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Policy support for BECCS and DACCS in Europe: the view of market participants

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Abstract

Carbon dioxide removal (CDR) is the essential 'net' in net zero. However, a thriving CDR industry will not come into being without government intervention. As governments start to devise CDR support policies, this paper solicits the views of market participants in two of the most prominent CDR methods: bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS). We survey 47 BECCS and DACCS project developers and financiers active in Europe, conducting in-depth interviews with 27 of them to identify their key challenges and preferred policy interventions to address them. We find that participants prefer compliance markets, such as links to emissions trading systems, to generate demand but seek government support to cushion early market risks. They acknowledge the need for stringent monitoring and regulation to ensure environmental integrity. Bearing industry expectations in mind, policymakers face five key challenges in developing CDR: reaching scale, striking a balance with emissions cuts, safeguarding integrity, ensuring fairness and accelerating the speed of deployment.

1. Introduction

Alongside rapid reductions in emissions, all Intergovernmental Panel on Climate Change (IPCC) scenarios that limit warming below 2 °C include the scaling up of carbon dioxide removal (CDR). For an equitable and feasible delivery of CDR in line with these temperature goals, CDR deployment has to start in this decade (Nemet *et al* 2023b, Yang *et al* 2023).

A range of CDR methods exists, differing by processes used to capture CO_2 from the atmosphere, types of carbon storage, levels of technology readiness, potential scales, and wider (non-CO_2) impacts (Babiker *et al* 2022). Some CDR methods are already well-established in practice and included in national proposals for meeting climate targets—namely afforestation and reforestation. Several other CDR methods are not, and often referred to as 'engineered' or 'novel' (Smith *et al* 2023).

Governments have made limited efforts to intervene and accelerate the development of engineered CDR (Schenuit *et al* 2021). Among the 62 countries that had submitted long-term low-emissions development strategies to the UN Framework Convention on Climate Change by 2023, only 26 explicitly mentioned engineered CDR, with 19 detailing specific plans and an additional 7 considering the option (Lebling *et al* 2023). Early activity the bioenergy with carbon capture and storage (BECCS) and direct air carbon capture and storage (DACCS) market is being driven largely by voluntary private purchases[4], but total volumes are small, totalling less than two million tonnes of carbon dioxide to date (Smith *et al* 2024).

In Europe, no policies currently operate to deliver engineered CDR at scale. However, several jurisdictions are actively developing proposals (e.g. European Commission 2022, Swedish Energy Agency 2022, DESNZ 2023), making it timely to examine how

[4] The largest purchases for engineered CDR as of end-2023 were for 2.76 MCO_2 of BECCS by Microsoft and 250 000 tCO_2 of DACCS by Amazon.

different potential policy interventions are viewed by the CDR industry.

This paper focuses on two types of engineered CDR in particular: BECCS and DACCS. While we recognise that BECCS and DACCS are not the sole technologies to achieve removal, our reasons for such a focus are four-fold.

First, BECCS and DACCS are the two predominant engineered CDR methods in scenarios analysed by the IPCC (Babiker *et al* 2022). Second, they are the primary focus of the above-mentioned proposals under active development in Europe (with particular reference to 'permanent' removals in European Commission 2022). Third, BECCS and DACCS both result in geological storage of captured CO_2, meaning they offer a 'durable net zero' (Fankhauser *et al* 2022, Allen *et al* 2022). A durable state of net zero emissions requires a balance not just in atmospheric carbon flows, but also of carbon in and out of the geosphere. To achieve this, any residual emissions of fossil CO_2 must be balanced by geological storage. Fourth, BECCS and DACCS are comparable in terms of the challenges and needs for infrastructure development and investment size, particularly regarding procurement of geological storage capacity.

Yet, we also recognise there are significant differences between the two technologies and indeed other CDR options, including the transportation and location flexibility. At this early stage in market development, policy support needs to be flexible, allowing the most suitable solutions to emerge.

This paper contributes to the debate by soliciting the views of BECCS and DACCS project developers and financiers, the key private actors who wish to operate in this market. Research on the business, policy, and social science aspects of CDR is still underdeveloped. The CDR literature is expanding but remains predominantly within the science and engineering disciplines. Only 3% is published in social science journals (Smith *et al* 2023).

Most previous studies aim to address the wider impacts of deployment, such as the risk of deterring emissions reductions (Carton *et al* 2023) and the impact of large-scale BECCS on nature (Heck *et al* 2018, Porritt *et al* 2022). Studies looking at holistic CDR support typically argue for a portfolio of measures, which may change over time as the policy context evolves (Honegger *et al* 2021, Zetterberg *et al* 2021). Specific support policies have been put forward by Jenkins *et al* (2021), Lundberg and Fridahl (2022), Richstein and Neuhoff (2022) and Rickels *et al* (2021).

We focus on policies that foster an active, well-regulated market for BECCS and DACCS. Extracting carbon from the atmosphere has no economic value *per se*. Creating demand for CDR therefore necessitates government intervention. However, policy support extends beyond mere demand creation and technology development. An entire CDR ecosystem needs to be created, with industry clusters, supply chains, support services, financing channels, product standards and regulatory structures, all underpinned by public support (a social license to operate) and a clear industrial strategy.

Building on Forster *et al* (2020), who engaged stakeholders on the feasibility of BECCS, and Wähling *et al* (2023), who focused on policy sequencing, this paper employs a mixed-methods approach to understand the policy needs of the CDR industry, focusing on BECCS and DACCS. We surveyed 47 project developers and financiers, all ready to operate and deploy capital under the right regulatory frameworks. Subsequently, we conducted follow-up interviews with 27 participants. To maintain focus, the survey and interviews were restricted to industry representatives who are active in, or consider entering, the European market for BECCS and DACCS.

While focused on just two technologies, the policy implications from our study hold for many engineered CDR solutions. CDR policy interventions need to promote CDR at scale, balance carbon abatement with removal, ensure integrity through regulation, achieve fairness in cost allocation, and accelerate the speed of deployment.

2. Methods

2.1. A framework for assessing policy needs

The guiding principle behind our framework is that policy interventions must be informed by and targeted at the specific market imperfections and barriers that impede CDR development. The literature offers various frameworks for classifying such interventions (Vivid Economics 2019, Honegger *et al* 2021, Zhou *et al* 2022, Hickey *et al* 2023). They are fairly consistent in the interventions they cover, but vary in their organising principles, emphasising either different policy approaches (market-led, government-led), intervention points (demand-side, supply-side) or policy objectives (i.e. the barriers targeted).

Table 1 categorises interventions based on three primary objectives and illustrates them with examples of BECCS or DACCS interventions in Europe. The three objectives are as follows:

(i) **Demand creation**: Arguably the most important barrier is the absence of an inherent demand. The most suitable policies to generate CDR demand are the subject of an ongoing debate, and countries are experimenting with both government-led and market-led approaches.
(ii) **Supply promotion:** Given the scale and speed at which CDR must be developed, bottlenecks are likely to occur. Government intervention

Table 1. Classification of CDR support policies.

Issue/intervention	Description	Examples within the European Economic Area
Demand creation		
Public procurement	Government *auctions for CDR*, similar to renewables auctions, would provide a government-backed source of demand (Lundberg and Fridahl 2022). This is particularly important at the early stages of market development (NIC 2021), but schemes with multiple rounds over several years can also serve as an *advanced market commitment* to stimulate investment.	SEK 36 billion (EUR 3.3 billion) earmarked for BECCS by the Swedish government from 2026 to 2046 to be shared among those capturing and storing biogenic CO_2 at the lowest cost[a].
Compliance demand	Regulators could force major carbon emitters to purchase CDR in proportion to their emissions (sometimes known as a *carbon take-back obligation*, Jenkins *et al* 2021). Another way to generate compliance demand is by embedding CDR into *emissions trading systems* (*ETS*). Once geological CDR is sufficiently mature, emitters could then meet their regulatory ETS obligations through CDR (Rickels *et al* 2021, Burke and Gambhir 2022).	The Swiss Agreement with Managers of Waste Treatment Installations creates a legal obligation for operators of waste treatment installations to put at least one CO2 capture plant into operation by 2030, with a minimum capacity of 100ktCO2/year[b]. The UK government has announced its intention to include engineered CDRs into the UK ETS as a long-term market[c]. By mid-2026, the EU Commission will review the inclusion of CDR in the EU ETS or potentially establish a separate removal trading system[d].
Demand-side subsidies	Government subsidies could promote either voluntary or compliance demand. Subsidies could for example take the form of *tax incentives* for CDR purchases or a *carbon contract for differences* (CfD; Richstein and Neuhoff 2022), where the government covers the difference between CDR costs and an agreed reference price (e.g. the price of emissions allowances).	The UK government is developing a CDR business model based on a carbon CfD structure. Additionally, the Power BECCS model is being developed as a dual CfD, offering incentives for both electricity generation and carbon removal[e].
Supply promotion		
Access to finance	The high cost of capital for commercially and technologically untested CDR solutions can hold back investment. *Capital subsidies* (e.g. in the form of tax breaks) or co-financing by specialist *green investment banks* are among the interventions that can improve the risk-return balance and unlock funding.	The European Investment Bank (EIB) provides project development assistance for innovative low-carbon energy demonstration projects, including demonstrations of environmentally safe carbon capture and storage (CCS) on a commercial scale within the EU[f].
Innovation support	The learning externalities and scale effects associated with early CDR investments can be internalised for example through *R&D and investment subsidies*. The demand-side interventions listed above are also designed to overcome innovation and learning externalities.	CDR initiatives have benefited from funding through EU programs like Horizon Europe and the Innovation Fund, enhancing research and deployment of these technologies across Europe[g]. The UK has allocated £100 million to support various CDR methods, alongside significant other measures to support research and development.

(Continued.)

Table 1. (Continued.)

Issue/intervention	Description	Examples within the European Economic Area
Demand creation		
Addressing resource limitations	Skill gaps and other resource limitations (e.g. storage, land, infrastructure) may delay deployment. Public policy can help to overcome them, for example, through *training programmes* and the establishment of *industry clusters*, which overcome network externalities and generate scale effects (Waxman *et al* 2021). In the case of DACCS there is also concern about *high energy demand*.	The UK plans to develop CCUS 'clusters' as hubs with co-located emitters and CO_2 transport & storage infrastructure.
Institutional and regulatory frameworks		
Long-term strategy	CDR developers and investors will look to governments for long-term policy clarity (e.g., in the form of firm *long-term targets*) and the integration of CDR into broader climate, environmental and industrial *policy frameworks*. Regulatory clarity is also needed on nuts-and-bolts issues such as *reporting and accounting standards* and clear *legal frameworks* around issues such as liability or the transboundary transport of carbon.	The EU, UK each have targets for net zero emissions of greenhouse gases by 2050, while Iceland aims to reach the same state by 2040. Norway has a target of a 90%–95% reduction in emissions by 2050. Strategies have been published for how to achieve these targets, including scenarios in which BECCS and DACCS reach 178–486 MtCO2/year by 2050 at EU level, and engineered removals reach 75–81 MtCO2/year at UK level[h, i].
Social and environmental safeguards	Greenhouse gas removal, as a sector, has been prone to regulatory failure. Although 'greenwashing' concerns are mostly about biological CDR (West *et al* 2020), geological CDR too will need strict environmental safeguards. This concerns both the integrity of CDR itself (e.g. with respect to safe storage) and *broader environmental, health and safety standards* to ensure CDR deployment is synergistic with societal priorities (e.g. with respect to biomass supply in the case of BECCS) (Prütz *et al* 2024). There is also some concern about *technology misuse*.	The EU recast Renewable Energy Directive defines sustainability criteria covering large-scale biomass for heat and power, in addition to biofuels and bioliquids for transport. Environmental safety of geological carbon storage is addressed in Norway's Regulation relating to exploitation of subsea reservoirs, and the EU's CCS Directive[j, k, l].
Public engagement	People's attitudes towards CDR are still forming (Cox *et al* 2020). Social and environmental safeguards will be a necessary, but not sufficient condition to ensure the public acceptability of CDR. Active *public engagement* will be essential to inform the public debate, build trust, generate consensus and address concerns responsively. Extensive *public consultation* is particularly important in informing the location and design of CDR facilities and associated supply chains.	The use of CDR was deliberated by a citizen's climate assembly convened by UK Parliamentary groups in 2020[m].

Based on Zhou *et al* (2022) table footnotes.
[a] Swedish Government 2022.
[b] FOEN 2022.
[c] UK Government 2023.
[d] European Parliament 2023.
[e] Department of Energy Security and Net Zero UK 2023.
[f] EIB 2020.
[g] European Union 2021.
[h] European Commission 2018.
[i] UK Government 2021.
[j] European Union 2018.
[k] Norwegian Offshore Directorate 2017.
[l] European Union 2009.
[m] UK Parliament 2020.

can encourage innovation, catalyse economies of scale and overcome supply-chain blockages (Fuss *et al* 2018, Vivid Economics 2019). Key barriers and associated policy interventions include access to finance gaps, innovation and network externalities, and resource limitations (e.g. public infrastructure, skills).

(iii) **Institutional and regulatory frameworks**: The required scale of CDR means that the investments needed for a meaningful market will predominantly come from the private sector. A key role of public policy is to create a business environment that is conducive to private entrepreneurship and investment in CDR. Simultaneously, stringent regulatory frameworks and active stakeholder engagement are essential to ensure social and environmental integrity.

2.2. Study participants

The study aimed to understand the policy preferences of active market participants with practical insights into project development and regulatory environments. As such, we did not involve representatives from academia, government, trade organisations, or the non-profit sector.

Specifically, we engaged with individuals who identify as project/technology developers or finance providers/investors of BECCS and DACCS (labelled 'TD' and 'I', respectively, in the results section). Geographically, we focused on market participants from Europe and North America who are already active in, or considering entering, the European CDR market (the European Union [EU], the United Kingdom [UK] and other countries of the European Economic Area [EEA]). All interviewees positioned themselves as ready to operate or invest in these jurisdictions, contingent upon the implementation of sufficient and appropriate regulatory frameworks.

We acknowledge that the study participants are not neutral market observers, but rather active market participants with vested interests who will advocate for favourable outcomes for their company and industry. Nevertheless, their insights shed light on the challenges facing the rapid rollout of engineered CDR and the ability of various policy approaches to overcome them. While the group of BECCS and DACCS developers in Europe is relatively small and well-defined, identifying potential financiers proved more difficult due to the ephemeral nature of financial flows.

The initial study phase involved a comprehensive exploration of the stakeholder landscape by leveraging publicly available online profiles and social media. We systematically identified companies and relevant employee profiles, including entities associated with government funding, CDR associations and strategic alliances. This was supplemented by snowball sampling, a method where existing study participants are invited to suggest additional participants to ensure a comprehensive pool of respondents.

We identified 81 potential financiers and 83 relevant technology companies, from which we secured 47 experts who participated in an online survey, covering close to 30% of the overall pool. Most of the respondents (26 out of 47) occupy positions at the executive or senior management level, with an average of 3.6 years of experience in the BECCS/DACCS field (see supplementary materials S4). Using the survey responses as a selection criterion, we invited a total of 27 respondents for follow-up interviews, based on a self-identified intermediate or high level of CDR knowledge. Their responses were also examined for notable inconsistencies.

We aimed for an equal split between BECCS developers, DACCS developers and financiers interested in either technology or both, along with a balanced geographical representation. The distribution at the survey stage leaned towards DACCS compared to BECCS, as well as technology developers above financiers. Survey participants ($n = 47$) represented institutions headquartered in the United Kingdom ($n = 18$), EU/EEA ($n = 17$), the United States ($n = 11$) and other (Israel, $n = 1$). In terms of technology expertise, 13 respondents were involved in BECCS projects and 34 in DACCS projects.

This imbalance was corrected at the interview stage (see supplementary materials S4). It is worth noting that we did not aim to collect data from a representative population. Instead, we focused on expertise and seniority in the selected participation. Hence, the characteristics and self-reported descriptive data of the survey respondents should solely be reviewed as such.

2.3. Survey and interview design

The survey, conducted online using Qualtrics, was designed and tested with input from academic and technical survey experts. Its objective was to identify prominent barriers, following the typology of table 1, and gather insights into participants' expert characteristics.

In the initial survey section, respondents ranked 19 barriers according to their respective negative impact on BECCS/DACCS deployment (see supplementary materials S1), across four categories: 'highest negative impact', 'medium negative impact', 'lowest negative impact' and 'do not know'. Following this, respondents confirmed the internal ranking within the 'highest negative impact' category.

Subsequently, respondents identified the most salient policy measures within table 1 categories, offering insights into their policy knowledge and preferences. The final section solicited descriptive responses to characterise respondents' backgrounds and expertise, including current and planned CDR projects in Europe, a crucial context for the subsequent analysis.

The typology of table 1 also shaped the design of the subsequent interviews (see supplementary materials S2). The interview protocol was designed to provide a flexible environment for participants to discuss their perspectives on CDR policy options. A pre-interview briefing ensured that participants had an approximately equal understanding of each policy option (see supplementary materials S3). The interviews started with a recapitulation of participants' perception of CDR barriers, as expressed in the earlier survey to anchor subsequent discussions.

The policy selection process unfolded in two phases: first, participants freely and unrestricted chose policies across table 1 categories (i.e. demand-side, supply-side and regulatory interventions), facilitating a comprehensive understanding of preferences without pre-set limitations; second, participants selected preferred complementary policy interventions following pre-determined initial policy interventions.

All interviews took place online from June to December 2023, except for one in-person interview conducted at COP28 in Dubai. The interviews lasted between 35 min to 60 min in total. No remuneration was provided for participation.

3. Results

3.1. Barriers and concerns

Survey respondents were asked to rank the main barriers to the development of BECCS and DACCS in Europe, using the structure introduced in table 1. All 13 respondents BECCS respondents and 27 out of 34 DACCS respondents completed the task (figure 1).

Both BECCS and DACCS respondents identified 'lack of inherent demand for removal' and 'lack of long-term policy certainty' as the most significant barriers, with over 50% selecting them as critical issues. Surprisingly, 'public acceptability' was not deemed as a highly negative barrier for either BECCS or DACCS, suggesting lower stakeholder concern in this regard.

For the BECCS community, technology barriers had less impact, potentially reflecting the sector's relative maturity. Alongside lack of demand, top concerns included regulatory and policy risks, with 62% and 46% selecting 'long-term policy certainty' and 'lack of policy integration', respectively. Regulatory risks such as 'lack of robust standards' and 'inadequate legal frameworks' were chosen by 46% and 23% of respondents, respectively, as having the highest negative impacts.

For the DACCS community, technology barriers are still a significant concern and among the top impact barriers, reflecting the sector's early-stage development. Financial barriers, including 'lack of long-term capital' (56%) and 'high cost of capital' (48%), emerged as high-impact concerns. Other key barriers included a lack of demand and policy risks, with comparatively fewer concerns about regulatory risk and resource limitations, except for concerns about high energy demand.

Table 2 presents selected quotes that illustrate the motivation of interviewees behind their choices.

3.2. Unrestricted policy preferences

During the follow-up interviews, 27 respondents provided detailed insights into their preferred policy interventions for supporting the development of BECCS and DACCS. Initially, respondents were invited to make unrestricted policy choices using the table 1 categories, with results depicted in figure 2.

The most favoured policies across the three generic categories were as follows. Linking to an Emission Trading System (ETS) was the preferred demand-side policy of 67% of respondents, with an average rank of 2.2 (that is, respondents ranked it about second on average). A Green Investment/Infrastructure Bank was the preferred supply-side policy of 78% of respondents, achieving an average ranking of 1.7. On the regulation side, accounting and MRV stood out as the preferred policy of 78% of respondents, with an average ranking of 1.4.

Other popular demand-side policies included tax breaks/credits and a carbon contract-for-differences (CfDs), each selected by approximately 50% of participants. Public procurement schemes and advanced market commitments (AMCs) were also popular, particularly in the DACCS community.

Supply-side measures, such as industry clusters and public funding, also received significant attention, chosen by 18 and 15 respondents, respectively. Across all categories, skills-related interventions (e.g. training, technology transfer, curriculum changes) were not deemed a priority.

The descriptive statistics mask nuances in participants' preferences. Many respondents pointed to the importance of the specific design characteristics. The devil is in the details. Preferences also varied with technology readiness. Tax breaks, for example, are seen as more suitable in the early stages, while an ETS link works for mature technologies that can compete at the prevailing carbon price. Tables 3 and 4 presents selected quotes that illustrate the motivation of interviewees behind their policy choices.

3.3. Conditional policy preferences

Given that low demand presents the primary obstacle to the deployment of BECCS and DACCS, demand-side policies are seen as a prerequisite. However, they may suffice alone. Consequently, a second exercise was devised to assess the interviewee's preferences for additional policies when an initial demand-side policy is already established.

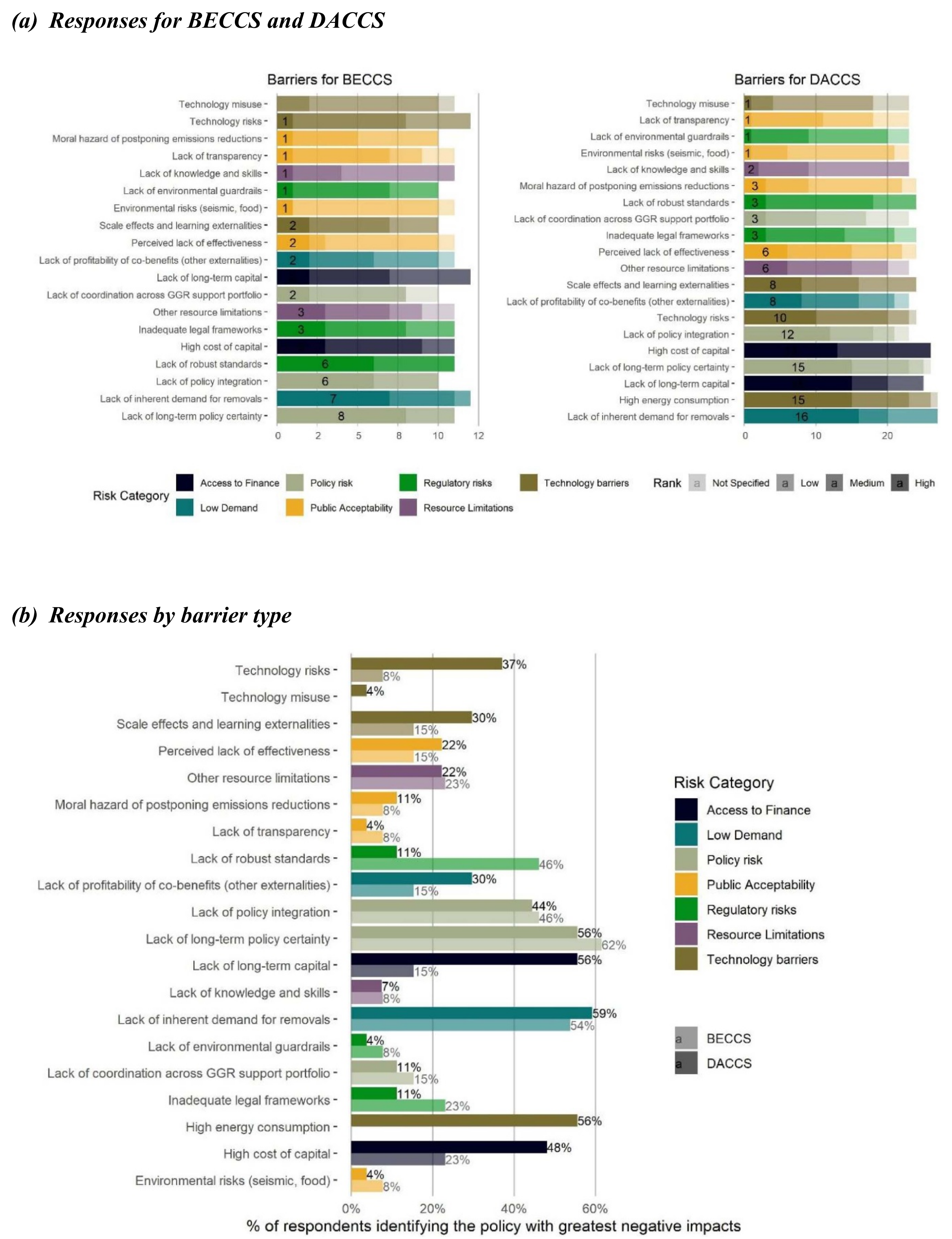

Figure 1. Selection and ranking of barriers.
Note: responses from 40 (out of 47) survey participants. 'Not specified' refers to responses where participants were not able to indicate a ranking.

Participants were asked to select two complementary policies to combine with four preselected demand-side policies: 'market-led (link to an emissions trading system, ETS)', 'fiscal incentives (including tax breaks and credits)', 'government-led initiatives (contracts-for-difference [CfDs] and public procurement schemes)', and 'other market-led options (producer responsibility and portfolio standards)'. Of the 27 interviewees, 25 engaged in this ranking exercise, while two expressed difficulties in selecting.

Despite limiting choices to two per scenario, participants demonstrated diverse preferences for complementary policies, with at least 14 different options chosen in each scenario (figure 3).

Table 2. Selected quotes explaining high-impact barrier choices.

Technology	Selected quotes
BECCS and DACCS respondents	
Lack of inherent demand for removal	'removals they do not in themselves actually represent something else. They only represent themselves. So, the only reason you would do them is because you sell them and not another product (…)Thus, this is the main product and the main product shall thus carry the entire CapEx and OpEx' (TD4) 'if you have demand, there will be capital flowing in, other barriers will disappear (…) inherent demand that's the underlying barriers that underpins all the other barriers' (TD8)
Lack of long-term policy certainty	'policy uncertainty prevents those [investment] conversations from getting too far (…). Investors are not willing to entertain these types of deals in places where policy certainty is not a prerequisite' (I5) 'we have had lots of warm words, but we have no clarity from government that they want our project to go ahead' (TD13) 'the lack of a time frame means in some ways it is a bit of a paper commitment at this stage, unless it is supported by a more tangible roadmap' (TD9)
BECCS respondents	
Lack of policy integration	'how will nations actually use these negative emissions, and the question, which is dear to my heart, in relation to how corporations may use them.' (TD4)
DACCS respondents	
Lack of long-term capital	'the people who have backed at least one company or more you can count them on maybe one hand, and that's about it' (I4) 'the nice way to put it is that we have kissed a lot of frogs, you know before like one turned into a Prince' (TD1)
High cost of capital	'debt capital make them extremely dilutive and so less attractive for their founding teams or for their early stage backers' (I4) 'nature of the capital is quite venture skewed, and that comes at a qualitative cost (…) it is certainly expensive because they expect you to have these multiples and to have an exit' (TD1) 'the need of those resources keeps going higher, and most of us, especially what we see in the DACCS sector, is that our CapEx is very, very high' (TD12)

Note. 'TD' refers to respondents that are technology/project developers; 'I' refers to respondents that are CDR investors/financiers.

Consistent support was observed for a Green Investment/Infrastructure Bank and the adopting accounting and MRV standards, regardless of the primary policy. Accounting and MRV was the most favourable complementary policy in three of the four scenarios. Notably, there was a moderate call for industry clusters on the supply-side and for regulatory standards as an institutional measure.

Strikingly, many respondents favoured an additional demand-side policy, such as complementing an ETS link with a CfD or vice-versa. An ETS link also emerged as the most popular complement to tax credits. However, the demand for a CfD or ETS link falls in scenarios where producer responsibility and portfolio standards were the preliminary measures.

3.4. Discussion

Our empirical results identify discernible patterns in policy preferences alongside notable heterogeneity among study participants.

Respondents broadly agreed on the key market barriers for BECCS and DACCS that call for government intervention. Over half of them highlighted the absence of a 'demand signal' (TD7) and the lack of a long-term policy framework as primary concerns. Conversely, respondents seem less concerned about skills gaps, disincentives for emissions reduction (moral hazard), transparency and environmental side effects.

The difference in risk perceptions between the BECCS and DACCS communities is broadly intuitive. BECCS stakeholders expressed greater concern over insufficient regulatory standards and environmental guardrails, reflecting the ongoing controversy around sustainable biomass supplies (e.g. Porritt *et al* 2022). DACCS proponents were less confident in their technology's maturity, emphasising technology risks, cost competitiveness and financing terms (both cost and repayment terms) as major concerns, alongside the high energy needs that are unique to DACCS.

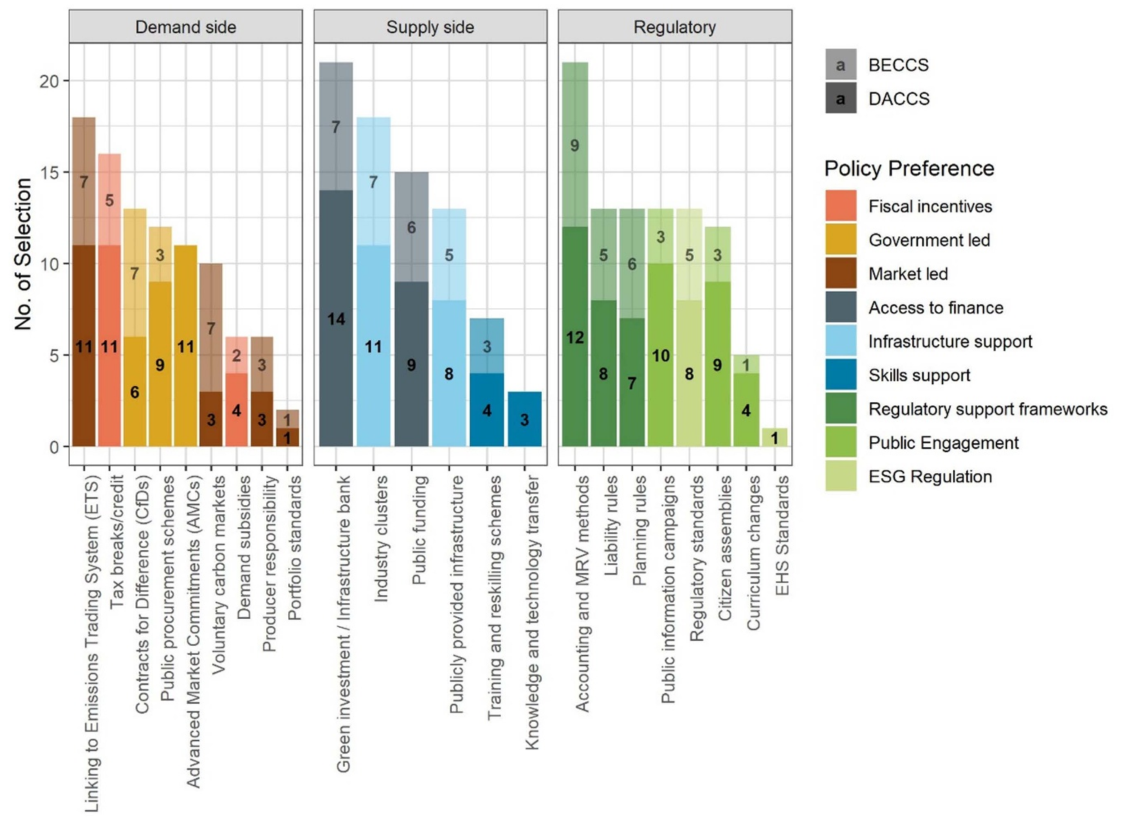

Figure 2. Unrestricted policy preferences.
Note: responses from 27 interview participants.

Table 3. Selected quotes explaining demand-side policy choices.

Policy	Position	Selected quotes
ETS link	(+)	'that's going to really help us a lot to have like a proper defined market, a centralised market' (TD12)
	(+)	'covering most of the heavy polluting industries and those are also the industries that will have a lot of residual emissions' (I1)
	(−)	'ETS price is not sufficient to hold up the business case' (TD15) and 'link to an ETS at a very low price you are not really helping CDR' (I11)
Tax breaks	(+)	'that's really beneficial for early stage companies' (TD1)
	(+)	'they allow market actors, including start-ups and incumbents, to find the niches where you could start out plucking the low hanging fruit' (TD10)
	(−)	'I worry that the small person cannot lobby for them' (TD11) and 'too much support for companies that are polluting' (I6)
CfD	(+)	'help reduce the risk in terms of pricing and delivery risk' (TD6) and therefore 'the most bankable investable proposition' (TD9)
	(+)	'path of least-resistance in terms of investors understanding the structure very well' (TD9)
	(−)	'If you do it badly, it can seriously inhibit the development of the industry. It sort of feels like a double edged sword on its own' (TD13)

(Continued.)

Table 3. (Continued.)

Policy	Position	Selected quotes
Public procurements	(+)	'the government creates an early guaranteed demand' (I4) and 'help that learning curve go down' (I11)
	(+)	'for governments to reach the net zero pledges they will probably need to purchase removals' (I2)
	(–)	'element of risk of bureaucracy associated with it' (TD9) and 'typically ends up with the most politically smooth contender winning' (TD10)
Advanced market commitments	(+)	'in the grand scheme of things would be a very small expenditure, but could have a catalytic effect on the industry' (TD7)
	(–)	'there's a risk that you actually destroy the company because of course the company needs money now and they are maybe a little bit over ambitious that they will be able to sell you those credits at such huge discounts' (I2)
Voluntary carbon markets	(+)	'could have a catalytic effect on the industry' (TD7) and "serve as the 'main driver in the coming years' (TD16)
	(-)	'[unlikely to exceed] the first few million tonnes a year capacity' (TD2) and 'too much of a Wild West' (I5)

Note. (+) indicates supportive perceptions. (–) indicates non-supportive perceptions. 'TD' refers to respondents that are technology/project developers; 'I' refers to respondents that are CDR investors/financiers.

Table 4. Selected quotes explaining supply-side and regulatory policy choices.

Policy	Position	Selected quotes
Green bank	(+)	'they need to fuel the system that we need to live in in the future' (I2), and 'the sooner we can get banks, we can become bankable' (TD5)
	(+)	'it is a concessional layer of financing that can help buy down the effects of that technology risk premium' (I5) and 'lower the cost of capital to start incentivising long term minded capital to come in' (I4)
	(–)	'another sort of gatekeeper in enabling the energy transition' (TD6)
Industry clusters	(+)	'industrial clustering that can move the needle' (I5) with 'soft benefits in terms of co-location, corporate partnerships, siting and permitting costs' (I5)
	(+)	'you are minimising transport as much as possible' (I10) to 'address chicken and egg situations' (TD8)'
	(–)	'it is picking winners' (TD10)
Public funding	(+)	'it is more targeted financial interventions to mitigate the specific risks' (TD9) and helps to get innovation out of the lab' (I1)
	(+)	'levels the playing field for the smaller companies' (TD11)
	(–)	'transparency and predictability into the funding schemes of pilots and technology development is really important' (I7)
Accounting and MRV	(+)	'critical for creating confidence' (TD14)
	(+)	'setting those policies up from the very beginning and not in hindsight when things go wrong' (I2)
	(+)	'if we would have more standardisation in place, faster, the whole ecosystem would move on quicker' (I2)
	(+)	'if there's not clarity on that, you […] end up with the wild west' (I10)
Planning & liability rules	(+)	'actual planning things because in the current democracies local community opposition can kill a project and slow down entire spaces' (I4)
	(+)	Reduce red tape—reducing planning and liability—and just trying to smooth those processes is helpful' (I5)
	(–)	'do not destroy ecosystem by having bad permitting regulation; do not destroy it with having outrageous liability rules' (TD10)

Note. (+) indicates supportive perceptions. (–) indicates non-supportive perceptions. 'TD' refers to respondents that are technology/project developers; 'I' refers to respondents that are CDR investors/financiers.

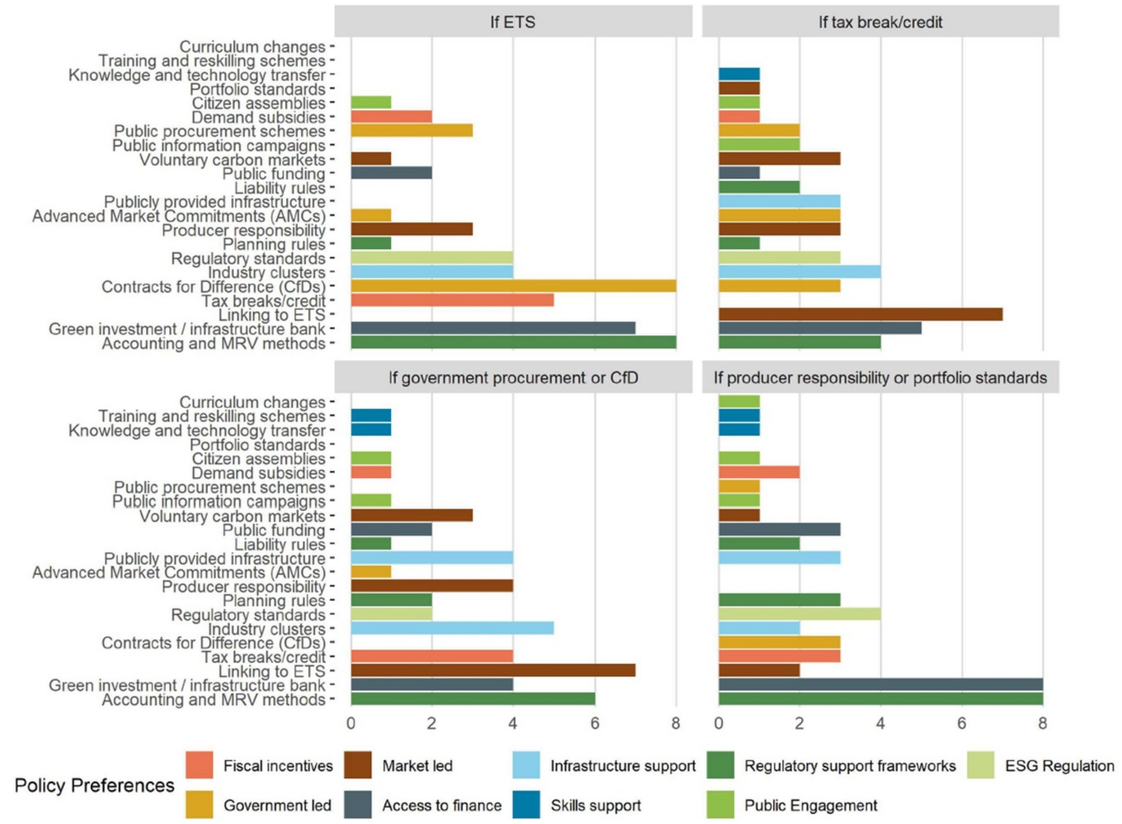

Figure 3. Conditional policy preferences, given an initial intervention.
Note: responses from 25 (out of 27) interview participants.

More surprising, and expressed only indirectly, were the divergent views on technology development. At the outset, the study aimed for an equal participation of BECCS and DACCS experts, with CDR financiers assumed to be agnostic between the two technologies. In the event, two-thirds of respondents signalled a primary interest in DACCS, suggesting that the market expects more rapid progress in this technology.

When identifying policy preferences, most interviewees prioritised rapid demand growth over market certainty and stringent regulatory standards. They were keen on market structures 'that can scale very fast' (I1). In this respect, they have more trust in regulated market solutions than government procurement schemes or the voluntary market.

Interviewees nevertheless saw an important role for the state, not as a market player but as an enabler and regulator. They looked to governments to 'provide tailwinds that private sector actors, buyers and investors can latch on to' (TD1). They wanted a policy regime that provides clarity, cohesion, flexibility and above all speed. They called for a coherent 'policy ramp or policy ratchet' (TD7) with 'a clear time scale' (I9). Interviewees are comfortable with both 'more carrots and more sticks' (I7), but they want governments 'to take decisions … [and] provide certainty to business as soon as possible' (TD14).

Linking to an ETS consistently emerged as a top choice for stimulating demand, particularly in the latter stages of market development when allowance prices and CDR costs begin to coalesce. Familiarity with emissions trading may have influenced this preference, as study participants tended to favour established policy solutions over untested new schemes. Perhaps they were also acknowledging the prevailing direction of travel, with ETS integration widely seen as 'inevitable' (I4).

There was less consensus about the best policy instruments to stimulate early-stage demand. Interviewees agree that government support was critical. Governments can 'take on a little bit more risk and potentially pay a somewhat higher price' (TD2) and 'be the first mover' (TD7). But interviewees expressed support for a diverse range of interventions, including tax breaks, CfDs, public procurement schemes, AMCs and infrastructure development. At the same time, they raised concerns about support schemes that mandate specific pathways or technologies, thereby limiting innovation and market efficiency. Some respondents also emphasised the need to 'minimise the burden on taxpayers' (TD4).

There was broad support for clear accounting rules and MRV standards, which were consistently selected as a key complementary intervention. However, interviewees saw better standards primarily as a means to rapid market development, rather than a safeguard against suspect market behaviour. As one respondent articulated, 'when the government takes leadership, set up the playing rules and then everybody starts working around that', money follows (TD12). Planning rules were described by one respondent as the 'biggest fish within the regulatory sea' (I8), as they expedite project timelines and ensure clarity when frontloading investments. However, our study did not go into further details, and we can expect disagreements about the specifics of such regulations.

Overall, our results suggest that the road ahead for CDR policy requires a multi-pronged approach. We anticipate a period of policy experimentation, as different jurisdictions explore different options for boosting demand, including technology subsidies, ETS links, carbon CfDs, AMCs and potentially producer responsibilities. In parallel, clear and transparent governance frameworks will need to be established to ensure the environmental integrity and sustainability of CDR projects, particularly surrounding biomass supplies for BECCS. International cooperation will be crucial, as few individual markets will be sufficiently large to generate learning effects at the required scale.

4. Conclusions

This paper presents the policy preferences of participants in Europe's nascent market for BECCS and DACCS. As active market players, study participants promote the vested interests of their specific industries. The interests of society and the preferred interventions for other CDR methods may be different. Few study participants expressed concerns about policy costs, for example, which will be foremost in the minds of policy makers. But even bearing those caveats in mind, the expectations of the BECCS and DACCS market are important and revealing. There is a sharp focus in the industry on boosting demand and providing a business environment that is conducive to market development. Market participants seek government leadership but prefer a supportive state rather than an intrusive approach. There is limited appetite for outright government procurement schemes. Standards should promote market development as well as market integrity.

While policymakers need to be mindful of industry concerns, their focus must be on the wider social and environmental objectives of CDR development. Here they face five main challenges. Some of them align with market interests, others may not.

The first challenge is scale. Engineered CDR must be scaled by an average factor of at least 30 by 2030 and over 1300 by 2050 (Smith *et al* 2023). This pace exceeds the typical market-driven speed of technology adoption (Fouquet 2016, Nemet *et al* 2023a), necessitating policy-driven deployment rates. Policy support has to be technology-neutral, supporting the most promising technologies without locking out others with potential.

The second challenge is balance. Although CDR requires rapid scaling, the priority of climate policy must be to reduce emissions (Fankhauser *et al* 2022). A debate persists regarding the extent to which the balance between carbon abatement and removal should be determined by policy, through separate emissions and CDR targets, or left to the market, which would arbitrage between abatement and removal costs.

The third challenge is integrity. The additionality and the permanence of geological carbon storage are fairly certain, unlike some forms of biological CDR. However, ascertaining the social and environmental integrity of engineered CDR is nevertheless essential, both in its own right and to retain a social license to operate within a wider climate strategy (Cox *et al* 2020). Clear industry standards will have to be agreed internationally and enforced nationally to ensure market integrity.

The fourth challenge is fairness. Justice in both process and outcomes is a key objective of climate policy (Khosla *et al* 2023), which also extends to CDR. Policymakers must decide how to allocate CDR costs between industry and taxpayers. They need to establish planning processes to address local impacts and resolve conflicts. Their decisions will determine whether CDR succeeds not just environmentally but also socially and economically.

The final challenge is speed. Despite the ongoing evolution of policy frameworks for CDR, the urgency of climate action necessitates their swift development. Well-designed policy instruments, as identified in this paper, combined with robust governance structures and international cooperation are critical for unlocking the potential of engineered CDR and helping to achieving a net zero future.

Data availability statement

The data cannot be made publicly available upon publication because they contain sensitive personal information. The data that support the findings of this study are available upon reasonable request from the authors.

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Conflict of interest

The authors have no conflicts of interest to declare.

Ethical review statement

This research was granted ethics approval by the Central University Research Ethics Committee at the School of Geography and the Environment, University of Oxford. All study participants received a participation information sheet with detailed information on the study and data management. All participants gave informed consent before the commencement of both the survey and interview stages. Interview participants were reminded of the study details, and their right to withdraw their consent and data at any time. All participants were 18 years of age or above. In all stages of the research, individually identifiable details have not been disclosed and pseudonyms have been consistently utilised.

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