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C-SINK

ACTIONS REQUIRED TO SECURE THE LARGE-SCALE DEPLOYMENT OF THE LEADING CDR APPROACHES TO MEET EU CLIMATE TARGETS

D5.1 Social acceptability of CDR technologies

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1.Information sheet

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2. Deliverable 5.1. – Social acceptability of CDR technologies

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Description

D5.1 Social acceptability of CDR technologies (SEI, M32) is linked to T5.2

T5.2 – Social impacts analysis: This task contains the social impact analysis for the different CDR technologies. It consists of firstly a survey to understand the social impacts the CDR approaches will have in each location, and by consequence their social acceptability. The survey answers will be analysed using an intersectionality lens (gender, ethnicity, class, education level, socio-economic standard, etc.), allowing to understand how different socio-economic groups perceive these technologies. Then, in workshops in each of the agreed locations, representatives from four types of organisations as identified in the quadruple helix model (i.e., government, industry, academia and citizens), will reflect on the survey results and provide further understanding of the societal barriers and incentives surrounding the implementation of CDR technologies. The multi-actor modelling approach, designed and modelled by CES (see section 7), will be used for the analysis as it allows to consider multiple viewpoints of different stakeholders. The findings will result in D 5.1 and links closely with task 4.3.

Abstract

Achieving climate neutrality requires rapid emissions reductions alongside responsible deployment of carbon dioxide removal (CDR). While policy and industry attention to CDR is increasing, social acceptability remains less studied than technical and economic feasibility, even though public perceptions, governance legitimacy, and justice considerations will shape whether CDR can be implemented and sustained over time. This report examines the social acceptability of six CDR solutions - afforestation, artificial soils, biochar, microbiological CO_2 fixation, BECCS, and enhanced weathering - across eight European case studies. We conceptualize acceptability as a process shaped by interacting political, economic, social, technological, environmental, legal, and ethical factors, and we combine an exploratory qualitative analysis of 73 interviews with a rapid-review–inspired literature review. The analysis provides a structured account of the conditions and concerns that stakeholders raise when CDR is discussed, designed, and governed, and it highlights implications for designing legitimate, transparent, and justice-sensitive policy frameworks. These insights are intended to support policymakers and practitioners in developing governance and communication approaches that enable responsible CDR deployment as a complement to deep emissions cuts.

Keywords : SOCIAL ACCEPTABILITY, CDR TECHNOLOGIES, CASE STUDY

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Glossary

AF	Afforestation
AS	Artificial Soils
BC	Biochar
BECCS	Bio-Energy Carbon Capture and Storage
CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
CDR	Carbon Dioxide Removal
DACCS	Direct Air Carbon Capture and Storage
EU	European Union
EW	Enhanced Weathering
FAA	Factors Affecting Acceptability
I	Interview
MCO_2	Microbiological CO_2 Fixation
MRV	Monitoring, Reporting, Verification
NIMBY	Not In My BackYard
NGO	Nongovernmental Organisation
PESTELE	Political, Economic, Social, Technological, Environmental Legal and Ethical
PyCCS	Pyrogenic Carbon Capture and Storage

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4. Executive summary

Background

Achieving climate neutrality requires not only rapid emissions reductions, but also large-scale deployment of carbon dioxide removal (CDR) solutions. Despite increasing policy and industrial attention, the social acceptability of CDR solutions remains underexplored compared to their technical and economic feasibility. Public perceptions, governance legitimacy and justice considerations will critically determine whether CDR solutions can be responsibly implemented and sustained over time. This study examines the social acceptability of six CDR solutions across eight case studies: afforestation, artificial soils, biochar, microbiological CO_2 fixation, bioenergy with carbon capture and storage, and enhanced weathering.

Methods

Our approach is that social (un)acceptability should not be seen as a static outcome of acceptance or unacceptance, nor something to overcome, but rather as a synthesis of political, economic, social, technological, environmental, legal and ethical factors affecting acceptability when CDR solutions are discussed, designed and implemented. Understanding these factors is crucial for designing governance frameworks and policies that enable responsible, legitimate and just deployment of CDR in Europe. To do this, we combined an exploratory qualitative analysis of 73 interviews and a rapid-review-inspired literature review.

Findings

In general, stakeholders perceive CDR solutions as necessary, but not a replacement for emissions reductions. Others question their resource intensity and climate change mitigation potential, emphasizing the risks of overreliance on CDR solutions to solve climate change. We identified factors affecting acceptability across the eight case studies. However, not all are applicable to each interviewee, CDR solution or case study, and preferences for specific CDR solutions vary between interviewees. For example, some prefer higher permanence over natural solutions and vice versa. Acceptability at the community level is described as context-dependent, and influenced by various ethical factors and localized impacts and risks. Acceptability at the market level is mainly driven by four interlinked conditions, including economic viability supported by stable policy incentives; credible and transparent monitoring, reporting and verification (MRV) and certification systems; technological maturity and demonstrated performance; and alignment with ethical and distributive principles that ensure legitimacy. Acceptability at the socio-political level is mainly driven by five interrelated conditions, including transparent and long-term policy frameworks; institutional accountability and cross-sector coordination; scientifically grounded and openly communicated decision-making; integration of distributive and procedural justice principles; and responsible narrative framing that positions CDR solutions as a complement to emissions reductions.

Discussion

Findings confirm that social acceptability is relational and processual, co-produced through interactions between communities, markets and institutions. Core factors such as trust, transparency, justice and accountability align with insights from the energy justice and renewable energy social acceptance literature. Social acceptability depends less on the solution itself than on how it is governed, communicated and embedded in local contexts. Without attention to distribution, recognition and procedural justice, CDR solutions risk repeating past failures of contested climate solutions. Durable acceptability requires participatory governance, credible MRV systems and clear long-term responsibility for storage integrity.

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5. Introduction

5.1 About carbon dioxide removals

Climate change poses one of the most pressing global challenges of the 21st century, with mounting evidence of its wide-ranging and intensifying impacts on ecosystems, human health, economies and societal stability (IPCC, 2023). Limiting a global temperature rise to well below 2°C, and ideally 1.5°C, will require not only drastic reductions in greenhouse gas emissions but also the active removal of carbon dioxide from the atmosphere, in particular given residual emissions from sectors like agriculture, aviation and heavy industry (IPCC, 2022).

Carbon dioxide removal (CDR) solutions have emerged as a necessary complement to conventional mitigation. These solutions aim to capture CO_2 from the atmosphere and store it for long durations, either in biological sinks such as forests and soils or in engineered systems, for example through carbon mineralization or injection into geological storage. Nature-based solutions include afforestation and reforestation, soil carbon enhancement and biochar, while engineered CDR solutions cover enhanced weathering (EW), carbon capture and storage (CCS), bioenergy with carbon capture and storage (BECCS), and direct air carbon capture and storage (DACCS). CDRs differ substantially in terms of their technological maturity, storage durability or carbon storage permanence, land and resource requirements, and potential co-benefits or trade-offs (Minx et al., 2018; Vaughan et al., 2024). For example, afforestation offers relatively low-cost and near-term mitigation potential but faces constraints related to land availability and permanence. In contrast, DACCS offers high durability of storage but remains energy-intensive and expensive at current scales. BECCS, while frequently included in climate models, raises concerns over biomass sourcing.

The deployment of CDR solutions is fraught with complex challenges that go beyond technical feasibility and cost effectiveness (Waller et al., 2020). For example, mitigation deterrence or the risk that the promise of future CDR deployment reduces the ambition or urgency of present-day emissions reductions is a growing concern among scholars and policymakers (Markusson et al., 2018; Olsson et al., 2024). Prevailing discourses around CDR are also dominated by techno-economic assessments and often assume that social acceptability will naturally follow once a solution proves viable on paper (Sovacool, Baum, et al., 2023). This assumption is increasingly challenged by scholars and practitioners who stress the importance of societal engagement, legitimacy, and justice in the development and scaling of CDR solutions (Gough & Mander, 2019; Low et al., 2024). Historical experiences with technologies such as nuclear power and large-scale bioenergy, for example, reveal that public trust, procedural fairness and distributional impacts critically shape the success or failure of climate innovations (Cotton, 2018; Valentine & Sovacool, 2010). Moreover, the social and political dynamics of CDR are inherently context-dependent (Cox et al., 2020; Nielsen et al., 2022; Prütz et al., 2024). Factors such as land-use implications, perceived risks and benefits, trust in institutions, and the inclusiveness of governance processes vary widely across geographies and technologies. Stakeholders' perceptions of different CDR solutions vary substantially (Cox et al., 2020; Low et al., 2024). For ecosystem-based removal such as afforestation, participants in the above-mentioned studies were relatively supportive, often referencing familiarity, naturalness, co-benefits (e.g. habitat, biodiversity) and local agency, whereas for engineered/novel removal solutions (e.g. DACCS, EW), concerns were raised about how they work, their

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scale, unintended consequences, trade-offs (land, energy, resources) and governance/justice aspects. As such, deploying CDR at scale without sufficient attention to its social dimensions could not only provoke resistance and controversy but also undermine the broader goals of climate justice and democratic legitimacy (Prütz et al., 2024; Sovacool, Baum, et al., 2023).

5.2 The purpose of this study

To address these challenges, the present study seeks to explore how different CDR solutions are perceived across a diverse set of contexts, and to identify the key factors that shape their social acceptability. They pose unique challenges that warrant a distinct analytical approach. Unlike energy infrastructures that are largely place-bound and immediately operational, several CDR solutions are speculative, distributed across time and space, and embedded in future-oriented promise-making (Low & Schäfer, 2020; McLaren & Markusson, 2020). This temporal and epistemic distance complicates stakeholder engagement and makes public trust both more fragile and more consequential. Adopting a comparative scope across diverse settings (i.e. geographical contexts, solutions and stakeholder groups) facilitates the identification of context-specific factors that shape the social acceptability of CDR solutions (see Gough & Mander, 2019). Importantly, this study moves beyond the descriptive task of cataloguing such factors by analytically distinguishing between those that are contingent upon specific contexts and those that are generalizable. Context-contingent factors are shaped by the specifics of deployment and place: local political dynamics, institutional histories, perceived proximity to risks, and the configuration of infrastructures and land uses that make impacts visible and uneven. Generalizable factors recur across technologies and settings because they reflect broad legitimacy logics (who bears costs and benefits, who decides, who is accountable), and whether monitoring and long-term stewardship are credible. Importantly, generalizable does not mean uniform; the same legitimacy concern can manifest differently depending on the technology and setting. By making this distinction explicit, the analysis clarifies when improving acceptability requires tailored local processes (e.g. siting, benefit-sharing, procedural safeguards) versus system-level measures that travel across contexts (e.g. transparent governance, liability clarity, robust monitoring, reporting and verification, and credible oversight). In doing so, the report provides a framework for interpreting acceptability as an interaction between technology characteristics and the institutional and political environments in which deployment occurs.

Understanding the social acceptability of CDR solutions in different settings is vital for ensuring that its deployment is both effective and equitable. Rather than treating public perception as a barrier to be overcome, it should be viewed as an integral part of sustainable innovation. Research approaches are required that move beyond simplistic surveys or awareness campaigns towards deeper engagement with the values, concerns and expectations of affected stakeholders (Batel, 2020; Batel et al., 2013). CDR introduces ethical and political dilemmas with the risks posed by mitigation deterrence (Markusson et al., 2018) and complex supply chains that intersect with issues of land use, energy demand, environmental justice and democratic oversight (Anderson & Peters, 2016). These intersections are not incidental, but central to how various actors make sense of and respond to CDR. Finally, we found that perceived social acceptability is one critical element for achieving social licence when establishing emergent innovations such as CDR solutions (Gough & Mander, 2019). A framework sensitive to both the novelty of CDR (in

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its temporal, material and institutional dimensions) and its embeddedness within existing structures of inequality and contestation is therefore required.

5.3 The structure of this report

This report contributes to the emerging literature on this topic by foregrounding stakeholder perspectives on a range of CDR solutions, drawing attention to the contextual, relational and justice-based factors that shape their acceptability. It is structured as follows. In Section 6, we describe our conceptual framework and the definitions used in this study. Section 7 outlines our methodology, consisting of a rapid-review-inspired literature review and an exploratory interview study. Findings can be found in Section 8, followed by a discussion of these findings in the wider context in Section 9. We conclude in Section 10.

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6 The conceptual framework

6.1 Defining social acceptability

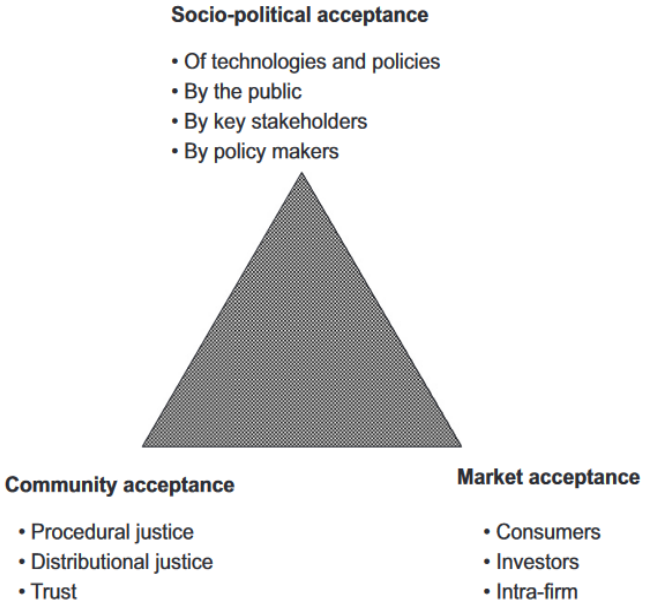
Despite the growing interest in social acceptance and acceptability studies, definitions and interpretations of social acceptance and acceptability vary (Cox et al., 2020; Gaede & Rowlands, 2018; Gough & Mander, 2019; Low et al., 2024). A range of dimensions have been considered, including social, legal, ethical, political and environmental (Gough & Mander, 2019), perceptions about risk and benefits (Cox et al., 2020), and stakeholders' hopes, concerns and expectations (Low et al., 2024).

The field of sustainability in which social acceptance and acceptability studies have been most extensively conducted is in the development and implementation of renewable energy technologies such as wind power, solar energy and bioenergy (see, for example, Haikola et al., 2019, 2024; Kirch Kirkegaard et al., 2021; Zimmermannová et al., 2018), and nuclear energy, particularly around reluctant acceptance and understanding the nuance in acceptance and decision-making (Kim et al., 2014; Guo et al., 2017). Social acceptance has often been framed as an individual or aggregate attitude, typically binary (support/oppose), passive and measured at a fixed point in time (Aitken, 2010). This framing implicitly assumes that individuals make rational decisions based on information and risk-benefit calculations, often in line with the so-called "deficit model" of science communication (Batel, 2020). In this model, resistance to novel technologies is seen as mostly stemming from ignorance, which can supposedly be overcome through better education or communication. Such perspectives tend to downplay the influence of structural conditions, cultural narratives and institutional (mis)trust in shaping public responses.

However, scholars have increasingly recognized the socially embedded, negotiated and often contested nature of people's perceptions, focusing on discrimination, injustices and inequalities (Batel, 2020). A foundational paper by Wüstenhagen and colleagues (2007), for example, challenged the one-dimensional, often inconsistent NIMBY (not in my backyard) explanation for opposition to renewable energy technologies, offering alternatives that emphasize the role of community perceptions and attitudes, such as socio-psychological factors, distributive justice and procedural justice. This research also expanded the focus to include various actors and scales beyond the immediate community. Indeed, they distinguish between three dimensions of social acceptance: (1) socio-political acceptance – the broadest dimension – referring to acceptance of both policies and technologies by the public, key stakeholders and policymakers; (2) community acceptance, "the specific acceptance of siting decisions and renewable energy projects by local stakeholders, particularly residents and local authorities"; and (3) market acceptance, or "the process of market adoption of an innovation" (Wüstenhagen et al., 2007, p. 2685), covering acceptance by customers, by investors and within a firm (Figure 1).

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Figure 1. The triangle of social acceptance of renewable energy technologies.



Source: Wüstenhagen et al., 2007

Fournis and Fortin (2017), in turn, also critique the "deficit model" for overlooking how perceptions are embedded in broader territorial and political contexts. They note that it fails to account for how projects align or misalign with local values, spatial imaginaries and governance structures. Acceptability, they note, is not an individual attitude but a socially embedded and territorially negotiated process. They distinguish between the concepts of social acceptance and social acceptability; whereas social acceptance is often treated as a post-hoc, individual attitude towards an innovation or project (e.g. "I support this wind farm"), social acceptability is framed as a socially and politically constructed process. They argue that social acceptability is not simply about whether a community or individual says "yes" or "no" to a project; rather, it involves negotiation, sensemaking and contestation over time, shaped by local identities, histories and power relations. Social actors, such as citizens, are neither passive nor static. Instead, social actors' perceptions are formative in the evaluation and implementation of emergent technologies (Pidgeon & Spence, 2017). Factors in planning that lead to unacceptance include top-down approaches, a lack of accountability for local complexity and heterogeneity, poor interaction between stakeholders, and perceived injustice. They propose a territorial approach to social acceptability, anchored in a multi-scalar framework that considers three interrelated levels: (1) the micro level (local/community level) focuses on individual and community perceptions, emotional attachments to place, and everyday experiences with the project or innovation; (2) the meso level (institutional or regional level) examines how institutions, planning processes and regional development agendas shape stakeholder involvement and procedural justice; and (3) the macro level (structural/political level) captures broader socio-political and economic dynamics, including state policies, historical marginalization, neoliberal reforms and power asymmetries between actors. This scalar lens allows researchers and policymakers to analyse how acceptability is negotiated in different contexts and scales, emphasizing that conflicts around energy or climate solutions are rarely reducible to isolated concerns. Instead, they often reflect deeper structural tensions and justice claims. This framework

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has been applied to a range of related empirical topics, such as wind turbines or dryland farming (see e.g. Busse & Siebert, 2018).

Social acceptability studies have contested the nature of acceptability. While one stream of research bounds social acceptability as "the quality of being acceptable" (Gough & Mander, 2019, p. 120), another stream of research demarcates social acceptability from social preference, with "preference representing an ideal outcome and acceptability representing a less propitious alternative outcome albeit not being opposed" (Duesberg & Dhubháin, 2019, p. 13). While we acknowledge the various definitions of social acceptability, this study understands social acceptability as a process. In this study's view, social acceptability encompasses a continuum of stakeholder perceptions about emergent technologies. Social acceptability is therefore seen as a synthesis of factors that stakeholders may consider when CDR solutions are discussed, designed and implemented.

6.2 The PESTELE framework

To identify the various possible factors affecting (social) acceptability, we draw on the PESTELE framework (see Table 1), which includes political, economic, social, technological, environmental, legal and ethical dimensions. While the PESTELE framework has its origins in strategic management (Aguilar, 1967), it has been frequently extended (Tseng & Pilcher, 2021) and applied in other fields (Katko, 2006; Richardson, 2006; Shilei & Yong, 2009), including socio-technological studies (Pihkola et al., 2017). The strength of the framework lies in its comprehensiveness and versatility, particularly for comparative or multi-case research. It also allows for obtaining insights into a variety of boundary conditions for emergent technologies where sustainability plays a critical role (Pihkola et al., 2017). Furthermore, it can predict situations that the implementation of a CDR solution might encounter in the future (Dinçer, 2004). Due to the fact that the CDR discourse is closely related to deterrence and unethical practices, including land-use change and social injustice towards vulnerable communities (Markusson et al., 2018; McLaren & Markusson, 2020), ethical factors are retained as a distinct category to ensure that explicitly moral considerations, such as intergenerational justice, rights-based critiques or conceptions of the common good, receive dedicated attention. At the same time, we acknowledge that justice-related concerns permeate all PESTELE dimensions. Issues of fairness in benefit distribution, legitimacy of governance processes and recognition of affected communities are not confined to the ethical domain but are intrinsic to political, economic, social and legal considerations as well (Jenkins et al., 2016; Waller et al., 2020).

In this study, we operationalize and apply the PESTELE framework following Brendel and colleagues (2021), where each PESTELE dimension is based on specific assumptions (see Table 1). Each assumption is considered to have a potential influence on the social acceptability of certain CDR solutions. In this vein, it needs to be considered that the factors affecting acceptability are abstracted; they may or may not influence the actual implementation of a certain CDR solution. This very structure can risk oversimplifying or fragmenting the complex and interdependent nature of socio-political dynamics (Andersen, 2025). Moreover, the PESTELE dimensions are interdependent and need to be considered holistically (Eren, 2002). The independent measurements of isolated dimensions might not be representative. For example, it is not possible to consider "legal arrangements or economic conditions in isolation from political conditions" (Yüksel,

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2012, p. 53). If applied mechanistically, the PESTELE framework may obscure the relational and power-laden processes through which social acceptability is formed. For example, trust in carbon accounting could be seen as a technological concern, yet may also be deeply entangled with political factors around governance transparency or ethical concerns about intergenerational equity. Each real-life CDR implementation might experience its own unique set of social acceptability factors to be decisive for its (social) licence to operate.

To address these limitations, we interpret PESTELE not as a neutral categorization tool, but as a heuristic to support deeper inquiry into how social, technical and institutional dimensions co-evolve. Following Fournis and Fortin's (2017) territorial framing and the multi-dimensional model of energy justice (Sovacool, Bell, et al., 2023), we use PESTELE for structuring empirical observations, but always situate findings within broader dynamics of trust, power and sense-making.

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Table 1. Overview of the PESTELE framework

Dimension	Assumption	Examples of factors
Political	What policy framework or political context may influence the perceptions of acceptability when a certain CDR solution is implemented?	– Local political dynamics, such as municipal decision-making, siting and permitting, local elections and coalitions, community–authority relations – The broader political landscape, including national policy stability, party competition, regulatory direction, and the wider EU/global political environment shaping climate and industrial policy
Economic	What economic, market, or business factors may influence the perceptions of acceptability when a certain CDR solution is implemented?	– Market factors – Economic impacts – Economic viability – Business management and practices – Labour market
Social	What social and cultural context may influence the perceptions of acceptability when a certain CDR solution is implemented?	– Social and cultural context – Societal factors – Broader effects on social well-being, health and community dynamics – Awareness, knowledge
Technological	What infrastructural and technological factors may influence the perceptions of acceptability when a certain CDR solution is implemented?	– Hard and soft infrastructure – CDR maturity, complexity and efficiency – Longevity of technology – Permanence and storge capacity
Environmental	What environmental and climate factors may influence the perceptions of acceptability when a certain CDR solution is implemented?	– Land use and land use change – Soil, air and water quality and impacts on quality – Biodiversity, climate and environmental impacts – Climate mitigation potential – Input sustainability; resource intensity
Legal	What legal framework and context may influence the perceptions of acceptability when a certain CDR solution is implemented?	– Set of government policies, frameworks, strategies, and guidelines – Legal complexities and limitations – Legal support – Legal feasibility – Liability – Compliance – Judicial precedents
Ethical	What ethical factors may influence the perceptions of acceptability when a certain CDR solution is implemented?	– Displacement – Social justice – Greenwashing – Deterrence

Source: Own illustration

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7 Methodology

Although the task description references survey-based insights, we adopted an exploratory qualitative design at this stage (Teddlie & Tashakkori, 2009) because no validated, CDR-specific inventory of factors affecting acceptability (FAAs) yet existed that could be translated into robust survey items without undue construct borrowing or leading question design. We therefore conducted stakeholder interviews to elicit and refine an initial FAA set grounded in stakeholders' own framings across technologies and contexts, complemented by a rapid-review–inspired synthesis of the literature. We systematically abstracted the qualitative input (section 7.3), which resulted in a reduced set of FAAs. An intersectionality-informed perspective is important for CDR because acceptability depends on how benefits, burdens, and voice are distributed across different social groups; however, this deliverable analyses acceptability primarily at the level of stakeholder organizations and governance contexts rather than testing individual-level socio-demographic differences, again, as no validated, CDR-specific inventory of factors affecting acceptability (FAAs) yet existed that could be translated into robust survey items.

Our foundation-building step strengthens conceptual validity and provides a defensible basis for any subsequent quantification (e.g., survey instruments). Robust intersectional testing, for example, requiring a dedicated population-based survey or complementary quantitative design, can be developed building on the FAAs identified in this report. Workshops across the Quadruple Helix could further validate and stress-test these factors and their governance implications. The methodology used is compatible with the integrated modelling approach that will be used in Task 5.5.

7.1 The semi-structured interview study

Our empirical data collection covered six CDR solutions across different contexts (Table 2). While other locations were feasible, we focused on these case studies for alignment with the economic and environmental assessments. For BECCS and EW, we collected data in two locations, resulting in a total of eight different cases.

Table 2. Case study overview

Solution	Country	Definition
Afforestation (AF)	Spain	Establishing forests on previously non-forested land to store atmospheric CO_2 via biomass.
Artificial soils (AS)	Spain	Engineered substrates created from waste materials to enhance soil carbon storage.
Biochar (BC)	Portugal	Pyrolyzed organic material used to enhance soil carbon retention and fertility.
Microbiological CO_2 fixation (MCO_2)	Germany	Microbial conversion of CO_2 into biomass or bio-products.
Bioenergy with Carbon Capture and Storage (BECCS)	Sweden, United Kingdom	Bioenergy production combined with carbon capture and storage to generate negative emissions.
Enhanced Weathering (EW)	Finland, Spain	Application of crushed silicate rocks to accelerate mineral weathering and absorb CO_2.

Source: Own illustration

To select interview participants for each case study, we first conducted a value chain mapping for each solution, identifying key processes in the chain (Annex 1, Figure 4-9).

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These maps were validated through consultations with representatives from the case study companies.

We then identified interview participants following the quadruple helix model (Carayannis & Rakhmatullin, 2014):

1. governmental actors, e.g. political decision-makers, governmental agencies
2. business actors, e.g. case companies, clients, suppliers, trade organizations
3. academic and other domain experts, e.g. university faculty, researchers, private research institutions
4. civil society representatives, e.g. local community representatives, non-governmental organizations (NGOs), not-for-profit organizations.

The quadruple helix model is designed to illustrate how various actors connect and drive structural changes beyond the scope of the possibilities of a single actor (Carayannis & Rakhmatullin, 2014). Furthermore, this approach to categorizing study participants has been found to be particularly relevant to explore the social legitimacy of governance systems or organizations (Campanella et al., 2017).

While exploratory studies often use purposive sampling to recruit participants with prior knowledge of the topic (Teddlie & Yu, 2007), we also included stakeholders, particularly from civil society, who may not have been familiar with CDR solutions but are nonetheless affected by them. Civil society actors often lack technical knowledge yet play a key role in assessing social legitimacy and public acceptance (Heidbreder, 2012; Selle & Wollebæk, 2015; Stemerding et al., 2009). To support informed participation, we provided a brief overview of CDR solutions during interviews. This approach is supported by research showing that meaningful insights can emerge when participants are introduced to relevant knowledge in the interview context (Chander et al., 2023; McLeod et al., 2025; Welzel & Roth, 1998).

Building from the mapping of lifecycle stages for each CDR intervention (Annex 1), we contacted project partners for referrals and searched public directories to recruit interview participants directly. Each case study focused on a single company, whose lifecycle often spans multiple geographical contexts. We aimed for an even distribution of stakeholders across different stages of the product lifecycle.

We contacted all identified interview participants and ultimately held 72 interviews with 74 interviewees and one informal conversation between October 2024 and April 2025 (Table 3). Informed consent was obtained from each interviewee.

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Table 3. Overview of interviews per case study

		Stakeholder group				
Case study	Country	Civil society	Academia & domain experts	Government	Industry	Total
Afforestation	Spain	2	4	0	2	8
Artificial soils	Spain	1	2	1	2	6
Microbiological CO_2 fixation	Germany	1	3	1	5	10
Biochar	Portugal	5	2	1	2	10
BECCS	Sweden	1	3	4	3	11
BECCS	UK	2	5	2	1	10
Enhanced weathering	Finland	1	2	2	4	9
Enhanced weathering	Spain	1	3	0	5	9
Total	-	15	24	10	24	73

Source: Own illustration

Relative to our list of identified interview participants, this is a response rate of 32%. Considering the study's purpose, we are confident that we reached data saturation after the 72 interviews and one informal conversation, as a data validation meeting showed that no new concepts or ideas were mentioned by the interview participants. At that point, we decided to discontinue recruiting additional interviewees for this study (Alam, 2020).

Our interviews were semi-structured, as these are particularly useful for the investigation of novel phenomena such as the social acceptability of CDR solutions (Adams, 2015). The interview guide covered topics such as general knowledge and interest in CDR solutions, perceptions of CDR solution implementation and future perspectives on the CDR solution (Annex 2). This flexible approach included probing questions and allowed interview participants to elaborate on the most salient aspects of their perceptions of a specific CDR solution (Saunders et al., 2009). Most interviews were conducted remotely using video meeting platforms such as Microsoft Teams and Zoom. Interviews were conducted in English, German, Portuguese, Spanish and Swedish. All 72 interviews were recorded and transcribed by the research team. Each interviewee was given the opportunity to read through and approve the transcript. The research team then translated the transcripts into English and anonymized the interviewees. The informal conversation was not recorded, but detailed notes were taken and analysed. A list of pseudonyms can be found in Annex 3 (Table 4).

7.2 The rapid literature review

For the literature review, we used a rapid-review-inspired approach. A rapid review can be defined as "a type of knowledge synthesis in which components of the systematic review process are simplified or omitted to produce information in a short period" (Tricco et al., 2015, p. 2).

The review was conducted from January to May 2025 in parallel with the interviews and interview analysis. The review aimed to validate the factors affecting acceptability which we identified in our interviews against those found in comparable studies, as well as explore additional such factors.

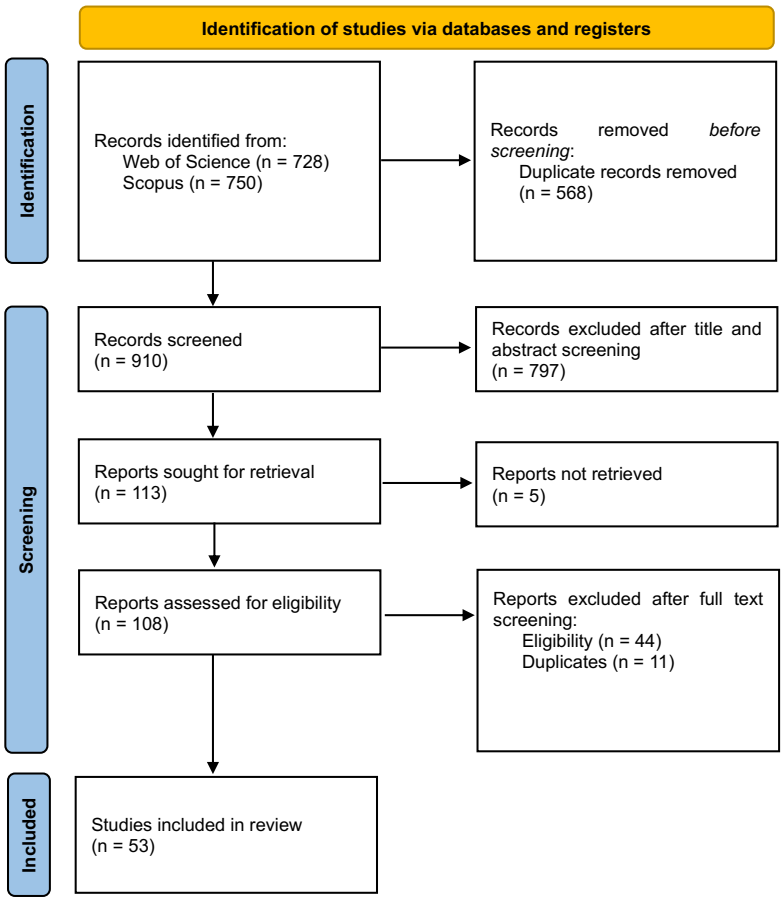
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To find relevant studies, we conducted the search in both the Scopus and the Web of Science databases with one search string per CDR. The search strings consisted of "accepta*" and different synonyms and spellings for the specific CDR (e.g. accepta* AND "enhanced weathering" OR "EW" OR "enhanced rock weathering" OR "ERW") to reduce evidence bias and enhance the internal validity of the rapid review (Frampton et al., 2022). The search strings can be found in Annex 4 (Table 5).

In total, 1478 articles were uploaded to Rayyan, a platform designed to facilitate efficient screening and collaboration in literature reviews. Articles were categorized by CDR solution. In a first step, 568 duplicates were removed. For each CDR solution, two reviewers individually screened articles for relevance at the title and abstract level. In order to be deemed relevant, an article needed to cover a CDR methodology as well as acceptability. After each screening level, a validation meeting was held by the reviewers to discuss consistency in the screening. In total, 108 articles were retained for full-text screening. Subsequently, one reviewer identified the final reading list through a quick screening of the geographical scope (Europe) and the journal quality (non-predatory only) to arrive at the final selection. In addition, 11 duplicates were removed when merging the lists of articles for each CDR solution. Ultimately, we retained 53 unique articles, organized according to the different case studies (Figure 2). For each case study, one reviewer screened all included articles to validate the factors affecting acceptability found in interviews and identify additional factors, adding these to the first round of interview statements (see below).

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Figure 2. PRISMA flow chart – rapid-review inspired literature review.



Source: Own illustration

7.3 Data analysis

We reviewed sentiments by type of stakeholder and by case study, and discussed with the research team overall impressions per case study. Across all case studies, we summarized similarities and topics where opinions diverged. The findings of this analysis are discussed in Section 8.1.

In parallel, interview transcripts were analysed using Braun and Clarke's (2006) six-phase method of thematic analysis: (1) data familiarization; (2) generating initial codes; (3) theme development; (4) theme review; (5) theme definition; and (6) final synthesis. This method is widely recognized for its rigour and flexibility in capturing patterns within qualitative data (Nowell et al., 2017).

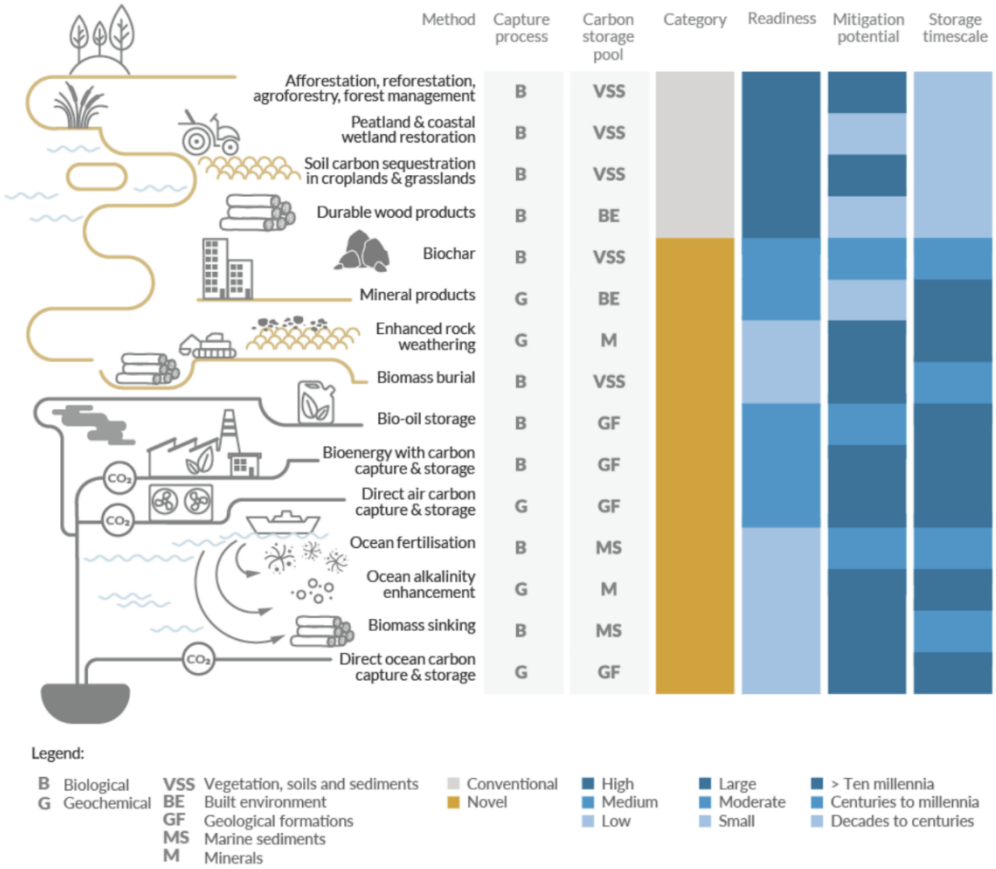
The interviews yielded nearly 2500 quotes. To distil this material into identifiable factors affecting acceptability, we applied a three-stage coding process. In the first step, quotes were broken down into single-sentence statements that captured distinct sentiments expressed by interviewees, for example: "A clear and stable political leadership guides the development of carbon markets", "(Unwanted) side effects on the environment are not well known" and "An MRV [monitoring, reporting and verification] process needs to be in place to make sure that carbon is captured and stored". This step enabled a systematic reduction of the qualitative data and facilitated comparison across case studies. In a second step, 58 additional statements identified in the rapid literature review

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were added to the statement pool. Examples include “Afforestation should contribute to structural strengthening of the landscape”, “People living close to a CCS facility are more positive than people living far away” and “Thinned forests are preferred over un-thinned forests, because they allow people to use them (for walking and biking)”. Finally, through three iterative rounds, four reviewers collaboratively allocated each statement to an emerging acceptability category, working inductively to cluster distinct sentiments into conceptually coherent themes. For practicality, each factor affecting acceptability was formulated as a short, descriptive label (e.g. carbon storage capacity, trust in actors, product, process, procedural justice).

In a next step, each statement was allocated to a PESTELE category and a location on the triangle of acceptability (Wüstenhagen et al., 2007), as explained in our conceptual framework in Section 6. In addition to generating structured thematic items and coding the data against the conceptual framework, we categorized each case study according to the State of Carbon Dioxide Removal’s categories of capture process, carbon storage pool, novelty of innovation, readiness, mitigation potential and storage timescale (Smith et al., 2024) (Figure 3). Classifying the case studies into these additional categories was useful for comparing the findings across specific technological characteristics/properties.

Figure 3. State of CDR’s categories of capture process, carbon storage pool, novelty of innovation, readiness, mitigation potential, and storage timescale.



Source: The State of CRD report (Smith et al., 2024)

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8 Results

Below, we first summarize the sentiments across the different cases in Section 8.1. Annex 5 (Table 6-13) contains a summary of the positive and negative impressions of each solution per case study, organized by type of actor in the quadruple helix model, with recommendations. Section 8.2 provides insight into the factors affecting acceptability resulting from the interview coding and rapid-review-inspired literature review.

8.1 Impressions of the interviewees

Across all case studies, interviewee perceptions reveal both optimism about the potential of CDR solutions and significant caution regarding their social, environmental and institutional implications. Overall, respondents perceived CDR as a necessary but insufficient component of climate mitigation – a complement to, rather than a substitute for, emissions reduction.

Natural or land-based solutions, such as afforestation, biochar, microbiological CO_2 fixation (MCO_2) and artificial soils, seemed to be viewed more favourably than highly engineered or industrial approaches like BECCS and EW. These nature-based solutions were associated with visible local co-benefits, such as ecosystem restoration, soil improvement and rural employment. However, even these "familiar" solutions were not free from controversy; interviewees warned that poorly designed afforestation projects could lead to land-use conflicts or biodiversity loss, and that claims about carbon sequestration permanence were often exaggerated. Respondents repeatedly called for integrating land-based CDR into broader territorial planning frameworks and for prioritizing ecological and social functions over carbon accounting alone.

In contrast, engineered or high-technology solutions such as BECCS and EW elicited mixed or sceptical reactions. While industry and some governmental actors highlighted their scalability and contribution to long-term climate targets, many experts and civil society representatives questioned their readiness, economic viability and potential unintended consequences. Concerns centred on technological uncertainty, high energy demand, reliance on untested infrastructures (e.g. pipelines, geological storage) and limited public understanding. Interviewees warned that framing these technologies as "silver bullets" risks eroding public trust if deployment outpaces evidence or regulation.

Justice considerations were prominent across both natural and engineered CDR types. Interviewees highlighted the importance of recognizing existing good practices, ensuring fair benefit distribution, and avoiding "sacrifice zones" where vulnerable communities bear disproportionate costs. Ethical concerns included intergenerational fairness, land access and the fear that CDR could perpetuate extractive models of development. Many respondents linked legitimacy to local empowerment, arguing that community-led or co-owned projects are more likely to achieve durable acceptance.

Institutional and policy factors also shaped perceptions strongly. Interviewees frequently pointed to fragmented or unclear governance as a barrier to both implementation and trust. Across the case studies, interviewees noted a lack of coordinated national and international frameworks for MRV and called for clear, science-based standards that could align emerging markets with environmental integrity. Several respondents

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emphasized that without stable policy signals and coherent regulation, investment and public confidence would remain limited.

Despite these concerns, the interviews revealed a shared sense of cautious optimism. Most interviewees agreed that CDR solutions hold meaningful potential, provided their deployment is transparent, just and embedded in participatory decision-making.

8.1.1 Afforestation

The afforestation case study in Spain centres on an initiative aimed at restoring degraded land through the planting of native tree species. The project integrates ecological recovery with social and economic objectives, including carbon credit generation, timber production and local job creation, particularly for vulnerable groups. We interviewed two industry actors (private-sector companies involved in re- and afforestation and carbon-related activities), four academic and domain experts (research institutes, universities and consultancies), and two civil society representatives (non-profits and NGOs engaged in environmental issues).

The academic and domain experts viewed afforestation as a context-dependent strategy with potential environmental and socio-economic co-benefits, particularly when linked to land restoration, erosion control and sustainable biomass production. However, they consistently stressed that afforestation should not be treated as a standalone climate solution. Instead, they argued it must be integrated into broader land-use planning and rural development frameworks. Key concerns included ideological polarization (e.g. debates over whether plantations "count" as forests), unrealistic assumptions about large-scale deployment (e.g. oversimplified global tree-planting targets that ignore local land-use priorities), and an overreliance on narrow climate metrics such as permanence and additionality. These metrics were seen as detached from real-world land dynamics, with permanence critiqued for assuming static carbon storage in inherently dynamic ecosystems, and additionality for excluding beneficial practices simply because they would have happened anyway. Several experts emphasized that afforestation efforts driven solely by carbon markets or external climate agendas risk overlooking local realities, land tenure complexities and long-term sustainability. A recurring theme was that ecosystem services that improve people's livelihoods should be the primary drivers, with carbon removal viewed as a co-benefit rather than the sole objective.

The interviewed industry actors emphasized afforestation's potential to deliver environmental, social and economic co-benefits when well-implemented. Both saw particular value in using afforestation to restore degraded or fire-affected land, generate local employment and strengthen rural economies through indirect spending in the area. However, they also stressed that such projects face important structural challenges, including long timeframes for ecological and financial returns (e.g. decades to reach mature forest conditions), lack of compensation for ecosystem services beyond timber (e.g. biodiversity enhancement or carbon sequestration), and complex administrative procedures that can delay or discourage implementation. Public sector involvement was viewed as critical for reducing bureaucratic barriers and improving the economic viability of projects. Both actors noted the importance of proactive communication for local acceptability, particularly in relation to public perceptions shaped by past experiences with controversial species like pine or eucalyptus.

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Civil society perspectives underscored the importance of grounding afforestation in ecological restoration rather than carbon offsetting alone. While both organizations saw potential value in afforestation when aligned with biodiversity and community goals, they raised concerns about poorly targeted interventions, such as planting in areas with ongoing natural regeneration or using non-native species for rapid carbon uptake. One interviewee critiqued Spain's voluntary carbon market for allowing compensation without prior emissions reduction, viewing this as a loophole that risks legitimizing continued pollution. Across both interviews, there was a call for stronger oversight, participatory planning and long-term accountability.

No government representatives participated in this case study (response rate: 0%), limiting insight into public sector perspectives on afforestation policy and implementation in Spain.

8.1.2 Artificial soils

The artificial soils case study in Spain focuses on a company that develops engineered soils using natural and industrially derived materials. While its key focus lies in pollution remediation, it is paying increasing attention to the carbon removal potential of artificial soils. We interviewed two industry actors (private-sector artificial soil producers), two academic and domain experts (universities), one civil society representative (environmental NGO) and one government representative (national ministry).

The interviewed academic and domain experts generally viewed artificial soils as a promising CDR method with multiple environmental and societal applications in land restoration and green infrastructure contexts. Both emphasized the potential to repurpose mineral, organic and construction residues for CO_2 removal, while emphasizing that artificial soils are not a standalone climate solution and should be evaluated within a broader land-use and material governance context. Key concerns included regulatory blind spots (e.g. insufficient quality control for materials used in soil formulations), limited funding for long-term trials and the risk of overlooking contamination risks when using industrial waste streams. While both experts pointed to growing public interest and strong educational potential, they underlined that scientific oversight and robust governance are essential for ensuring environmental integrity and social benefit in deployment.

The interviewed industry actors highlighted the multifunctionality of artificial soils, particularly their ability to valorize waste, restore degraded land and contribute to carbon sequestration. While carbon removal was not initially a central goal of artificial soils, it is now seen as a valuable co-benefit, especially with emerging market opportunities. Both actors noted major barriers to wider uptake, including limited public awareness, lack of national policy support and the absence of certification frameworks for soil-based CDR. They also pointed to a broader disconnect between EU-level soil ambitions and the relatively low political prioritization of soil in Spain. Carbon market integration was seen as promising, but contingent on clearer regulation and verifiable methodologies.

The civil society actor, with long-standing experience in environmental advocacy and land restoration, expressed cautious interest in artificial soils, viewing them primarily as a tool for circular waste management and the rehabilitation of degraded areas. While acknowledging their utility in specific contexts such as post-industrial or mining

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landscapes, they questioned the method's relevance for meaningful carbon removal at scale. Concerns centred on the risk of overpromising climate benefits, especially if used by high-emitting industries to justify continued emissions. They emphasized the importance of prioritizing systemic emissions reductions over compensatory strategies and cautioned against framing emerging CDR methods as scalable climate solutions in the absence of robust evidence.

The interviewed government actor, working in public environmental administration, viewed artificial soils as a potentially useful tool for land restoration and circular resource use, particularly in regions facing erosion and soil degradation. While noting that they had limited direct experience with the method, they emphasized its relevance within broader strategies to preserve or regenerate soils, especially in drier regions of the country. They highlighted that the effectiveness of artificial soils depends on site-specific conditions, including climate and topography, the presence of protective vegetation to prevent erosion, and adequate long-term monitoring and maintenance. They expressed general support for the innovation but stressed that artificial soils should complement, not replace, efforts to conserve existing ecosystems and reduce emissions at the source.

8.1.3 Microbiological CO_2 fixation (MCO_2)

Microbiological CO_2 fixation (MCO_2) refers to processes where microorganisms use CO_2 and convert it into biomass or bio-products. In the case study, this is framed as a microbial conversion of CO_2 into biomass or bio-products, often linked to applications where the carbon benefit is discussed alongside other functions (e.g., soil-related co-benefits). For MCO_2, we interviewed five industry actors (two focal company representatives and three representatives from companies that participate in the MCO_2 lifecycle), two academic and one non-academic expert (two universities and one not-for-profit research institute), one governmental agency representative, and one civil society organization that was part of piloting the solution.

The focal company is headquartered in Germany. All industry actors had their business involved in the development and deployment of the solution. Overall, they had a hopeful attitude to MCO_2, however, they raised three significant concerns. One concern was about the legal framework that excludes MCO_2 from participating in the market. The second concern was about the market power inhibited by a limited number of multinational companies, making it difficult for smaller companies to gain market shares. And thirdly, that the main purpose of MCO_2 was framed to improve soil characteristics and quality, rather than to capture and store carbon. Hence, both the academic experts and the non-academic experts left a rather sceptical impression that was grounded in the limited scientific evidence to support the CDR solution. They pointed out the importance to develop robust scientific evidence for the effectiveness of MCO_2, including soil improvement and carbon capture and storage potential.

The representative from the governmental agency was not aware that MCO_2 was being developed in the area and was doubtful whether the city could play a driving role in promoting it, given that climate mitigation and adaptation are not anchored in legal structures.

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Finally, the civil society representative reported that the CDR solution potentially creates a wide range of positive impacts (environmental and social). The carbon capture and storage potential, however, played a secondary role.

8.1.4 Biochar

The biochar case study in Portugal focuses on a company producing biochar for carbon removal and land restoration, using forestry and agricultural biomass as a key feedstock. We interviewed two industry actors (a biochar company and a forestry sector organization), two academic and domain experts (a university and an industry consortium), one government representative (a national authority) and six civil society organizations (NGOs, non-profits and activist groups).

The academic and domain experts regarded biochar as a promising and already deployable CDR option, particularly when embedded in broader PyCCS (pyrogenic carbon capture and storage) systems. They emphasized its capacity to deliver both climate and non-climate benefits, such as improving urban tree survival, stabilizing manure in livestock systems or replacing fossil-based materials in construction and industry. Rather than viewing biochar as a silver bullet, both experts framed it as a modular tool whose effectiveness depends on context-specific applications and integration with other practices. Key enabling factors included robust certification schemes, consistent regulatory frameworks and early public sector support. Both stressed that biochar's greatest contribution in the near term may lie in helping to scale CDR infrastructure and build public and investor confidence, buying time for more complex solutions to mature.

Industry actors viewed biochar as a pragmatic and scalable carbon removal option with strong market potential due to its applicability in multiple sectors, from soil enhancement to industrial materials like concrete and steel. They emphasized that its value lies not only in carbon storage but also in co-benefits such as improved soil resilience, waste valorization and fossil carbon substitution. A key concern was the risk of market distortion from low-quality producers, highlighting the need for certification and third-party verification to protect environmental integrity and ensure fair competition. Both pointed to the importance of supportive policy frameworks, including targeted incentives and clear regulatory definitions, to facilitate industrial deployment. They also noted that limited public and institutional understanding remain a barrier to adoption, calling for better communication and cross-sector engagement to build trust and legitimacy.

Civil society perspectives on biochar were diverse but generally open to its potential when embedded in clear environmental and social safeguards. Most interviewees emphasized the importance of local-scale applications that support sustainable land management, cautioning against industrial upscaling or export-driven models that disconnect biochar production from its territorial context. Several highlighted concerns about unknowns in long-term impacts, the need for site-specific studies, and potential trade-offs if biomass use is not carefully regulated. The importance of public awareness, transparency and environmental education emerged as recurring themes, with calls for broader consultation and clearer communication on how biochar is produced, applied and monitored. There was a shared view that its legitimacy depends on scientific oversight, equitable benefit-sharing and alignment with broader climate and land-use goals.

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Due to low response rates, only one government representative was interviewed. They viewed biochar as a promising way to valorize unused biomass in Portugal but emphasized the need for strong, science-based regulation. Concerns included contamination risks, possible negative effects on already acidic soils and uncertainty about whether biochar production results in net carbon savings, since it requires energy, which may or may not come from clean sources. They warned against treating biochar as a standalone climate fix and stressed the importance of pilot projects that consider the full value chain, including economic and land-use impacts. They noted that widespread adoption will depend on clear standards, scientific validation, public education and alignment with well-regulated carbon markets.

8.1.5 BECCS

In our case study, BECCS is defined as bioenergy production combined with carbon capture and storage to generate negative emissions, and it is discussed as an engineered pathway that depends on sustainable biomass sourcing and reliable storage governance. For the focal company headquartered in Sweden, we interviewed three industry actors (an energy company involved in BECCS, an industry association and an energy-sector organization), two academic and domain experts (universities), five government representatives (municipal, national and sectoral authorities) and one civil society organization (an environmental NGO).

The industry actors were positive about BECCS and saw opportunities in implementing it as an add-on to existing facilities to achieve permanent negative emissions needed to meet climate goals. All industry actors underlined that BECCS should be a complementary measure and not replace emissions reductions, and recognized uncertainties related to the regulatory framework and financing.

The experts were sceptical about the possibility of scaling up BECCS within the timeframe that would be needed due to high costs, lack of a market and uncertain climate policy. They emphasized the risks of placing too much faith in BECCS as an extraordinary climate measure that will solve the climate crisis.

Among the governmental actors, sentiments ranged from cautiously positive to optimistic. BECCS was generally seen as a necessary complementary measure to reach climate goals because of its potential to achieve negative emissions, but not as a replacement for emissions reductions. Scaling opportunities were seen to depend on the development of clear regulatory frameworks, long-term climate policies, financing mechanisms, solutions for transport and storage of CO_2, and supply of sustainable biomass.

The civil society organization representative expressed a cautiously critical sentiment towards the implementation of BECCS. While the BECCS implementation was seen as preferable to other local industrial expansions, it was perceived to come with high costs and significant risks and impacts to living environments, cultural heritage and the broader environment. Additional concerns were raised about potential leakage from geological storage.

For the focal company located in the UK, we interviewed one industry actor (an energy company involved in BECCS), four academic experts and one domain expert (universities

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and a public research institute), two government representatives (an informal conversation with a national authority and a local council) and two civil society organizations (a policy-oriented NGO and environmental NGO).

The industry actor spoke positively about BECCS. Developing BECCS in existing industry infrastructures was seen as a mechanism to mitigate generational emigration, but frustration emerged from the perceived lack of interest in this CDR solution by the public.

The expert sentiments ranged from pragmatism to scepticism. While some experts highlighted the lack of alternatives to reach national net-zero targets, other experts doubted the validity of scientific evidence based on the mathematical calculations of actual capture rates. A main concern revolved around the environmental impacts of producing/using biomass in volumes needed for reaching national targets and social impacts for local communities.

The two government representatives did not take a clear position either for or against BECCS, instead expressing a conditional/undecided view. Notably, one representative opposed scaling BECCS if it required a CO_2 pipeline, expressing concerns over the depth at which the pipeline would be constructed as well as possible pipe ruptures.

Finally, the two civil society organizations were unsupportive of BECCS. They criticized the current understanding of accounting for carbon neutrality as well as the discrepancy between theoretical renewability and actual practice. One respondent noted that trees are not automatically renewable and that their use for BECCS might not fit the purpose. The other respondent noted that burning wood is not carbon neutral but is accounted as such.

8.1.6 Enhanced weathering

Enhanced weathering (EW) accelerates a natural geochemical process by applying crushed silicate rocks (or similar materials) so they react and take up CO_2. In our case, it is defined as the application of crushed silicate rocks to accelerate mineral weathering and absorb CO_2, often highlighting the role of material sourcing (e.g. quarrying/mining by-products), monitoring/verification challenges and local environmental considerations. For the first focal company, located in Finland, we interviewed four industry actors (companies involved in mining and/or EW), two academic and domain experts (a university and a research organization), two government representatives (a national ministry and a municipal authority) and one civil society organization (an environmental NGO).

Among industry actors, familiarity with the solution was high and sentiments ranged from very sceptical to highly supportive. For the Finnish case, scepticism focused on uncertain climate benefits, risks of perceived greenwashing, slow mitigation potential, toxic mining waste, a weak business case and rushed piloting, though the pilot itself was seen as low-impact and largely unnoticed. In contrast, support highlighted existing infrastructure, which enables EW without added costs or environmental burdens. Perspectives on EW in general from actors outside the focal company were characterized by strong trust in the solution and its scalability, while noting political focus on “shiny” interventions over farming solutions, greater willingness outside Europe to use EW for soil improvement, and MRV and CDR uncertainties even as they saw potential in corporate offsetting.

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Experts were cautiously positive towards EW and saw opportunities in using waste rock for carbon capture, but stressed that it is a context-specific solution. Concerns included unresolved issues such as restoration, long-term land and water impacts, MRV and limited scientific evidence.

The government representatives and the civil society organization were generally not familiar with EW and did not know that a pilot was planned for a mining area in the region. While they expressed interest in EW if it could bring climate and local benefits, the actors had questions around its scalability, cost, energy demand, site selection, local impacts and monitoring.

For the focal company located in Spain, we interviewed five industry actors (auditing firms, industry organizations and EW distributors), three academic and domain experts (universities and a research institute), and one civil society organization (a natural heritage NGO).

The academic and domain experts shared deep technical expertise and generally regarded EW as a promising CDR solution, particularly when implemented as a soil amendment with co-benefits for agriculture and land restoration. Several emphasized its scalability and potential to integrate into existing supply chains and farming practices, especially in regions with degraded soils. However, all highlighted significant challenges related to MRV, long-term carbon accounting and site-specific uncertainties such as trace metal accumulation or soil-climate interactions. There was broad agreement that the current carbon market framework is ill-suited for EW, and that future uptake may depend more on public subsidies, regulatory support or integration into agricultural policy.

The interviewed industry actors had varying levels of prior engagement with EW and expressed mixed views on its potential. While some saw promise in the approach, especially when connected to agricultural applications or broader sustainability strategies, others questioned its viability due to high material requirements, unclear carbon removal efficiency or perceived lack of market readiness. Regulatory clarity, MRV standards and economic feasibility were seen as key conditions for broader adoption. Public and industry awareness was generally considered low, with some concern that the solution might be misunderstood or underused if these enabling factors are not addressed.

Only one civil society actor was interviewed for this case due to a low response rate among this group. The interviewee expressed initial interest in EW as a potentially beneficial strategy but emphasized the need for thorough environmental assessments, particularly concerning extraction impacts and land application. Concerns were raised about social acceptability, especially in areas with past negative experiences related to industrial projects. Transparency, local engagement and clearly demonstrated ecological benefits were seen as essential for any future implementation.

No government representatives participated in this case study, limiting insight into public sector perspectives on EW policy and implementation in Spain.

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8.2 Factors affecting acceptability

This section displays the results from the study, with statements organized by community, market and socio-political acceptability, as well as into political, economic, social, technological, environmental, legal and ethical categories. Annex 6 (Table 14-15) contains detailed results (factors affecting acceptability and statements; and levels of acceptability, factors affecting acceptability and PESTELE category). Across the case studies, several acceptability dynamics recur regardless of technology; stakeholders repeatedly evaluate CDR options through questions of who benefits, who bears risks and costs and who has decision-making power, alongside the credibility of governance, monitoring and long-term responsibility. At the same time, the content of concerns differs in ways that reflect each technology's deployment characteristics. For BECCS, perceptions often hinge on system-scale infrastructure and permanence questions (e.g. capture performance, transport and storage arrangements, and the distribution of risks linked to CO_2 networks), as well as broader debates about biomass sourcing and competing land uses. For EW, acceptability is more tightly linked to the upstream and local ecological implications of material supply and application (e.g. mining/quarrying, dust and runoff, and uncertainty about site-specific impacts and monitoring). For MCO_2, discussions tend to foreground how "naturalness", co-benefits and perceived controllability shape support, while also raising questions about scalability, verification and governance of deployment contexts. Overall, these cases suggest that stakeholders' perceptions are shaped less by the label of a technology alone than by where and how it would be implemented, the visibility and reversibility of impacts, and whether the institutional arrangements for oversight and accountability are seen as trustworthy.

8.2.1 Acceptability at the community level

For acceptability at the community level, ethical factors and localized impacts following the implementation of the CDR solution were the most frequently mentioned considerations. Ethical factors relate to distributive justice, intergenerational justice, and mitigation deterrence and additionality. For distributive justice, statements include:

- "CDR efforts should ensure fair distribution of burdens and benefits by preventing unequal advantages or disadvantages caused by market rules, standards, or regulations" (I15, I18, I19, I23, I34, I49, I50, I51, I52, I55, I65);
- "Recognition and fair compensation should be given to existing good practices and contributions, especially from local and vulnerable communities involved in or affected by CDR" (I3, I8, I7, I27, I61); and
- "CDR development should avoid creating or perpetuating environmental sacrifice zones, exploitative supply chains, or neo-colonial dynamics that marginalize vulnerable populations" (I50, I52, I53).

Intergenerational justice statements include:

- "A holistic approach to CDR is needed, considering social and environmental impacts while striving to maximize benefits equitably across current and future generations" (I39, 40, 47); and
- "Monitoring and maintaining carbon storage integrity is a long-term responsibility that could extend to future generations" (I47, I55).

Across interviews, community acceptability emerged as the most context-dependent and relational dimension of CDR acceptability. Interviewees emphasized that community

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responses were less about abstract attitudes towards the solution and more about how CDR solutions interacted with local environments, economies and cultural practices.

Localized impacts and physical proximity concern environmental risks and societal impacts (physical proximity to the CDR solution's implementation; resource intensity, impact on the local environment; visual impact, health impacts) as well as economic impacts (local job creation and local economic growth). Environmental and societal impact statements include:

- "CDR approaches should be planned and managed to prevent pollution, contamination and harm to human health and ecosystems, considering local environmental and site-specific factors" (I9, I12, I29, I30, I33, I56, I60, I63, I65, I68, I69, I71, I73);
- "Concerns about environmental risks, including impacts on wildlife and ecosystems, contribute to scepticism and opposition toward CDR technologies" (I17, I22, I24, I58, I62);
- "CDR technologies could enhance food security by improving degraded soils and increasing arable land availability" (I26, I66, I67); and
- "Allocating land or space for new purposes can displace existing uses, leading to conflicts with agriculture, cultural activities or other established sectors" (I1, I6, I7, I9).

Societal and economic impact statements include:

- "CDR can create direct economic value by generating new income streams from land use and natural resources" (I1, I6, I8, I27, I65);
- "CDR can generate positive economic effects at the local community level through job creation and enhanced economic activity" (I59, I61, I62, I64); and
- "Employment in CDR sectors could involve health and safety considerations for workers involved in production and application processes" (I20, I43, I57, I64).

Particular statements for visual impacts include:

- "Activities that visibly alter landscapes can strongly influence how local communities perceive and accept them, especially when familiar views are changed" (I1, I7, I12, I66);
- "People tend to pay more attention to impacts they can see, while invisible or hidden processes often go unnoticed or unconsidered" (I46, I49, I51, I54); and
- "Industrial facilities often appear visually similar to existing structures, which could affect public perception" (I46).

Interviewees also highlighted that physical proximity alone does not determine acceptability. Instead, what matters is whether local communities perceive control, transparency and fair benefit distribution. Projects that are co-designed with local actors or provide visible public goods, such as ecosystem restoration, recreational spaces or rural employment, tend to foster a stronger sense of ownership and legitimacy. Conversely, projects that are imposed top-down or associated with external profit motives are likely to face opposition, even when local environmental risks are minimal.

Procedural justice is an important political factor that can increase acceptability at the community level. More specifically, statements include:

- "Successful CDR solutions require early, continuous and inclusive engagement of all relevant stakeholders to build trust and facilitate acceptability" (I2, I3, I4, I6, I7, I8, I10, I19, I26, I31, I33, I40, I65, I67, I69);

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- "Empowering local and marginalized communities through inclusive decision-making and control over natural resources is critical to avoid reinforcing existing social inequities" (I50, I51, I54, I55, I63); and
- "Local NGOs provide valuable expertise but are often excluded or have limited participation in environmental decision-making processes" (I42).

The data show that procedural justice is closely tied to perceptions of agency. Community actors tend to support CDR solutions when they are engaged from the early design phase, have channels to influence monitoring and benefit-sharing, and see their knowledge recognized as legitimate. Transparency in communication and accountability of implementing actors were repeatedly identified as prerequisites for trust-building.

Trust in actors, products and processes is connected to:

- "Trust in CDR technologies is influenced by the perceived integrity and transparency of the institutions and actors involved" (I2, I9, I47, I62, I64);
- "Transparent, honest disclosure and unbiased communication about projects and their monitoring are essential to building trust in markets and society" (I1, I2, I32, I34); and
- "Misrepresentation or exaggeration of benefits by policymakers could hinder credibility and public trust" (I53).

Community trust is therefore not automatically extended to a specific CDR solution but earned through demonstrated fairness and the reliability of the institutions managing it. This aligns with broader findings from the environmental justice literature (Scott-Buechler et al., 2024), where procedural transparency and consistent communication are stronger predictors of acceptability than technical performance or economic compensation alone.

Interviewees also acknowledged socio-cultural backgrounds as pertinent to community acceptability, with statements including:

- "Cultural norms, traditions and entrenched beliefs contribute to reluctance in adopting CDR technologies" (I4, I6, I7, I10, I28);
- "Acceptability of innovative solutions depends on local culture, traditions and how communities relate to their environment and resources" (I8, I9, I26, I68, I69);
- "The connection between communities and technologies is shaped by local historical and cultural contexts" (I15, I19); and
- "While younger generations tend to be more open to adopting new CDR technologies, debates around CDR can become highly emotional, sometimes challenging purely rational decision-making" (I21, I55).

For afforestation, one statement from the literature alluded to increased acceptability if a forest had recreational value.

These insights underscore that CDR solutions are interpreted through existing cultural and territorial narratives, such as stewardship, rural identity or environmental justice. Solutions perceived as "natural" or restorative (e.g. afforestation, biochar) generally encountered greater initial openness than highly industrial or infrastructural ones (e.g. BECCS, EW), which were often associated with external control and risk.

To a lesser extent, technological maturity and complexity, in particular concerning environmental safety and the fact that several technologies cannot be reversed,

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influence acceptability at the community level. Examples of technologies that are hard to reverse include the spreading of biochar and EW to land, and large-scale land-use conversions for biomass for BECCS.

Referring back to the literature, we note that community acceptability is dynamic and evolves over time. While we did not incorporate a single-sentence statement that referred to this temporal aspect, we found initial scepticism in communities related to certain projects (I7, I28, I31, I69). These sentiments may shift towards trust through transparent engagement with communities and visible local benefits (I61, I64), while even initially supported projects can lose legitimacy if expectations are unmet (I53). Sustained dialogue, adaptive governance and participatory monitoring are therefore essential to maintain long-term community consent and acceptability.

8.2.2 Acceptability at the market level

For market acceptability, we found four interlinked conditions for CDR solutions to obtain social acceptability: (1) economic viability supported by stable policy incentives; (2) credible and transparent MRV and certification systems; (3) technological maturity and demonstrated performance; and (4) market demand.

Economic factors concern economic viability, cost-effectiveness, business models, supply chains and certification mechanisms that shape the credibility and competitiveness of CDR solutions. Financial incentives and transparent carbon accounting frameworks are essential, as indicated by statements such as:

- “Financial incentives, including taxation, subsidies and carbon markets, play a crucial role in motivating individuals, companies and industries to adopt and invest in CDR technologies” (I1, I2, I3, I4, I6, I7, I10, I14, I26, I28, I30, I31, I32, I33, I46, I49, I58, I62, I64, I68, I71, I73);
- “High investment costs per project site present a significant financial challenge for CDR project deployment” (I35, I37, I39, I40, I42, I51);
- “Financing structures, capital investments and operational expenses critically affect the affordability and scalability of CDR projects” (I65, I67); and
- “Investor confidence is weakened by uncertainty around financial returns, performance outcomes and timelines” (I51, I55).

These findings illustrate that market acceptability is deeply influenced by perceptions of economic predictability and institutional reliability. Interviewees, particularly from industry, viewed the nascent CDR market as fragile and uncertain, dependent on coherent long-term policy design and trustworthy certification systems.

Interviewees also stressed that market confidence hinges on verifiability. MRV, even for technically sound projects, risks being dismissed as speculative. Across the case studies, interviewees called for harmonized EU-level or international standards to reduce transaction costs and ensure comparability between different removal pathways. Statements include:

- “Certification systems must balance capturing the full climate benefits of CDR projects, including principles like co-claiming, to ensure fair valuation and facilitate carbon credit trading, which currently requires simplification and standardization to reduce labour intensity” (I1, I41, I56, I61, I65, I73);

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- "Implementation of safeguards and certification frameworks is essential to ensure CDR sustainability and prevent unintended environmental or social harms" (I5, I29, I33, I34); and
- "Divergent regulations, fragmented market systems and inconsistent rules across regions create significant uncertainty and complexity for coordination and implementation across borders" (I1, I2, I32).

Interviewees further linked market confidence to innovation capacity and technological readiness. Relevant statements include:

- "The complexity and operational status of CDR technologies influence the ease and speed of implementation and monitoring" (I42, I46, I56, I57, I58, I59, I61, I62, I64);
- "CDR innovation involves complex and interdependent processes across disciplines, scales and learning curves, where scaling up can introduce new technical, logistical and systemic challenges" (I3, I26, I31, I65); and
- "Uncertainty around scaling opportunities can hinder the adoption and impact of new solutions" (I59, I60, I62, I64).

This reflects a widely shared understanding that technological maturity directly underpins market trust. Early-stage solutions like EW or MCO_2 were often perceived as scientifically promising but commercially premature, whereas more established methods like biochar or afforestation were seen as closer to market readiness.

Finally, some interviewees emphasized the role of demand-side factors in market acceptability, noting that buyer trust and communication matter as much as supply-side readiness. Statements include:

- "Market development relies on the presence and growth of demand-creating frameworks that support the adoption of new solutions" (I2, I7, I8, I28, I29, I67); and
- "Consumer and market demand play a critical role in driving the adoption of new technologies" (I18).

8.2.3 Acceptability at the socio-political level

Our data suggest that the socio-political acceptability of CDR solutions is driven by five interrelated conditions: (1) transparent, stable and long-term policy frameworks; (2) institutional accountability and cross-sector coordination; (3) scientifically grounded and openly communicated decision-making; (4) integration of distributive and procedural justice principles; and (5) responsible narrative framing that positions CDR solutions as a complement to, not a replacement for, emissions reductions.

Across the CDR solutions, socio-political acceptability was found to depend strongly on the coherence and transparency of national and regional governance frameworks. Interviewees repeatedly stressed that unclear responsibilities between ministries or levels of government undermine both investor confidence and public trust. Actor commitment and long-term policy consistency are regarded as essential to avoid stop-start cycles that have previously plagued renewable energy deployment. Another recurring theme was the perceived credibility of political institutions and their ability to ensure transparency and fairness. Relevant single-sentence statements include:

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- "Strong and consistent political leadership at all levels is essential to drive the development and implementation of carbon removal policies" (I16, I17, I18, I19, I22, I46, I47);
- "Political and ideological forces significantly shape which carbon removal technologies receive attention and funding" (I1, I8, I29, I65, I71); and
- "Stable, predictable and adaptive regulatory frameworks are crucial to reduce investment risks, provide long-term policy certainty and allow flexibility to respond to technological and environmental changes" (I6, I26, I68).

Some interviewees also pointed to the importance of cooperation and collaboration. Statements include:

- "Tackling global challenges requires sustained international political commitment and coordinated agreements to align efforts among nations" (I6, I30, I34, I71);
- "Greater collaboration and coordination among all relevant stakeholders is essential for effective progress" (I17, I18, I51); and
- "Coordinated collaboration between multiple levels, from local communities to international actors, is necessary to align interests and effectively scale CDR initiatives" (I2, I3, I34).

These findings highlight that socio-political acceptability operates across scales; national credibility is influenced by transnational norms and perceived fairness in global climate governance. Interviewees viewed multilevel coordination between the EU, national governments and local authorities as a precondition for coherent and legitimate CDR governance.

Interviewees across the quadruple helix emphasized that the social legitimacy of CDR policy is contingent upon political accountability. Government actors were expected not only to set clear targets but also to demonstrate fairness in how the burdens and benefits of CDR are distributed across sectors and regions. Civil society respondents particularly underscored that political endorsement alone is insufficient without inclusive governance processes. Actors expressed that CDR markets must align with societal values, particularly fairness, sustainability and co-benefits for local economies. Social legitimacy, built through transparent communication about how removals are achieved and monitored, was deemed necessary to attract investors and consumers. Such ethical and political dimensions are captured by statements including:

- "Industry players, including petrochemical and mining sectors, bring essential resources and expertise, but their involvement requires transparent legitimization through non-private and associative actors" (I21, I38, I39, I46, I47, I51, I54, I58, I59, I62);
- "Relying on carbon removal can create incentives to delay or avoid necessary long-term emissions reductions" (I16, I18, I19, I21, I23, I51, I54); and
- "Long-term carbon storage must ensure high permanence and durability to effectively contribute to climate goals" (I39, I40, I41, I44).

Several statements refer to the role of scientific evidence and communication in shaping socio-political legitimacy. These include:

- "The safety and stability of carbon storage, including risks of leakage or reversal, require ongoing scientific assessment and management" (I1, I2, I6, I8, I9, I25, I28, I30, I32, I38, I40, I42, I43, I46, I65, I73);

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- "Scientific consensus is often lacking on key aspects of CDR technologies, highlighting the need for ongoing research to assess both benefits and potential negative side effects" (I15, I17, I18, I19, I21, I23); and
- "Independent and scientific research reduces the perceived risks related to the technology" (I24, I51, I55).

This indicates that the perceived alignment between science and policy is central to socio-political acceptability. Policymakers who acknowledge uncertainty and remain open to adaptive regulation were viewed as more trustworthy than those presenting overly deterministic claims about technological readiness. Interviewees also highlighted the need for institutional learning and cross-sector collaboration. Statements include:

- "Effective CDR deployment requires coherent and aligned policies across different governance levels and jurisdictions" (I1, I5, I7, I8, I12, I14); and
- "The broader political environment, including governance structures and centralization of decision-making, significantly influences CDR policy outcomes" (I1, I2, I7, I68).

Interviewees frequently linked socio-political acceptability to distributive justice, given the following relevant statement:

- "The distribution of costs and responsibilities for financing carbon storage and removal remains unclear, creating uncertainty for widespread implementation" (I35, I36, I37, I39, I40, I41, I43, I44, I45, I46, I47, I48, I49, I51, I54, I55).

Policies that are perceived as reinforcing inequities, such as privileging industrial actors over local communities, risk eroding not only community acceptability but also broader socio-political support.

Finally, ethical and narrative framing also shape socio-political legitimacy. Statements include:

- "Overemphasizing carbon removal risks enabling continued pollution by shifting responsibility away from direct emissions cuts" (I2, I35, I37, I39, I40, I41, I43, I44, I45, I47, I62);
- "New interventions may displace or reduce the effectiveness of existing mitigation options that offer equal or greater climate benefits" (I3, I5, I11, I13, I27, I32, I71);
- "There is a suspicion that certain CDR methods may enable polluting entities to avoid reducing their own emissions, undermining genuine climate action" (I2, I5, I13, I14, I71);
- "Climate discourse should focus on emissions avoidance and prevention rather than overreliance on carbon removal as a solution" (I17, I19); and
- "Carbon storage or removal does not eliminate emissions immediately but may temporarily mask ongoing environmental impacts" (I49, I53).

These concerns echo the wider academic debate around mitigation deterrence and moral hazard. Socio-political acceptability is thus tied not only to institutional trust but also to the broader story policymakers tell about CDR, whether it serves the common good or merely prolongs the carbon economy.

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9. Discussion

This study set out to understand how the social acceptability of CDR solutions is shaped in different contexts and actor groups. Examining diverse settings also enables us to test the widely shared hypothesis that CDR acceptability is contingent on "when, where, at what scale, and how it might be implemented" (Gough & Mander, 2019, p. 120), and to identify which factors are broadly generalizable versus deeply contextual. The findings confirm this proposition: while some determinants, such as transparency, procedural justice and long-term accountability, appear universal, others depend strongly on territorial, institutional and socio-cultural specificities. The analysis demonstrates that acceptability is not a fixed or measurable attitude, but rather a process of negotiation, reflecting local experiences, power relations and governance arrangements.

Gaede and Rowlands' (2018) bibliometric review shows that most social acceptability research focuses on renewable energy and relies on attitudinal surveys rather than process-oriented inquiry. Our findings directly address this gap. Across six CDR solutions, interviewees emphasized acceptability as relational and contingent, constructed through interactions between actors, institutions and territorial settings. By using the PESTELE framework, the study moves from cataloguing factors to tracing how political, economic, social, technological, environmental, legal and ethical dimensions intertwine to shape legitimacy. This supports Gaede and Rowlands' (2018) call for more integrated and theory-driven approaches, while also extending it by embedding acceptability within justice and governance structures rather than individual preference formation. Our study confirms that interviewees foregrounded acceptability as a negotiated, relational process rather than a static attitude (Gaede & Rowlands, 2018) and reinforces the idea, developed in Wüstenhagen and colleagues (2007) and revisited by Batel (2020), that acceptability is dynamic and processual, not a fixed attitude. Interviewees did not describe their views in terms of stable "support" or "opposition", but in terms of conditions under which CDR might become acceptable. This aligns with process-based conceptualizations of social acceptability as an ongoing negotiation, rather than a one-off decision outcome.

This study's results highlight the multi-scalar nature of social acceptability. Community-level perceptions around trust, fairness and inclusion were found to be inseparable from meso-level institutional coordination and macro-level governance legitimacy. The data confirm that conflicts over CDR are seldom about technical feasibility alone but reflect broader tensions over control, accountability and distribution of benefits and risks.

Indeed, local opposition can scale up into national resistance when procedural injustices or governance ambiguities remain unresolved (Haikola et al., 2019, 2024). Municipal veto powers, fragmented responsibilities and opaque planning processes were shown to transform site-specific disputes into system-level political controversies. We observe similar patterns across the CDR cases, especially for BECCS and EW, where unclear institutional roles, top-down framings and contested narratives (e.g. utilizing biomass and mining waste) amplified scepticism beyond host communities. Interviewees consistently linked acceptability to governance clarity, transparent MRV systems and tangible local co-benefits, echoing the same mechanisms that have been identified as decisive for renewable energy expansion in Sweden (Haikola et al., 2019, 2024). These parallels suggest that procedural justice and institutional coordination are not technology-specific

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frictions but structural prerequisites for scaling any climate mitigation innovation in decentralized political contexts. Like Swedish wind research, we also found that grievances at the local level (visual/noise, land-use trade-offs) escalate when meso-level governance is ambiguous.

These findings resonate strongly with the energy justice literature (Heffron & McCauley, 2018; Jenkins et al., 2016, 2017). Interviewees frequently linked acceptability to distributive and procedural justice, as well as to recognition of existing good practices. This aligns with the "energy justice triad" (distribution, recognition, procedure), suggesting that trust is contingent not only on equitable outcomes but also on recognition of local knowledge, participation in decision-making and accountability for long-term responsibilities. Our results converge strongly; interviewees emphasized liability clarity, long-term MRV and enforceable duties across the CDR chain (from feedstocks to storage) as prerequisites for trust. Across all CDR solutions, trust and transparency emerged as decisive factors shaping perceptions. Interviewees expressed a consistent need for independent verification, accessible information and long-term accountability from both public and private actors. Mistrust tended to arise when solutions were associated with opaque corporate agendas, weak public oversight or perceived greenwashing. Importantly, the interviews extend this justice framing towards responsibility and intergenerational stewardship, echoing Jenkins and colleagues (2016). Interviewees emphasized that acceptability depends on clarity about who is responsible for monitoring, storage integrity and long-term maintenance. Where responsibilities were diffuse, confidence eroded, underscoring that justice without enforceable responsibility remains fragile. The results also align with Sovacool and colleagues (2023) and Newell and Mulvaney (2013) in showing that distributive and procedural dimensions of justice cannot be separated from underlying political economy structures. For example, interviewees expressed concern that offsetting and carbon trading mechanisms could reinforce existing inequalities between industrial actors and local communities, especially if economic benefits are unevenly distributed. Where responsibilities are diffuse, trust erodes, a fragility also diagnosed by Jenkins and colleagues (2016). They emphasize that unclear accountability structures weaken procedural justice by obscuring who bears responsibility for outcomes and for redressing harms. In their framework, the absence of clearly defined duties not only undermines trust but also destabilizes the broader legitimacy of energy governance institutions. Subsequent syntheses in the energy justice literature reinforce this need for responsibility-centred policy frameworks, not merely distributive or recognition remedies. They also broaden the concept of responsibility to include intergenerational stewardship, ensuring permanence of storage and long-term monitoring obligations, which several respondents explicitly identified as ethical imperatives.

While much of the literature frames social acceptability as a function of governance quality or participation, scholars such as Stirling (2008, 2019) and Jasanoff (2004) remind us that participation itself is shaped by power relations and epistemic hierarchies, deciding who is recognized as a legitimate knower and which forms of expertise are valued. The CDR solutions studied here reveal similar dynamics; trust and transparency were not only informational issues but matters of epistemic credibility. Interviewees' confidence in MRV systems or certification frameworks depended on who controlled the knowledge and how uncertainties were communicated. This finding resonates with Felt and colleagues (2016), who argue that legitimacy arises from epistemic inclusion, when

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affected publics are engaged not merely as consultees but as contributors to knowledge-making. Many interviewees expressed scepticism towards technocratic framings of MRV, describing them as opaque and inaccessible. Hence, enhancing acceptability involves not only open communication but also redistribution of epistemic authority.

Recent scholarship has emphasized that acceptability is not purely rational but also emotional and identity-based (Batel & Rudolph, 2021; Corner et al., 2013; Low & Schäfer, 2020). While this study did not focus explicitly on affect, the qualitative data reveal underlying emotional landscapes – hope, scepticism, pride and fear – that mediate trust and engagement. For example, afforestation projects were more readily accepted when perceived as extensions of local stewardship traditions, whereas industrial-scale BECCS projects elicited anxiety about loss of control and landscape change. These findings support calls for more attention to affective and cultural framings in future research on CDR acceptability.

Acceptability is also temporal. As Bellamy and colleagues (2021) and Markusson, McLaren and Tyfield (2018) argue, the politics of CDR are deeply anticipatory; solutions are judged not only by what they are but by what they promise to become. Interviewees recognized that their perceptions might evolve as solutions mature and accountability mechanisms solidify. Early scepticism could shift towards trust through transparent engagement and visible benefits, while initial support could erode if expectations are unmet. The results therefore affirm that social acceptability is dynamic and revisable, co-produced through evolving interactions between policy promises, scientific credibility and lived experience.

We also found that the application of the PESTELE framework proved valuable as a heuristic but also revealed its limitations when treated as a static categorization. As highlighted by Andersen (2025) and Yüksel (2012), the dimensions are interdependent; political clarity influences economic incentives, technological robustness affects perceived ethics, and legal arrangements structure social trust. Our results affirm this interdependence empirically; for instance, trust in MRV systems (technological) was deeply linked to perceptions of accountability (political and legal) and fairness (ethical). This reinforces our interpretation of PESTELE as a relational tool that helps to map, but not reduce, the complexity of acceptability processes. Its application also revealed that categorization risks simplifying complex social dynamics into discrete domains, potentially masking the interdependencies and power asymmetries among them (see also Stirling, 2019; Turnhout et al., 2020). In practice, for example, political clarity influences market confidence, which shapes perceptions of fairness and trust. Our data suggest that rather than treating PESTELE dimensions as separate boxes, it is more productive to interpret them as interacting spheres of legitimacy. This relational reading better captures how social acceptability emerges from the alignment, or misalignment, of political, ethical and institutional processes.

Finally, the findings contribute to the emerging literature on the global politics of CDR governance. Recent studies have warned that the scaling of CDR could reproduce historical inequalities between lower- and higher-income countries if implemented through market-based or offsetting mechanisms detached from justice principles (Buck et al., 2024; Carton et al., 2020; Dooley & Kartha, 2018). Although this study's empirical focus was European, similar concerns surfaced regarding fairness, transparency and distributive impacts. Interviewees questioned who benefits from carbon removal and

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who bears the long-term responsibility for storage integrity. These reflections suggest that social acceptability debates must be situated within a broader discussion of climate justice and postcolonial responsibility, recognizing that legitimacy operates across, not just within, national borders.

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10. Conclusions

This report aimed to shed light on the social acceptability of selected CDR solutions, namely afforestation, artificial soils, biochar, MCO_2, BECCS and EW, by identifying and measuring perceived political, economic, social, technological, environmental, legal and ethical factors that affect acceptability. Through 73 stakeholder interviews and a rapid-review-inspired literature review, the study examined how contextual, relational and justice-oriented dimensions shape the social acceptability of CDR across Europe.

Overall, the findings reveal that the social acceptability of CDR is not static but relational, negotiated and deeply context-dependent. While most interviewees acknowledged the necessity of CDR to complement emissions reductions, they consistently warned against narratives that position it as a substitute. Nature-based approaches such as afforestation, MCO_2 and biochar were generally viewed more positively due to their tangible co-benefits, including biodiversity gains, soil regeneration and community participation. Engineered solutions such as BECCS and EW faced greater scepticism, largely due to concerns about technological readiness, energy intensity, governance gaps and unclear long-term responsibilities for storage integrity.

The study identified various factors affecting acceptability, showing that trust, transparency, distributive and procedural justice, and political stability are among the most critical cross-cutting conditions for legitimacy. Applying the PESTELE framework helped structure this complexity but also underscored the interdependence of its dimensions; for instance, technological reliability shapes perceptions of fairness and accountability, while economic incentives are inseparable from political and ethical legitimacy. This calls for a dynamic, relational understanding of social acceptability, one that recognizes it as co-produced through interactions between institutions, markets, communities and ecological realities.

Finally, this study contributes to a growing recognition that social acceptability and climate justice are mutually constitutive. The European focus of this report reflects wider global questions about responsibility and fairness in carbon removal: who benefits, who bears the costs and whose voices are heard in shaping the CDR agenda. Addressing these questions is essential for ensuring that CDR not only contributes to climate mitigation but does so in a way that is socially legitimate, ethically grounded and aligned with broader goals of sustainable and equitable transformation.

Taken together, these results provide socio-political and governance parameters, such as legitimacy conditions, justice considerations, and MRV expectations, that can be used to contextualize and inform the technical and economic modelling undertaken in C-SINK's Task 4.3.

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Annex 1. Life cycle stage mapping per solution

A1.1 Afforestation

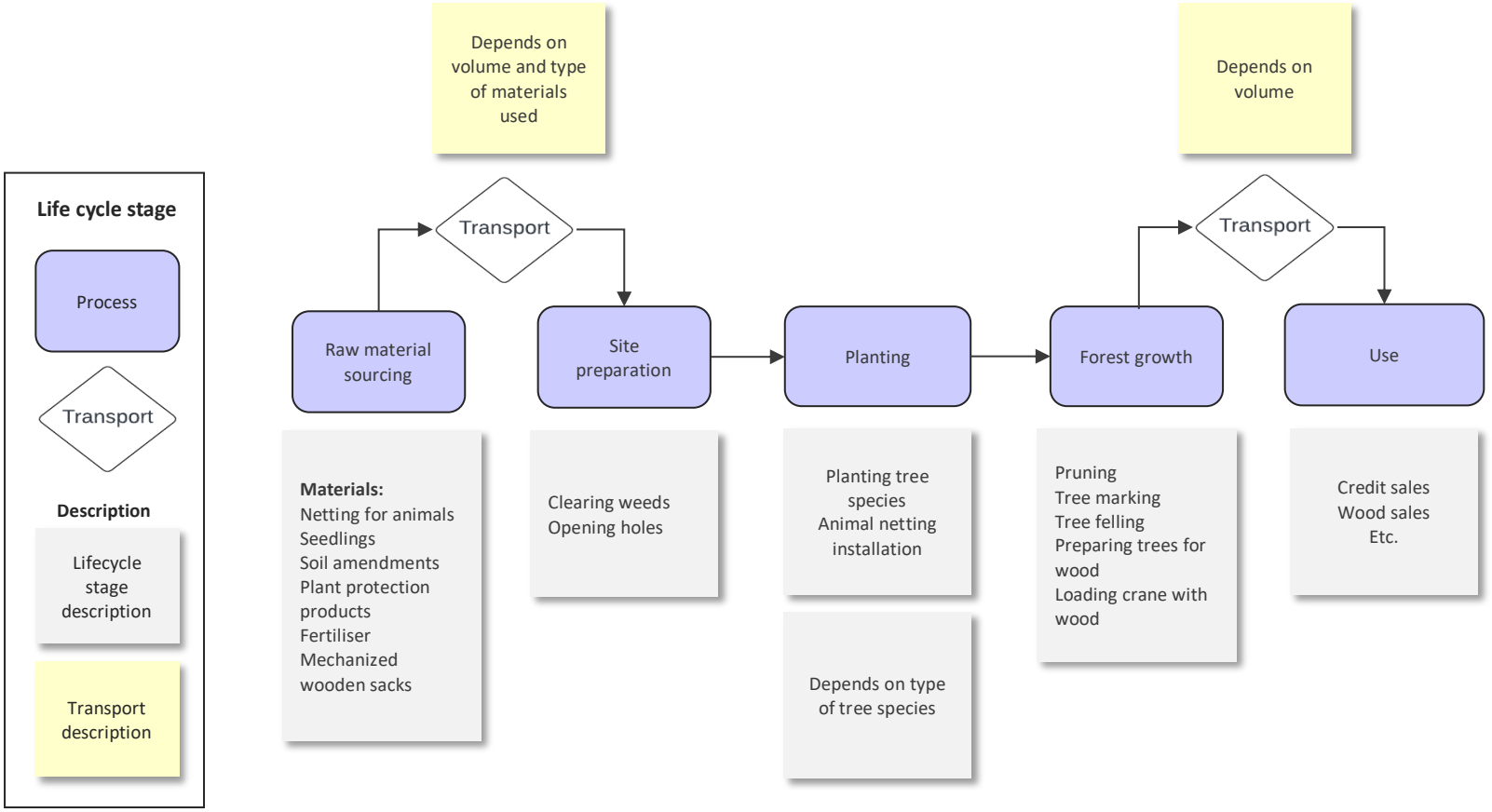


Figure 4. Afforestation life cycle stages. Source: Own illustration

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A1.2 Artificial soils

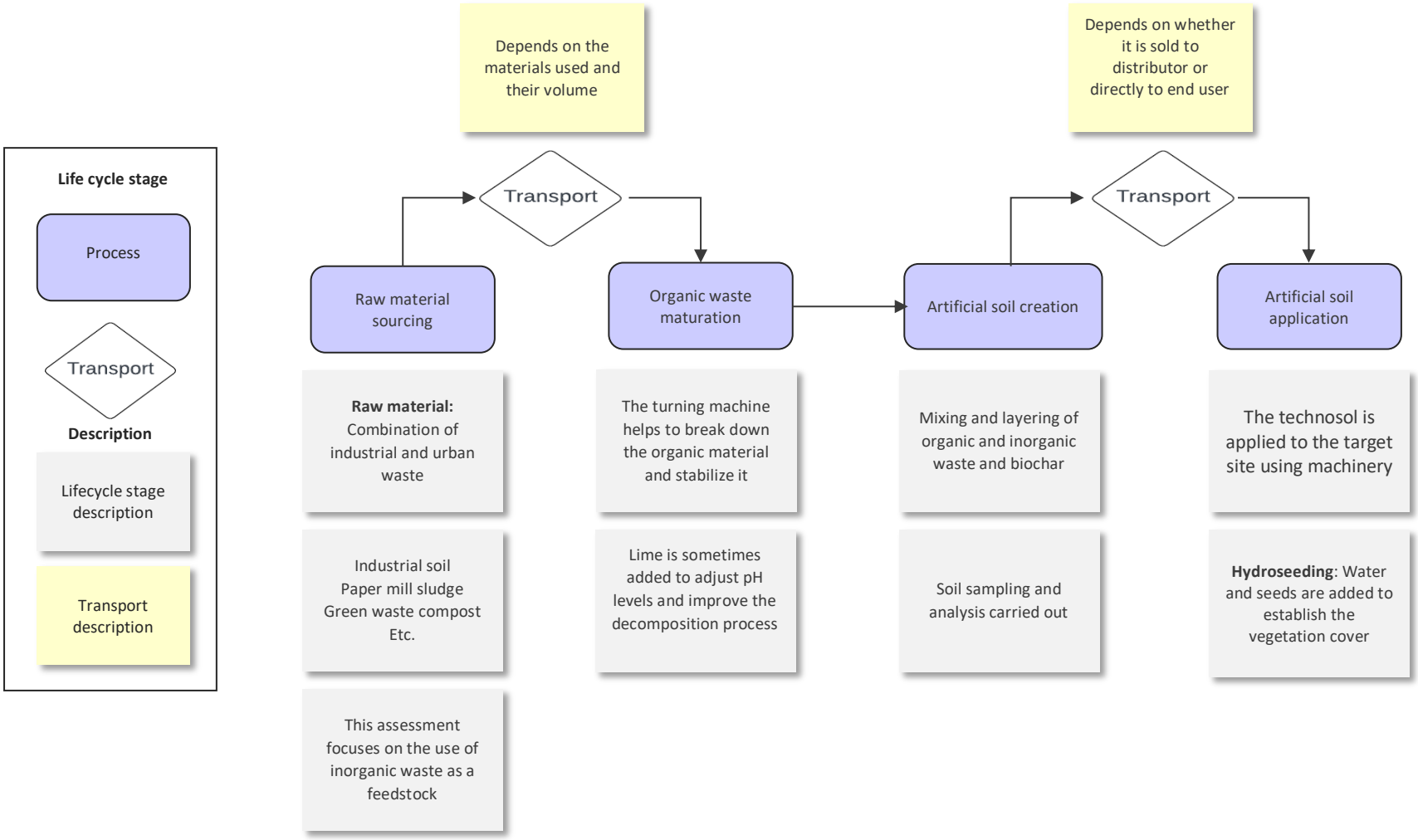


Figure 5. Artificial soil life cycle stages. Source: Own illustration

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A1.3 Biochar

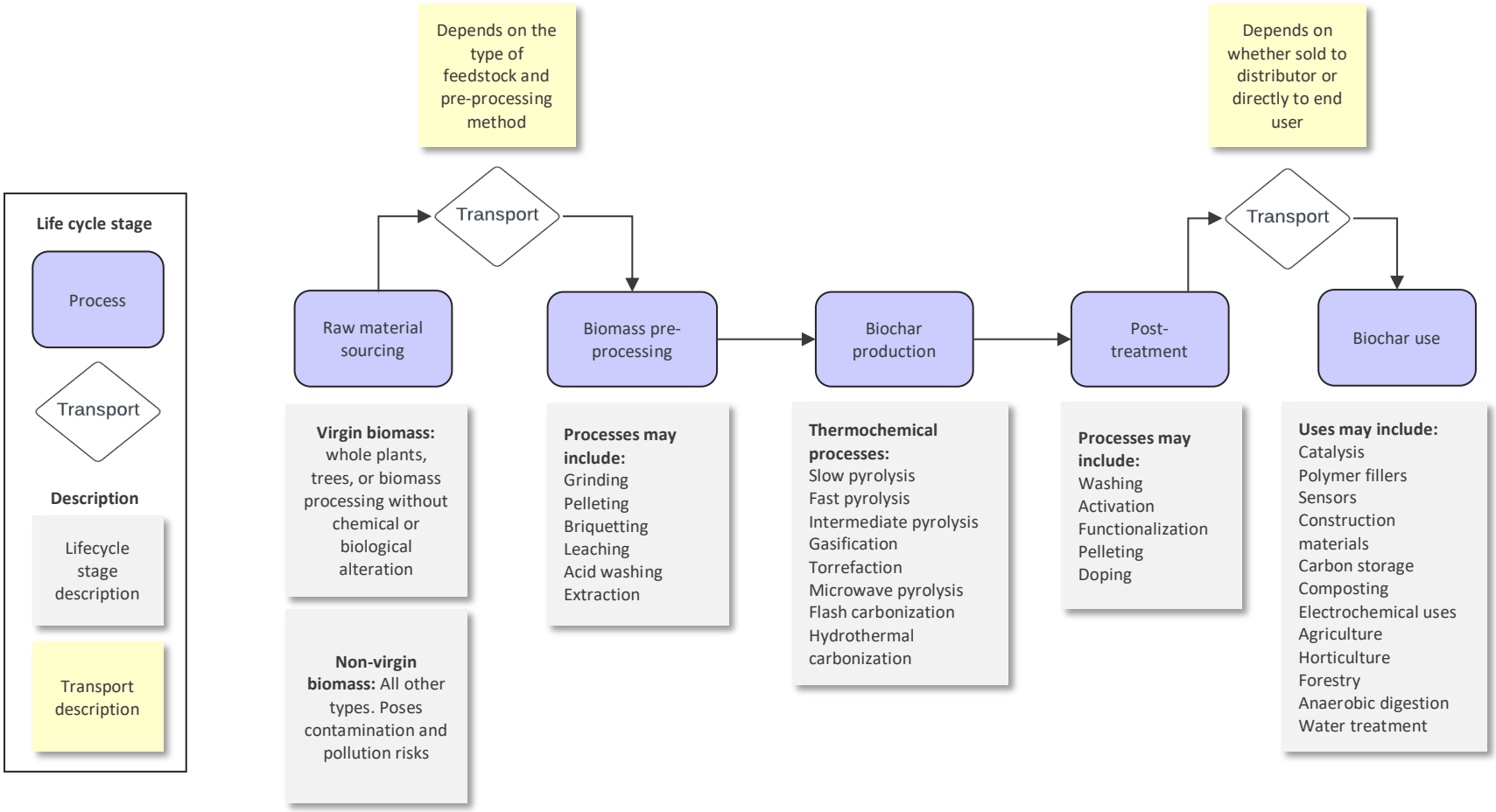


Figure 6. Biochar life cycle stages. Source: Own illustration

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A1.4 Microbiological CO_2 fixation

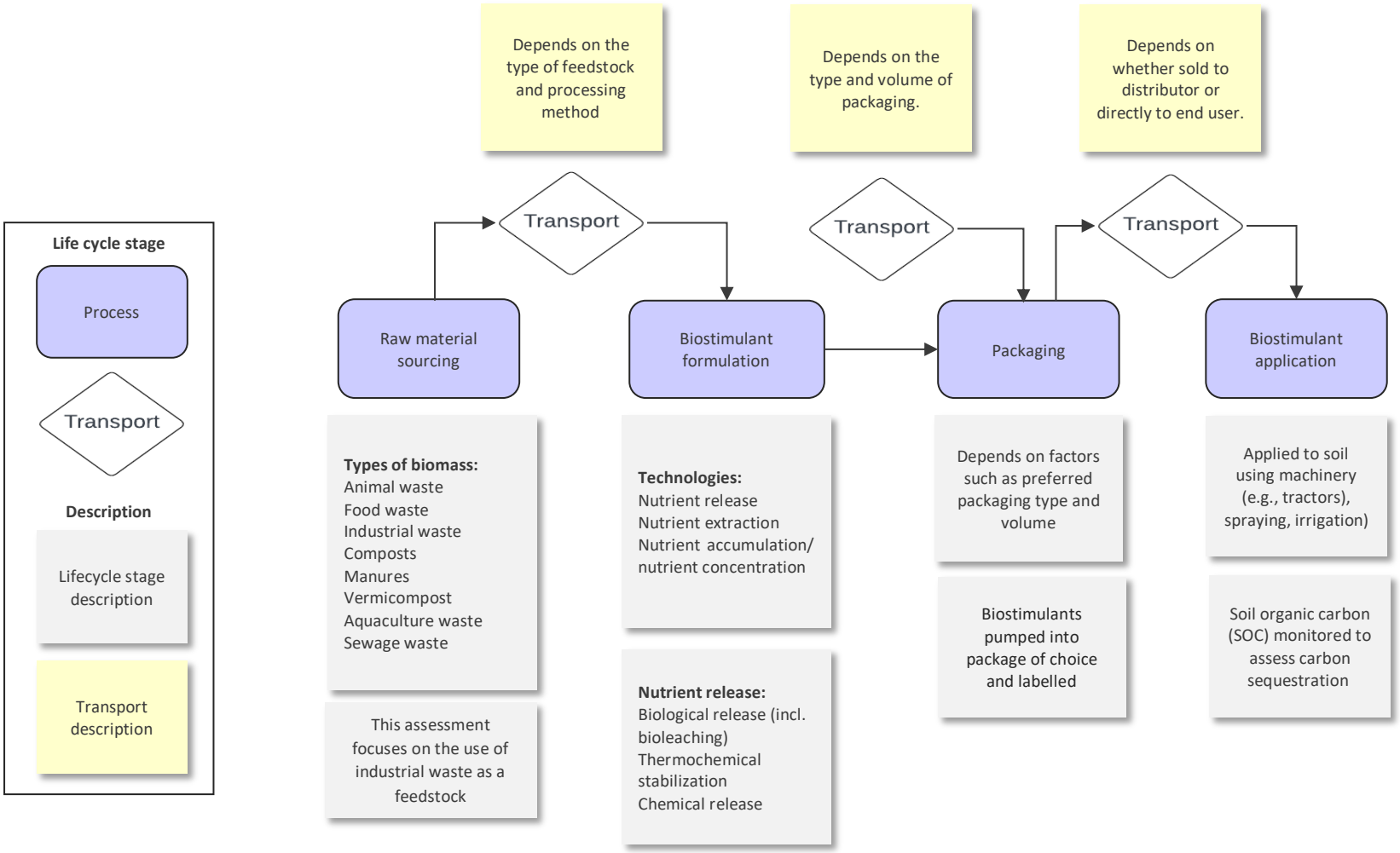


Figure 7. Microbiological CO_2 fixation life cycle stages. Source: Own illustration

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A1.5 BECCS

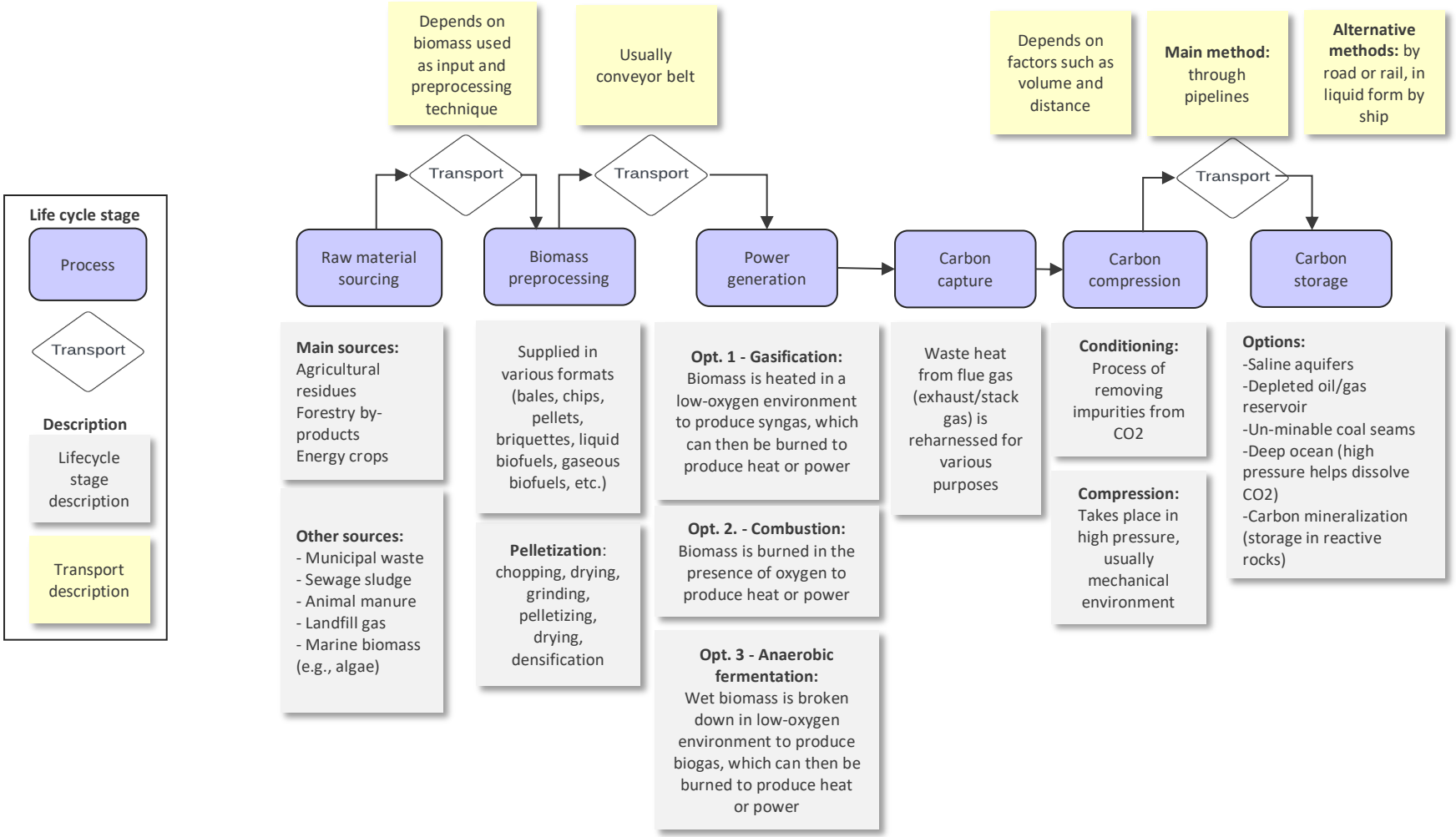


Figure 8. BECCS life cycle stages. Source: Own illustration

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A1.6 Enhanced weathering

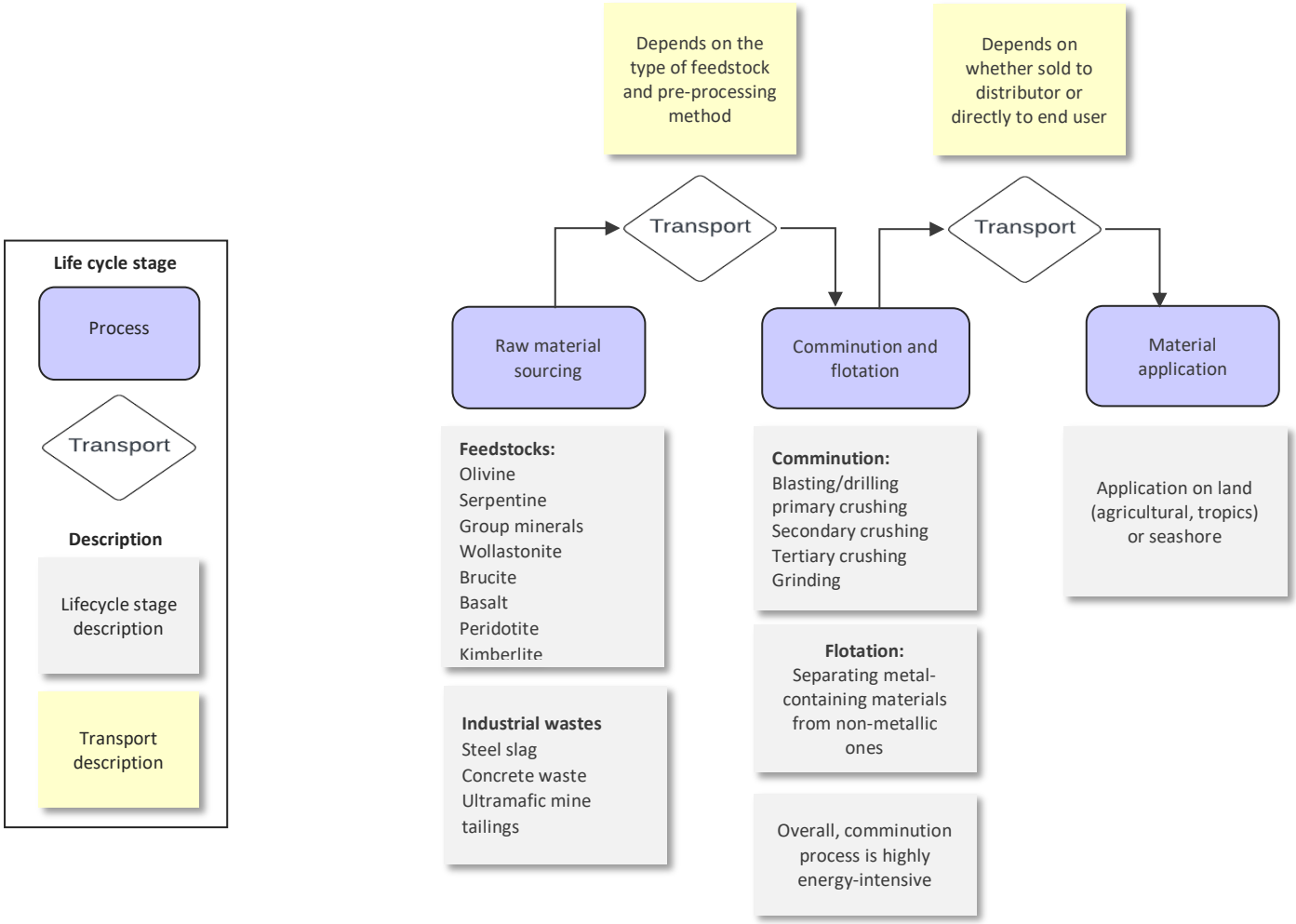


Figure 9. Enhanced weathering life cycle stages. Source: Own illustration

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Annex 2. Interview guide

Introduction

First part – Knowledge and interest

1. Could you tell us a bit about your current job role?
2. Do you have any background in CDR (general)?
3. Do you have any background in [CDR technology] specifically?

Second part – Perceptions of CDR

1. When you think about [CDR technology], what thoughts come to your mind?
2. Which actors, or members of society, do you think are most likely to be impacted by [CDR technology]?
3. Which actors, or members of society, do you think could influence the uptake of [CDR technology]?
4. Do you think [CDR technology] could help reduce GHG emissions?
5. What do you think the future of [CDR technology] might look like?
6. Are there any important points we have not covered today that you think we should discuss? If so, could you tell us more about them?

Closing interview

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Annex 3. Overview of interviews

Table 4. List of pseudonyms

Case code	Regional context	Interview code	Quadruple helix category
AF-SPA	Spain	I1	Industry
AF-SPA	Spain	I2	Civil society
AF-SPA	Spain	I3	Academia & other domain experts
AF-SPA	Spain	I4	Industry
AF-SPA	Spain	I5	Civil society
AF-SPA	Spain	I6	Academia & other domain experts
AF-SPA	Spain	I7	Academia & other domain experts
AF-SPA	Spain	I8	Academia & other domain experts
AS-SPA	Spain	I9	Academia & other domain experts
AS-SPA	Spain	I10	Industry
AS-SPA	Spain	I11	Government
AS-SPA	Spain	I12	Academia & other domain experts
AS-SPA	Spain	I13	Civil society
AS-SPA	Spain	I14	Industry
MCO_2-GER	Germany	I15	Industry
MCO_2-GER	Germany	I16	Industry
MCO_2-GER	Germany	I17	Industry
MCO_2-GER	Germany	I18	Industry
MCO_2-GER	Germany	I19	Academia & other domain experts
MCO_2-GER	Germany	I20	Academia & other domain experts
MCO_2-GER	Germany	I21	Industry
MCO_2-GER	Germany	I22	Government
MCO_2-GER	Germany	I23	Academia & other domain experts
MCO_2-GER	Germany	I24	Civil society
BC-POR	Portugal	I25	Civil society
BC-POR	Portugal	I26	Academia & other domain experts
BC-POR	Portugal	I27	Civil society
BC-POR	Portugal	I28	Industry
BC-POR	Portugal	I29	Government
BC-POR	Portugal	I30	Civil society
BC-POR	Portugal	I31	Civil society
BC-POR	Portugal	I32	Academia & other domain experts
BC-POR	Portugal	I33	Civil society
BC-POR	Portugal	I34	Industry
BECCS-SWE	Sweden	I35	Government
BECCS-SWE	Sweden	I36	Government
BECCS-SWE	Sweden	I37	Industry
BECCS-SWE	Sweden	I38	Government
BECCS-SWE	Sweden	I39	Academia & other domain experts
BECCS-SWE	Sweden	I40	Government
BECCS-SWE	Sweden	I41	Industry
BECCS-SWE	Sweden	I42	Civil society
BECCS-SWE	Sweden	I43	Industry
BECCS-SWE	Sweden	I44	Academia & other domain experts

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Case code	Regional context	Interview code	Quadruple helix category
BECCS-SWE	Sweden	I45	Government
BECCS-UK	UK	I46	Academia & other domain experts
BECCS-UK	UK	I47	Academia & other domain experts
BECCS-UK	UK	I48	Government*
BECCS-UK	UK	I49	Government
BECCS-UK	UK	I50	Academia & other domain experts
BECCS-UK	UK	I51	Academia & other domain experts
BECCS-UK	UK	I52	Industry
BECCS-UK	UK	I53	Civil society
BECCS-UK	UK	I54	Civil society
BECCS-UK	UK	I55	Academia & other domain experts
EW-FIN	Finland	I56	Industry
EW-FIN	Finland	I57	Government
EW-FIN	Finland	I58	Industry
EW-FIN	Finland	I59	Government
EW-FIN	Finland	I60	Academia & other domain experts
EW-FIN	Finland	I61	Industry
EW-FIN	Finland	I62	Academia & other domain experts
EW-FIN	Finland	I63	Civil society
EW-FIN	Finland	I64	Industry
EW-SPA	Spain	I65	Industry
EW-SPA	Spain	I66	Industry
EW-SPA	Spain	I67	Academia & other domain experts
EW-SPA	Spain	I68	Industry
EW-SPA	Spain	I69	Civil society
EW-SPA	Spain	I70	Academia & other domain experts
EW-SPA	Spain	I71	Industry
EW-SPA	Spain	I72	Industry
EW-SPA	Spain	I73	Academia & other domain experts

*I48 was an informal conversation.
Source: Own illustration

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Annex 4. Search string used for the rapid review-inspired literature review

Table 5. Search string and results for the rapid-review inspired literature review

CDR	String WOS	String Scopus	Output WOS	Output Scopus	Included after removing duplicates	Included at TI and ABS level	Maybe at TI and ABS level	Included at full text level
AF	TS= ((accepta*) AND (afforestation OR “new forest planting” OR “forest establish*”))	TITLE-ABS-KEY((accepta*) AND (afforestation OR "new forest planting" OR "forest establish*"))	119	120	152	34	4	21
AS	TS= ((accepta*) AND ("artificial soil" OR "artificial soil*" OR “technosol” OR “technosol*” OR “engineered soil” OR “engineered soil*” OR “synthetic soil” OR “synthetic soil*”))	TITLE-ABS-KEY ((accepta*) AND ("artificial soil" OR "artificial soil*" OR "technosol" OR "technosol*" OR "engineered soil" OR "engineered soil*" OR "synthetic soil" OR "synthetic soil*"))	28	36	44	1	0	0
BC	TS= ((accepta*) AND (biochar))	TITLE-ABS-KEY ((accepta*) AND (biochar))	370	347	428	14	5	7
MCO_2	TS= ((accepta*) AND (“biological CO_2 fixation” OR “bio CO_2 fixation” OR “biological carbon dioxide fixation” OR “soil regeneration” OR “regenerative soil” OR "biostimulant" OR "biostimulants"))	TITLE-ABS-KEY ((accepta*) AND ("biological CO_2 fixation" OR "bio CO_2 fixation" OR "biological carbon dioxide fixation" OR "soil regeneration" OR "regenerative soil" OR "biostimulant" OR "biostimulants"))	40	44	48	0	4	0
BECCS	TS= ((accepta*) AND (BECCS OR ”bioenergy with carbon capture and storage” OR bioCCS OR “bio CCS” OR “bio-CCS”))	TITLE-ABS-KEY ((accepta*) AND (BECCS OR "bioenergy with carbon capture and storage" OR bioCCS OR "bio CCS" OR "bio-CCS"))	45	46	51	40	1	31
EW	TS= ((accepta*) AND (”enhanced weathering” OR EW OR “enhanced rock weathering” OR ERW))	TITLE-ABS-KEY ((accepta*) AND ("enhanced weathering" OR EW OR "enhanced rock weathering" OR ERW))	126	157	187	6	4	5

Source: Own illustration

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Annex 5. Overview of stakeholder perspectives

A5.1 Afforestation

Table 6. Afforestation – Spain

Actor	Benefits of afforestation	Challenges of afforestation	Recommendations for afforestation
Industry	– Scalable, measurable results, and multiple co-benefits (I1). – Aligns profit with environmental and community benefits, especially in degraded areas (I1). – Key strategy for climate action, rural development, and ecosystem restoration, addressing issues like soil erosion and depopulation (I8).	– Limitations of carbon market rules (I1). – Fire risk, but manageable (I1). – Slow returns on investment (I8). – Lack of ecosystem service incentives (I8). – Species-related social resistance (I8). – A shortage of skilled workers (I8). – Bureaucracy often deters private investment (I8).	– Need for coherent policies to support afforestation's role in climate strategy (I1). – The need for clearer public communication (I8). – Administrative reform (I8). – Better incentives to fully realise afforestation's potential (I8).
Academia & other domain experts	– Has value for carbon sequestration, biodiversity, and ecosystem restoration, particularly in degraded, semi-arid areas (I3), multiple benefits for carbon capture, pollution reduction, soil health, biodiversity, and public well-being (I6); benefits like erosion control and carbon sequestration (I7). – Role in productive land-use systems rather than carbon storage (I8).	– Not a stand-alone climate solution (I8). – Overestimation of its climate benefits (I3). – Criticises carbon credit schemes that may drive harmful land-use changes (I3). – Its effectiveness depends on site-specific factors (I6, I7). – Warns against implementation in sensitive ecosystems (I6). – It may harm biodiversity, water resources, and soil if poorly implemented (I7). – Success requires climate-smart strategies, resilient species, and attention to pressures like climate change, pests, and land-use competition (I6). – Criticizes overly ideological or technical approaches that ignore local realities and economic viability (I8). – Concepts like "permanence" and "additionality" are seen as artificial constructs (I8)	– Need for community support (I3). – Proper management and tailored project design (I3). – Inclusive decision-making (I3); involve various actors (I7). – Need for long-term, science-based planning and communication (I6). – Align efforts with local conditions (I7). – Consider rural resistance due to land-use conflicts and cultural factors (I7). – Should be scaled only when it brings broader socio-economic benefits and fits real-world land economies (I8).
Civil society	– Valuable climate solution (I2). – Co-benefits like biodiversity restoration, job creation, and regional development (I2).	– Complex climate solution (I2). – Slow and non-permanent carbon storage (I2). – Fragmented regulations and land ownership structures can obstruct progress (I2). – Social acceptance remains a major challenge (I2). – Only when embedded in broader ecological restoration (I5). – One-size-fits-all approaches (I5). – Carbon offset schemes that favour non-native species like eucalyptus (I5). – Poor site selection (I5).	– Need for a long-term, pan-European plan (I2). – Better public communication (I2). – Better third-party verification (I2). – A clear position that afforestation should complement, not compete with, other carbon removal methods (I2). – Forest management and ecosystem functionality should take precedence over tree planting alone (I5). – Stricter standards, multidisciplinary leadership, community involvement, and long-term

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Actor	Benefits of afforestation	Challenges of afforestation	Recommendations for afforestation
		– Lack of follow-up (I5). – The systemic flaw of allowing emission compensation without prior reductions (I5).	monitoring, especially in vulnerable Mediterranean landscapes.

Source: Own illustration

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A5.2 Artificial soils

Table 7. Artificial soils – Spain

Actor	Benefits of artificial soils	Challenges of artificial soils	Recommendations for artificial soils
Industry	– Transforms waste into a resource for restoring degraded or mined lands, improving soil health (I10, I14). – Multiple co-benefits (e.g., reduces methane emissions from waste, enhances vegetation, improves local ecosystems) (I10, I14). – Can complement existing CDR markets and attract green investment (I14). – Growing market potential through carbon-credit systems and sustainable agriculture niches (e.g., high-value crops, green investors) (I14).	– Low awareness and acceptance among landowners and farmers, leading to reluctance to adopt new practices (I10). – Weak regulatory and policy support, as soil restoration lacks attention, and dedicated funding compared to other sectors (I10, I14). – Availability of nearby waste feedstocks is essential for economic and environmental viability (I10). – Weak connection between research, policy, and business sectors slows innovation uptake (I14).	– Raise awareness and demonstrate results through pilot projects to build trust among landowners and farmers (I10). – Develop supportive regulatory frameworks recognizing soil-based CDR methods and restoration practices (I10, I14). – Integrate soil restoration into national and EU environmental policies (e.g., EU Soil Mission) (I14). – Strengthen local waste-supply chains and partnerships with regional recycling and waste-management plants (I10).
Academia & other domain experts	– Potential to capture and store carbon through mineral carbonation and long-term stabilization of organic matter (I9, I12). – Enables restoration of degraded and mined areas, improving soil fertility and landscape recovery (I9, I12). – Supports a circular economy by reusing crushed rock, demolition material, and organic residues in restoration and green infrastructure (I9, I12). – Can combine synergistically with other CDR approaches (biochar, enhanced weathering, afforestation) to improve CO_2 removal efficiency (I12). – Can generate co-benefits, such as biodiversity, urban greening, wellbeing, and social inclusion (e.g., carbon-capture gardens, community projects) (I9).	– Immature and under-researched CDR solution, lacking robust data, standardized methods, and long-term field validation (I12). – Uncertain carbon cycle dynamics (i.e. hard to isolate and measure net CO_2 effects in open, heterogeneous environments) (I12). – Regulatory and planning barriers make it difficult to integrate in infrastructure or restoration projects once contracts/tenders are approved (I9). – Limited policy recognition and fragmented governance hinder mainstreaming into restoration frameworks (I12). – Logistical constraints (e.g., high material volumes needed; sustainability depends on local availability and short transport distances) (I12). – Environmental and contamination risks, as crushed materials may contain pollutants (plastics, asbestos, pyrites, etc.) (I9, I12).	– Advance scientific evidence (e.g., systematic monitoring, long-term experiments, robust quantification of carbon fixation and permanence) (I9, I12). – Promote policy visibility and early integration into restoration planning (e.g., link to EU Nature Restoration Law and Soil Mission) (I9, I12). – Establish quality standards and safety protocols for material sourcing and use, avoiding contaminated inputs (I9). – Promote interdisciplinary collaboration (soil science, engineering, ecology, policy) to refine methodologies (I9, I12). – Engage public authorities and local communities early to build legitimacy and ensure site-specific adaptation (I12). – Create stable funding mechanisms for continued experimentation (e.g., EU programs, carbon-credit pilots) (I9, I12).
Civil society	– Promotes circular use of organic waste, avoiding landfilling or burning of residues from municipalities, forestry, and agriculture (I13). – Could be useful for restoration of degraded or mined areas, road embankments, or	– Viewed as greenwashing (“false solution”) if used to offset rather than reduce emissions, due to its minor contribution to CO_2 mitigation compared to systemic emission cuts (I13).	– Communicate it as a circular-economy or land-restoration tool rather than a core climate solution (I13). – Ensure strict environmental and safety standards for waste use in soil creation (I13).

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Actor	Benefits of artificial soils	Challenges of artificial soils	Recommendations for artificial soils
	semi-arid soils lacking organic matter (I13). – May create local environmental benefits in degraded regions, improving soils and supporting re-vegetation (I13).	– Potential contamination risks from sewage sludge and industrial waste-derived feedstocks (e.g., heavy metals) (I13). – Not scalable at national level due to volume, logistics, and funding constraints (I13). – Limited public awareness and low policy priority for land restoration (e.g., few dedicated funds) (I13).	– Ensure public investment and clear regulation for safe, limited-scale restoration use (I13). – Embed in restoration policy frameworks (e.g., waste management or regional recovery programs) (I13).
Government	– Could help address global soil loss and erosion, particularly in arid or degraded areas (I11). – Offers an alternative means to regenerate soil where natural recovery is slow or impossible (I11). – Potential to valorise waste materials (e.g., from incineration or construction) (I11). – Can benefit agricultural and forestry sectors by restoring productivity and supporting rural resilience (I11).	– Limited understanding and prioritization of soil preservation among land users and the general public (I11). – Uncertainty about long-term soil stability, as artificial soils may erode or degrade without vegetation cover (I11). – Limited inter-institutional coordination, including fragmented governance between ministries and regions (I11). – Fear of costs or uncertain returns may limit uptake among landowners (I11). – Scepticism toward novel or “artificial” environmental solutions may create social resistance (I11).	– Raise awareness through participatory pilots and education on soil conservation (I11). – Integrate vegetation and ecological restoration as essential components (I11). – Enhance collaboration between public authorities, research institutions, and industry (e.g., MAPA, MITECO, private sector) (I11). – Provide incentives (e.g., subsidies) to landowners and farmers to pilot soil-restoration initiatives (I11).

Source: Own illustration

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A5.3 Biochar

Table 8. Biochar – Portugal

Actor	Benefits of biochar	Challenges of biochar	Recommendations for biochar
Industry	– Scalable, ready-to-use CDR option with long-term carbon stability and measurable results (I28). – Can be produced locally from residues, supporting circular, low-carbon economies and rural development (I28, I34). – Multiple co-benefits for soil health, water retention, pollution control, and industrial decarbonization (I28, I34). – Synergies with other sectors (e.g., concrete, steel, cork, paper) through heat recovery and material substitution (I34).	– Unclear or inconsistent regulations for pyrolysis plants and carbon accounting (I28, I34). – Limited policy awareness and outdated information hinder uptake (I28). – Risk of poor-quality or unregulated production undermining credibility (I34). – Biomass availability and competition with other uses (I28).	– Develop clear EU and national rules, certification schemes, and third-party verification to ensure quality (I28, I34). – Increase awareness among policymakers and NGOs through better communication (I28). – Support industrial integration to scale production (I34). – Balance regulation (strong enough for standards, flexible enough to enable innovation) (I34).
Academia & other domain experts	– Mature, ready-to-deploy CDR solution with measurable carbon benefits (I26, I32). – Multiple co-benefits: soil restoration, waste valorisation, and renewable-energy co-production (I26, I32). – Especially valuable in degraded or low-carbon Mediterranean soils (I26). – Versatile use of diverse biomass and by-products (I32). – Links energy, agriculture, and industry through circular economy applications (I26, I32).	– Weak business case and high investment risk without stable policy support (I26, I32). – Uneven economic feasibility, including high costs for farmers (I32). – Fragmented regulation and permitting (I32). – Limited awareness (I26). – Narrow focus on CDR over broader system value (I26). – Effectiveness depends on feedstock and local conditions (I26, I32).	– Create stable, coherent policy and incentive frameworks (I26, I32). – Integrate biochar into wider soil-health and carbon strategies (I26, I32). – Improve coordination between technical experts, economists, and policymakers (I26). – Harmonize and simplify regulation and certification across Europe (I32). – Support early projects and investment through subsidies or guarantees (I32).
Civil society	– Promotes circular use of forestry and agricultural residues, reducing waste burning (I25, I27, I31). – Offers long-term carbon storage and complements other CDR or regenerative methods (I25, I27, I30). – Improves soil quality and water retention, especially in degraded or dry areas (I27, I30, I31). – Can enhance crop productivity and plant resilience (I30).	– High production and application costs for small farmers (I30, I31). – Limited awareness and technical knowledge among landowners (I27, I31). – Climate benefit varies widely with production methods (e.g., traditional burning or poorly controlled pyrolysis may not result in net carbon removal) (I27, I31, I33). – Fire-safety risks and lack of proper small-scale equipment (I31). – Sometimes viewed as greenwashing or minor compared to direct emission cuts (I25, I27).	– Provide public support or incentives to offset costs and enable pilot projects (I30). – Integrate biochar into soil, forestry, and climate policies (I25, I33). – Support long-term field trials and monitoring (I30, I33). – Adopt strict feedstock and environmental standards (I25, I33). – Raise awareness and build capacity through farmer associations and demonstrations (I27, I31).

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Actor	Benefits of biochar	Challenges of biochar	Recommendations for biochar
	– Supports biodiversity and rural resilience when linked with sustainable forestry or agroforestry (I27, I30, I31). – Low-tech, locally scalable solution, encouraging community use (I31). – Creates local economic value for forest residues and certified forest owners (I27, I30, I33).	– Limited field validation and mixed results across soils and crops (I30, I33). – Risk of unsustainable or poorly controlled feedstocks, since clear production and quality standards are still lacking (I25, I33). – Unclear regulation and limited policy support (I25, I33).	– Raise awareness and establish clear standards distinguishing sustainable, carbon-negative biochar from traditional charcoal production (I27, I31, I33). – Frame as a restoration and circular-economy tool, not a carbon offset (I25, I27). – Develop safe, low-emission kilns and safety guidelines (I31).
Government	– Potential to valorise unused biomass and organic residues that currently go to landfill (I29). – Can improve soil quality, structure, and water retention relevant for Portugal's generally poor, dry soils (I29). – Offers a pathway for carbon fixation and long-term carbon storage in soils or construction materials (I29). – Opportunity to link circular-economy and climate-policy goals (I29).	– Strong need for clear regulation and scientific standards, since norms for quality, monitoring, and verification are still lacking (I29). – Environmental risks include possible soil acidification, contamination, and uncertain energy balance depending on feedstock and production methods (I29). – Potential economic and resource competition, as biochar could divert biomass from other industries (e.g., wood panels, agriculture) (I29). – Awareness and political attention are still limited (I29). – Risk of treating biochar as a "miracle" solution instead of reducing emissions (I29).	– Establish robust, science-based regulation and certification systems (I29). – Support pilot projects and research to build reliable evidence before large-scale deployment (I29). – Integrate biochar into broader policy frameworks for climate, agriculture, waste, and energy to avoid resource conflicts and align incentives (I29). – Strengthen public communication and education so that adoption is guided by scientific evidence rather than business interests (I29). – Connect biochar initiatives to carbon-market mechanisms to mobilize investment (I29).

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A5.4 Microbiological CO_2 fixation

Table 9. Microbiological CO_2 fixation – Germany

Actor	Benefits of Microbiological CO_2 fixation	Challenges of Microbiological CO_2 fixation	Recommendations for Microbiological CO_2 fixation
Industry	– Co-benefits such as increased soil quality, nature restoration, increased yields, making agricultural land sustainable by restoring soil, and improvement of quality of life (I15, I16, I17, I18, I21). – Relatively resource-saving as the natural processes take care of the weathering (I15, I17, I21). – It is likely that the public will prefer CDR solutions that improve the beauty of landscape and soil quality (closeness to local people) (I15, I16, I18). – Improve resilience of plants against climate change (I15, I16, I17, I21). – Wide range of possible applications (not limited to agriculture) (I17, I18, I21). – Relatively cost-effective CDR solution (I21).	– Concentrated power in a handful of global actors (I15, I16, I17, I18, I21). – Risk of failure can be directly linked to farmers income (I15, I21). – Current dependencies between users (farmers) and global actors who distribute products (I15). – Connect certificate trading scheme to small businesses, such as farmers (I15, I16). – Risk of mitigation deterrence; discourse focus should be more on reducing CO_2 emissions (I16, I17, I18). – Effectiveness of CDR solution is contingent on environmental factors (weather, etc) (I17, I21). – There is a scepticism about microorganisms in Western Europe as compared to Eastern Europe (I17, I18, I21). – Northern actors are less interested in innovative solutions such as Biological CO_2 fixation as compared to Southern actors (I21).	– Regulatory framework that allows for new products to enter the European market (I15, I17, I18). – Faster permits for new CDR solutions (I15, I17, I21). – Increased communication about the CDR solution at EU-level and national levels (I16). – Making a certificate trading scheme also economically viable for small businesses (I16, I17, I18, I21).
Academia & other domain experts	– The potential of soil-based CDR is large (I19). – Restoration of ecosystems (I19, I23). – Much of the knowledge already exists for a couple of decades (I19). – Co-benefits, such as improved plant growth, livelihoods (I20, I23). – Resource-efficient/saving type of technology (I23).	– Risk of mitigation deterrence (I19, I20, I23). – The infrastructure is too decentralized to scale soil-based CDR efficiently (I19). – Concentrated power of a handful of global corporations (I19, I20). – Farmers are more open in the South for new CDR solutions than in the North (I19). – Western societies are divorced from nature and therefore have difficulties in understanding nature-based solutions (I19). – Effectiveness of technology is contingent on environmental factors (weather, etc) (I20) – People are sceptical towards bacterial solutions (I20, I23).	– Green CDR should not compensate for brown emissions (I19). – The commercialization process of the product needs to be economically just (I19). – Institutional incentives need to be adapted to market structures (include benefits for small farmers) (I19). – Research and financing should be channelled into reducing carbon emissions rather (I19). – Frameworks should be applicable to systems and not to individual households (I20). – Regulations are lagging behind and should be implemented faster (I23).
Civil society	– Co-benefits, such as restoration of land (I24). – Relatively cost-effective CDR solution (I24).	– Concentrated power of a handful of global corporations (I24)	– Increased educational work to reduce knowledge gaps in public (I24).

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Actor	Benefits of Microbiological CO_2 fixation	Challenges of Microbiological CO_2 fixation	Recommendations for Microbiological CO_2 fixation
		– People are sceptical towards bacterial solutions (I24)	– The media should take a greater role in communicating about new technologies (I24).
Government	– Relatively simple to scale MCO_2 (I22).	– Municipalities are rather risk averse in adopting new technologies (I22). – The implementation of the CDR is contingent on election cycles (I22). – Climate protection is not on the top of agendas in national politics (I22). – People are sceptical towards bacterial CDR solutions (I22). – Concentrated power of a handful of global corporations (I22).	– Improved framework that encourages the adoption of new technologies on municipal level (I22). – Political stability (I22). – Increased education work for public sector employees to reduce knowledge gaps (I22).

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A5.5 BECCS

Table 10. BECCS – Sweden

Actor	Benefits of BECCS	Challenges of BECCS	Recommendations for BECCS
Industry	– Scalable opportunity for negative emissions (I37, I41, I43). – Relatively easy to verify, as compared to agriculturally based carbon sinks (I37). – Cheaper than DACCS (I37). – Permanent sink for emissions (I41). – High quality CDR product (I41).	– Absence of natural market (I37). – Risk of mitigation deterrence (I37; I41). – Land-use conflicts (I37). – Energy use conflicts for capturing carbon (I37, I41, I43). – CCU might be more useful than CCS (circularity vs linearity if carbon is a resource) (I37, I43). – Conflicts between nature restoration and carbon removal goals (I37). – Limited growth of forest (climate, space) (I37). – Storage is expensive and risks are still unclear (I41, I43).	– Need for financing system via public sector (I37, I43). – Need for a political framework that is stable over time (I37). – Need for resilient defence mechanisms to protect energy infrastructure (I37) . – Clear distinction between green and black carbon (I37, I41). – Framework for voluntary market to avoid offsetting (I37, I41, I43).
Academia & other domain experts	– BECCS is needed for achieving net-zero goals (I39). – BECCS is needed as a complementary technology (I44). – Simple technology has been around for many years (I44).	– Expensive climate measure (I39, I44). – Scalability is questionable since technology has existed in many years (I39, I44). – Other measures are cheaper and easier to be implemented (I39). – Long value chains increase risks of environmental and social impacts (I39). – Social injustice (I39). – Rich actors will benefit most financially (I39). – Storage part is a big uncertainty (I39). – Mapping of potential is unrealistic (I39, I44). – Risk for mitigation deterrence (I44). – The need for electricity does not match the prospected roll out of BECCS to reach net-zero (I44).	– Need for scaling projects (majority of BECCS trials are discontinued) (I39). – Need for clear regulations around “hard-to-abate” sectors (I39). – Framework for accounting CDR certificates needed (I39, I44). – Policy for future risks and maintenance of stored carbon (I39). – Political stability and support (I44).
Civil society	– BECCS is needed for achieving net-zero goals (I42). – BECCS is one of many measures that can help to reduce carbon dioxide concentrations in the atmosphere (I42).	– Increased risks for local communities (air pollution, noise pollution, visual pollution, security issues) (I42).	– Need for an integration of local voices, current “citizen” dialogues are one-sided (I42). – Need to separate industry from residential areas (I42). – Need for stronger environmental protection laws (I42).
Government	– BECCS is needed for achieving net-zero goals (I35, I36, I40, I45).	– CCU vs CCS, best use of captured carbon (I35, I36).	– Need for framework that separates green and black carbon certificates (I35, I45).

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Actor	Benefits of BECCS	Challenges of BECCS	Recommendations for BECCS
	– Co-benefit of creating electricity and heating for municipalities (I35, I38). – Scalability of BECCS as compared to other CDR measures, yet not a solution to the problem (using fossil fuels) (I35, I36). – Permanence and safety of storage (I36, I38). – Technology is not new (I45).	– Costly technology that needs to be financed via the public and private sector (I35, I40, I45). – Risk for mitigation deterrence (I35, I36, I40, I45). – Bioenergy is a limited resource in itself (I35, I36, I40, I45). – Inefficient process to produce bioenergy (I35, I40). – Land-use conflicts (I35). – Nature restoration vs CDR goals (I35, I45) – Access and dependency of storage places in the world (I36, I40, I45).	– Need for a framework that also makes poorer countries and actors benefit financially from BECCS (I35). – Future oriented monitoring system of stored carbon needed (I35). – Better to act with the technologies at hand than to wait even longer for the optimal solutions (I35, I40). – Political stability needed (I36, I40, I45). – Political support needed for exploring local storing locations (I38). – Need for scaling projects (majority of BECCS projects are discontinued) (I38). – People need to be more involved (via education etc) in BECCS (I40).

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Table 11. BECCS – UK

Actor	Benefits of BECCS	Challenges of BECCS	Recommendations for BECCS
Industry	– Renewable and sustainable (I52). – Balancing of energy system (I52). – Creating value from abundant and by-products (I52). – Social impacts (e.g., job creation) (I52).	– Finding appropriate locations, near both feedstock sources and storage sites (I52). – Social impacts (I52). – Gap in knowledge and communication about the safety and efficiency BECCS (I52). – Resistance (I52).	– Need for participatory processes to understand local needs and concerns (I52). – Need for a healthy carbon market (I52).
Academia & other domain experts	– Important complementary measure to combat climate change (I46, I47, I51, I55). – Benefits for whole value chain if a market can be created (I46, I51). – Few people are affected e.g., CO_2 is not explosive, safe storage offshore, limited visual impact if CCS is added to existing bioenergy plant (I46, I51). – Balancing of energy system (I51, I55). – Job creation (I51, I55). – Fair energy transition (I51). – Tested technology (I46, I51). – Permanence (I55). – Cheaper than DACCS (I55). – Creating value from by-products (I55).	– Overreliance/mitigation deterrence (I47, I50). – Social impacts and injustice (I47, I50, I55). – Environmental justice issues e.g., related to biomass import (I47, I50, I55). – Low social licence to operate (I46, I55). – Transportation and storage uncertainty (I46) and risks to people and the environment (I47, I50, I51). – Limited government support (I46). – Sustainability of feedstock, reliance on imported feedstock and domestic land availability (I46, I47, I50, I51, I55). – Complex system and value chain - Who pays? (I46, I51, I55). – Resistance to transportation and storage (I47), and for oil and gas companies to provide storage sites (I46, I50, I51, I55). – Costs and financial incentives (I47, I51, I55). – BECCS follows the logic to combat climate change by producing/consuming more energy (I50). – Large-scale implementation is too challenging (I50). – Energy penalties (I51). – CCU vs CCS, best use of captured carbon (I55). – Cultural value of forests (I55).	– Need for informed government decisions and stable political support (I46, I47). – Oil and gas companies have the technologies and competence for storing CO_2 (I46, I51). – Regulatory framework, laws and monitoring are required (I46) for reliability (I47, I51, I55) . – Better understanding of public perceptions on how climate change should be tackled (I47). – Long term engagement with local communities (I47, I51). – Verify carbon intensity (I51) and change carbon accounting for biomass fuel rules (not net zero) (I50). – Ensure and demonstration of safety of CO_2 storage (I51, I55). – BECCS done well (I55).
Civil society	– Better that using fossil fuels (I54).	– Trees are not renewable by default (I53, I54). – Mitigation deterrence (I54) / BECCS will not deliver negative emissions (I53). – BECCS will have negative impacts on forests, ecosystems, land use change food supply and the climate (I53, I54). – Environmental justice issues e.g., related to biomass import (I53). – Economic interests outperform environmental interests (I53, I54). – Depends on subsidies (I53, I54).	– Better to reduce energy use and/or subsidy renewable energy such as wind, solar etc. to reduce emissions (I53, I54). – Bioenergy should not be counted as net zero (I53).

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Actor	Benefits of BECCS	Challenges of BECCS	Recommendations for BECCS
		– Cultural value of forests (I54).	
Government	– Negative emissions (I48). – Plants can be retrofitted (I48).	– Cultural value of forests (I48). – Business case, high costs and risks (I48). – Long lead times (I48). – Impacts on residents (e.g., from building of pipelines) (I49). – Leakage risks (I49). – CCU vs CCS, best use of captured carbon (I49). – Greenwashing (e.g., captured CO_2 can be used for enhanced oil recovery) (I49). – High costs supported by government money (I49). – Pushing problems to the future / Mitigation deterrence (I49).	– Clusters needed (I48). – Open and transparent communication with local communities (I49).

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A5.6 Enhanced weathering

Table 12. Enhanced weathering – Finland

Actor	Benefits of enhanced weathering	Challenges of enhanced weathering	Recommendations for enhanced weathering
Industry	– Availability of mining waste and infrastructure (I56, I58, I64). – No problem with social licence to operate if placed within the mining area (I56). – Potential carbon removal, allowing growth through compensating for hard-to-abate sectors (I56). – No environmental impact or additional resource use as it is implemented in existing tailing facility (I58). – Preventing climate change (I58, I61). – Duality of EW (e.g., soil restoration opportunities depending on rock and its toxicity) (I61, I64). – Necessary to reach net-zero (I64) – Probably the most scalable CDR (I64) – High permanence (I64).	– New and unknown technology (I56, I58, I64). – The urgency of emission reduction requirements limits the possibilities for researching new solutions (I56). – Slow process and risk for reversals (I56). – Use in agriculture restricted due toxicity (I56, I64). – Unclear economic viability (I56, I58, I61, I64) – Implementation is a political issue as scientific validation and market creation are based on EU policy (I56). – Uncertain carbon removals (I58) -technological complexity is challenging implementation, scaling and MRV (I56, I61, I64). – (Unwanted) side-effects on the environment are not well known (I56, I64). – Expensive to transport (I56). – Stakeholder concerns about environmental impacts (I58). – Diversity of CDR generates competition between technologies (I61). – Political decision makers don't have the background or resources to review all technologies and favour certain CDR (I61).	– CO_2 calculations should be conservative (to avoid giving a sense of greenwashing) (I56) – Main opportunities for EW are in location with non-toxic mining waste with high carbon capture potential and proximity to infrastructure and carbon sources (I56, I58, I64). – More research and trials are required to understand the potential and to roll it out safely (I58, I61. I64). – MVR processes are needed (I58, I61, I64) – CDRs are necessary, but should not replace emission reductions (I64). – Trust-building (I64).
Academia & other domain experts	– EW could be one of many measures that can help to reduce carbon dioxide concentrations in atmosphere (I60, I62) – Advantageous if mining waste can be used (I60) – Availability of appropriate rock (I62). – No land competition (I62). – Soil restoration opportunities (depending on rock and its toxicity) (I62).	– New and unknown technology (I60, I62). – (Unwanted) side-effects on the environment are not well known (I60, I62). – Monitoring is challenging (e.g., depends on local conditions) (I60, I62). – Unclear scaling opportunities (I60, I62). – In Finland, focus is mainly on natural carbon storage (I60). – Mitigation deterrence (large corporations using EW for greenwashing purposes) (I62). – Local societal and environmental impacts if increases mineral extraction locally (I62). – Low trust in mining industry (I62).	– Consider all CDR as different CDR have different potential depending on the context, time frame and the technological maturity (I60). – In general, soil restoration can be the main frame of EW (I62). – Resource need should not outweigh the removed CO_2 (I62). – MVR need to be sorted for EW to scale (I62). – Need for long-term trials (I62).

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Actor	Benefits of enhanced weathering	Challenges of enhanced weathering	Recommendations for enhanced weathering
Civil society	– EW could be one of many measures that can help to reduce carbon dioxide concentrations in the atmosphere (I63).	– New and unknown technology (I63). – Unclear resource demand (e.g., costs and energy) (I63). – (Unwanted) side-effects on the environment are not well known (I63). – Mitigation deterrence (large corporations using EW for greenwashing purposes) (I63).	– CDRs are necessary, but should not replace emission reductions (I63).
Government	– EW could be one of many measures that can help to reduce carbon dioxide concentrations in the atmosphere (I57). – Advantageous if mining waste can be used (I59).	– New and unknown technology (I57, I59). – Unclear scaling opportunities (I57, I59). – Not included in the government programme (I57). – The market needs to take EW forward (I57). – Unclear resource demand (e.g., costs and energy) (I57, I59). – (Unwanted) side-effects on the environment are not well known (I57, I59). – Public perceptions on mining and its impact on nature (I59).	– Monitoring required (I57, I59). – More research and trials are required to understand the potential and to roll it out safely (I57, I59). – Resource needs should not outweigh the removed CO_2 (I57, I59). – Consider all CDRs as different CDRs have different potential depending on the context, time frame and the technological maturity (I57).

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Table 13. Enhanced weathering – Spain

Actor	Benefits of enhanced weathering	Challenges of enhanced weathering	Recommendations for enhanced weathering
Industry	– Enables natural, durable CO_2 removal using existing mining and farming infrastructure (I65, I68). – Improves soil pH and fertility, supporting agriculture and coastal ecosystems (I65, I66, I68, I71). – Reuses mining byproducts and connects to local sectors like forestry (I65, I66). – Low-tech and scalable (I65, I68, I71). – Creates income potential for farmers through carbon credits (I65, I68, I71). – Encourages collaboration between industry, research, and authorities (I65, I71, I72).	– High material, energy, and transport demands (I65, I68, I71). – Slow CO_2 uptake and long timeframes for measurable results (I65, I68, I71). – EU fertilizer rules restrict ultramafic rocks due to naturally high nickel and chromium content (I65). – Weak incentives, unclear regulation, and low awareness among landowners and officials (I66, I71, I72). – Risk of social resistance or greenwashing perceptions (I65, I72) – Environmental risks if mining expands or residues are misused (I66, I68).	– Launch pilot projects to demonstrate safety, carbon value, and agronomic benefits (I65, I66, I71). – Develop clear EU and national regulations and monitoring standards (I65, I71, I72). – Introduce carbon-credit or subsidy schemes for verified removals (I65, I68, I71). – Build trust through transparent communication and local stakeholder engagement (I65, I66, I72). – Foster partnerships between mining, agriculture, and public authorities (I65, I71, I72).
Academia & other domain experts	– Removes CO_2 while improving soil health, crop yields, ecosystem resilience, and food security through nutrient release and pH regulation (I67, I73). – Offers co-benefits beyond CDR, such as reversing ocean acidification and supporting long-term soil fertility (I67, I73). – Reuses mining by-products and existing industrial infrastructure, reducing new extraction needs and costs (I70). – Supports circular-economy goals by valorising mining residues and restoring degraded land (I70). – Complements rather than disrupts existing land uses (I70). – Scalability by leveraging agricultural land and established logistics networks for rock spreading (I70, I73).	– Absence of standardized, verifiable methods for MRV of carbon removal (I67, I70). – Potential contamination risks from trace metals such as nickel and chromium in ultramafic rocks (I70, I73). – Scientific uncertainty about carbon permanence and complex geochemical pathways from soils to oceans (I67, I73). – High upfront costs, limited financial incentives, and weak carbon-credit mechanisms for farmers and operators (I67, I70). – Low public and policy awareness (i.e., the concept is still unfamiliar even within scientific and land-use communities) (I70). – Research fragmentation and uneven policy attention compared to more established CDR methods (I67).	– Establish internationally accepted MRV and life-cycle assessment standards with independent verification systems (I67, I70). – Define clear environmental safety criteria and feedstock screening protocols to avoid toxic inputs (I70, I73). – Fund long-term field trials and interdisciplinary research to quantify CO_2 permanence and agronomic impacts (I67, I73). – Integrate enhanced weathering into agricultural subsidies, restoration programs, and carbon-market frameworks (I70, I73). – Raise awareness through demonstration projects, education, and transparent communication of co-benefits (I70). – Promote coordination among research, policy, and industry actors (I70). – Diversify applications beyond cropland (I70).
Civil society	– May contribute to CO_2 removal if application is based on solid scientific evidence (I69). – Could improve thin or degraded soils if proven safe and beneficial (I69). – Supports circular economy by reusing mining by-products such as dunite (I69).	– Low public awareness and understanding of the method (I69). – Strong mistrust toward mining due to past environmental impacts in the region (I69).	– Ensure transparent communication on objectives, methods, and risks (I69). – Present enhanced weathering as a restoration and research tool, not a carbon-offset scheme (I69). – Begin with small-scale, participatory pilots to build trust (I69).

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Actor	Benefits of enhanced weathering	Challenges of enhanced weathering	Recommendations for enhanced weathering
	– Offers opportunities for environmental education and community engagement (I69).	– Extraction and transport entail energy use, leading to an uncertain carbon balance (I69). – Possible ecological risks if ultrabasic materials alter soil or water chemistry (I69). – Potential social resistance in areas with strong land-stewardship traditions (I69).	– Involve communities managing *montes vecinales en mano común* (i.e., community-owned lands collectively managed by local residents) in pilots (I69). – Collaborate with local researchers and NGOs for adaptation and legitimacy (I69). – Conduct independent environmental and life-cycle assessments (I69).

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Annex 6. Detailed results

Table 14. FAAs and statements

Actor commitment & influence
− Adoption of CDR technologies heavily depends on the ideology and willingness of individual decision-makers and societal actors. − Ambitious emission reduction goals are essential to effectively address global climate challenges. − Ambitious national targets stimulate research and innovation toward diverse solutions. − Bioenergy with carbon capture and storage (BECCS) plays a critical role in meeting international climate targets. − CDR can be implemented through decentralized systems that utilize locally available resources, avoiding reliance on large-scale centralized facilities. − Civil society and NGOs both support and contest CDR, influencing projects through advocacy, action, and debate. − Conflicting values and contradictions often arise when actors reject some solutions while accepting others with similar or opposing principles. − Different CDR approaches, such as BECCS, forest carbon uptake, CCS, and CCU, can compete spatially and economically, requiring careful policymaker balancing. − Effective CDR development requires actors to engage responsibly, demonstrating competence and clear mandates in their advocacy and actions. − Effective climate strategies combine multiple CDR approaches within broader portfolios that also support ecosystem restoration. − Effective implementation depends on political frameworks, as scientific progress and market development rely on policy support. − Entrenched market structures create barriers that delay the adoption of innovative technologies. − Environmental activism can sometimes oppose or challenge the development and acceptance of CDR solutions. − European experts are not supportive towards integrating AF in ETS trading schemes. − Experts are positive towards the deployment of BECCS. − External political pressures impact national and regional strategies for carbon removal implementation. − Industrial actors from related sectors, such as mining or energy, can play a key role in promoting and advancing the deployment of CDR technologies. − Industry players, including petrochemical and mining sectors, bring essential resources and expertise, but their involvement requires transparent legitimization through non-private and associative actors. − Local governance structures and policies need to evolve to accommodate and support emerging climate mitigation technologies like CDR. − Local stakeholders such as biomass producers and landowners play crucial roles and bear significant responsibility in advancing carbon removal efforts. − Long-term climate policies are necessary to enable the ongoing implementation and scaling of CDR solutions. − Policy frameworks that support integration with current industrial systems help promote the adoption and spread of CDR solutions. − Policy instruments supporting CDR technologies are often temporary and need careful design to ensure sustained impact. − Policymakers and government agencies play a crucial role in clarifying ambiguities in legislation and international agreements. − Political and ideological forces significantly shape which carbon removal technologies receive attention and funding. − Political commitment and credible emission reductions are fundamental to aligning CDR efforts with climate objectives. − Political commitment and prioritization at multiple levels are critical for advancing CDR within broader climate and environmental agendas. − Political preferences can bias research agendas toward specific CDR approaches while sidelining others. − Political preferences often lean toward technological fixes rather than natural or systemic approaches when pursuing ambitious goals. − Political will and awareness are critical prerequisites for the successful deployment and acceptance of CDR technologies. − Powerful industry actors and lobby groups influence policy decisions and the development of carbon removal markets. − Powerful market players may slow down innovation to protect their economic advantages. − Public acceptance of CDR is limited and selective, with skepticism especially pronounced toward certain technologies like CCS, and a need for stronger public sector leadership in driving development and market uptake. − Regional willingness to adopt new technologies influences their successful implementation. − Scientific independence in carbon dioxide removal is challenged by actor influence, with academics and authorities shaping evidence and often engaging in adversarial rather than collaborative critique.

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– Strong and consistent political leadership at all levels is essential to drive the development and implementation of carbon removal policies. – Tackling global challenges requires sustained international political commitment and coordinated agreements to align efforts across nations. – Technological progress in CDR often depends on breakthroughs supported by enabling political conditions. – The broader political environment, including governance structures and centralization of decision-making, significantly influences CDR policy outcomes. – The commercial motivations behind some CDR projects raise concerns about the true effectiveness of their climate impact. – The geographical focus of CDR research and deployment is often determined by political priorities and interests. – The involvement of large corporations and industries is essential to enable the scaling of CDR technologies. – The uptake of new technologies largely depends on the interests and decisions of market actors.
Administrative feasibility & coordination
– Clear and enforceable regulations are necessary to guarantee compliance in relevant activities. – Clear regulations are needed to define limits on resource use or activity levels at specific locations to ensure safe and compliant project operation. – Clear regulatory frameworks and legal adaptations are essential to support the development and implementation of CDR technologies. – Dedicated programs and administrative mechanisms are required to enable and sustain the deployment of CDR at scale. – Divergent regulations, fragmented market systems, and inconsistent rules across regions create significant uncertainty and complexity for coordination and implementation across borders. – Existing stringent regulations for biomass use provide a foundation for maintaining safety and sustainability within CDR-related biomass practices. – Legal restrictions can pose significant challenges to site establishment and project deployment. – Permitting and administrative processes for projects are often complex, fragmented, and require coordination with multiple authorities, extensive documentation, and preparatory studies, which can hinder implementation. – Regulations often struggle to keep pace with the rapid advancement of new technologies. – Regulatory frameworks need to strike a careful balance to prevent excessive administrative burdens that could slow down certification processes and hinder market growth. – Unclear, excessive, or poorly adapted regulations create uncertainty and block CDR development, as rules are often undefined, inconsistent, or imposed without full understanding of the technologies.
Carbon storage capacity
– Carbon dioxide removal (CDR) technologies contribute directly to mitigating climate change by reducing the amount of CO_2 in the atmosphere. – CDR effectiveness is often limited by temporary or saturation effects, reducing long-term removal potential. – CDR effectiveness is uncertain and depends on balancing potential carbon removal with associated limitations and side effects. – CDR performance must meet a reasonable threshold to justify its implementation. – Storage capacity should be sufficient to accommodate the amount of carbon captured, but uncertainties about availability remain. – The effectiveness of different CDR approaches varies, and some methods currently have limited impact on reducing climate change effects. – The storage of carbon dioxide raises biggest concerns.
Communication & education
– Clear, accessible, and transparent information is essential to improve public understanding but does not always translate into higher acceptance of CDR. – Clear, transparent, and tailored communication about project goals, benefits, and potential impacts is essential to address concerns and secure broad social support. – Effective communication from policymakers is important for how AF is perceived – Effective communication must address complexity and abstractness to prevent misconceptions and build informed awareness. – Effective demonstration of additionality is to prove that emissions reductions would not have been realized without the offset credit. – Effective education and knowledge dissemination are essential to raise awareness and understanding of carbon dioxide removal across diverse societal groups. – Familiarity with existing carbon removal technologies can influence how they are perceived and accepted by the public and stakeholders. – Familiarity with the technology increases the reliance on the own knowledge – How concepts, benefits, and mechanisms are explained greatly affects public comprehension, making clear, accessible, and accurate framing crucial.

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– Informal communication channels, such as peer-to-peer exchange and community networks, play a crucial role in spreading knowledge and encouraging adoption of CDR practices. – Media coverage and societal discourse play a critical role in shaping public perceptions, though understanding of the links between CDR and broader climate goals remains limited. – Ongoing efforts to understand and address public knowledge gaps, fears, and attitudes strengthen stakeholder engagement and contribute to a just and informed transition toward CDR. – Political leaders require comprehensive knowledge of CDR options to support sound policy decisions and climate action. – Resistance to CDR often stems from skepticism about its promises, potential risks, and unintended consequences. – Sensationalized and misleading media coverage about carbon dioxide removal fosters public confusion and misperceptions, distorting the information landscape and undermining market confidence in CDR. – Simplifying complex CDR technologies into accessible language is key for engaging local communities and fostering informed public dialogue. – Social media platforms often amplify misinformation and skepticism, creating barriers to public acceptance of carbon dioxide removal technologies. – The availability of knowledge, tools, and established practices supports smoother implementation and greater acceptance of CDR approaches. – The decline of local media and the rise of social media have weakened public discourse, compromising accurate understanding of carbon dioxide removal technologies. – The positive economic contributions of climate-related projects to local municipalities should be clearly recognized and communicated.
Complementarity of technologies and trade-offs
– A broad and diverse mix of CDR methods is essential to address the varied strengths and limitations of individual approaches. – Exploring all possible CDR methods is critical to effectively tackle the complexity of the climate challenge. – Implementation of CDR technologies often involves trade-offs among environmental goals, economic interests, political agendas, and social needs, creating tensions among stakeholders. – No single CDR approach can solve the climate challenge alone; diverse solutions are necessary to address different emission sources. – Technologies should be adaptable and flexible, enabling tailored approaches to diverse goals and contexts.
Cooperation
– Collaboration and co-ownership between municipalities and companies shape the legitimacy and local acceptance of CDR projects like BECCS. – Coordinated collaboration across multiple levels, from local communities to international actors, is necessary to align interests and effectively scale CDR initiatives. – Coordinating different CDR methods is essential to enhance positive interactions and minimize potential conflicts. – Coordination challenges arise from unclear roles and responsibilities among authorities and institutions involved in CDR. – Effective CDR deployment requires coherent and aligned policies across different governance levels and jurisdictions. – Greater collaboration and coordination among all relevant stakeholders is essential for effective progress. – Lower level governments are less likely to participate in forest carbon offsets due to the lack of information and communication between different scales of government. – Managing complex project chains requires clear and well-structured contractual relationships. – Successful implementation of complex solutions depends on collaboration across multiple sectors and disciplines, combining expertise from technology, economics, industry, government, and environmental groups.
Distributive justice
– CDR development should avoid creating or perpetuating environmental sacrifice zones, exploitative supply chains, or neo-colonial dynamics that marginalize vulnerable populations. – CDR efforts must ensure fair distribution of burdens and benefits by preventing unequal advantages or disadvantages caused by market rules, standards, or regulations. – It is preferable that solutions can be widely used by many different users. – Recognition and fair compensation should be given to existing good practices and contributions, especially from local and vulnerable communities involved in or affected by CDR. – Solutions that can be applied by a broad range of users tend to have greater impact and adoption. – The distribution of costs and responsibilities for financing carbon storage and removal remains unclear, creating uncertainty for widespread implementation.

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Economic impact (local, general)
– (No matching summary statement, as this is a contextual note rather than about employment/workforce impact) – Afforestation projects can reduce poverty in rural areas. – CDR activities offer pathways for a just transition by providing alternative employment options, especially for workers affected by the decline of fossil fuel industries. – CDR can create direct economic value by generating new income streams from land use and natural resources. – CDR can generate positive economic effects at the local community level through job creation and enhanced economic activity. – CDR development and deployment can generate new job opportunities and contribute to local economic growth through increased employment and tax revenues. – CDR provides broader economic co-benefits by stimulating growth across multiple industries, markets, and value chains. – Economic benefits from co-products and by-products of CDR-related activities can support sustainable land use and resource management. – Innovative solutions have greater chances of success when they align with and support existing industries by offering mutual benefits without disrupting ongoing economic activities. – Local communities are directly influenced by the availability and quality of jobs created by CDR projects, which can have both positive and negative social impacts. – Sustainable environmental activities can bolster local economies by generating income, supporting businesses, and empowering rural and resource-dependent communities. – The deployment of CDR technologies can contribute to reducing costs in related sectors, such as agriculture and resource production. – The integration of CDR within existing industrial sectors can promote economic growth by enabling emissions reductions alongside production. – With BECCS local heat prices can be stabilized.
Economic viability & business case
– BECCS has a higher potential in high-income countries in the short-term due to available funding, technology, etc. – Carbon removal projects often face financial challenges due to upfront investments and delayed returns, affecting landowners and businesses. – Commercial viability depends on businesses identifying profitable opportunities and scaling to meet growing demand. – Consumer willingness to pay higher prices is limited, as there is often resistance to increased costs or difficulty passing them along the supply chain. – Corporate actors increasingly view CDR as a strategic tool to meet net zero targets, which can accelerate investment but also raise questions about market dynamics and fairness. – Cost-effectiveness (of afforestation abroad) increases acceptance – Economic interests frequently take precedence over environmental priorities in decision-making around CDR projects. – Economic viability and profitability are crucial factors influencing the adoption and scaling of carbon dioxide removal solutions. – High costs associated with transaction, verification, and implementation can limit the feasibility of small-scale or early-stage CDR initiatives. – High investment costs per project site present a significant financial challenge for CDR deployment. – Insurance and financial services sectors are showing growing interest in supporting emerging technologies. – Landowners will only participate in ETS trading schemes if the price per offset reaches a certain threshold that is beneficial for them. – Risks related to limited infrastructure options, such as storage availability, can increase costs and impact the economic viability of CDR technologies. – Technological advancements and scaling have the potential to reduce costs, improving the economic feasibility and competitiveness of carbon removal compared to conventional practices. – The cost of conventional energy sources strongly influences the adoption of new solutions. – The development of robust and clear business models is essential but currently uncertain across many carbon removal technologies. – The overall cost competitiveness of CDR technologies compared to alternative climate solutions is a key factor influencing their adoption. – The utilization rates of the CDR plant (BECCS) is sensitive for electricity prices and fuel prices. – There are uncertainties regarding the biomass prices, CO_2 prices, as well as prices for electricity and heat. – Valorizing mining waste is often costly and requires careful risk assessment, transport logistics, and regulatory permits.
Environmental impact & risk
– (Urban) AF must be compatible with urban planning – Active interventions in ecosystems are often necessary to optimize carbon sequestration outcomes.

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- AF should contribute to structural strengthening of the landscape
- Allocating land or space for new purposes can displace existing uses, leading to conflicts with agriculture, cultural activities, or other established sectors.
- BECCS contributes to enhanced environmental justice.
- CDR approaches must be planned and managed to prevent pollution, contamination, and harm to human health and ecosystems, considering local environmental and site-specific factors.
- CDR contributes to ecosystem restoration and resilience while removing carbon from the atmosphere.
- CDR generates multiple climate and environmental co-benefits beyond carbon removal, promoting overall ecosystem and landscape health.
- CDR helps mitigate pollution by capturing or immobilizing harmful substances.
- CDR improves soil health, agricultural productivity, and plant resilience.
- CDR interventions can pose risks to water quality, soil health, and local environmental conditions, requiring careful management to minimize harm.
- CDR supports biodiversity and enhances a range of ecosystem services.
- CDR technologies can enhance food security by improving degraded soils and increasing arable land availability.
- Choices to enhance one CDR method (e.g., increasing forest carbon sinks) may conflict with other land uses or environmental objectives, necessitating compromises.
- Concerns about environmental risks, including impacts on wildlife and ecosystems, contribute to skepticism and opposition toward CDR technologies.
- Deploying new solutions can limit alternative uses of resources that support food production, livelihoods, or ecosystem services.
- Different CDR methods may prefer distinct storage environments, including onshore and offshore options, depending on suitability.
- Effective land management and restoration are essential to maintain or enhance ecosystem functions critical for carbon removal.
- Efficient use of biomass and other natural resources is important to maximize the climate benefits of CDR.
- Environmental impacts of CDR technologies are complex and not yet fully understood, with potential for unintended negative effects on ecosystems, biodiversity, and natural resources.
- Environmental solutions provide direct support to local agricultural and farming operations.
- Existing geological formations, including those used for oil and gas, can provide potential sites for carbon storage if properly evaluated.
- In afforestation, local environmental benefits, such as air quality, can be accounted for in other places when integrated in international offset schemes.
- Increased industrial activity often raises concerns about associated risks and potential negative impacts.
- Infrastructure development and operation associated with CDR may introduce additional environmental risks, such as habitat disruption, pollution, and safety hazards.
- Inputs and materials used must be sustainable and non-harmful to the environment.
- It is preferable if AF has an ecological quality
- Localized implementation models adapt CDR deployment to local contexts by using locally available resources, infrastructures, and applications tailored to specific sites and communities.
- Natural risks (e.g. wildfire, insect damage) compromise the permanence of storage.
- Site selection should prioritize locations with optimal natural characteristics to maximize carbon storage capacity.
- Soil restoration plays a valuable role in improving the effectiveness of carbon removal strategies.
- Sometimes the primary goal of a technology lies beyond its main headline function, with key benefits arising in related areas such as resource or ecosystem improvement.
- Supply chain activities can generate emissions that reduce the overall environmental benefits of a solution.
- Sustainable CDR requires thorough understanding of local environmental factors such as soil quality, climate, and ecosystem resilience.
- Sustainable implementation of CDR, including producing power through BECCS, is necessary to deliver meaningful climate benefits.
- The effectiveness and environmental safety of CDR depend on context-specific factors, including technology type, site conditions, and stakeholder trust and engagement.
- The energy needed for processing, transporting, and applying CDR methods raises concerns about their overall feasibility and emissions impact.
- The environmental renewability and impacts of CDR inputs (e.g., biomass sources) depend on their origin and management, emphasizing the need for context-specific assessment and precaution.
- The risk to animals should be minimized when EW is employed.
- The suitability of technological interventions is shaped by specific local environmental conditions and land characteristics.

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– Using agricultural land for non-food purposes should be minimized to protect food availability and affordability.
Evidence base
– Advancing knowledge requires strong scientific cooperation and interdisciplinary partnerships. – Comprehensive research, trials, and evidence are essential to fully understand the potential, risks, and safe deployment of CDR approaches. – Current scientific knowledge supports some CDR methods but also reveals significant uncertainties and knowledge gaps that require further investigation. – Decision makers often lack sufficient technical background and resources to thoroughly evaluate and govern the range of CDR technologies. – Increasing research about EW is generally supported by the general public. – Independent and peer-reviewed studies must address methodological limitations and openly disclose uncertainties to build credible validation for CDR deployment. – Independent and scientific research reduces the perceived risks related to the technology. – Keeping up-to-date with the evolving state-of-the-art in research and practice across diverse CDR methods is challenging for stakeholders. – Pilot projects and early large-scale implementations showcase technological feasibility, inform policy leadership, and help accelerate the broader scaling of CDR solutions. – Scientific consensus is often lacking on key aspects of CDR technologies, highlighting the need for ongoing research to assess both benefits and potential negative side effects. – Scientific research and rigorous, transparent measurement are essential to verify the effectiveness, safety, and environmental impacts of all CDR approaches. – Seeing successful local examples and early adopters encourages others to replicate and adopt CDR technologies by building trust and reducing perceived risks. – Societal interest and support tend to focus on a limited subset of well-known or familiar CDR technologies, potentially sidelining emerging options. – Systematic approaches to selection of potential sites strengthens the acceptance of local authorities – The coexistence of numerous positive claims about CDR technologies can create confusion and reduce overall trust in their legitimacy. – The safety and stability of carbon storage, including risks of leakage or reversal, require ongoing scientific assessment and management. – Time constraints driven by emission reduction goals limit the opportunity for prolonged research and development phases. – Uncertainty regarding outcomes and timing can limit willingness to commit investment resources.
Financial incentives
– Effective climate policies and legislation are essential to create economic incentives and regulatory certainty for CDR deployment. – Existing subsidies often favor established industries or technologies rather than emerging solutions. – Financial incentives play a key role in motivating stakeholders to participate in carbon removal activities. – Financial incentives, including taxation, subsidies, and carbon markets, play a crucial role in motivating individuals, companies, and industries to adopt and invest in CDR technologies. – Financing structures, capital investments, and operational expenses critically affect the affordability and scalability of CDR projects. – Forest carbon offsets are a mechanism that ensures sectors not included in the ETS to be included in incentivizing emissions reduction and technological development – Forest carbon offsets should follow domestic priority when being integrated in international trading schemes (local over international offsets accounting) – Incentive systems can encourage prioritizing profits, subsidies, or offsets over genuine impact or sustainability. – Initial government funding and public subsidies are essential to kick-start carbon removal projects. – Investor confidence is weakened by uncertainty around financial returns, performance outcomes, and timelines. – Market mechanisms like carbon certificates alone may not provide sufficient or ideal incentives; diversified income sources are preferred to support CDR projects. – Market mechanisms like carbon offset trading can stimulate adoption of new technologies. – New markets for innovative solutions often begin as voluntary initiatives. – Policymaking around CDR deployment must balance cost-effectiveness and efficient use of public funds to ensure sustainable financing. – Smaller firms are less likely to participate in offset markets, while large firms who have carbon reduction obligations are more likely to participate in forest carbon offset markets. – Sustainable and adequate investment is critical to support the development, deployment, and scaling of CDR technologies. – The speed and scale of carbon removal implementation depend heavily on available financing. – Voluntary and compliance-based financial mechanisms both contribute to incentivizing CDR, but voluntary markets alone are insufficient to drive large-scale adoption.

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– Voluntary market mechanisms without sufficient oversight tend to reduce trust in the overall CDR system.
Infrastructure availability
– Achieving scalability requires addressing practical constraints like infrastructure demands, minimum viable scale, slow processes, and challenges in moving from pilot projects to large-scale deployment. – Careful planning of transportation logistics is essential to manage increased traffic and operational complexity as CDR scales up. – Existing industrial infrastructure and processes can be leveraged to facilitate the deployment and expansion of CDR at scale. – Existing infrastructure and access to efficient transport options improve the feasibility of CDR deployment. – Integrating new solutions into existing infrastructure can help reduce the need for additional resource consumption. – Large-scale CDR deployment depends on coordinated logistics and infrastructure involving multiple sectors and stakeholders. – Proximity between resource inputs, capture sites, and storage locations is critical for maintaining economic and environmental feasibility. – Proximity to suitable storage sites enhances the efficiency and feasibility of CDR implementation. – Scalability depends on broad applicability, availability of resources, existing infrastructure, and the ability to replicate solutions through smaller units or integration with current systems. – The development of infrastructure in shared environments can impact other stakeholders and users. – Transporting large volumes of materials and CO_2 over long distances presents significant cost, environmental, and operational challenges.
Intergenerational justice
– A holistic approach to CDR is necessary, considering social and environmental impacts while striving to maximize benefits equitably across current and future generations. – CDR is perceived as a short-term solution to long-term problems. – CDR measures provide additional long-term benefits by addressing climate impacts on ecosystems and vulnerable communities. – Monitoring and maintaining carbon storage integrity is a long-term responsibility that may extend to future generations. – The ethical legitimacy of any intervention is questioned when profit motives dominate or when actions risk violating moral boundaries by excessively altering natural systems. – There are temporal dilemmas between short-term and long-term implications of CDR. – There is a moral obligation to contribute to climate change
Labor & skills availability
– Adequate availability of trained workers is crucial for effective CDR implementation and acceptance, as labor shortages hinder project success and stakeholder confidence. – The workforce needs during CDR project construction are higher due to specialized labor demands, while operational phases typically require fewer personnel focused on corporate and technical management.
Liability & enforceability
– Careful oversight is essential to avoid unintended environmental impacts such as ecosystem disruption, fire risks, and habitat degradation associated with CDR activities. – Effective compliance mechanisms are essential to ensure that all actors meet their responsibilities and do not misuse solutions to evade proper mitigation efforts. – Monitoring and oversight systems are critical but often remain inadequate for ensuring effective management and results. – Robust governance and institutional structures must be established to support the planning, implementation, and oversight of CDR technologies. – Uncertainty over which party holds responsibility or credit can create legal and operational risks. – Unclear allocation of responsibilities and regulatory frameworks among different sectors or jurisdictions adds to the complexity of managing innovative solutions. – Weak global policy frameworks can undermine motivation for collective action.
Market demand
– Certain solutions may initially serve niche markets before broader expansion. – Consumer and market demand play a critical role in driving the adoption of new technologies. – Market development relies on the presence and growth of demand-creating frameworks that support the adoption of new solutions.
Mitigation deterrence & additionality
– Carbon dioxide removal should work alongside emission reduction efforts, playing varying roles at different stages of climate action. – Carbon removal is important, but prioritizing actual emission reductions remains essential to effectively address climate change.

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– Carbon storage or removal does not eliminate emissions immediately but may temporarily mask ongoing environmental impacts. – CDR is about mitigation, so it does not help to solve the root of the "problem" - non-transition solution. – Climate discourse should focus on emission avoidance and prevention rather than overreliance on carbon removal as a solution. – Climate-related political pressure motivates policymakers to act, impacting the prioritization of carbon removal strategies. – Exploiting fossil resources to enable emission reduction or capture contradicts the goal of decarbonization and should be avoided. – Incorporating captured carbon into long-lived products helps extend climate benefits by delaying re-emissions and replacing carbon-intensive materials. – Innovative solutions can support the transition away from fossil fuels by providing renewable or carbon-neutral alternatives while reducing overall emissions. – Negative emissions achieved through CDR are essential for meeting global climate targets and complement emission reduction efforts. – New interventions may displace or reduce the effectiveness of existing mitigation options that offer equal or greater climate benefits. – Overemphasizing carbon removal risks enabling continued pollution by shifting responsibility away from direct emission cuts. – Pragmatic approaches, rather than rigid ideological views, are essential for effective climate action. – Relying on carbon removal can create incentives to delay or avoid necessary long-term emission reductions. – Responsibility for addressing carbon dioxide removal is often diffused, with political, industrial, and societal actors sometimes deflecting accountability. – Some companies use certain solutions primarily to enhance their sustainable or social responsibility image, without addressing underlying systemic issues. – The critical urgency requires utilizing all available methods without delay, rather than waiting for perfect or future solutions. – The pressing nature of the global climate crisis demands immediate action to deploy effective solutions. – There is scepticism that certain CDR methods may enable polluting entities to avoid reducing their own emissions, undermining genuine climate action. – There is the risk that emissions reductions are not realized under the ETS schemes. – There remains a need for technologies that address emissions even as fossil fuel use persists during the transition to cleaner energy systems.
MRV & certification
– Additionality requirements are often seen as complex, subjective, and lacking clear global standards. – Additionality rules may create unintended incentives that distort ecological or project design choices. – Allowing multiple claims on the same outcome undermines environmental integrity completely. – Certification systems must balance capturing the full climate benefits of CDR projects, including principles like co-claiming, to ensure fair valuation and facilitate carbon credit trading, which currently requires simplification and standardization to reduce labor intensity. – Changing how resources are classified and valued can drive shifts in societal norms and behaviors. – Clear distinctions between related but different concepts are essential to avoid confusion in communication and decision-making. – Conservative and cautious accounting of CO_2 removal is necessary to prevent misleading impressions of environmental benefit. – Effective certification systems for CDR require robust, scientifically supported monitoring, reporting, and verification (MRV) procedures to ensure credibility, trustworthiness, and accurate measurement of carbon removal and storage. – Global and regional certification frameworks, such as those being developed at the EU level, play a crucial role in enabling wider acceptance and scaling of CDR technologies, but their methodologies and implementation remain critical. – Governmental and market support for CDR is often contingent on meeting sustainability certification requirements, emphasizing the need for integrated frameworks that link biomass sustainability and carbon removal certification. – Implementation of safeguards and certification frameworks is essential to ensure CDR sustainability and prevent unintended environmental or social harms. – Laws and regulations must compel businesses to adopt socially and environmentally responsible practices. – Legal and contractual risks arise from unclear ownership, limited contract frameworks, timing issues, and lack of enabling regulations. – Major challenges of afforestation offset schemes are leakage, permanence, additionality and complexity of carbon accounting schemes. – Market mechanisms should operate within a well-defined climate policy framework to guide CDR uptake. – Stable, predictable, and adaptive regulatory frameworks are crucial to reduce investment risks, provide long-term policy certainty, and allow flexibility to respond to technological and environmental changes. – Technologies that are more controllable and transparent tend to be viewed as more trustworthy by stakeholders.

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– The carbon dioxide movement tracking (under ground) is challenging. – The complexity and development of MRV and certification frameworks vary significantly across different CDR approaches, creating challenges and gaps in standardization, recognition, and eligibility within carbon markets. – The development and evolution of policy frameworks and regulatory guidelines are necessary to provide clear pathways for CDR adoption. – The development of CDR markets and policies should be grounded in robust, evidence-based understanding of the technologies' actual carbon removal capacity and environmental performance. – Transparency and robustness in CDR claims, certifications, and monitoring are essential to maintain credibility and public trust.
Permanence
– Anthropogenic risks (e.g. logging) compromise the permanence of storage. – Different types of carbon removal approaches vary in permanence, which should be carefully considered in their application and accounting. – Long-term carbon storage must ensure high permanence and durability to effectively contribute to climate goals. – Matching the type of carbon removal to the specific emissions being targeted improves overall effectiveness and efficiency.
Physical proximity
– Local communities often experience direct impacts from CDR projects situated near them, which can influence their support or opposition. – People living close to a CCS facility are more positive than people living far away.
Preference for naturalness
– Afforestation programmes with polycultures is preferred – CDR does not reflect the idea that the general public has about a vision of a sustainable future. – CDR is needed as climate change is a concern – CDR should not tamper with nature (to be receive public support) – Differences in professional roles and personal values influence preferences between technological and nature-based carbon removal approaches. – Fossil fuel sources of CO_2 are less favourable than industrial or bioenergy sources. – General trust in carbon dioxide removal arises from its proven environmental effectiveness and alignment with natural processes, fostering broad social acceptance and resilience to changing political conditions. – Generally, least intensive forest management is the most preferred way for afforestation. – Many individuals and environmental entrepreneurs are deeply motivated by emotional connections to nature and a strong sense of moral responsibility to protect the environment. – Market-driven systems tend to favor technical solutions over natural or ecosystem-based ones, raising concerns about ethical priorities. – Natural processes themselves are often distinguished from engineered methods and may be valued differently in climate strategies. – People's willingness to engage with climate action is often driven by intrinsic values rather than external rewards or incentives. – Renewable and bio-based solutions generally receive more positive acceptance compared to fossil-based alternatives. – Solutions that align with or mimic natural processes are generally perceived as more environmentally appropriate and gain higher acceptance. – Technologies seen as more natural tend to be more attractive and positively valued by the public. – The preference for natural or nature-inspired approaches varies depending on regional and cultural contexts. – The public prefers natural/conventional CDR technologies over technological CDRs.
Procedural justice
– Conflicts often arise between business interests and the need for open, transparent communication with local communities and the public. – Empowering local and marginalized communities through inclusive decision-making and control over natural resources is critical to avoid reinforcing existing social inequities. – Farmers need to have the option to opt out from afforestation programs. (flexibility of contracts) – Local NGOs provide valuable expertise but are often excluded or have limited participation in environmental decision-making processes. – Participatory processes that involve affected communities and societal actors in decision-making help ensure policies and implementations are equitable and responsive to local needs.

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– Successful carbon dioxide removal projects require early, continuous, and inclusive engagement of all relevant stakeholders to build trust and facilitate acceptance.
Public understanding & awareness
– Attention towards CDR has grown over the last years. – Awareness and understanding gaps among stakeholders influence the willingness and capacity to adopt and implement carbon dioxide removal solutions effectively. – Local communities and policymakers often lack sufficient awareness of CDR projects, leading to questionable decisions and missed opportunities for engagement. – Misinformation, limited communication, and unfamiliarity with technical details create barriers to social acceptance and trust in CDR initiatives. – Novel or less-known CDR methods often face challenges in acceptance due to limited awareness and understanding. – People tend to relate new risks to familiar hazards, sometimes amplifying their concerns beyond actual risk levels. – Public knowledge and awareness of CDR technologies remain low, limiting widespread understanding of their potential and implications. – Public misconceptions and lack of awareness about carbon removal technologies present ongoing barriers that education efforts must address. – Public perception may overlook distinctions between different carbon removal methods or land uses, leading to simplified or generalized views. – Risk perception is strongly influenced by uncertainty and limited knowledge, which can lead to cautious or negative responses. – The general awareness about EW is low. – The majority of the general public tends to be neutral about EW as a CDR method. – There is a higher awareness towards natural CDRs (afforestation) than technological CDRs. – While younger generations tend to be more open to adopting new CDR technologies, debates around CDR can become highly emotional, sometimes challenging purely rational decision-making. – Perceived risks has a negative effect on the public support for CDR
Resource intensity
– Circular carbon use enables the transformation of captured CO_2 into valuable products, linking carbon sequestration with resource efficiency. – Complex chains of processes often require substantial electrical energy input. – High demand for natural resources can create competition among different sectors and uses. – It is important that production processes minimize or avoid generating additional carbon emissions. – Limitations such as resource scarcity, competition, production capacity constraints, and uncertain assessments can hinder technology scalability and raise concerns about long-term material sufficiency. – Meaningful impact often requires substantial physical inputs such as labor, equipment, materials, and space. – Ongoing innovation and integration of new materials and processes are key to expanding and enhancing CDR capabilities. – Some climate solutions inherently involve producing or consuming large amounts of energy as part of their operation. – Successful deployment and scaling of removal technologies depend on the reliable availability, accessibility, and sustainable sourcing of necessary materials from natural deposits, waste streams, or byproducts. – The choice of transport fuels and logistics plays a significant role in the total emissions footprint. – The demand for raw materials in one application may divert resources from alternative valuable uses, increasing cross-sector competition. – The mining industry's ability to use its waste in CDR could provide beneficial synergies, but practical challenges remain. – The overall supply of biomass and other critical inputs for certain removal methods is inherently limited by sustainability and ecological constraints. – The physical and chemical characteristics of materials determine their compatibility with different CDR processes and impact overall efficiency and effectiveness. – The scale-up of biomass use influences landscape composition and forest management practices. – The sustainable use and protection of natural resources, such as forests and bioresources, require ongoing environmental and social debate and responsible management. – Unintended side-effects, including the consumption of extra resources, should not exceed the benefits delivered by the solution. – Using existing infrastructure for new solutions can help maintain overall energy efficiency. – Utilizing by-products or residual resources from one sector to support another can enhance overall efficiency and create beneficial synergies. – Utilizing waste streams, including mining waste, as feedstocks for CDR presents opportunities to add value and integrate carbon into industrial processes. – Variability and heterogeneity in materials can introduce operational challenges and limit the optimization and reliability of CDR technologies.

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– While global reserves of essential raw materials may be ample, local extraction capacities and infrastructure often need to expand to meet demand for technology deployment.
Risk management & best practices
– Careful planning, design, and strict adherence to established best practices are necessary to minimize risks and optimize CDR effectiveness. – In the absence of national guidelines, reliance on best practices is critical but can still pose safety risks for CDR projects. – Safety risks related to handling hazardous materials are a common source of public worry. – Technological control combined with rigorous operational standards is vital for the safe and effective deployment of industrial-scale CDR methods.
Societal impact
– Changes in land use associated with CDR can generate resistance when they negatively affect local residents' livelihoods or environment. – Employment in CDR sectors may involve health and safety considerations for workers involved in production and application processes. – Innovations can contribute to broader social transformations towards more sustainable practices. – Innovative solutions offer versatile applications, providing multiple benefits beyond their primary purpose. – Land or resource allocation decisions must consider competing provisional, cultural, and economic uses to manage conflicts effectively. – Minimizing environmental and social harm is critical, favoring solutions with low impact and consideration of cumulative, long-term, and regional effects. – Minimizing negative impacts on land use is a key consideration for sustainable carbon dioxide removal approaches. – Perceived benefits is a main driver for public support of CDR – Positive side-effects enhance the attractiveness and acceptance of a technology for implementation. – Social acceptance and trust require alignment between the technology's readiness and the broader societal and stakeholder expectations. – Technologies can provide multiple simultaneous benefits across different sectors, combining their core function with additional environmental and economic advantages. – Technologies should be recognized for their potential to deliver benefits beyond their primary objective, contributing to broader sustainability goals. – The appropriateness of deploying a technology depends on environmental factors as well as socio-economic, cultural, and political conditions of the region. – The risk to humans should be minimized when EW is employed. – There is a need to balance short-term benefits with potential long-term impacts when implementing infrastructure or technologies.
Socio-cultural background
– Acceptance of innovative solutions depends strongly on local culture, traditions, and how communities relate to their environment and resources. – Cultural norms, traditions, and entrenched beliefs contribute significantly to reluctance in adopting new CDR technologies. – Cultural values, such as the significance of trees, play an important role in shaping public attitudes toward CDR solutions. – It is preferable if AF has a recreational value – Land-based CDR is preferred over ocean-based CDR. – Local values and priorities, including political considerations, significantly influence how CDR projects are planned and accepted. – Social and cultural perceptions of technologies can vary significantly between regions and groups. – Social opposition from affected communities significantly affects political and public acceptance of CDR initiatives. – The connection between communities and technologies is shaped by local historical and cultural contexts. – Understanding and acceptance of new approaches are influenced by the specific social and cultural backgrounds of each community. – While younger generations tend to be more open to adopting new CDR technologies, debates around CDR can become highly emotional, sometimes challenging purely rational decision-making.
Technological maturity & complexity
– Accelerating development and improving the efficiency of emerging CDR technologies is essential to meet economic and practical viability. – Achieving climate targets necessitates swift and successful deployment of technologies, with little room for prolonged delays or failures. – Achieving net zero emissions requires scaling up all available carbon dioxide removal technologies. – Carbon dioxide removal technologies are at varying stages of development, with limited practical examples and a need for continued innovation and learning. – Carbon dioxide removal technologies differ widely in their level of technological readiness and maturity, affecting their potential for deployment.

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– CDR innovation involves complex and interdependent processes across disciplines, scales, and learning curves, where scaling up can introduce new technical, logistical, and systemic challenges. – CDR must strive for simplicity to enhance feasibility and adoption. – Certain resource use practices can be inefficient in their energy conversion or production. – Integrating multiple functions or outputs in a technology can create synergies that increase overall efficiency and value. – It is preferable if AF can be immediately realized – Local communities frequently express safety concerns regarding new technologies or interventions. – Proven and well-established CDR methods are more likely to be adopted and scaled by industry and stakeholders. – Rapid implementation and timely results are essential to address urgent environmental challenges. – Some CDR approaches require long timeframes to reach full operational maturity and effectiveness. – Some CDR approaches require the development of new industrial systems, while others can be incorporated into existing operations. – The application of biochar (and EW and MCO_2) cannot be reversed once applied to the soil. – The complexity and operational status of CDR technologies influence the ease and speed of implementation and monitoring. – The potential for scaling an innovation must be realistic and feasible. – The potential of a technology varies depending on the context, timing, and level of maturity, and no option should be dismissed prematurely. – Uncertainty around market demand, user acceptance, and the readiness of applications influences the success and scaling of innovations. – Uncertainty around scaling opportunities can hinder the adoption and impact of new solutions.
Trust in actors, product, & process
– Higher level of trust in institutions (industry/science/government) strengthens public perceptions – Misrepresentation or exaggeration of benefits by policymakers damages credibility and public trust. – Past negative experiences and scandals can significantly undermine public trust in new CDR technologies and their governance. – Transparent, honest disclosure and unbiased communication about projects and their monitoring are essential to building trust in markets and society. – Trust in CDR technologies is strongly influenced by the perceived integrity and transparency of the institutions and actors involved.
Visual impact
– Activities that visibly alter landscapes can strongly influence how local communities perceive and accept them, especially when familiar views are changed. – Afforestation in rural areas can create a feeling of social isolation (being visually disconnected from neighbours). – CDR-related construction, transport, and operational activities can significantly affect local communities and wildlife, necessitating mitigation of noise and other disturbances. – Industrial facilities often appear visually similar to existing structures, which can affect public perception. – People tend to pay more attention to impacts they can see, while invisible or hidden processes often go unnoticed or unconsidered. – Perceived intrusiveness or threats from CDR projects can lead to strong local opposition, including protests and conflicts. – The visual attractiveness of forests (afforestation programs) is important. (type of tree, how the "margins" look, etc.) – Thinned forests are preferred over unthinned forests, because it allows people to use it (walk and bike in it).

Source: Own illustration

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Table 15. Triangle of social acceptance and level of acceptability, FAA and PESTELE category

		PESTELE						
Triangle of SA	FAA	Political	Economic	Social	Technological	Environmental	Legal	Ethical
Community acceptability	Distributive justice							x
	Economic impact (local, general)		x					
	Environmental impact & risk					x		
	Intergenerational justice							x
	Physical proximity			x		x		
	Preference for naturalness			x				
	Procedural justice	x						
	Resource intensity					x		
	Societal impact			x				
	Socio-cultural background			x				
	Technological maturity & complexity				x			
	Trust in actors, product, & process			x				
	Visual impact			x				
Market acceptability	Actor commitment & influence	x						
	Administrative feasibility & coordination						x	
	Carbon storage capacity				x			
	Economic viability & business case		x					
	Environmental impact & risk					x		
	Financial incentives		x					
	Infrastructure availability		x					
	Labor & skills availability		x					
	Liability & enforceability						x	
	Market demand		x					
	MRV & certification						x	
	Resource intensity		x		x	x		
	Technological maturity & complexity				x			
Socio-political acceptability	Actor commitment & influence	x						
	Carbon storage capacity				x			
	Communication & education	x		x				
	Cooperation	x						
	Distributive justice							x
	Economic impact (local, general)		x					
	Environmental impact & risk					x		
	Evidence base				x			
	Liability & enforceability						x	
	Mitigation deterrence & additionality				x			x
	MRV & certification						x	
	Permanence				x			

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		PESTELE						
Triangle of SA	FAA	Political	Economic	Social	Technological	Environmental	Legal	Ethical
	Preference for naturalness			x				
	Public understanding & awareness	x		x				
	Resource intensity					x		
	Risk management & best practices						x	
	Societal impact	x		x				
	Technological maturity & complexity				x			
	Trust in actors, product, & process			x				
	Complementarity of technologies and trade-offs				x			

Source: Own Illustration

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References

1. Aguilar, F. (1967). *Scanning the Business Environment*. MacMillan.
2. Aitken, M. (2010). Why we still don't understand the social aspects of wind power: A critique of key assumptions within the literature. *Energy Policy*, *38*(4), 1834–1841. https://doi.org/10.1016/j.enpol.2009.11.060
3. Andersen, P. D. (2025). *The PESTEL Framework and its Variants for Analysing the Strategic Environment: Evolution, Limitations and Adoption in Energy Policy Research* (SSRN Scholarly Paper No. 5266562). Social Science Research Network. https://doi.org/10.2139/ssrn.5266562
4. Anderson, K., & Peters, G. (2016). The trouble with negative emissions. *Science*, *354*(6309), 182–183. https://doi.org/10.1126/science.aah4567
5. Batel, S. (2020). Research on the social acceptance of renewable energy technologies: Past, present and future. *Energy Research & Social Science*, *68*, 101544. https://doi.org/10.1016/j.erss.2020.101544
6. Batel, S., Devine-Wright, P., & Tangeland, T. (2013). Social acceptance of low carbon energy and associated infrastructures: A critical discussion. *Energy Policy*, *58*, 1–5. https://doi.org/10.1016/j.enpol.2013.03.018
7. Batel, S., & Rudolph, D. (2021). A Critical Approach to the Social Acceptance of Renewable Energy Infrastructures. In S. Batel & D. *A critical approach to the social acceptance of renewable energy infrastructures: Going beyond green growth and sustainability* (pp. 3–19). Springer International Publishing. https://doi.org/10.1007/978-3-030-73699-6_1
8. Bellamy, R., Geden, O., Fridahl, M., Cox, E., & Palmer, J. (2021). Editorial: Governing Carbon Dioxide Removal. *Frontiers in Climate*, *3*. https://doi.org/10.3389/fclim.2021.816346
9. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa
10. Brendel, A. B., Mirbabaie, M., Lembcke, T.-B., & Hofeditz, L. (2021). Ethical Management of Artificial Intelligence. *Sustainability*, *13*(4), Article 4. https://doi.org/10.3390/su13041974
11. Busse, M., & Siebert, R. (2018). Acceptance studies in the field of land use—A critical and systematic review to advance the conceptualization of acceptance and acceptability. *Land Use Policy*, *76*, 235–245.
12. Campanella, F., Della Peruta, M. R., & Del Giudice, M. (2017). The Effects of Technological Innovation on the Banking Sector. *Journal of the Knowledge Economy*, *8*(1), 356–368. https://doi.org/10.1007/s13132-015-0326-8
13. Carayannis, E. G., & Rakhmatullin, R. (2014). The Quadruple/Quintuple Innovation Helixes and Smart Specialisation Strategies for Sustainable and Inclusive Growth in Europe and Beyond. *Journal of the Knowledge Economy*, *5*(2), 212–239. https://doi.org/10.1007/s13132-014-0185-8
14. Carton, W., Asiyanbi, A., Beck, S., Buck, H. J., & Lund, J. F. (2020). Negative emissions and the long history of carbon removal. *WIREs Climate Change*, *11*(6), e671. https://doi.org/10.1002/wcc.671
15. *Climate Change 2022—Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. (2023). Cambridge University Press. https://doi.org/10.1017/9781009157926
16. Corner, A., Parkhill, K., Pidgeon, N., & Vaughan, N. E. (2013). Messing with nature? Exploring public perceptions of geoengineering in the UK. *Global Environmental Change*, *23*(5), 938–947. https://doi.org/10.1016/j.gloenvcha.2013.06.002
17. Cotton, M. (2018). Environmental Justice as Scalar Parity: Lessons From Nuclear Waste Management. *Social Justice Research*, *31*(3), 238–259. https://doi.org/10.1007/s11211-018-0311-z

18. Cox, E., Spence, E., & Pidgeon, N. (2020). Public perceptions of carbon dioxide removal in the United States and the United Kingdom. *Nature Climate Change*, *10*(8), 744–749. https://doi.org/10.1038/s41558-020-0823-z
19. Dinçer, Ö. (2004). *Stratejik yönetim ve işletme politikası*. Beta Yayınları.
20. Duesberg, S., & Dhubháin, Á. N. (2019). Forest intensification in Ireland: Developing an approximation of social acceptability. *Land Use Policy*, *85*, 368–386.
21. Eren, E. (2002). *Stratejik yönetim ve işletme politikası*. Beta Yayınları.
22. Felt, U., Igelsböck, J., Schikowitz, A., & Völker, T. (2016). Transdisciplinary Sustainability Research in Practice: Between Imaginaries of Collective Experimentation and Entrenched Academic Value Orders. *Science, Technology, & Human Values*, *41*(4), 732–761.
23. Fournis, Y., & Fortin, M.-J. (2017). From social 'acceptance' to social 'acceptability' of wind energy projects: Towards a territorial perspective. *Journal of Environmental Planning and Management*, *60*(1), 1–21. https://doi.org/10.1080/09640568.2015.1133406
24. Frampton, G., Whaley, P., Bennett, M., Bilotta, G., Dorne, J.-L. C. M., Eales, J., James, K., Kohl, C., Land, M., Livoreil, B., Makowski, D., Muchiri, E., Petrokofsky, G., Randall, N., & Schofield, K. (2022). Principles and framework for assessing the risk of bias for studies included in comparative quantitative environmental systematic reviews. *Environmental Evidence*, *11*(1), 12. https://doi.org/10.1186/s13750-022-00264-0
25. Gaede, J., & Rowlands, I. H. (2018). Visualizing social acceptance research: A bibliometric review of the social acceptance literature for energy technology and fuels. *Energy Research & Social Science*, *40*, 142–158. https://doi.org/10.1016/j.erss.2017.12.006
26. Gough, C., & Mander, S. (2019). Beyond Social Acceptability: Applying Lessons from CCS Social Science to Support Deployment of BECCS. *Current Sustainable/Renewable Energy Reports*, *6*(4), 116–123. https://doi.org/10.1007/s40518-019-00137-0
27. Haikola, S., Anshelm, J., & Niskanen, J. (2024). Beyond the backyard: Scaling up of resistance to wind power in Sweden. *Environmental Challenges*, *16*, 100987. https://doi.org/10.1016/j.envc.2024.100987
28. Haikola, S., Hansson, A., & Anshelm, J. (2019). From polarization to reluctant acceptance–bioenergy with carbon capture and storage (BECCS) and the post-normalization of the climate debate. *Journal of Integrative Environmental Sciences*, *16*(1), 45–69. https://doi.org/10.1080/1943815X.2019.1579740
29. Heffron, R. J., & McCauley, D. (2018). What is the 'Just Transition'? *Geoforum*, *88*, 74–77. https://doi.org/10.1016/j.geoforum.2017.11.016
30. Heidbreder, E. G. (2012). Civil society participation in EU governance. *Living Reviews in European Governance*, *7*(2).
31. IPCC. (2022). *Carbon Dioxide Removal (Factsheet)*.
32. Jasanoff, S. (Ed.). (2004). *States of Knowledge: The Co-Production of Science and Social Order*. Routledge.
33. Jenkins, K., McCauley, D., Heffron, R., Stephan, H., & Rehner, R. (2016). Energy justice: A conceptual review. *Energy Research & Social Science*, *11*, 174–182. https://doi.org/10.1016/j.erss.2015.10.004
34. Jenkins, K., McCauley, D., & Warren, C. R. (2017). Attributing responsibility for energy justice: A case study of the Hinkley Point Nuclear Complex. *Energy Policy*, *108*, 836–843. https://doi.org/10.1016/j.enpol.2017.05.049
35. Katko, T. S. (2006). Road Safety Fatalities, Management, and Policy in Finland, 1970-2003. *Public Works Management & Policy*, *11*(2), 126–138. https://doi.org/10.1177/1087724X06294066
36. Kirch Kirkegaard, J., Cronin, T., Nyborg, S., & Karnøe, P. (2021). Paradigm shift in Danish wind power: The (un)sustainable transformation of a sector. *Journal of Environmental Policy & Planning*, *23*(1), 97–113. https://doi.org/10.1080/1523908X.2020.1799769

37. Low, S., Fritz, L., Baum, C. M., & Sovacool, B. K. (2024). Public perceptions on carbon removal from focus groups in 22 countries. *Nature Communications*, *15*(1), 3453. https://doi.org/10.1038/s41467-024-47853-w
38. Low, S., & Schäfer, S. (2020). Is bio-energy carbon capture and storage (BECCS) feasible? The contested authority of integrated assessment modeling. *Energy Research & Social Science*, *60*, 101326. https://doi.org/10.1016/j.erss.2019.101326
39. Markusson, N., McLaren, D., & Tyfield, D. (2018). Towards a cultural political economy of mitigation deterrence by negative emissions technologies (NETs). *Global Sustainability*, *1*, e10. https://doi.org/10.1017/sus.2018.10
40. McLaren, D., & Markusson, N. (2020). The co-evolution of technological promises, modelling, policies and climate change targets. *Nature Climate Change*, *10*(5), 392–397. https://doi.org/10.1038/s41558-020-0740-1
41. Minx, J. C., Lamb, W. F., Callaghan, M. W., Fuss, S., Hilaire, J., Creutzig, F., Amann, T., Beringer, T., de Oliveira Garcia, W., Hartmann, J., Khanna, T., Lenzi, D., Luderer, G., Nemet, G. F., Rogelj, J., Smith, P., Vicente Vicente, J. L., Wilcox, J., & del Mar Zamora Dominguez, M. (2018). Negative emissions—Part 1: Research landscape and synthesis. *Environmental Research Letters*, *13*(6), 063001. https://doi.org/10.1088/1748-9326/aabf9b
42. Newell, P., & Mulvaney, D. (2013). The political economy of the 'just transition'. *The Geographical Journal*, *179*(2), 132–140. https://doi.org/10.1111/geoj.12008
43. Nielsen, J. A. E., Stavrianakis, K., & Morrison, Z. (2022). Community acceptance and social impacts of carbon capture, utilization and storage projects: A systematic meta-narrative literature review. *PLOS ONE*, *17*(8), e0272409. https://doi.org/10.1371/journal.pone.0272409
44. Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, *16*(1), 1609406917733847. https://doi.org/10.1177/1609406917733847
45. Olsson, A., Rodriguez, E., Hansson, A., Jansson, S., & Fridahl, M. (2024). Forerunner city or net-zero opportunist? Carbon dioxide removal in Stockholm, residual emissions and risks of mitigation deterrence. *Energy Research & Social Science*, *113*, 103567. https://doi.org/10.1016/j.erss.2024.103567
46. Pidgeon, N. F., & Spence, E. (2017). Perceptions of enhanced weathering as a biological negative emissions option. *Biology Letters*, *13*(4), 20170024. https://doi.org/10.1098/rsbl.2017.0024
47. Pihkola, H., Tsupari, E., Kojo, M., Kujanpää, L., Nissilä, M., Sokka, L., & Behm, K. (2017). Integrated Sustainability Assessment of CCS – Identifying Non-technical Barriers and Drivers for CCS Implementation in Finland. *Energy Procedia*, *114*, 7625–7637. https://doi.org/10.1016/j.egypro.2017.03.1895
48. Prütz, R., Fuss, S., Lück, S., Stephan, L., & Rogelj, J. (2024). A taxonomy to map evidence on the co-benefits, challenges, and limits of carbon dioxide removal. *Communications Earth & Environment*, *5*(1). https://doi.org/10.1038/s43247-024-01365-z
49. Richardson, J. V. (2006). The Library and Information Economy in Turkmenistan. *IFLA Journal*, *32*(2), 131–139. https://doi.org/10.1177/0340035206066410
50. Scott-Buechler, C., Cain, B., Osman, K., Ardoin, N. M., Fraser, C., Adcox, G., Polk, E., & Jackson, R. B. (2024). Communities conditionally support deployment of direct air capture for carbon dioxide removal in the United States. *Communications Earth & Environment*, *5*(1), 175. https://doi.org/10.1038/s43247-024-01334-6
51. Selle, P., & Wollebæk, D. (2015). The Complex Relationship Between Civil Society and Trust. *Italian Sociological Review*, *Vol 5*, 273 Pages. https://doi.org/10.13136/ISR.V5I3.110
52. Shilei, L., & Yong, W. (2009). Target-oriented obstacle analysis by PESTEL modeling of energy efficiency retrofit for existing residential buildings in China's northern heating

region. *Energy Policy*, *37*(6), 2098–2101. https://doi.org/10.1016/j.enpol.2008.11.039
53. Smith, S. M., Geden, O., Gidden, M. J., Lamb, W. F., Nemet, G. F., Minx, J. C., Buck, H., Burke, J., Cox, E., Edwards, M. R., Fuss, S., Johnstone, I., Müller-Hansen, F., Pongratz, J., Probst, B. S., Roe, S., Schenuit, F., Schulte, I., & Vaughan, N. E. (2024). *The State of Carbon Dioxide Removal—2nd Edition*. The State of Carbon Dioxide Removal. https://osf.io/f85qj/
54. Sovacool, B. K., Baum, C. M., & Low, S. (2023). Reviewing the sociotechnical dynamics of carbon removal. *Joule*, *7*(1), 57–82. https://doi.org/10.1016/j.joule.2022.11.008
55. Sovacool, B. K., Bell, S. E., Daggett, C., Labuski, C., Lennon, M., Naylor, L., Klinger, J., Leonard, K., & Firestone, J. (2023). Pluralizing energy justice: Incorporating feminist, anti-racist, Indigenous, and postcolonial perspectives. *Energy Research & Social Science*, *97*, 102996. https://doi.org/10.1016/j.erss.2023.102996
56. Stemerding, D., De Vriend, H., Walhout, B., & Van Est, R. (2009). Synthetic Biology and the Role of Civil Society Organizations: Shaping the Agenda and Arena of the Public Debate. In M. Schmidt, A. Kelle, A. Ganguli-Mitra, & H. *Synthetic Biology* (pp. 155–176). Springer Netherlands. https://doi.org/10.1007/978-90-481-2678-1_10
57. Stirling, A. (2008). "Opening Up" and "Closing Down": Power, Participation, and Pluralism in the Social Appraisal of Technology. *Science, Technology, & Human Values*, *33*(2), 262–294. https://doi.org/10.1177/0162243907311265
58. Stirling, A. (2019). *Engineering and Sustainability: Control and Care in Unfoldings of Modernity* (SSRN Scholarly Paper No. 3336826). Social Science Research Network. https://doi.org/10.2139/ssrn.3336826
59. Teddlie, C., & Tashakkori, A. (2009). *Foundations of Mixed Methods Research: Integrating Quantitative and Qualitative Approaches in the Social and Behavioral Sciences*. SAGE.
60. Teddlie, C., & Yu, F. (2007). Mixed Methods Sampling. *Journal of Mixed Methods*, *1*(1), 77–100. https://doi.org/10.1177/1558689806292430
61. Tricco, A. C., Antony, J., Zarin, W., Strifler, L., Ghassemi, M., Ivory, J., Perrier, L., Hutton, B., Moher, D., & Straus, S. E. (2015). A scoping review of rapid review methods. *BMC Medicine*, *13*(1), 224. https://doi.org/10.1186/s12916-015-0465-6
62. Tseng, P.-H., & Pilcher, N. (2021). Examining the opportunities and challenges of the Kra Canal: A PESTELE/SWOT analysis. *Maritime Business Review*, *7*(2), 161–174. https://doi.org/10.1108/MABR-02-2021-0011
63. Turnhout, E., Metze, T., Wyborn, C., Klenk, N., & Louder, E. (2020). The politics of co-production: Participation, power, and transformation. *Current Opinion in Environmental Sustainability*, *42*, 15–21. https://doi.org/10.1016/j.cosust.2019.11.009
64. Valentine, S. V., & Sovacool, B. K. (2010). The socio-political economy of nuclear power development in Japan and South Korea. *Energy Policy*, *38*(12), 7971–7979. https://doi.org/10.1016/j.enpol.2010.09.036
65. Vaughan, N., Fuss, S., Buck, H., Schenuit, F., Pongratz, J., Schulte, I., Lamb, W. F., Probst, B., Edwards, M., Nemet, G. F., Cox, E., Smith, S., Injy Johnstone, Geden, O., Burke, J., Gidden, M., Roe, S., Müller-Hansen, F., & Minx, J. (2024). *The State of Carbon Dioxide Removal—2nd Edition*. https://doi.org/10.17605/OSF.IO/F85QJ
66. Waller, L., Rayner, T., Chilvers, J., Gough, C. A., Lorenzoni, I., Jordan, A., & Vaughan, N. (2020). Contested framings of greenhouse gas removal and its feasibility: Social and political dimensions. *WIREs Climate Change*, *11*(4), e649. https://doi.org/10.1002/wcc.649
67. Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, *35*(5), 2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001

68. Yüksel, I. (2012). Developing a Multi-Criteria Decision Making Model for PESTEL Analysis. *International Journal of Business and Management*, *7*(24), p52. https://doi.org/10.5539/ijbm.v7n24p52
69. Zimmermannová, J., Pawliczek, A., & Čermák, P. (2018). Public Support of Solar Electricity and its Impact on Households—Prosumers. *Organizacija*, *51*(1), 4–19. https://doi.org/10.2478/orga-2018-0001

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