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DEEP DECARBONIZATION: BECCS (P PATRIZIO AND N MAC DOWELL, SECTION EDITORS)

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# Beyond Social Acceptability: Applying Lessons from CCS Social Science to Support Deployment of BECCS

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## Abstract

**Purpose of Review** This paper assesses social science research relating to BECCS and considers the applicability of research on CCS to BECCS.

**Recent Findings** In recent years, social science research on CCS and BECCS has gone beyond an evaluation of public acceptance to provide a more nuanced analysis of the wider social political, ethical, and governance contexts in which large-scale deployment might be achieved. This raises issues at global, local, and regional scales, requiring a wide array of methods and approaches.

**Summary** Awareness of the scale and urgency needed to act on climate change is growing and the role of BECCS in delivering carbon dioxide removal forms a central argument for the use of this family of technologies. Here, framing becomes a critical factor in how society responds to BECCS technologies and we argue that making the case for BECCS as a means of extending mitigation to make a 'net zero' goal achievable could be the key to its acceptable and sustainable deployment.


**Keywords** CCS · BECCS · Carbon dioxide removal (CDR) · Negative emissions · Social responses · Acceptability

## Introduction

Carbon capture and storage, or CCS, is a set of technologies which capture, transport, and store $CO_2$ over the long term in geological formations, either onshore or offshore. The approach can be applied in the context of a variety of $CO_2$ sources, including fossil- or biomass-fuelled power generation (BECCS) and industry. Although it was featured as a component of proposed climate mitigation portfolios for nearly two decades, CCS remains an emerging technology. Globally, there are currently only 18 large-scale CCS projects in operation (and a further 25 planned or under construction [1]) but it is far from widely deployed at a commercial scale and many of the existing projects are linked to enhanced oil recovery (EOR) rather than dedicated $CO_2$ storage applications. With the 1.5 °C aspiration set out in the Paris agreement focusing efforts for ambitious carbon reductions across all economic sectors, and the prospect of delivering carbon dioxide removal (CDR)[1] through coupling biomass energy with CCS, there are signs that the technology is picking up momentum. The implementation of BECCS depends on establishing CCS infrastructure to capture, transport, and store $CO_2$; societal responses to BECCS relate to each stage of the CCS chain, to the biomass feedstocks that might be used, and to the principle of using it to deliver a net reduction in $CO_2$ (negative emissions) as part of a strategy to mitigate against climate change. Furthermore, there remain political, governance, economic, and investment challenges in establishing CCS infrastructure and extending the technology to BECCS applications will introduce additional issues in these areas.

In this paper, we reflect on the contribution of social science research to informing the debate around the implementation of CCS and BECCS technologies, over the past five years. Social science research into CCS has developed alongside technical, scientific, and engineering studies from the outset, with publications on possible public reactions to the technology dating

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[1] Carbon dioxide removal (CDR), greenhouse gas removal (GGR), and negative emissions technologies (NETs) are terms that are used, often interchangeably, to describe the family of approaches with the potential to deliver net reductions in atmospheric $CO_2$ concentration. In this paper, we use the term "CDR" throughout.

back to the early 2000s (e.g., [2, 3]). It is important to go beyond understanding public perceptions of a technology and acknowledge the diversity of social responses, such as uncertainty about a technology or risk awareness, and the underlying reasons for these responses. Thus, social responses to CCS and BECCS are shaped by factors which affect people and their values, to the social context in which a technology is to be deployed (e.g., institutions), and to the characteristics of the technology and its potential location. The last five years has seen more analysis into how the wider social acceptability of CCS technology and its deployment might be improved, introducing concepts such as social licence to operate.

Recent reviews have been published relating to public perceptions of CCS [4], carbon capture and utilisation (CCU) [5], BECCS [6•], and CDR, covering all disciplines [7], and focusing on the social and political dimensions of BECCS and afforestation as greenhouse gas removal approaches [8]. The present paper builds on these reviews, which demonstrate the strong analytical base from which to build communications material and procedural good practice for establishing projects, to explore what is known about social responses to BECCS from research focused on BECCS and from the wider CCS literature. We begin in the 'Acceptability in Context' section by considering how context affects acceptability, in terms of sources of $CO_2$ and geographical location, from different theoretical perspectives. We include both CCS and BECCS in the 'Introduction' section as there is much to be learnt from literature relating to CCS. Social science research has begun to address BECCS specifically in the past five or six years but, in the absence of proposed projects, has initially focused on wider issues around the potential for the sustainable deployment BECCS, including issues relating to policy and governance and ethics and its role within climate change mitigation. Thus, the 'From CCS to BECCS and Greenhouse Gas Removal' section looks at these broader issues that become more pertinent as the context moves away from a focus on CCS for climate change mitigation at a project-based level to a broader carbon dioxide removal (CDR) agenda associated with large-scale BECCS deployment. The 'Conclusions' section provides a reflection on how this body of literature has evolved to provide a more nuanced understanding that goes beyond assessing public acceptance to a consideration of the wider context and framings which apply.

## Acceptability in Context

### BECCS is Part of the CCS Family

BECCS is a specific application of CCS where the $CO_2$ is captured from a process using a biomass feedstock; it was initially conceived as a stop-gap solution which could allow more ambitious climate change targets to be achieved. More recently, the need for greater levels of emission reduction, driven by the 1.5° C imperative combined with an understanding of the potential role for CCS in reducing emissions across the whole economy and its potential to deliver CDR, has changed the policy context and BECCS is now a mainstay of proposed climate mitigation portfolios. Not surprisingly, given that CCS was more commonly associated with fossil-fuelled electricity generation, there has historically been more work looking at CCS from fossil sources or which does not distinguish between different types of CCS. One of the earliest studies, which does distinguish between different sources of $CO_2$, [9], found that fossil fuel sources of $CO_2$ were perceived less favourably by survey respondents than industrial or bioenergy sources. Whilst research has started to consider different applications for carbon capture (e.g., carbon capture and utilisation (CCU) [10]), we found that BECCS is often compared with other CDR technologies (e.g., [11]), or other sources of $CO_2$, (e.g., [12, 13]) rather than considered on its own. More favourable responses to CCS have been observed when it is combined with bioenergy and increased support has been reported for CCU—notably amongst climate sceptics, for whom addressing concerns about waste carried greater traction than climate change mitigation [10]. Utilisation of captured $CO_2$ for enhanced oil recovery (EOR) could provide a revenue stream to reduce the costs and accelerate CCS infrastructure development [14, 15]. However, the potential scale of $CO_2$ reductions which could be made through CCU options, including EOR, remains limited (Mac Dowell et al., 2017). Furthermore, the use of captured $CO_2$ as a feedstock for industrial processes (CCU) presents its own set of issues from a societal and governance perspective (e.g., [16]), and Jones et al. [5, 17] explore some of these issues across three dimensions of social acceptance (socio-political, market, and community).

Storage has been shown to be the most contentious part of the CCS chain (e.g., [10, 18–20]) whereby people living closer to storage sites express a lower acceptance of CCS [19] and offshore storage is more likely to be seen as acceptable (e.g., [21]). These findings are relevant for BECCS, and acceptance of storage has been shown to depend on national policy contexts, local industry and identity, and perceived risks and benefits (e.g., [18]). The greater support observed for CCU may arise because capture is the most accepted element of the CCS chain. CCU brings the potential to offset capture costs, is seen as an incremental change to existing industrial processes (e.g., [22]), and is viewed in relation to perceptions of the industry and local history, in contrast to $CO_2$ transport, which affects multiple communities along its route [23•] and storage, which is seen as the most novel element of CCS [17].

There is, as yet, little research that has been undertaken on BECCS compared with other forms of CCS. Drawing on experience and expertise with CCS, Dowd et al. [6•] reflect on the need for a social licence, trust and procedural fairness, and provision of information and sources (e.g., the media). Furthermore, views of BECCS reflect perceptions of the bioenergy and particularly the need for sustainable biomass with associated environmental and food implications, as well as perceptions of CCS (e.g., [24, 25]).

### Geographical Contexts and Place-Based Studies

Whilst research into BECCS is in its infancy and there is limited deployment of the technology, research into CCS highlights the influence of geographical context on the social responses. CCS studies have explored responses in countries where there are already operational CCS projects e.g., Canada [26] and Norway [27], where there is policy interest in CCS e.g., the UK [18, 22, 28–30], the wider Nordic region [21], and New Zealand [31], and where there has been opposition to CCS projects e.g., The Netherlands [32] and Germany [9, 19, 33, 34]. These studies emphasise the importance of understanding the specific social context for deployment as a dynamic interaction of people, places, and events which drive public perceptions. Familiarity with the technology, or other related industries, influences perceptions or risk and benefits (e.g., [26, 35]), particularly in terms of the trust in an established local industry and the local policy context under which those industries are governed (e.g., [22]).

Cross-national studies have explored how different factors, e.g., geographical, social, psychological and informational [10], and cultural [36], affect views on CCS amongst lay publics. Karimi et al. [36] found that although cultural characteristics did influence public perceptions of CCS and its potential risks, responses were unlikely to be predicted by cultural factors alone, highlighting the critical role of contingent factors at a local scale. Whitmarsh et al. [10] found marked differences in awareness of and support for CCS between the countries included in the study (Netherlands, Canada, Norway, USA, UK). The greatest support was reported in the UK where, for example, storage sites will be located offshore and the lowest in the Netherlands, which has previously seen high-profile opposition to a proposed project [37].

With 20 projects planned or operational (GCCSI), China is a key region for global CCS deployment; here, CCS costs are likely to be much lower than, for example, in the EU, and Chen et al. suggest that it could be economically competitive in China, without the need for support, by 2030 [38]. Despite this, there is limited social research published relating to this region—what there is shows that there is very low awareness of CCS amongst lay publics in China and limited support for the technology [39, 40].

### Methods and Theoretical Contexts

Research has drawn on varied theoretical concepts including social licence to operate [22, 41], media representations (e.g., [42, 43]), and justice and human rights (e.g., [44]). There has been a strong emphasis on risk and risk communication; L'Orange Siego et al. [26] highlight the importance of mental models and knowledge to draft risk communication material, and the importance of benefit perceptions and trust, the importance of stakeholder engagement and experience of other technologies, findings echoed by many [4, 19, 31, 36, 45, 46].

The potential for public acceptance of CCS and the factors which impact upon it have been explored using a variety of methods, depending on the theoretical framework underpinning the research. For example, qualitative methods including focus groups [31] support an in-depth understanding of alternative viewpoints and the reasons behind different responses, whereas surveys (e.g., [12, 19]) provide a more superficial analysis from an extensive sample of people. In a recent study, Bellamy et al. [25] used a mixed methods approach, presenting alternative policy scenarios to different groups and assessing perceptions of BECCS using a limited survey and group discussions to understand the differences between the groups. Given the emergent nature of CCS, and lack of familiarity with the technology, analogies have been used for CCS and to explore how people's attitudes are shaped by reference to other technologies e.g., fracking [22, 47] and nuclear [18].

## From CCS to BECCS and Greenhouse Gas Removal

### Extending Mitigation

The 2015 Paris Agreement, and its aspiration to limit global average temperature rise to 1.5 °C, introduces a new urgency and ambition to climate policy. Conventional mitigation approaches may be complemented by methods to remove carbon dioxide from the atmosphere, as 'net zero' $CO_2$ becomes the policy benchmark. In principle, by removing atmospheric $CO_2$ at a level that matches emissions from 'hard to abate' sectors (such as aviation, for example), CDR approaches could compensate for these residual emissions to make a 'net zero' pathway achievable. Afforestation and BECCS are the two primary CDR approaches currently represented in integrated assessment models (IAMs) which inform the IPCC on pathways to deliver Paris temperature goals. The central role for CDR in achieving both the 1.5° C and the 2° C ambition introduces a new imperative to establish CCS as part of a sociotechnical imaginary [48] in which the policy aspiration of 'net zero' plays an important role in the framing and implementation of CCS, BECCS (and other CDR), technologies [49, 50].

The notion of geoengineering—the intentional manipulation of the earths' climate—is a challenging and controversial concept which conventionally distinguishes between CDR and solar radiation management (SRM) approaches [51, 52]. Fossil CCS has not typically been identified as a geoengineering approach; however, its role in CDR through

BECCS places it within a geoengineering framing [52]. Thus, some studies exploring ethical, social, and policy implications of BECCS as a CDR method analyse the approach as a method of geoengineering (e.g., [44, 53, 54]). Others, however, make the case for separating BECCS (and other CDR approaches) from a geoengineering 'climate recovery' framing, arguing that it is better identified as an 'emission offsetting' strategy [55] to complement mitigation in a way that is comparable to existing 'enhancement of sinks' policies [56] and consistent with a view of CDR as SRM's less-risky cousin [57•]. This conceptual distinction becomes important, not just for how CDR can be incorporated into policy frameworks [56] but also when considering the ethical and governance implications [58] and, consequently, how it is perceived by different actors [25, 58]. This distinction is, in part, predicated on whether CDR is used to enable deeper emission cuts in the near term or to allow an 'overshoot' in carbon budgets. In this sense, BECCS can be seen as a means of separating abatement from emissions over time, by allowing $CO_2$ emissions to be 'removed' from the atmosphere at a future date (allowing an overshoot), or separated in space by potentially geographically extensive supply chains [59] (extended mitigation framing).

The IAMs that inform the IPCC pathways and, hence, the global policy dialogue, are central to the debate about the potential role of CDR measures in relation to carbon budgets and have attracted significant attention in the literature, which highlights the uncertainties and ethical implications associated with representing global-scale CDR through BECCS, the level of influence that this might have on the policy agenda and the assumptions made within the models [50, 60–66]. The key is that BECCS and CDR are not alternatives to conventional emission mitigation; the magnitude of CDR required to meet carbon budgets associated with the Paris Agreement is highly challenging even with ambitious emission reductions in the near term [20, 63, 67, 68].

Furthermore, there is a mismatch between how BECCS may be viewed at a national or regional level and its significance within global analyses [69]. This gap between global, regional, and national priorities, combined with complex and pervasive non-technical challenges [70], places limitations on the potential for BECCS [61, 66]. With limited awareness of BECCS and CDR beyond expert communities, and very little empirical research into potential public responses, understanding the broader ethical, political, and governance issues will be critical to how societies view the 'acceptability' of CDR through BECCS.

## BECCS, CCS, and Ethics

The literature in this area calls for a more democratic process, one which opens up critical discussion of wider implications, differentiating by scale rather than 'technology', to consider social, ethical, and political impacts of different levels of deployment and decision making (for example, 58, 59). Ethical mapping of CCS has identified justice, prevention of harm, and techno-scientific and regulatory competence as potential faultlines or areas of contention [71–73]. With extended BECCS supply chains, where biomass feedstock and storage of $CO_2$ potentially takes place across multiple countries and continents, in addition to technical and sustainability challenges [20, 74], there are deep underlying ethical issues associated with its implementation [70]. Separating the emission and removal of $CO_2$ spatially and temporally further increases the ethical implications, particularly in terms of inter- and intra-generational justice.

Concerns persist that the promise of CCS and BECCS might allow society to continue to fail to adequately address the causes of climate change [58, 63, 67]. The potential for CDR approaches, and BECCS in particular, to deter or obstruct mitigation in the near term is widely addressed. This presents a moral hazard, of which Lenzi identifies three types presented by CDR: obstructing mitigation, taking a climate policy 'gamble', and exaggerated potential (hubris) [57]. The complexities of understanding the issue of mitigation deterrence have been further explored from a cultural political economy perspective [75].

## Governance Implications and Policy Responses

Introducing bioenergy feedstocks to the CCS process will require advanced and innovative regulatory frameworks to manage BECCS' potential deployment at a scale consistent with carbon budget constraints. Delivering genuine 'negative emissions' with a sustainable use of biomass brings an additional layer of complexity to maintain multiple sustainability goals (such as food security, ecosystem and biodiversity impacts, water availability *inter alia*) and recognise conflicting values [20, 70, 76, 77].

A recent special issue on the politics and governance of 'negative emission technologies' explores wide-ranging issues in this field [78], including the potential for mitigation deterrence [57•, 75] and the need to develop policies which mitigate against direct or indirect impacts to social and natural systems, paying attention to equity and justice, particularly in the context of the potentially significant role of developing countries [44, 60]. Geden and Scott et al. argue that large-scale 'comprehensive' $CO_2$ removal challenges current low-carbon policies at an EU level, suggesting that a more 'limited' role in delivering 'net zero' emissions in the coming decades is likely to gain more traction than a longer-term 'net negative' framing [49, 50, 79, 80].

There are currently no international policy mechanisms to support the implementation of CDR approaches or to incentivise the financing of projects and protect against undesirable sustainability implications [81, 82]. Consideration of trade-offs between sustainability goals and CDR potential will impact supply chain configurations [74] and new regulatory frameworks should account for the diverse and interconnected impacts of BECCS. To achieve effective CDR, international standardised regulatory frameworks must be in place to monitor, report, and verify (MRV) carbon flows across projects [83]. Challenges with carbon accounting arise with BECCS supply chains crossing sectoral and national boundaries—how to allocate and ensure genuine effective CDR is further complicated by temporal aspects associated with carbon sequestered in biomass [84]. Other literatures explore the possible mechanisms through which BECCS could be incentivised or credited [83, 85–87], the potential relevance of existing policies exploiting co-benefits (such as utilising local waste products) [82] and how different policy approaches might influence public opinion or support [25, 88]. McLaren et al. (2019) recommend that to avoid a mitigation deterrence effect, policies relating to CDR should be separated from mitigation across four areas: defining targets, offsetting and emission trading, incentivisation, and modelling and evaluation [89].

## Conclusions

There is a large body of literature presenting research on social responses to CCS. As the social science on CCS and BECCS technologies matures, analysis moves beyond assessments of 'acceptance' or 'public perceptions' to provide a more nuanced and holistic understanding of the societal impacts and contexts. Recognising how different cultural, social, political, ethical, and governance contexts shape the wider socio-technical environment can contribute to a more sustainable implementation and the 'responsible development' [8] of BECCS technologies. Fostering acceptability (that is, the quality of being acceptable) is one element of achieving a social licence and establishing emergent technologies in a 'fair and competent' manner [90], in which the role of citizens is neither passive nor static. However, CCS is currently deployed in only a few locations and awareness of the technologies remains very low worldwide. Support or opposition for CCS cannot be predicted [10], its acceptability depends on when, where, at what scale, and how it might be implemented.

For new technologies to be successfully deployed at scale, they have to be acceptable to wider society. Understanding what constitutes acceptability and how it can be facilitated in a way that is inclusive and transparent is the first step to ensure that technologies work within and for society, in all its complexity. To make good decisions with sustainable outcomes requires an alignment between social, political, and technical priorities, an understanding of trade-offs, and the ability to navigate across conflicting goals. The social science research described here helps us to unpack the different dimensions of acceptability relating to CCS and BECCS (i.e., social, legal, ethical, political, environmental) but also supports greater understanding of how 'acceptable' technologies may thrive or fail.

As the scale of the climate change mitigation challenge grows, and greater policy ambitions combine with a continued lack of progress in decarbonisation of the wider energy system, including heat, transport, and industry, there is a growing emphasis on the potential role for CCS. CCS now is not only seen as an essential means of reducing emissions but also the possibility of delivering carbon dioxide removal through its use with biomass feedstocks expands the potential for the CCS technologies and potentially allows greater emission reductions in the power sector to compensate for sectors which are harder to abate. The 1.5 °C and 'net zero' framings change the deployment landscape for CCS. However, progress on deploying CCS infrastructure remains slow; a renewed sense of urgency elevates the need to understand the CCS and BECCS innovation systems in order to establish the infrastructure, with enhanced social learning from near-term deployment informed by context-specific research. There is an urgent need to integrate research into the social and political implications of large-scale bioenergy with that relating to CCS, taking analysis of BECCS beyond the separate literatures. With little familiarity within lay publics about CCS, BECCS is even less familiar—not surprising perhaps that social science literature is directed more towards global issues, such as ethics and governance associated with using BECCS to deliver negative emissions, than on potential responses at a community level. Moreover, with the potential for extended supply chains spanning multiple locations, BECCS projects are likely to affect multiple 'host' communities.

The wider framing which extends the role of CCS/BECCS beyond one of conventional mitigation brings opportunities for more empirical work to broaden participation in addressing some of the bigger questions around BECCS and CDR. Its prominence in IAMs has raised the profile of BECCS as a critical means of delivering 1.5 °C-consistent emission pathways but the socio-political dimensions of BECCS and CDR are poorly represented in these models. There is much that social science can contribute to improving the understanding and representation of non-technical issues, for example through methods to support the co-production of knowledge and which make normative aspects of modelling approaches more explicit (see [60]).

As awareness of the scale and urgency needed to act on climate change is becoming more widespread, so is the recognition that systemic change is needed—even with the potential to deliver CDR from approaches such as BECCS. Against this backdrop, the 'extended mitigation' concept can be constructive—BECCS is not an alternative to 'conventional mitigation'; without very deep cuts in emissions, CDR measures will not be sufficient to bring atmospheric concentrations down in line with 1.5 °C or to deliver 'net' $CO_2$ removal at a global scale. Here, language and framing become important; if CDR becomes part of the net zero framing, rather than as a conventional 'offsetting' measure, it can become part of a wider, more integrated, and fully accounted strategy. There is a strong case for pursuing BECCS as part of the route to net zero $CO_2$, enabling a focus on decarbonisation, reducing the mitigation deterrent potential and working with current policy paradigms [49, 79]. With many questions unanswered around the potential role for CCS/BECCS, there is a huge potential for social science to guide the path towards more sustainable climate futures. The contexts and details of deployment are critical and without an understanding of the consequences of these wider effects, CCS, and ultimately BECCS, will struggle to become acceptable.

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## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent

This article does not contain any studies with human or animal subjects performed by any of the authors.



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