these goals must be expanded (Buck, 2016).

4 | THREE FRAMINGS OF GGR AND ITS FEASIBILITIES

Existing literatures on highly policy-relevant topics such as GGR often reflect a range of positions, each resting on "underlying structures of belief, perception and appreciation" (Schon & Rein, 1995:23). In the policy sciences, and in science and technology studies (STS), these structures are commonly referred to as "frames" or "framings" (Hulme, 2009). These may often not be articulated explicitly, and it is possible for texts to express more than one frame concurrently. Differences in framing manifest themselves not only in epistemological terms (e.g., in competing definitions of GGR feasibility) but also in terms of the significant differences in the roles that are attributed to the disciplines of natural and physical sciences on the one hand, the social sciences on the other, and their relationship to policy making processes.[9]

As the previous section has shown, across the literature corpus we find diverse accounts of the social and political aspects of BECCS and AR and their significance for emissions scenarios that assume large-scale GGR. Within and across the social and political dimensions presented in Section 3, we find that GGR approaches and their possible future feasibility are framed in several ways. Through undertaking a more interpretive analysis of the literature corpus, informed by the aforementioned concept of framing, we identified three main framings of GGR and its feasibilities: (a) a *techno-economic* framing; (b) an *acceptability* framing; and (c) a *responsible development* framing. A summary of these three framings is presented in Table 1, which are further explained and exemplified in the sections that follow. While each is presented in turn, it is important to note that the three framings are by no means mutually exclusive and

TABLE 1 Key features of technoeconomic, acceptability and responsible development framings of GGR in the literature corpus

Key feature	Techno-economic framing	Acceptability framing	Responsibility framing
Main emphasis	Can GGR be accomplished technically, environmentally and economically?	Can social and political barriers to acceptance of GGR be overcome?	Can GGR be responsibly developed in relation to alternative pathways for addressing climate change?
Most apparent feasibility dimensions	Technical, carbon reduction, environmental, economic	Political support, carbon accounting, market incentives, public acceptance	The relation between feasibility and questions of directionality, justice, responsibility
Relation to politics	Science is seen as separate from and informing politics in a linear fashion	The politics of GGR can be managed and contained through better procedures and policies	Any climate solutions (including GGR) are potentially political, with imagined social orders and futures that should be openly debated
Relation to society	Society is a second order concern—experts can know what's in the public interest	Society and individual public concerns can be definitively captured by sound social science methods and invited public engagements	Societal concerns and publics are diverse, multiple, multivalent, and can shape research and policy problem-framings
Mode of governance	Technocratic, expert-led	Top-down, decisionist	Polycentric, distributed, reflexive[10]

often co-existed in the papers that formed part of our review. Having said this, in most cases a dominant frame was evident or a particular framing was forgrounded.

4.1 | The techno-economic framing

A variety of papers assess the feasibility (or infeasibility) of BECCS and AR principally in terms of the physical, technical and economic determinants of 1.5°C scenarios. Such techno-economic framings of feasibility are widely premised on more-or-less linear understandings of relations between scientific findings, policy choices and innovation pathways (Table 1). This frame reduces climate politics to centralized global policy-making processes centred around the IPCC and UNFCCC, taking as given the IPCC's distinctions between "policy relevant" and "policy prescriptive" climate science.[11] The feasibility of GGR approaches is thus determined by the natural, physical and engineering sciences and economics independent of actual policy-making processes. In this framing, social science research is broadly understood as second order and an aid to engaging technical assessments with policy-making, innovation processes, and technology deployment.

An overarching imperative underlying techno-economic appraisals of GGR approaches is whether, or the extent to which, levels of carbon dioxide removal projected in IAMs are achievable in cost-effective terms (Fuss et al., 2014, 2018; Minx et al., 2018). In more instrumental understandings of IAMs, resource availability and carbon pricing are proposed as determining the limits for policy choices between competing GGR pathways (see discussions in Fuss et al., 2018; Otto et al., 2015). Comparative modeling studies in the corpus tend to highlight uncertainties in interactions between physical, technological, and economic aspects of BECCS and AR: For instance, comparing assumptions about crop yields across economic and ecological models (Creutzig, 2016). Issues raised in the latter group of studies include potential land-use conflicts with impacts relating to food security, energy security, and biodiversity conservation as potentially constraining the feasibility of large-scale GGR using these approaches (Bui et al., 2018; Creutzig et al., 2015; Dooley & Kartha, 2018; Fajardy & MacDowell, 2018; Hansen et al., 2017).

In techno-economic framings of large-scale GGR, BECCS, and AR are understood as "negative emissions technologies" (NETs); that is, approaches defined reductively in terms of their instrumental value for carbon capture and sequestration (Minx et al., 2017; Minx et al., 2018). Articles highlight the nascent stage of development of most NETs (McLaren, 2012a, 2012b; Nemet et al., 2018). Techno-economic assessments of BECCS also make clear multiple dimensions of "scale" relevant to GGR, relating not only to net levels of CO_2 sequestered (i.e., across the life cycle of a BECCS supply chain) but also to relative energy returns in comparison with fossil CCS supply chains (Fajardy & MacDowell, 2018; Haszeldine, 2016; Kemper, 2015). Assessments of innovation pathways for scaling AR as a NET, by contrast, appear much more uncertain in the techno-economic frame. Currently very little literature on AR as a NET exists (Minx et al., 2018; Nemet et al., 2018), and debates about scaling up AR as a "technology" have arguably tended to obfuscate the dominant problem-framing of avoided deforestation as the focus of debate about the role the forestry sector should play in mitigation pathways (Dooley & Gupta, 2017; Krug, 2018). The apparent lack of scientific literature on large-scale AR-for-GGR outside of IAMs research is perhaps pertinent for considering some limitations of techno-economic framings of the feasibility of large-scale GGR (Dooley, Christoff, & Nicholas, 2018; Geden, 2016; Moe & Røttereng, 2018).

Social science and humanities research features in this frame when it directly engages technical assessment with global climate policy and governance processes. For instance, research on integrating negative emissions into GHG accounting frameworks plays a central role to techno-economic framings of the governance challenges around GGR pathways (Coffman & Lockley, 2017; Zakkour et al., 2014). Despite externalizing politics, some ethical questions are included in a range of techno-economic assessments of large-scale GGR feasibility, particularly linked to equitable distributions of carbon budgets (Hansen et al., 2017; McKinnon, 2015; Tavoni et al., 2012).

4.2 | The social and political acceptability framing

Although existing scientific literature on GGR is heavily weighted toward the natural and physical sciences (Belter & Seidel, 2013; Minx et al., 2018), the overwhelming majority of papers in the literature corpus exhibit concerns about the social and political acceptability of BECCS and AR. Articles focusing on social and political acceptability typically articulate feasibility challenges in terms of "barriers" to policy decisions and support for technology adoption (see discussion in Buck, 2016; Campbell-Arvai, Hart, Raimi, & Wolske, 2017; Cummings et al., 2017). The question of the social and political acceptability of GGR can, in narrower versions, overlap techno-economic framings that assume the central barriers to GGR approaches such as BECCS and AR lie in their deployment in society. In contrast, a range of more "upstream" versions of the acceptability problem framing highlights the ways in which policy-making processes and public perceptions can shape the trajectories along which technologies develop, from their earliest stages of inception. In this latter version, the gaining of acceptance is often understood to involve pre-emptive engagement with policy-makers and public concerns, and social science research is attributed a role in identifying risks, evaluating choices and harmonizing policy frameworks (Table 1).

Almost all studies of BECCS in our corpus exhibit concerns for social and political acceptability, ranging from reflexive GGR assessments (McLaren, 2012a, 2012b)[12] to bioenergy policy analysis (Dale et al., 2013; Magar, Pelkonen, Tahvanainen, Toivonen, & Toppinen, 2011) to studies of CCS perceptions (Dowd et al., 2015; L'Orange Seigo et al., 2014). A variety of studies highlight the gap between scientific research on BECCS and awareness and understanding among policy-makers and stakeholder groups (Fridahl, 2017; Lock, Smallman, Lee, & Rydin, 2014; Thomas et al., 2018). The relative nascent stage of BECCS development means that public demonstration projects are likely to play a central role in future innovation process (Kemper, 2015; Markusson et al., 2017; Nemet et al., 2018) and therefore public responses to BECCS are widely acknowledged as important in shaping, and in other ways constraining, the trajectory of technology development and its relation to incumbent fossil-energy infrastructure (Vergragt, Markusson, & Karlsson, 2011). However, some articles also question the extent to which public awareness and support for BECCS will directly translate into a transition toward renewable energy infrastructure, given existing asymmetries in energy systems and the potential compatibility between many BECCS technology applications and fossil fuel infrastructures (McLaren, 2012b; Vergragt et al., 2011). For instance, the use of carbon capture, storage and utilization (e.g., for enhanced oil recovery) suggests the potential for public confusion over intended aims of BECCS technology (Lock et al., 2014; Mabon et al., 2015).

Our literature search returned a particularly high number of public perceptions studies of CCS, a fact noted in the literature (Dowd et al., 2015; Gough et al., 2018). These studies typically focus on identifying opportunities and risks in the immediate context of implementation of a CCS project or demonstration (Feldpausch-Parker, Burnham, Melnik, Callaghan, & Selfa, 2015). Almost without exception, they highlight the relatively low levels of public awareness about the particular CCS project of study and more generally about the role that CCS may play in climate and energy futures (Duetschke et al., 2014; L'Orange Seigo et al., 2014). This latter point has fuelled skepticism about the capacity of perception-focused research to account for the dynamics of "public opinion" in relation to CCS (Gough et al., 2018) as well as criticism that some studies, particularly those adopting a "deficit" model of the public (Lock et al., 2014), may simply be driven by narrowly instrumental aims such as managing potential backlash from so-called NIMBY groups. The prominence of methodological debate about CCS perceptions studies might suggest the need for more empirical specificity in social science treatments of CCS, such as approaches differentiating the ethical issues likely to emerge at different stages of CCS development (Mabon & Littlecott, 2016; McLaren, 2012b).

Research addressing the social and political acceptability of large-scale GGR focuses on the development of policy instruments and incentives for financing the development of different approaches. Unlike cost-optimal models of the techno-economic frame that foreground carbon price as the primary economic determinant of GGR feasibility, acceptability framings foreground a range of policy and market designs through which negative emissions might be costed and traded. Articles examining the complexities of GHG accounting frameworks, particularly those associated with land-based emissions (policy debates about accounting for forest management are exemplary in this respect; e.g., Krug, 2018), highlight that the challenge of accounting for negative emissions is deeply linked to both scientific tools for measuring and monitoring sequestered carbon and to policy-processes through which notions such as "baseline measurements" are negotiated (see also, Ehrenstein, 2018). Where literatures on BECCS are necessarily speculative about the kinds of policy instruments best suited to commercial development (Honegger & Reiner, 2018), AR literatures on challenges in LULUCF (land use, land-use change, and forestry) accounting processes and the role of policy instruments (like REDD+) in market design are much more empirically substantive (Malkamäki et al., 2018; Nabuurs et al., 2017).

A central tension that pervades the social and political acceptability framing is the extent to which the feasibility of large-scale GGR depends on overcoming policy barriers to commercial development and adoption, and relatedly, the extent to which social scientists should assume the scale-up of BECCS and AR as a foregone conclusion. A range of articles in the corpus introduce ethical questions into such policy debates, highlighting the potential "moral hazard" associated with policy instruments that simply translate recorded negative emissions into tradable "offsets" (Markusson et al., 2017; Meadowcroft, 2013; Merk et al., 2019), that is, the risk of rolling back ongoing mitigation targets on the basis of projected future negative emissions. Here the potential for conflicts between barriers to acceptance of GGR pathways and barriers to deep mitigation arguably not only represent trade-offs between divergent policy choices but also ethical and political conflicts between divergent modes of climate and energy governance (Bellamy & Healey, 2018; Cox, Pidgeon, Spence, & Thomas, 2018; Dooley & Kartha, 2018).

4.3 | The responsible development framing

A central concern across the corpus is the extent to which assessments of speculative GGR scenarios as "feasible" may deter mitigation activity (Anderson & Peters, 2016). The final frame we identified in the literature therefore not only focuses on definitively assessing the feasibility (or infeasibility) of GGR but also attends to the consequences such assessments may have for developing (or constraining) other pathways to meeting the temperature targets of the Paris Agreement (Table 1). In this frame, assessing the feasibility of GGR is understood as a value-laden process that not only provides evidence for decision-makers but also distributes the capacity to represent and act on climate change (Dooley et al., 2018). Contestations over scientific and political responsibility for addressing climate change are valued for their potential to broaden the expertise and knowledge considered relevant to the development of GGR approaches. Although there is a developing field of research on responsible innovation in geo-engineering (Bellamy et al., 2013; Stilgoe, Owen, & Macnaghten, 2013), few papers in the corpus develop empirical research on conflicts between pathways to 1.5°C scenarios (although several propose this as a focus central to scaling-up GGR) (Minx et al., 2018).

Several papers in the corpus highlight the ways in which assessment processes can be understood as sites of political negotiation over the feasibility of GGR pathways. Dooley et al. (2018), for instance, examine collaborations between modeling teams and policy-makers and suggest the potential for more "unconstrained" approaches focused on "co-producing" knowledge in the context of land-based GGR approaches. In the task of attending to multiple and distributed contestations, several studies foregrounded public controversies as a means of broadening appraisals of the feasibility of GGR approaches (Markusson et al., 2011; Mohr & Raman, 2013; Tomei & Helliwell, 2016). As Mohr and Raman (2013) argue, public controversies over bioenergy, far from being antithetical to the process of technology assessment, can be seen to fulfill an important assessment function in articulating issues and governance challenges relevant to future innovation processes (see also Gamborg et al., 2014).

Both the techno-economic and acceptability frames assess BECCS and AR principally in terms of their instrumental value for sequestering carbon. In contrast, a range of papers in our corpus highlighted the importance of differentiating between the modes of governance, forms of valuation, evidencing, and monitoring practices of particular carbon sequestration approaches (Dooley & Gupta, 2017; Gamborg et al., 2014). In the case of AR, for instance, governance procedures for recording and managing forest carbon stocks are longstanding (Krug, 2018), and global policy instruments for financing reforestation and certifying offsets for carbon trading markets have been substantially experimented with (Ehrenstein, 2018). Where governance regimes and policy debates on AR and carbon sequestration are well established—even if it is not yet clear how "net negative emissions" will be accommodated within them (Dooley & Gupta, 2017; Meadowcroft, 2013; Moe & Røttereng, 2018)—the governance landscape for BECCS is much more uneven and patchy. The relative failure of large-scale fossil CCS projects to progress beyond demonstration stages has been widely understood as a failure of uneven political support as much as of technological limitations (Bui et al., 2018; Gough et al., 2018; Haszeldine, 2016; Kemper, 2015; Markusson et al., 2011). The relative failure of bioenergy to significantly reshape energy systems, in contrast, appears to have less to do with the problem of policy incentives or economic costs relating to sequestering carbon but is rather linked to precautionary governance concerns about limiting environmental and social impacts of large-scale energy crop cultivation (such as ecological damage and disruptions to food systems; Gamborg et al., 2014; Magar et al., 2011; Mohr & Raman, 2013; Röder, 2016; Thornley & Cooper, 2008; Tomei & Helliwell, 2016). As a variety of authors highlight, challenges in scaling up GGR are likely not only to differ by approach but may be driven by conflicting governance imperatives around climate and energy systems (Buck, 2016; McLaren et al., 2016; Nemet et al., 2018).

In relation to potential conflicts, several studies in our corpus developed participatory approaches—in both cases involving heterogeneous groups of experts—to detect uncertainties around development trajectories of BECCS and AR (Bellamy & Healey, 2018; Vaughan & Gough, 2016). Participatory research approaches have been argued to be central to the development of responsible innovation (Stilgoe et al., 2013). Distinctions between participatory approaches in this frame and research on societal perceptions and public opinion covered in the acceptability frame are far from clear cut (Cox et al., 2018; Fridahl, 2017; Thomas et al., 2018). However, it is possible to draw loose distinctions between social research approaches that aim to represent the public and those that aim to intervene in problem-definition and shape innovation processes (e.g., Bellamy & Healey, 2018).

While less evident in the overall corpus, we have found the frame relating to responsible development of GGR to be evident and emerging in the literature. This broader concern over whether GGR can be responsibly developed in relation to alternative pathways for addressing climate change is comparable to developments occurring across other areas of emerging technology such as nanotechnology, biotechnology, information communication technologies, as well as earlier work on geoengineering of climate change (Macnaghten & Chilvers, 2014; Stilgoe et al., 2013). As with other areas of technological development, here we see within the nacent GGR field attempts to move beyond predominant linear relationships where science "speaks truth to power" associated with "deficit models" of public understanding and engagement (Jasanoff et al., 1998) and also beyond more instrumental forms of public and political engagement driven by concerns over technological acceptance (Chilvers & Kearnes, 2016; Stirling, 2008). While the close linkage of BECCS and AR to land use change has highlighted issues of complexity and uncertainty, our review has otherwise found comparable matters of concern about social and political dimensions evident in relation to other emerging technologies, including about the purposes and directionality of scientific developments, issues of equity and justice, and challenges of regulating and governing emerging technologies (see for example, Macnaghten & Chilvers, 2014).

5 | CONCLUSION

In a short space of time, prospective GGR approaches have become central to scenarios and policy commitments that seek to realize net-zero emissions futures. The feasibility of these nascent approaches has been widely questioned in physical, technical, environmental and economic terms, but often in ways that take social and political realities for granted. Our analysis of the peer-reviewed literature has identified a range of social and political dimensions—namely, economic incentives, innovation, societal engagement, governance, uncertainty, and equity and justice—which need to be more effectively and realistically accounted for in future appraisals of and commitments to GGR approaches and alternative pathways for mitigating climate change. This is particularly crucial given that the social and political dimensions identified in our review are typically either implicit or, in the case of economics and innovation, over-optimistically represented in most IAMs and other quantitative assessments of climate change in which GGR approaches are often implicated (Forster et al. 2020). While AR is the primary GGR approach represented in most IAMs, our review found few social science studies of large-scale AR, and thus we flag this as an area which is ripe for further research.

The framing out of social and political complexity in many assessments of GGR corresponds with a further finding of our analysis which has shown techno-economic and acceptability framings of GGR feasibility to be predominant in the interdisciplinary and social science literatures. These two framings ask "can we do GGR?", whether that be technically in terms of cost-effectiveness and carbon reduction, or in overcoming social and political barriers to acceptance. While we found these to be predominant in the literature corpus, our review has identified a third frame as pertinent to future attempts to demonstrate and scale-up GGR. We have termed this a responsible development framing, which remains marginal at present but has become more evident in social science research on GGR in recent years. This third frame does not take the future development of GGR for granted, and thus opens up social and political dimensions and contextualizes GGR in relation to alternative climate solutions, innovations and futures.

It is crucial that this responsible development frame is further developed in future research and practice, given that it was found to be more marginal in our review. New frameworks and approaches are emerging in this regard, spanning responsible assessment (e.g., Beck & Mahony, 2018), responsible innovation (e.g., Stilgoe et al., 2013) and reflexive governance (e.g., Voss, Bauknecht, & Kemp, 2006). We suggest future research in this frame should aim to offer practical ways to ensure the six social and political dimensions identified in the earlier part of our review are actively attended to and accounted for in future assessments, demonstrations and governance of GGR. Instead of seeing responsible assessment, innovation and governance as separate or discrete processes, we suggest a more systemic and connected sense of "distributed responsibility" needs to be cultivated across ways of knowing, doing and governing GGR and climate futures. This means that new ways of mapping and accounting for the social, political, and public dimensions of science and technology (e.g., Chilvers & Kearnes, 2016; Marres, 2015), and the formation of new relationships between science, politics and society, will be crucial to the responsible development of GGR in relation to alternative climate futures.

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CONFLICT OF INTEREST

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ENDNOTES

[1]The term greenhouse gas removal (GGR) is used in this review over the more commonly used policy term carbon dioxide removal (CDR). We believe GGR more accurately describes both the technical and pragmatic challenges of mitigating increasing climate change risks as well as offering a potentially more pluralistic understanding of relations between climate science, policy and innovation (see Lomax, Workman, Lenton, & Shah, 2015).

[2]Distinctions between afforestation and reforestation, although typically relating to land, are far from clear-cut in practice. In line with a range of other research on GGR (Minx et al., 2018), we treat afforestation and reforestation here together.

[3]Fuss et al. (2018), for instance, estimate that up to 1 billion small-holder farmers may be implicated in land-use changes proposed by models of GGR potentials. It has been widely noted that both BECCS and AR may engender land-use conflicts (Royal Society & Royal Academy of Engineering, 2018).

[4]The concept of "negative emissions technologies" (NETs) is central to contemporary policy debates about GGR approaches. In relation to the longstanding role of forests in mitigation policy—widely understood in terms of conservation and ecology as much as their value for carbon sequestration—we are not the first to remark on the counter-intuitive connotations implied in treatments of forests as "technologies" for GGR.

[5]These queries were constructed drawing on query designs from existing systematic reviews on GGR (Belter & Seidel, 2013; Minx, Lamb, Callaghan, Bornmann, & Fuss, 2017; Oldham et al., 2014)

[6]These queries were constructed drawing on query designs from existing systematic reviews on BECCS and negative emissions technologies more generally (Minx et al., 2018). For reasons discussed below, substantive literature on AR for large-scale GGR appeared largely absent. We therefore used the phrase "Paris Agreement" as a proxy search term.

[7]Some authors suggest it is possible to view BECCS as synonymous with the entire "negative emissions technologies" policy agenda (Beck & Mahony, 2018).

[8]Although REDD+ only applies to the enhancement of carbon stocks in developing countries, developing countries that host tropical forests have to date provided the dominant focus for AR in mitigation policy.

[9]For further discussion of the ways in which science and policy processes can "frame" social problems and can hold different assumptions about relationships between science, politics and society see (Chilvers & Kearnes, 2016; Hulme, 2009; Jasanoff, 2004; Jasanoff et al., 1998; Stirling, 2008).

[10]On reflexive governance, see Feindt and Weiland (2018); on polycentric governance, see Jordan, Huitema, van Asselt, and Forster (2018).

[11]Controversies over the relation of the IPCC to policy-making processes are long-standing, it is notable that the prominence of BECCS in the IPCC's AR5 net-zero emissions scenarios has sparked a series of debates over the scope of "policy relevant" climate science (Anderson, 2015; Beck & Mahony, 2018; Geden, 2015).

[12]By reflexive we mean a self-critical examination of one's own assumptions and presuppositions (Stirling, 2008) and conscious of the effects of different problem conceptualizations on "opening up" or "closing down" policy debate (Stirling, 2008).

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A. APPENDIX 1: LITERATURE QUERIES ON WEB OF SCIENCE AND SCOPUS

GGR

TS = ((CDR AND [CO_2 OR carbon*]) OR "negative carbon dioxide emission*" OR "negative CO_2 emission*" OR "negative GHG emission*" OR "negative greenhouse gas emission*" OR "carbon negative emission*" OR ("negative emission*" NEAR/10 carbon) OR ("negative emission*" NEAR/10 CO_2) OR (geoengineering AND ((carbon OR CO_2)

NEAR/3 (sequest* OR accumulat* OR storage OR capture))) OR ([“geoengineering” OR “climate engineering”] AND CDR) OR “greenhouse gas removal” OR GGR) AND (legislat* OR politic* OR polic* OR regulat* OR “public opinion*” OR “public debat*” OR “public controvers*” OR “public percept*” OR “public attitud*” OR “public engag*” OR “public participat*” OR “public accept*” OR “public understand*” OR “public protest*” OR “public reject*” OR “social accept*”).

BECCS

TS = ((“carbon capture and storage” OR “Carbon dioxide capture and Storage” OR “CO_2 capture and storage” OR CCS OR CCUS OR bio-CCS) NEAR/3 (bioenerg* OR biomass)) OR ((bioenerg* OR biomass) AND BECCS).

Afforestation/reforestation

TS = (afforestation OR reforestation) AND ((“public opinion*” OR “public debat*” OR “public controvers*” OR “public percept*” OR “public attitud*” OR “public engag*” OR “public participat*” OR “public accept*” OR “public understand*” OR “public protest*” OR “public reject*” OR “social accept*”) AND (legislat* OR politic* OR polic* OR regulat*)).

TS = forest* AND “Paris agreement” AND (legislat* OR politic* OR polic* OR regulat* OR “public opinion*” OR “public debat*” OR “public controvers*” OR “public percept*” OR “public attitud*” OR “public engag*” OR “public participat*” OR “public accept*” OR “public understand*” OR “public protest*” OR “public reject*” OR “social accept*”).

Bioenergy

TS = (Bioenerg* OR [biomass NEAR/3 energy]) AND ((“public opinion*” OR “public debat*” OR “public controvers*” OR “public percept*” OR “public attitud*” OR “public engag*” OR “public participat*” OR “public accept*” OR “public understand*” OR “public protest*” OR “public reject*” OR “social accept*”) AND (legislat* OR politic* OR polic* OR regulat*)).

Carbon capture and storage

TS = (“carbon capture and storage” OR “Carbon dioxide capture and Storage” OR “CO_2 capture and storage” OR (CCS NEAR/3 energy) OR (CCUS NEAR/3 energy)) AND ((“public opinion*” OR “public debat*” OR “public controvers*” OR “public percept*” OR “public attitud*” OR “public engag*” OR “public participat*” OR “public accept*” OR “public understand*” OR “public protest*” OR “public reject*” OR “social accept*”) AND (legislat* OR politic* OR polic* OR regulat*)).