DTU Entrepreneurship
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Carbon Removal Credits

Current and Future Value Development on Voluntary and Compliance Markets with a Focus on Scaling Biochar Carbon Removals in the EU

Master Thesis

Carbon Removal Credits – Current and Future Value Development on Voluntary and Compliance Markets with a Focus on Scaling Biochar Carbon Removals in the EU

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Approval

This thesis has been prepared over six months at the Department of Technology Entrepreneurship, at the Technical University of Denmark, DTU, in partial fulfillment for the degree Master of Technology Entrepreneurship, MSc Eng.

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28.02.2024

Date

Abstract

Achieving global climate targets, particularly limiting warming to 1,5°C, requires large-scale carbon dioxide removal (CDR). Biochar Carbon Removal (BCR) is the most mature CDR technology, currently delivering 90% of all permanent removals. However, significant scaling is needed for BCR to make a meaningful impact. This requires coordinated efforts from industry and policymakers to establish effective incentives and market structures to scale the industry.

This study assesses current and future value development in voluntary and compliance markets, focusing on scaling BCR in the EU. It analyses market opportunities for industry players, identifies current and future value trends, and proposes a plan to incorporate BCR into the EU compliance market for policymakers.

The methodology combines market assessment, regulatory analysis, expert interviews and transaction data analysis using Python. Data collection prioritizes grey literature (policy documents, regulatory drafts, industry reports) and insights from semi-structured interviews with industry experts, policymakers, and market analysts. Interviews were used to identify industry bottlenecks, market trends, and policy recommendations.

The findings suggest that the demand and scale of BCR largely depend on buyers motivated by self-imposed (voluntary) or national compliance climate targets, typically guided by frameworks. However, the recognition of BCR as a viable tool for achieving these targets in relevant frameworks remains limited, restricting market opportunities. As of 2024, the voluntary market values BCR at approximately €155 per ton of CO_2 through BCR. While literature and industry surveys anticipate cost reductions over time due to technological advancements and economies of scale, expert interviews highlight persistent cost drivers—such as feedstock availability, regulatory uncertainties, and logistical constraints—that create uncertainty around long-term price trends. The market is evolving, potentially leading to expanded opportunities in the future. A key bottleneck for scaling BCR, identified by both industry and policymakers, is the lack of reliable and predictable demand. The integration of BCR into compliance mechanisms, particularly the EU ETS, is considered the most promising approach to establishing strong incentives and addressing this barrier. A three-stage plan—starting with a public purchase program in 2026, transitioning to a regulated ETS inclusion, and ultimately mixed policy tools including removal obligation for polluters and a general waste disposal fee to finance further public purchases by 2050—is proposed. One highly debated topic in the industry and policy circles is double accounting, - claiming, - subsidizing. Clear guidelines and definitions are needed to define BCR’s eligibility across different frameworks regarding accounting, claims, and subsidies. These guidelines should balance incentives for buyers with transparency to accurately assess progress toward global climate targets.

Overall, BCR holds significant potential for advancing toward the global climate target but requires stronger buyer incentives and a well-structured regulatory framework. Successful scaling will depend on coordinated efforts between industry and policymakers. Future research could expand on this thesis by exploring expert-driven hypotheses on historical market outliers and industry bottlenecks, conducting a comprehensive assessment of CDR integration pathways into the EU ETS, or examining the conflicting expectations of future value development presented in academic literature, industry surveys, and expert interviews.

Acknowledgment

This is the final act of my masters degree at DTU. Thomas and Mia, I am grateful for your input and guidance while allowing me a great degree of flexibility—as well as to the Entrepreneurship faculty at DTU for creating a space where curiosity and initiative shape master degrees rather than rigid curriculums.

A heartfelt thanks to the team at Stiesdal, especially Peter and Morten, for engaging in discussions and circulating thesis ideas, providing insightful feedback along the way.

Thanks to the 17 industry experts who each took an hour to share their knowledge, perspectives, and challenges with me. Your contributions added significant depth to this thesis and allowed me to learn from diverse voices. This thesis has strengthened my enthusiasm for working further on these topics, shaping the path as we walk it. Additionally, I extend my appreciation to CDR.fyi for providing crucial data that enriched this thesis and made it more interesting to industry players. Your work is so important—data drives our world, and the CDR industry should be no exception.

Finally, a big thank you to my friends, flatmates, Joan and my family. Your presence ensured that my weekends were filled with laughter, sports, and vivid discussions about the world over delicious meals and not only writing. Denmark would not be the same without you.

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List of Abbreviations

Beyond Value Chain Mitigation (BVCM)
Biochar Carbon Removal (BCR)
Bioenergy and Carbon Capture Storage (BECCS) Bundes-Immissionsschutzgesetz - Federal Emission Control Act (BImSchG)
Bundes-Immissionsschutzverordnung - Federal Emission Control Implementation Act (BImSchV)
Carbon Capture and Storage (CCS)
Carbon Capture, Utilization, and Storage (CCUS)
Carbon Central Bank (CCB)
Carbon Dioxide Removal (CDR)
Carbon Intensity score (CI score)
Carbon Removal Certification Framework (CRCF)
Contracts for Difference (CfD)
Danish Centre for Environment and Energy (DCE)
Direct Air Capture and Storage (DACCS)
Effort Sharing Regulation (ESR)
European Union Allowance (EUAs)
Environmental Product Declaration (EPD)
European Commission (EU COM)
European Union (EU)
European Union Emissions Trading System (EU ETS)
Forest, Land, and Agriculture (FLAG)
Greenhouse Gas (GHG)
Greenhouse Gas Protocol (GHG Protocol)
Intergovernmental Panel on Climate Change (IPCC)
Land use, Land-use change, and Forestry (LULUCF)
Life Cycle Assessment (LCA)
Market Stability Reserve (MSR)
Net-Zero Banking Alliance (NZBA)
EU Monitoring and Reporting Regulation (MRR)
Product Environmental Footprint (PEF)
Proof of Sustainability (PoS)
Renewable Energy Directive (RED)
Removal Trading System (RTS)
Science Based Targets Initiative (SBTi)
Union Database (UDB)
United Nations (UN)
United Nations Framework Convention on Climate Change (UNFCCC)

Units and synonyms

1 ton BCR = 1 ton CO_2 permanently removed from the atmosphere through BCR
1 ton CDR = 1 ton BCR = 1 ton CO_2 permanently removed from the atmosphere

Value of BCR = Price of BCR
BCR = Biochar removal

Conversion rate USD: EUR

1,0718 US $ = 1 €

1 Introduction

1.1 Problem Statement

Climate change mitigation is one of the most pressing global challenges of the 21st century. The Paris Agreement sets a global climate target of keeping global temperature to 1,5°C (United Nations Climate Change, n.d.). Climate models by the United Nations (UN) highlight the necessity of carbon dioxide removal (CDR) technologies to achieve this goal. Without carbon removal efforts, it will be impossible to meet the necessary emissions reduction targets.

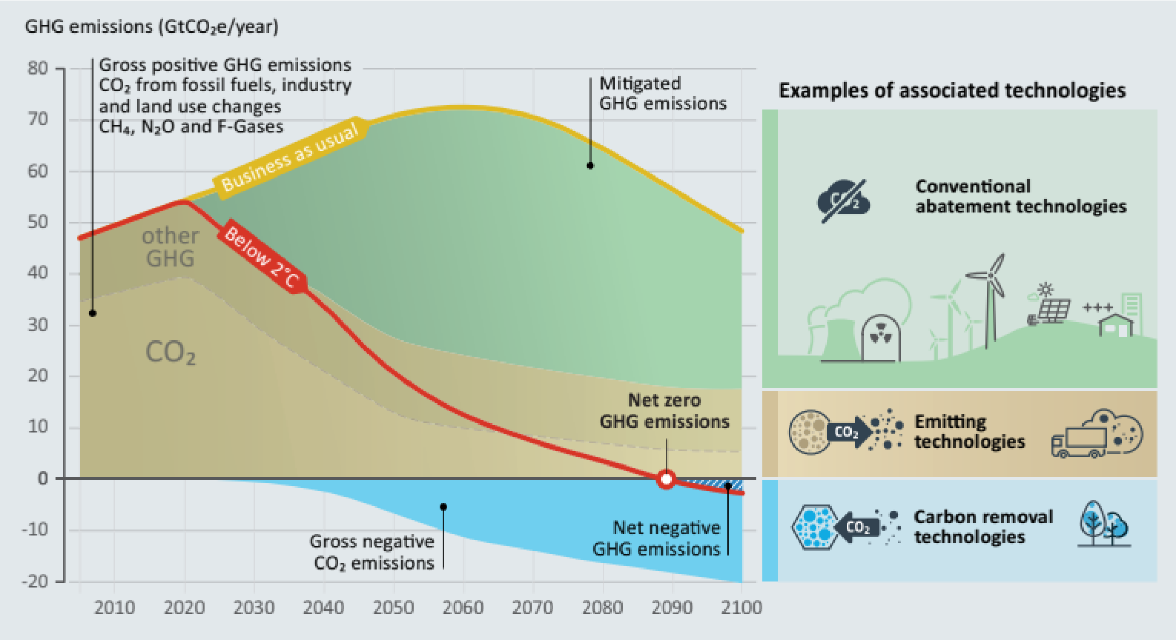

Figure 1: Carbon Removals Needed to Stay Well Below 2°C Target
Source: UNEP (2017).

The scale of permanent carbon dioxide removal (CDR) technologies is far too small to meet the climate targets needed to keep global warming well below 2°C. In 2023, novel CDR methods removed only about 1.35 million tons of CO_2 per year, yet climate models indicate that by 2035 we will need to remove around 2.5 gigatons per year using permanent approaches (Smith, et al., 2024). This gap highlights an urgent need to incentivize the growth of the CDR industry. The enormous gap in current versus required removal volumes is not just a technical challenge—it's also a market challenge. The market can be roughly divided into a voluntary and a compliance market. In the voluntary market, companies purchase credits to meet self-imposed greenhouse gas reduction targets. Conversely, a compliance market is regulated by law, requiring entities to account for and reduce their emissions. To meet these legal obligations compliance markets can allow entities to counterbalance emissions by doing or purchasing CDR credits.

To understand the current market, assessing the price of carbon removals is central to understanding the current volume and what it takes for the industry to scale. It requires a joint effort from industry players and policymakers to establish the right incentives and market conditions for deployment.

Two research gaps emerge in the current landscape. First, there is a lack of academic research and transparency regarding market opportunities and the pricing of carbon removal credits, which serve as an important income source and incentive for further investment in CDR technologies. Highly relevant for all CDR industry players. Second, although nations are committed to global climate target, policymakers continue to debate how best to support CDR to reach the global climate target; there is little in the academic literature that provides concrete proposals or tools to guide them.

Therefore, this research aims to address these gaps. Due to the limited scope of this thesis, the study will focus on specific aspects. In particular, it will concentrate on one key CDR technology to illustrate potential market opportunities and assess its pricing dynamics. Biochar Carbon Removal (BCR) is selected because it accounts for approximately 90% of the delivered carbon removal credits in 2023, demonstrating both its technological readiness and its potential for significant scale-up (Höglund, et al., 2024; Harvey, 2023). The geographical focus is on the EU, where 18% of all global biochar removals occur. In addition, the EU has strong climate initiatives—such as the world's largest cap-and-trade system (EU ETS) that sets a price on CO_2 emissions—which provide an interesting context for CDR (Smith, et al., 2024; EU Directive 2003/87/EC). Lastly, for the price assessment, demand and supply are relevant. It is acknowledged that numerous supply-side factors—such as the price of BCR co-products, biomass feedstock costs, and capital expenditures for facilities—can impact overall pricing; however, this thesis focuses primarily on demand-side aspects. This is because the demand is based on the global climate target and nations as well as private entities trying to meet them. Thereby the price for CO_2 or non-compliance behavior set by nations is interesting to investigate as its impact on BCR future credit value development. Furthermore, this study investigates how the lack of recognition for CDR technology in emission accounting frameworks may act as a barrier to new demand. (EU Directive 2003/87/EC; Science Based Targets initiative, Science Based Targets, 2024).

Based on the problem statement, the thesis investigates three concrete research questions:

1. What are the market opportunities for BCR?

2. What is the current value of BCR credits, and what are its future projections?

3. How can policymakers, particularly in the EU, create effective incentives and market conditions to support the large-scale deployment of BCR and help close the gap toward achieving the global climate target of within 1,5°C temperature rise?

1.2 Project Objectives of this Thesis and Structure

To address the problem statement, this thesis has the following project objectives (table 1):

No.	Project objective
1	Introduce the BCR technology and its place in the carbon landscape
2	Assess current and future market opportunities for BCR credits by analyzing voluntary and compliance frameworks for industry players
2	Determine the current value of biochar carbon removal credits on different markets
3	Identify bottlenecks in scaling the BCR industry and enhancing value development
4	Provide an overview of the industry's stance on double counting, double claiming, and double subsidization resulting from overlapping frameworks

5	Review potential BCR integration designs into compliance frameworks
6	Develop a policy proposal based on literature and expert interviews
7	Project future BCR credit value

Table 1: Project Objectives

The structure of this analysis is intentionally designed so that each chapter builds on the insights of the previous one. It begins by explaining the technology behind BCR, distinguishing it from related carbon strategies such as CCS and natural carbon removals. With these definitions in place, the thesis then turns to current market opportunities, which serve as the foundation for an analysis of present pricing. The focus here is on the demand side—exploring what drives demand for BCR and at what price. This section navigates various climate target-setting and emission accounting frameworks that are essential to understanding these market opportunities. First, it reviews frameworks that already recognize BCR to achieve climate targets. Then it explores the ongoing debates across different frameworks regarding how CDR methods (incl. BCR) can be integrated in a chapter on future BCR accounting. The market assessment concludes with a brief overview of policies related to BCR that shape certain aspects of those market opportunities on EU level.

The second part of the thesis is geared more towards policymakers. Various frameworks create market opportunities at the product, corporate, and national levels. However, overlapping elements within these frameworks have sparked considerable debate in both industry and policy circles regarding what should be permitted. This section provides a detailed overview of the underlying technical aspects and the different industry positions. Following this, interviews are used to pinpoint bottlenecks in the industry, with a particular emphasis on bottlenecks where political support could play a crucial role. One such bottleneck leads to a discussion on how demand might be stimulated by integrating BCR into the ETS system, culminating in a proposal based on existing academic suggestions and refined by industry experts for policymakers. The analysis wraps up with projections of BCR's future value—derived from a blend of research methods—and concludes with key takeaways, limitations, and recommendations for future research.

This thesis is intended for two key audience groups: industry stakeholders—including suppliers, operators, and investors in BCR technology—and policymakers. Therefore, this thesis deviates from a traditional academic structure. It adopts a conceptual approach, combining elements of a market assessment with a regulatory analysis and its structure and elements are inspired partly by industry reports. The author's contribution includes conceptual structuring, selecting analytical perspectives (identification of relevant experts), identifying and analyzing frameworks, analyzing transaction data and trends, developing a policy proposal, designing the interview guide, conducting and assessing 17 expert interviews and utilizing value forecasts from various frameworks to develop a projection for the future value of BCR credits.

2 Methodology

2.1 Research Design

The research design is based on mixed methods to investigate the problem statement and its research questions. The mixed method approach was chosen to accommodate the different available data sources depending on the topic.

For the market opportunity and current price assessment, a mixed-methods approach was employed, integrating both quantitative and qualitative techniques. The literature review provided the foundation for identifying relevant market opportunities, examining voluntary and compliance frameworks, and assessing BCR’s position within them. To analyze current prices and market trends, a quantitative exploratory data analysis and time series analysis were conducted using a dataset of historical BCR transactions provided by CDR.fyi. The data analysis was performed in Python. Additionally, qualitative research was conducted through semi-structured expert interviews to validate the data analysis, generate hypotheses for historical value outliers, and identify potential bottlenecks. The market assessment approach was inspired by Kujanpää et al. (2023), though the conceptual framework of this research was independently developed to integrate theoretical insights with practical stakeholder input. To address the first research question (market opportunities) and partially the second (current price level), secondary data sources were primarily utilized, supplemented by primary data from interviews to explore potential explanations for the data analysis findings.

For the future value projection, a quantitative approach using prediction-based forecasting models with data from CDR.fyi was initially considered. However, due to data quality limitations and findings from the trend analysis of current prices, this approach was not feasible. Instead, secondary data sources, like industry survey results, and literature review insights were utilized. These were further supplemented with primary data from semi-structured interviews to address the second research question regarding future projections.

The third research question was explored through a combination of semi-structured interviews and a literature review. The literature review helped identify potential integration designs and existing proposals, forming the basis for developing a new proposal. The interviews served two key purposes: first, to gather feedback and refine the proposed design; and second, to identify additional integration options, assess design elements beyond those found in the literature, and capture the perspectives of different stakeholder groups on how the integration should be implemented.

A significant portion of the literature review is based on grey literature due to the nature of the research topic. This reliance is necessary for three reasons. First, the subject matter has only a limited academic focus, with formal scholarly publications on BCR credits and their market implications being scarce. Second, regulation plays a critical role in shaping the market, and policy documents, regulatory assessments, and industry reports are more relevant sources of information than traditional academic studies. Third, the future development of BCR credits is highly uncertain, with much of the discussion taking place among policy advisors, industry stakeholders, and governmental bodies rather than within academic circles. As these actors are shaping future regulations and frameworks, their assessments, proposals, and reports provide critical insights that would otherwise be unavailable in peer-reviewed literature. Consequently, the review incorporates policy evaluations, regulatory drafts, and industry white papers as key sources of analysis.

2.2 Semi-Structured Interviews

Given the complex and evolving nature of BCR credit markets, semi-structured interviews were chosen as the primary research method (Kallio, Pietilä, Johnson, & Kangasniemi, 2016). This approach provides flexibility to explore expert perspectives on regulatory and market aspects of BCR while maintaining a structured yet adaptable format that accommodates different expertise areas of the interviewees. Furthermore, it allows for an exploratory and participatory element, facilitating hypothesis development and the collaborative refinement of the policy proposal (Cargo & Mercer, 2008; Rahi, 2017; Salimi, et al., 2012). The interviews served multiple research objectives, including the validation of research findings and data analysis, projecting the future value developments, generating new hypotheses on factors influencing BCR credit's value, assessing the feasibility and effectiveness of different policy proposals, and evaluating the author's proposal.

A purposive sampling strategy was employed for the selection of interviewees to ensure that participants had relevant expertise in BCR markets, regulatory frameworks, or policy development. As outlined by Adeoye-Olatunde & Olenik (2021), purposive sampling allows for the selection of participants based on specific criteria relevant to the study's objectives. The sample includes a mix of industry stakeholders, policy advisors, policymakers and market analysts of banks to provide a comprehensive perspective. Rather than being based on demographic representativeness, participant selection prioritized subject matter expertise, particularly in regulatory and market aspects of BCR credits. The selection results in 17 conducted interviews. Interviewees combined more than six different backgrounds as presented in figure 3.

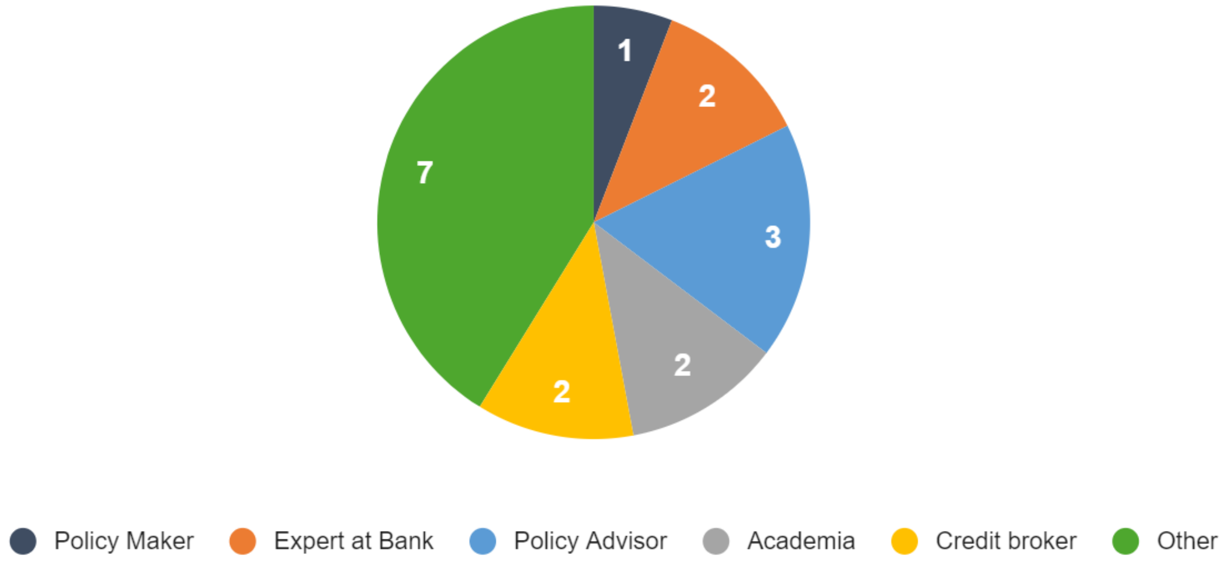

Figure 2: Overview Professional Background of 17 Interviewees
Source: Author.

The interviewees categorized under "others" include professionals from various backgrounds, such as a BCR supplier, an MRV provider (specializing in digital infrastructure for carbon credit tracking), a think tank, a gas trader, and a representative from industry associations for pyrolysis.

Many interviews focused on two to three topics (see graph 4). The largest group discussed ETS and integration, aligning with the thesis goal of developing and refining a policy proposal.

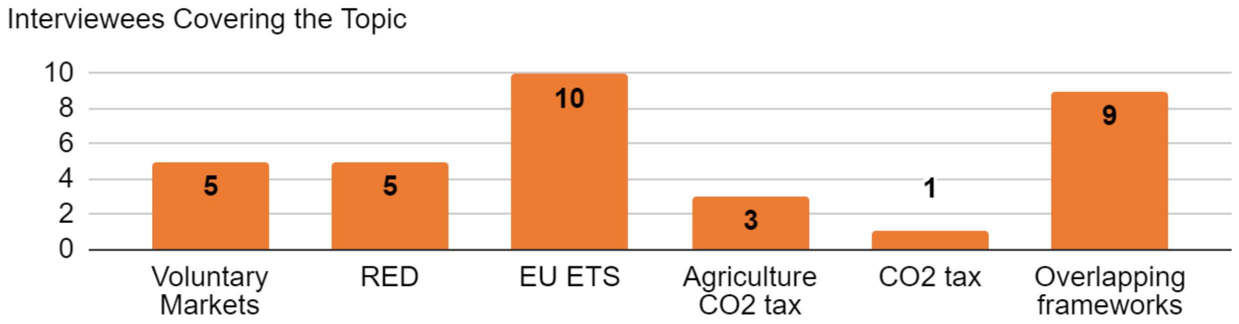

Figure 3: Amount of Interviewees per Topic Area
Source: Author.

To ensure a balance between consistency and adaptability, two interview guides were developed featuring open-ended questions tailored to each participant's expertise. One of the guides focused on identifying key challenges and gaps in the current regulatory frameworks, evaluating potential policy incentives and compliance integration strategies, and gathering feedback on the proposed policy framework for iterative refinement. The other guide was developed to explore industry experts' opinions on market drivers for BCR credits, develop hypotheses for historical price outliers and identify patterns behind the value development of BCR credits in the past. While the core questions remained consistent across interviews depending on which interview guide was chosen, follow-up questions varied depending on the participant's expertise, ensuring a deeper exploration of their area of expertise.

Due to the geographical distribution of experts, all interviews were conducted online except for one in-person interview. The interviews were transcribed and afterward summarized where certain interpretations were needed to align wording among different interviewees. Based on those summaries, key themes such as regulatory barriers, market trends, and policy recommendations were identified. This approach was chosen due to the diverse backgrounds of the interview experts, which resulted in minimal overlap in terminology and vocabulary. Additionally, the varied focus of each interview made direct comparisons challenging.

Participants were assured of confidentiality, with sensitive information anonymized in reporting. Informed consent was obtained from all experts before participation, ensuring transparency regarding the study's objectives. The study aimed to objectively represent diverse industry perspectives along the value chain by balancing different viewpoints. However, the purposive sampling method resulted in a selection of advocates of CDR. Consequently, the interview outcomes focus on varying perspectives among CDR proponents rather than contrasting advocates with critics.

Key points

- The study employs a mixed-methods approach, integrating market assessment, data analysis, regulatory review, and expert interviews to assess BCR credit value trends and explore policy integration.
- Grey literature (policy reports, industry assessments, regulatory drafts) is the primary source due to the limited academic focus on BCR markets and the dominant role of policymakers and industry stakeholders in shaping discussions.
- Semi-structured interviews with purposive sampling are conducted with 17 experts from diverse backgrounds, including industry stakeholders, policymakers, and market analysts, to validate findings and refine policy proposals.
- Data synthesis from interviews and market analysis identified key insights, such as regulatory barriers, price trends, bottlenecks, ensuring a comprehensive understanding of BCR market dynamics.

3 Biochar Carbon Removal Technology and Classification in Carbon Landscape

This chapter delves briefly into the fundamentals of BCR technology, its production processes, and the definition of BCR credits. It also presents BCR's classification within the broader carbon management landscape, distinguishing it from related concepts such as Carbon Capture and Storage (CCS), Carbon Capture, Utilization, and Storage (CCUS), and nature-based carbon removal approaches.

3.1 The Pyrolysis Technology Explained

The technology behind BCR is called pyrolysis. A technique that has been utilized for quite some time, involves heating organic material in an oxygen-depleted environment, resulting in the simultaneous production of gas, bio-oil, and biochar (Svarer, et al., 2024). In a natural cycle, biomass captures carbon from the atmosphere during its lifetime and releases it back as soon as it starts to rot. However, the pyrolysis process stabilizes approximately 50% of the carbon content from the original biomass in biochar for a longer period. The biochar is the foundational component for BCR credits (Arhnung & Jepsen, 2024). It is not a uniform material; its properties can vary significantly depending on the type of biomass used and the specific conditions during pyrolysis. These variations influence its effectiveness in applications such as soil enhancement or carbon sequestration (Thomsen, Introduction to Production and Use of Biochar 2022: working towards a more circular and bio-based Danish economy, 2022).

A BCR credit represents the permanent removal of one metric ton of CO_2 equivalent, accomplished through the production and final storage (sequestration) of biochar. It is certified as a permanent net carbon removal benefit and registered by an appropriate certification scheme specified by the framework it is issued under (EU Regulation 2024/3012; EU COM, n.d.). The definition of "permanent" is laid out by the framework's rules of the market it is sold on. In the EU context, it is currently defined vaguely as "durably for several centuries" (EU Regulation 2024/3012). Similarly, what is considered sequestration is also defined by the framework under which credit is traded. Common sequestration applications of biochar are in soil or long-lasting materials like building materials (Chiaramonti, et al., 2024; EU COM, n.d.). An overview of a BCR value chain from biomass sourcing to final sequestration is provided in the annex (figure 29, annex I).

3.2 Biochar Carbon Removal within the Carbon Management Landscape

Within the broader landscape of carbon management, various technologies differ significantly in both the sources of CO_2 they address and their methods of sequestration (CarbonGap, 2022). The category of CDR encompasses various methods aimed at extracting CO_2 directly from the atmosphere and securely storing it to mitigate climate change. BCR fits within this framework, it is extracting CO_2 by converting biomass into a stable form of carbon that can be sequestered in soils or products for extended periods, often spanning centuries (CarbonGap, 2022). Other common CDR technologies are Bioenergy and Carbon Capture Storage (BECCS) and Direct Air Capture and Storage (DACCS). They all produce the same product (substitute), a carbon removal credit. A (permanent) carbon removal credit represents one ton of CO_2 removed from the atmosphere and stored permanently through specific technologies (Friedmann & Potts, 2023; EU Regulation 2024/3012).

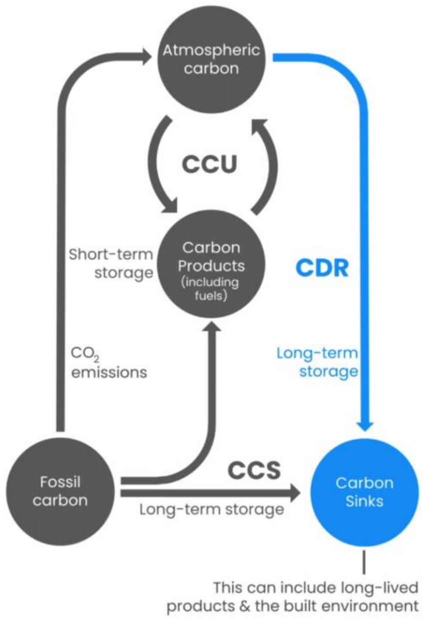

Figure 4: Difference CCS, CCUS and CDR
Source: CarbonGap (2022).

These are other common categories and technologies on the carbon management landscape that need to be distinguished from CDR:

- Carbon Capture and Storage (CCS): This technology captures CO_2 emissions from industrial processes or power generation before they are released into the atmosphere and stores them in geological formations underground. Unlike BCR, CCS deals with preventing new emissions rather than removing existing atmospheric CO_2 (see figure 5).

- Carbon Capture, Utilization, and Storage (CCUS): Similar to CCS, CCUS involves capturing CO_2 emissions but differs by utilizing the captured CO_2 in various applications, such as in the production of chemicals, fuels, or building materials, before potentially storing any surplus. This approach focuses on creating value from captured carbon, whereas BCR emphasizes long-term sequestration (CarbonGap, 2022).

- Nature-Based Removals: These include afforestation, reforestation, and soil carbon sequestration practices that enhance the natural absorption of CO_2 through biological processes. The duration of stored carbon is much shorter than for permanent CDR methods. While BCR shares similarities with these methods by utilizing biomass, it offers a more controlled and durable form of carbon sequestration through the pyrolysis process (EU COM, n.d.). For this thesis, natural-based removals are not meant when referring to CDR methods.

Key points

- BCR converts biomass into biochar via pyrolysis, stabilizing about 50% of carbon for long-term sequestration.
- BCR credits certify the removal of 1 ton of CO_2 equivalent through biochar, with applications in soils or long-lasting materials.
- BCR removes CO_2 and stores it in stable forms, unlike CCS and CCUS, which focus on capturing emissions before they go into the atmosphere or utilizing emissions.
- It is more controlled and durable than nature-based removals like afforestation or soil carbon practices.
- This chapter was the base to define and differentiate BCR (credits) from other methods and categories. The next chapter will introduce buyers' intention to purchase BCR credit

4 Climate Targets as the Reason Why BCR is Demanded Today

This chapter explores the underlying reasons why BCR is in demand today, which is the base for analyzing market opportunities.

More than 1.3 million tons of BCR have been bought in the last three years by private companies (table 5 in annex).

According to De Luna (2024), the primary motivation for private companies is achieving their net-zero targets. Microsoft, for example, has stated:

> “They (Microsoft) are not a CDR charity donor; they have ambitious climate objectives, and they are in the business of durable CDR to put agreements in place to meet those goals.” – CDR.fyi, 2024

Beyond net-zero commitments, other motivations include:

- Industry Building: Early purchases of carbon removal credits support the development of the market and attract investment.
- Securing Future Supply**:** Due to the growing gap between demand and available credits, buyers pre-purchase removals to ensure access to future supply.
- Trade Opportunities: As the market matures, companies anticipate financial gains by acquiring credits that may appreciate in value (De Luna, 2024).

Those companies are private-sector entities that set climate targets voluntarily, therefore referred as voluntary buyers and the voluntary market (De Luna, 2024; CDR.fyi, 2024). Voluntary buyers are guided by available industry target-setting and emission accounting frameworks. Those frameworks are often based on the global climate target of staying well below 2°C of temperature rise (Science Based Targets initiative, 2024). Voluntary buyers typically include large multinational corporations from technology, finance, and heavy industry (Smith, et al., 2024; De Luna, 2024). Notable participants include Microsoft, Apple, Amazon, and Meta, which purchase both permanent and nature-based removal credits (CDR.fyi, 2024).

Voluntary buyers generally share four common characteristics (De Luna, 2024):

- Pressure from stakeholders and customers to adopt greener practices.
- Competitive labor markets where climate commitments enhance talent retention and recruitment.
- Higher financial margins, enabling investment in sustainability initiatives.
- Significant indirect emissions, necessitating the purchase of carbon removal credits to offset environmental impact.

The demand for BCR credits in the voluntary market stems from companies incorporating BCR into their corporate climate strategies. Their willingness to pay is driven by the need to meet self-imposed climate targets (CDR.fyi, 2025). This creates a market opportunity for BCR.

Denmark is currently demonstrating how nations can shape future market opportunities for BCR by incorporating BCR as a tool in its national climate strategy. The country is planning to implement this through fiscal incentives, particularly a subsidy scheme (Heick, 2024). Other potential approaches can include public procurement, as seen with BECCS in Sweden (Beccs Stockholm, n.d.), or market-based mechanisms where a carbon price or penalty incentivizes private entities within a national or EU framework to adopt or purchase BCR credits (Hickey, Fankhauser, Smith, & Allen, 2023). All activities where entities engage in BCR (doing BCR operations or buying resulting BCR credits) to comply with national law, avoid a penalty, qualify for a subsidy or public purchase program are referred to as a compliance market. The demand for BCR in compliance markets is largely dependent on whether it is recognized within official emissions accounting frameworks by the authorities. This will lead to the following chapters, where 5 and 6 will explore in detail whether and how these incentive structures are applied and where BCR is acknowledged or will be acknowledged in the future.

Both voluntary and compliance markets can create demand for BCR credits, though with differing motivations. Voluntary buyers prioritize net-zero commitments, stakeholder expectations, and strategic market positioning, whereas compliance-driven purchases and BCR activities are dictated by regulatory mandates and national climate strategies. This chapter investigated why BCR credits are demanded. The answer, achieving targets, leads to the next chapter about the different regulatory and voluntary frameworks on which targets are set.

Key points

- The chapter explores the underlying reasons for the demand for BCR (credits).
- The market can be broadly divided into a voluntary and a compliance segment.
- Motivations for buyers to demand BCR vary but the overall goal is to achieve climate targets.
- On the voluntary market, private companies primarily purchase removals to meet self-set climate targets that contribute to the global climate target to limit temperature rise to 1,5 °C, guided by frameworks.
- In the compliance market, nations aim to fulfill their climate targets as part of their contribution to the global climate goal of 1,5°C.
- If nations decide to integrate BCR into their climate strategy, future market opportunities can follow in various forms:
- Either nations could purchase themselves BCR credits or incentives or oblige private companies to do BCR or buy credits within their territory.
- Achieving targets leads to the next chapter, which examines the regulatory and voluntary frameworks that define these targets and determine whether BCR is recognized as a valid mechanism for meeting them.

5 Today's Rules on Climate Targets and Accounting of BCR

This chapter explores further market opportunities for BCR. It aims to show the underlying frameworks that guide nations and companies that set climate targets on national, company and product levels. It explores whether and how BCR is currently recognized as a viable method for achieving these targets. The analysis highlights how market opportunities are closely linked to accounting frameworks that influence voluntary demand and enforce compliance obligations. Therefore, it identifies the most used standards among voluntary BCR buyers and analyzes how EU law addresses biochar and carbon removals by using expert interviews, literature and legal analysis. Finally, the current price of BCR is analyzed with the help of transaction data from the voluntary market and penalty levels on the compliance market.

Illustration 6 provides an overview of the identified frameworks and their levels of application. The list is not exhaustive but a selection of relevant frameworks. It distinguishes between compliance and voluntary frameworks. It also highlights biochar-related rules and accounting standards that influence these markets. Some standards blur the line between setting guidelines and creating markets, especially in the voluntary sector, but this differentiation reflects the author's best understanding. On the voluntary framework side, different industries established frameworks (Net Zero Banking Alliance, n.d.), however, one is chosen on the company level that is commonly used.

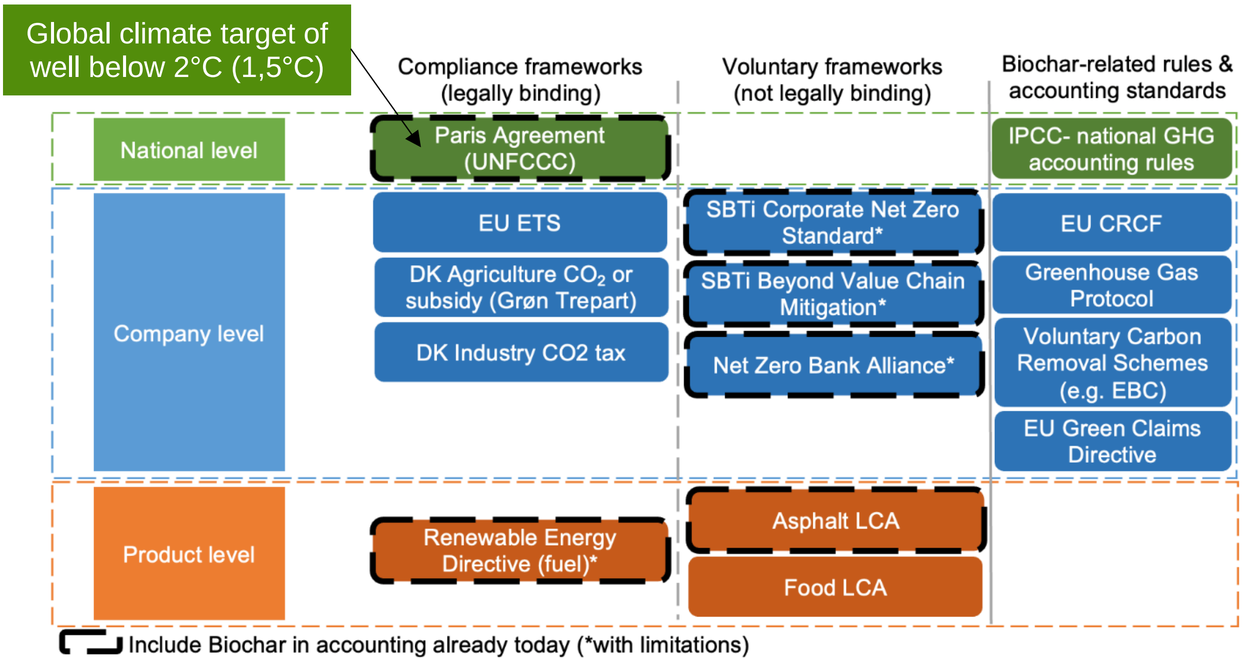

Figure 5: Overview frameworks relevant for BCR on product-, company-, national level
Source: Science Based Targets initiative (2024); Dale & Ripoll (2023); EU Directive 2018/2001; European Commission (n.d.); United Nations Climate Change (n.d.); Wright (2024); Heick (2024).

The analysis first examines voluntary frameworks and price trends, then shifts to relevant compliance frameworks.

5.1 Voluntary Market: Accounting Frameworks & Price Analysis

5.1.1 Corporate Net-Zero Standards by SBTi

The first framework is called “Corporate Net-Zero Standard by Science Based Targets Initiative. SBTi is a collaboration between organizations such as the United Nations Global Compact and WWF, supported by corporate funding from major companies like IKEA, Amazon, and the Bezos Earth Fund (Carrillo Pineda, 2022; Science Based Targets initiative, n.d.). More than 7200 companies have science-based targets (Science Based Targets initiative, n.d.).

SBTi’s primary goal is to guide companies in reducing their greenhouse gas (GHG) emissions in alignment with the Paris Agreement and the IPCC Special Report on 1.5°C (2018) (Science Based Targets initiative, n.d.). It sets clear standards for defining corporate climate targets, emission scopes and reduction strategies (Science Based Targets initiative, 2024). The underlying accounting rules for GHG are from another organization, called the Greenhouse Gas Protocol (GHG Protocol) (Ranganathan, et al., 2015). The interplay between the different organizations, frameworks and standards is shown in illustration 7. In addition, the illustration reveals which of the different SBTi guides (in blue) include BCR and which ones do not.

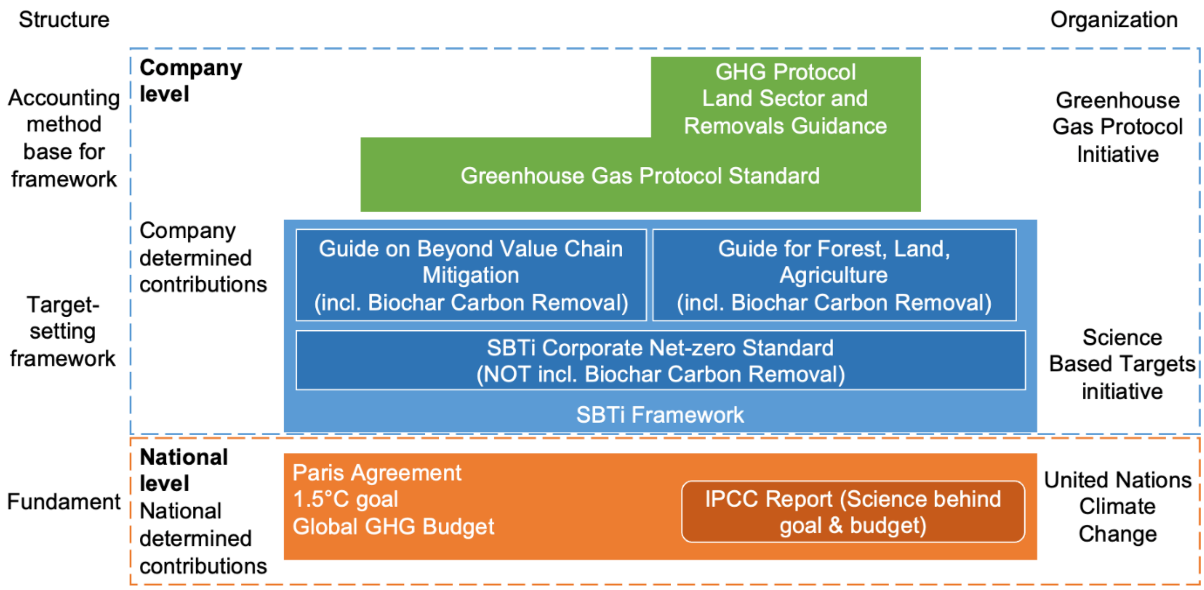

Figure 6: SBTi Net Zero Standard Structural Overview
Source: Carla Soleta based on Science Based Targets (2024); Benson et al. (2024); Carrillo Pineda (2024); Anderson et al. (2023); Greenhouse Gas Protocol (n.d.).

The framework has sector-specific guidelines based on the industry and company operations that specify rules in addition to the general standard. The scope of SBTi’s framework accounts for emissions under Scope 1 direct emissions, Scope 2 indirect emissions from energy use, and Scope 3 supply chain and indirect emissions (Ranganathan, et al., 2015; myclimate, n.d.).

SBTi recognizes biochar as a valid carbon removal method under the Forest, Land, and Agriculture (FLAG) Guidance, which applies specifically to land-intensive industries (Science Based Targets initiative, 2022). Companies must set FLAG targets if more than 20% of their emissions come from land-related activities (Anderson, Bicalho, Wallace, Letts, & Stevenson, 2023). While biochar can be used to meet these targets, it cannot be applied to Scope 1, 2, or 3 reduction targets for non-agriculture emissions (myclimate, n.d.).

An example, a dairy producer has more than 20% of its emissions in Scope 3 from land-use activities of its farmers that deliver raw milk. It sets a FLAG target alongside its corporate net zero target. The use of biochar leads to more removals than emissions stemming from land use. He can counterbalance the emissions from land-use activities with BCR until those reach zero. However, once land-use emissions are neutralized, any additional biochar removals cannot be used to offset non-FLAG emissions from other activities within Scope 1, 2, or 3.

Within the FLAG framework, removals like biochar must meet quality standards, including ongoing storage and monitoring. However, biochar removals sold as carbon credits cannot be counted toward FLAG-based SBTi targets to prevent double counting in corporate emissions reporting (Anderson, Bicalho, Wallace, Letts, & Stevenson, 2023).

In summary, while SBTi recognizes biochar's potential for carbon removal, its role in corporate net-zero targets remains restricted. Companies cannot count BCR credits toward their required reductions. An exception exists for land-intensive industries. BCR is included in its guidelines but does not allow it to be used to offset emissions in other areas of the company or sold to others on the voluntary market. As corporate climate strategies evolve, future updates from the GHG Protocol and SBTi may offer more flexibility in integrating biochar into corporate sustainability frameworks as discussed in chapter 6.1.

5.1.2 Beyond Value Chain Mitigation by SBTi

Companies that buy BCR credits or invest in BCR activities can report them under SBTi even if they do not have FLAG targets and emissions. Carbon removal credits are classified as Beyond Value Chain Mitigation (BVCM) activities under SBTi, meaning they can be reported separately but do not count toward SBTi reduction goals. While SBTi encourages companies to engage in BVCM, it is not a requirement under the Net-Zero Standard neither is the reporting. However, both are recommended by SBTi (Benson, et al., 2024; Science Based Targets initiative, Beyond Value Chain Mitigation, n.d.).

BCR is explicitly recognized as a carbon sequestration method within SBTi's BVCM Guidelines (Benson, et al., 2024). If carbon credits are used for BVCM, they should be verified by an independent third party under a recognized carbon standard, and emissions reductions and removals should be reported separately (Benson, et al., 2024)

5.1.3 Net Zero Bank Alliance: Guidelines for Climate Target Setting for Banks

Some industries developed their own target-setting guidelines. One of them is the banking industry. The Net-Zero Banking Alliance (NZBA) is a global coalition of banks committed to aligning their lending and investment portfolios with net-zero emissions by 2050, in line with the Paris Agreement (United Nations Environment Programme Finance Initiative, 2024) with over 500 members (Net Zero Bank Alliance, n.d.). Their climate target-setting guidelines provide a framework for banks to set science-based decarbonization targets, prioritizing direct emissions reductions while allowing limited use of high-quality carbon removals for residual emissions (United Nations Environment Programme Finance Initiative, 2024).

The NZBA guidelines emphasize the prioritization of reduction before removals. However, to reach end-state net zero in 2050, carbon removal credits are allowed but limited to Scope 3 emission (category 15: emissions from investments that are not covered by 1 or 2) instances where technologically or financially viable emissions elimination alternatives do not exist – residual emissions. For interim targets (so earlier than 2050), even carbon avoidance credits can be used.

The guideline expects banks to use high-quality carbon credits and is referring to initiatives that as the Voluntary Carbon Market that publishes standards and guidance for that (United Nations Environment Programme Finance Initiative, 2023). As SBTi, NZBA is using the Greenhouse Gas Protocol for accounting emissions (Scope 1-3).

It shows an example of an industry-specific approach on company level that already today acknowledges CDR credits as a tool to reach climate targets limited to specific emission scopes.

5.1.4 Environmental Product Declaration: example of a UK-based asphalt aggregate

One unique example of BCR accounting on the product level is the application and accounting of biochar for an asphalt product. It is certified by an Environmental Product Declaration (EPD) for a product called ACLA from a UK-based company (Low Carbon Materials, 2024). An EPD is a standardized document that provides transparent and comparable information about the environmental impact of a product throughout its life cycle (International EPD System, n.d.).

The EPD refers to "biogenic carbon removals from biogenic sources" rather than explicitly mentioning biochar. However, the company confirmed that biochar was used. The specific amount of biochar in the asphalt is not disclosed.

A challenge to classify BCR on a product level is that those EPDs are based on Life Cycle Assessments (LCA). When biochar is integrated into construction materials like asphalt, accounting for its carbon removal benefits within an EPD requires specific considerations. In ACLA's case, adjusting the LCA with a module called "virtual emissions" was necessary to account for the BCR (EPD International AB, 2024). A typical LCA evaluates the environmental impacts of a product from raw material extraction through production, use, and end-of-life stages (Klöpffer, 1997). The LCA usually calculates in the last disposal phase the release of all remaining emissions of the product into the atmosphere (Guinée & Heijungs, 2024). The concept of removals does not fit into that LCA approach. Thus, the incorporation of BCR into a carbon footprint required adjustment of scope and special guidelines as mentioned before. For construction products, the EN 15804 standard and EPD International's Construction Products Product Category Rules (PCR 2019:14) outline the core rules for creating EPDs (EPD International AB, 2024).

This product serves as an example of how BCR could be accounted for on product level. However, an extension of the current industry standard was needed.

5.1.5 Voluntary Market: Transaction Data Analysis of BCR Prices (CDR.fyi database)

Previous chapters explored the reasons behind the voluntary demand, such as meeting climate targets and how to account for it. This chapter examines the historical and current value of BCR in the voluntary market, analyzing transaction data and using expert interviews to identify potential trends and value drivers.

The BCR market has expanded significantly in the past two to three years. Traditionally, carbon markets focused on avoidance and reduction projects, while removal efforts prioritized afforestation and land use initiatives (nature-based solutions). Industrial carbon removals, including BCR, have only gained traction recently (Kujanpää, et al., 2023).

To assess BCR's current market value, this chapter utilizes data from CDR.fyi, an independent database tracking CDR transactions on the voluntary market (CDR.fyi, n.d.). BCR transaction prices from June 2021–September 2024 are analyzed to evaluate value development, and the attempt to identify trends and key drivers in data. The analysis also assesses data quality, representativeness, and outliers. Five expert interviews help evaluate results, compare observations, and develop hypotheses on high-value outliers and price drivers.

The dataset from CDR.fyi aims to track purchases, deliveries, and verifications, sourcing data from buyers, suppliers, and marketplaces. The analysis filtered the dataset to focus on BCR transactions with a reported price. The following table shows key metrics over the last four years based on the author's analysis. Note 1 ton of BCR is defined as 1 ton of CO_2 sequestrated through biochar, meaning 1 ton BCR = 1 ton of CO_2 removed from the atmosphere (by any permanent CDR technology).

Year	Average (€)/ton BCR	Median (€)/ton BCR	Min (€)/ton BCR	Max (€)/ton BCR	Mode (€)/ton BCR	Share of public prices
2021	169	95	93	502	93	4%
2022	165	140	91	560	140	25%
2023	147	131	100	233	233	4%
2024	156	149	83	434	126	10%

Table 2: Overview of Price Development on the Voluntary Market (CDR.fyi dataset)
Source: Author's analysis based on CDR.fyi's dataset.

The average price per transaction has generally declined, dropping from 169 € in 2021 to 147 € in 2023, before recovering to 156 € in 2024 (see table 2). This pattern indicates fluctuations, with 2023 marking the lowest point. On the contrary, the median increase over time, apart from 2023, indicates an upward trend. The average and median showing different trends suggest strong variation in the prices and outliers. Overall, the market has remained largely non-transparent, with a low share of publicly available prices. The proportion of transactions with disclosed prices increased from 4% in 2021 to 25% in 2022, then declined to 4% in 2023 before rising slightly to 10% in 2024. As a result, drawing definitive conclusions from the limited data is challenging, and the significant fluctuations in publicly available prices may introduce biases regarding trends.

The highest recorded price peaked in 2022 at 560 €, indicating a significant outlier. By 2024, this had dropped substantially to 434 €, suggesting a contraction in the highest price range over time. Interviewees suggest several possible reasons for this high-value outlier and fluctuations:

- A still-developing market with inexperienced buyers as a reason
- A lack of transparency in the past, as buyers had little visibility into what other suppliers were offering or what prices were being paid
- Philanthropic buyers who were more interested in co-benefits of BCR and the storyline behind the project with a higher willingness to pay
- Prices that have been set based on the most expensive substitute of BCR, the DACCS technology

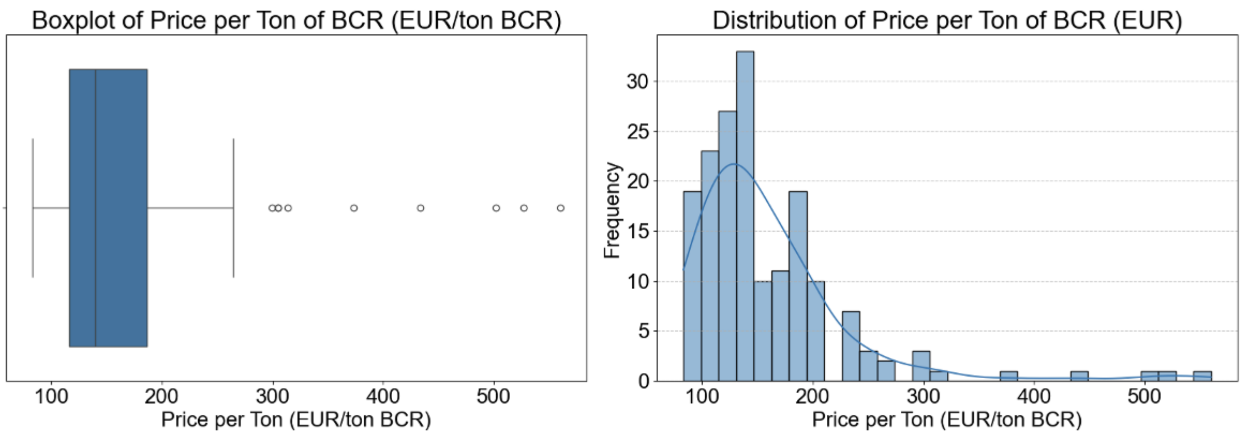

Figure 7: Boxplot & Distribution of Price (€) Per Ton of BCR
Source: Author's analysis based on CDR.fyi's dataset.

The boxplot above shows that most transaction prices fall between 117-187 €/ton BCR, with 50% of the data concentrated in this range (figure 8, left). The right figure reveals that the distribution is right-skewed, meaning most prices are on the lower end, while a few high-value transactions create a long tail. Nine outliers, above 305 €/ton BCR and reaching up to 560 €/ton BCR, contribute to this skew. The histogram indicates a wide price spread, the most common price point is 140 €/ton and BCR (table 6 in annex I).

For the trend analysis, all BCR transaction data with published prices have been plotted (figure 9).

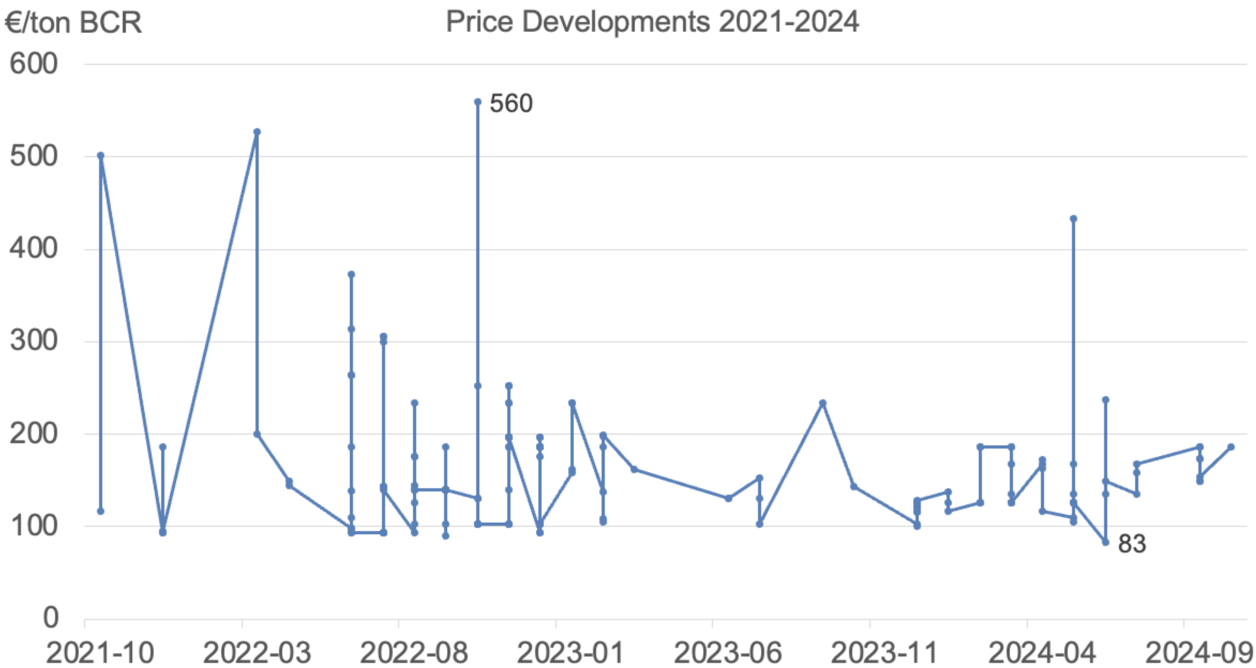

Figure 8: Price Developments 2021-2024 as a Dot Plot
Source: Author's analysis based on CDR.fyi's dataset.

The figure above displays transaction prices over time. A visual inspection suggests high variability and no clear linear pattern or correlation which was confirmed by a trend analysis in Python (results in table 7 and 8 annex I). However, in autumn of all years, the prices increase, indicating a seasonality (see figure 33, annex I). The Python scripts are stored in a GitHub repository (link 1, annex I).

To summarize, no clear linear, but a seasonal pattern was identified. Due to a lack of a linear trend and the presence of extreme outliers, the median price is the best metric for tracking price developments. The median has increased from 2021 to 2024. Another key observation is that, on average, only 10% of BCR transactions had published prices, raising questions about whether reported prices are skewed toward higher or lower values that are publicly reported.

The following subsection will analyze the influence of factors such as marketplace involvement and supplier or buyer patterns based on available data in the dataset.

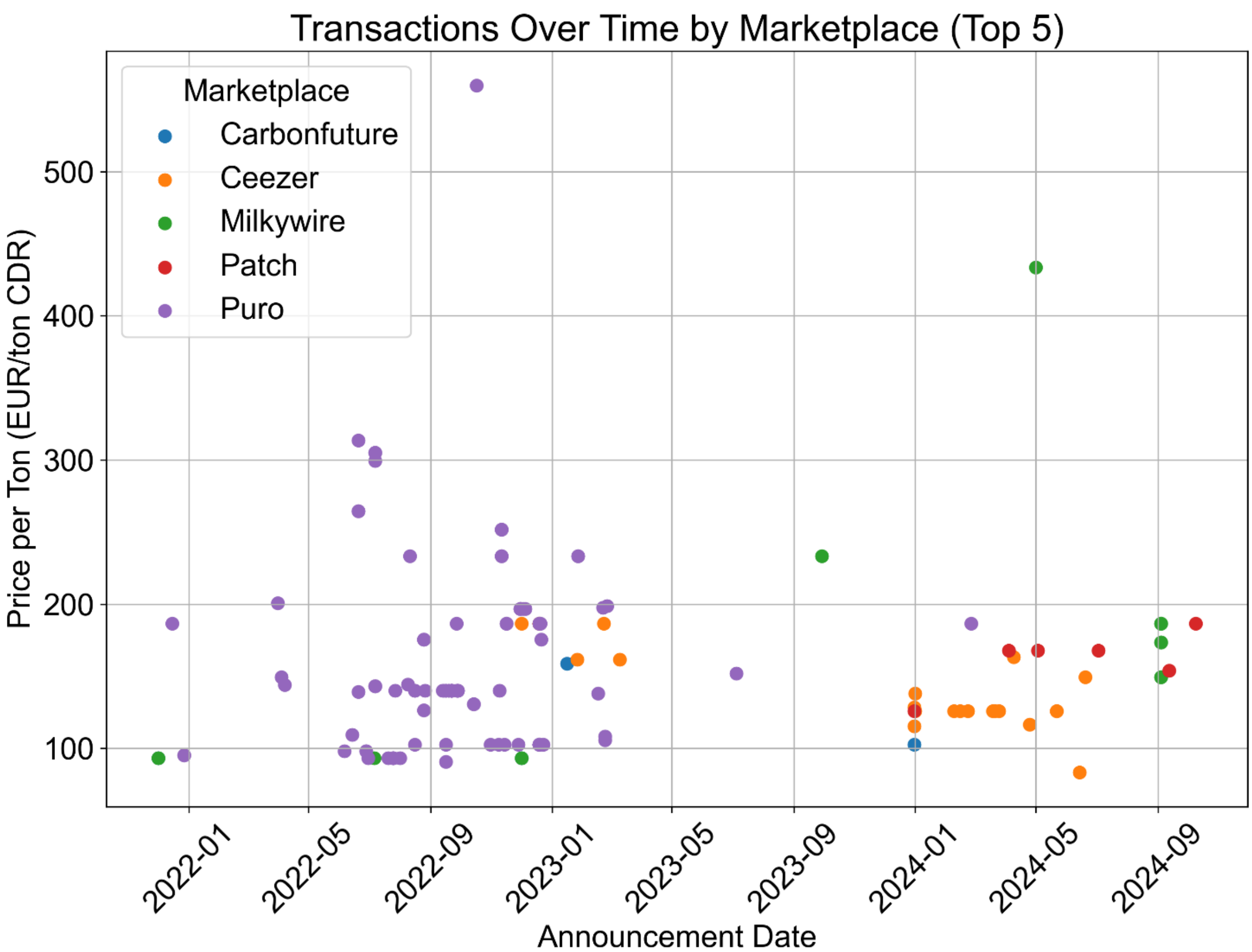

Figure 9: Transaction Over Time by Marketplace (Top 5)
Source: Author's analysis based on CDR.fyi's dataset.

An analysis of the prices based on transactions made by marketplaces reveals that most transactions fall between 100-200 €/ton BCR, consistent with previously identified price ranges. Puro dominates the dataset, with transactions spanning this range but also accounting for a few outliers above 300 €/ton BCR. However, Puro stopped its marketplace activity in 2022, which explains its fading presence in 2023 (Puro.earth, n.d.). Ceezer and Patch show similar price distributions (100-200 €/ton) with fewer outliers. Milkywire, though less represented, includes both low-end prices (below 100 €/ton BCR) and a high outlier (above 500 €/ton BCR BCR), suggesting price extremes.

An outlier analysis of the nine transactions above 305 €/ton BCR shows only four outliers originated from marketplaces (see Graph 32 in annex I), suggesting also no marketplace-specific impact on extreme pricing. Expert interviews confirm this observation.

The majority of buyers, accounting for 55 transactions, remain undisclosed, making it difficult to identify buyer patterns. High-price transactions involve only one or two purchases per buyer within the 500–250 €/ton BCR range, which is not enough to identify a consistent buying pattern (see figure 30 in annex I). Among the buyers, several tech companies and banks are presented, which aligns with De Luna's (2024) analysis of common characteristics of buyers. However, overall, no distinct pattern emerges among the buyers.

The supplier side shows a similar picture. There is no high-value transaction with more than 2 transactions per supplier (see figure 31 in annex I). The only standout supplier is Carbofex, with 6 transactions at an average price of 300 € per ton BCR. Other suppliers have a high number of transactions, but their prices mostly range between 100 € and 200 € per ton BCR. In conclusion, there is no clear pattern among buyers or suppliers.

In the following, interview insights are used to validate findings in the data and learn which key factors are influencing BCR value according to industry experts. Experts confirmed that the price range observed in CDR.fyi's data (120–190 € per ton BCR) aligns with their experience. A broker attributed the autumn seasonality to increased spot price activity by companies nearing the end of their reporting years, a pattern he observed and aligns with the data analysis.

Industry experts identified several key drivers of BCR pricing. There is a strong agreement that production costs significantly shape price trends, aligning with the observed price range of 120–190 € per ton BCR (see blue box graph 8, left side). The ongoing imbalance between supply and demand remains a driver of higher prices on the spot market, especially in autumn.

Experts observe a chicken-and-egg dilemma in project financing. Projects struggle to secure funding without guaranteed offtake agreements, while buyers hesitate to commit without assurances that projects are fully financed. This cycle slows market growth. Additionally, some suggest geographical variations affect pricing, as revenue streams linked to biochar production—such as heat, oil, and physical biochar demand—impact voluntary carbon credit prices. Higher revenue from these streams allows for lower carbon credit prices. Cost-side differences, such as feedstock availability, further contribute to price disparities. There were mixed views on whether geography plays a role in pricing. Some interviewees noted that regional cost differences among suppliers could be a factor, but the dataset did not allow for a detailed analysis. However, there was agreement that marketplace dynamics do not influence prices, which aligns with the findings from data analysis.

Other factors experts named as influences on the price included the permanence and durability of biochar, standards and certifications, additional co-benefits, biochar quality, perceived risk, and the role of storytelling and marketing.

To conclude, the analysis of transaction data in the voluntary BCR shows that the average price per ton declined while the median price increased with a price drop in 2023, but the highest value is in 2024 (149 €/ton BCR). However, prices have fluctuated over the years with no clear trend emerging. Factors such as market immaturity, transparency issues, and the role of philanthropic buyers have influenced price variations and created significant price outliers, alongside fundamental supply and demand imbalances. Data limitations, particularly the low proportion of publicly available prices, introduce uncertainty regarding the representativeness of reported transactions and limit conclusions. Ultimately, no strong patterns could be identified among buyers or suppliers, reinforcing the conclusion that the BCR market remains highly fragmented.

The persistence of supply constraints and project financing challenges suggests that BCR prices may remain volatile in the near future. Moreover, while some interviewees pointed to regional cost differences as potential price drivers, the dataset did not provide sufficient evidence to confirm this hypothesis.

Key points

- There are several standards that guide voluntary buyers mainly on corporate level.
- SBTi is the commonly used framework, prohibiting CDR while assigning a special role to BCR for the agriculture industry.
- Other industries are only recommended by SBTi to purchase CDR credits but cannot account for them in targets - called Beyond Value Chain Mitigation activities.
- Banks and tech companies are seen as the largest buyer group, their partly have their own target-setting guidelines that permit CDR credits as a tool for meeting targets.
- A single example of accounting for BCR on product level has been found, a UK-based company integrating biochar in asphalt and accounting for it under Environmental Product Declarations (EPDs).
- The BCR market is young, with limited data and transparency.
- Most transactions are priced between 120–190 €/ton BCR. The median price has shown an overall upward trend, with a dip in 2023, followed by a recovery in 2024, reaching 140 €.
- The average price in 2024 is lower than in 2021, showing a contrary development to the median, likely linked to more high-value outliers in earlier years.
- High-value outliers are attributed to factors such as philanthropic buyers or inexperienced participants.
- These were the market opportunities in the voluntary market, followed by those in compliance markets.

5.2 Compliance Markets: Frameworks & Current BCR Value

As of now, two compliance frameworks allow for BCR accounting. One on (supra-)national level and the other on product level. The framework on a national level is classified as a compliance framework for this thesis. However, the UN, which established it, lacks enforcement power. The underlying agreement (Paris Agreement) is legally binding. While it is an international treaty and countries are legally bound to submit nationally determined contributions and report progress transparently, the targets themselves are not legally enforceable. There are no penalties or sanctions for failing to meet these targets (Tso, 2021).

5.2.1 UNFCC Agreements & IPCC accounting on a national level

The Paris Agreement and its prior and its predecessors, such as the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC), establish the framework for national GHG emissions reporting and target-setting (United Nations Climate Change, n.d.). Its backbone lies in the Intergovernmental Panel on Climate Change (IPCC) accounting rules, which establish the methodologies for measuring and reporting emissions and removals. These rules are crucial for BCR (Intergovernmental Panel on Climate Change, n.d.). They define which CDR technologies are allowed to be accounted for in national emission inventories. IPCC accounting follows the territorial principle, meaning emissions and removals are attributed to the country where they physically occur (Task Force on National Greenhouse Gas Inventories, 2006).

The guidelines do not yet fully integrate emerging CDR technologies like BCR and all its final application forms. But some are already accepted. Biochar is partially recognized under IPCC 2019 guidelines but only within the land use, land-use change, and forestry (LULUCF) sector. This means it is allowed to be accounted as a negative emission when applied to agricultural soils (Svarer, et al., 2024; Kujanpää, et al., 2023). Despite ongoing refinements, current IPCC guidelines lack default emissions factors for biochar soil amendments. Member states must develop country-specific emission factors reflecting local characteristics before accounting for BCR (European Environment Agency, 2024). Denmark, for instance, is working on a national methodology for biochar application on agricultural land, expected to be completed by 2026, subject to approval by the Danish Centre for Environment and Energy (DCE) and later reviewed by the UN (Klima-, Energi- og Forsyningsministeriet Danmark, 2024; Svarer, et al., 2024).

A key challenge in accounting for BCR is whether carbon storage in agricultural soils qualifies as permanent sequestration, a criterion required for inclusion as a removal (Svarer, et al., 2024). While geological storage meets this definition, growing research and recent advancements have significantly improved our understanding of biochar's long-term stability in soils. Evidence increasingly supports its durability over centuries, though studies continue to refine the estimated fraction of carbon that remains stable over time (Sanei, et al., 2024). If not considered permanent, any emissions released over time must be accounted for (Svarer, et al., 2024).

The accounting of biochar feedstock, biochar and pyrolysis co-products fall into multiple accounting categories under IPCC. Illustration 11 provides an overview of the various accounting categories products. The hierarchical structure, from the UN level to Danish national accounting.

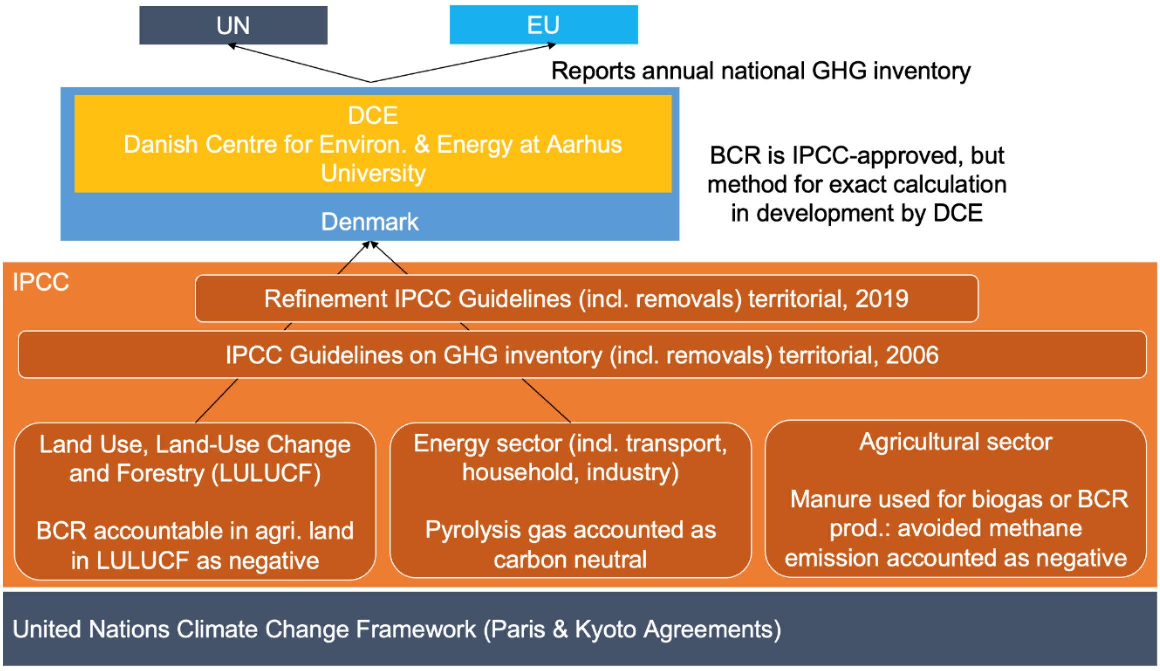

Figure 10: BCR Accounting in National GHG according to IPCC and UN rules
Source: Carla Soleta based on United Nations Climate Change (n.d.); Expert Group on Green Transition Denmark (2024); IPCC (n.d.).

As of January 2024, UN Member States have commissioned the IPCC to develop a methodology report on CDR technologies and CCUS, set for completion by 2027 (Chay & Smith, 2024). This could mark an important step toward recognizing and standardizing various CDR methods, potentially including BCR in applications beyond soil amendments, such as in products.

5.2.2 Renewable Energy Directive (RED II/III)

This compliance framework integrates BCR on product level. The compliance market for renewable energy in the European Union operates under an EU Directive, which means it legally binds all EU member states to achieve specific results. However, each country has some flexibility on how to implement the directive within its national law (European Union, n.d.). Currently, there are 27 national implementations, which follow similar principles but are not entirely uniform.

The main goal of this framework is to promote the use of renewable energy within the EU (EU Directive 2018/2001). It sets specific reduction targets for different industries, including the road transport sector, where rules are established to reduce emissions. One of the key mechanisms for achieving this is the use of fuels with a lower carbon intensity compared to their fossil fuel equivalents. The law requires companies in the sector to cut their emissions by a specific percentage and mandates that they distribute a certain amount of specific advanced fuels to the market (EU Directive 2018/2001; BImSchG). To ensure consistency in measuring carbon intensity, the directive and its implementing regulations provide clear rules for calculating the carbon footprint of these advanced fuels.

BCR is acknowledged in the Implementing regulation (2022/996) concerning fuels derived from biogenic sources, such as biofuels. An example of this is biomethane, which can be used in trucks running on liquefied or gaseous (natural) gas. The framework assesses emissions by evaluating the carbon intensity of biofuels, factoring in both the biomass source and the emissions generated during production. The carbon intensity score (CI score) of the fuel is calculated to be lower when biochar from fuel production is spread on farmland (Commission Implementing regulation 2022/996). Fuels with lower carbon intensity can be sold for higher prices on the market to companies that are regulated by the national implementation of RED (Emmerich, 2023). The lower the CI score, the less advanced biofuel a company needs to buy to comply with its targets.

The current EU regulatory approach incorporates carbon removal technologies such as CCS and BCR as shown in illustration 12:

$$E = e_{ec} + e_{l} + e_{p} + e_{td} + e_{u} - \boxed{e_{sca}} - e_{CCS} - e_{CCR} - e_{ee}$$

E	-	Total GHG emissions from supply and use of the fuel (in g CO_{2eq}/MJ)
e_{ec}	-	GHG emissions from the extraction or cultivation of raw materials
e_{l}	-	Annualized (over 20 years) GHG emissions from carbon stock change due to land use change
e_{p}	-	GHG emissions from processing
e_{td}	-	GHG emissions from transport and distribution
e_{u}	-	GHG emissions from the fuel in use (shall be taken to be zero)
e_{sca}	-	GHG emissions savings from soil carbon accumulation via improved agricultural management
e_{ccs}	-	GHG emissions savings from carbon capture and geological storage
e_{ccr}	-	GHG emissions savings from carbon capture and replacement
e_{ee}	-	GHG emissions savings from excess electricity from cogeneration

Figure 11: Carbon Intensity Score Formula
Source: Directive 2018/2001, Annex VI methodology B.

However, BCR does not fall under the CCS category but is classified as enhanced soil carbon accumulation (E_{sca}), according to Commission Implementing Regulation 2022/996. The contribution of BCR to emission reductions is subject to a cap, with a maximum allowable deduction of 45 g CO_2/MJ of fuel produced. The actual value must be determined through field measurements.

The use of field measurements to calculate the BCR-based carbon removals presents significant challenges. Measuring carbon stock in soil before and after biochar application requires long-term commitments from farmers. Results from a field study in Switzerland imply that it is not possible to reliably confirm the presence of biochar over several years through carbon stock changes in the soil (Thiébaud, et al., 2023). Changes in carbon soil levels short-term are mainly caused by crop rotation, organic fertilizer and weather conditions rather than biochar application (Thiébaud, et al., 2023). Thus, the implementation of BCR for the CI score is deemed to be infeasible in practice. Likely, this is the reason why there are no known cases where BCR has been successfully claimed as part of the CI score of fuels yet, according to interviewed industry experts. Regulatory clarification and a change of method will be necessary to unfold BCR's potential for the transport sector.

The following example of Germany's implementation illustrates how the overall system operates, including EU regulations, national adaptations, and certification schemes based on EU law:

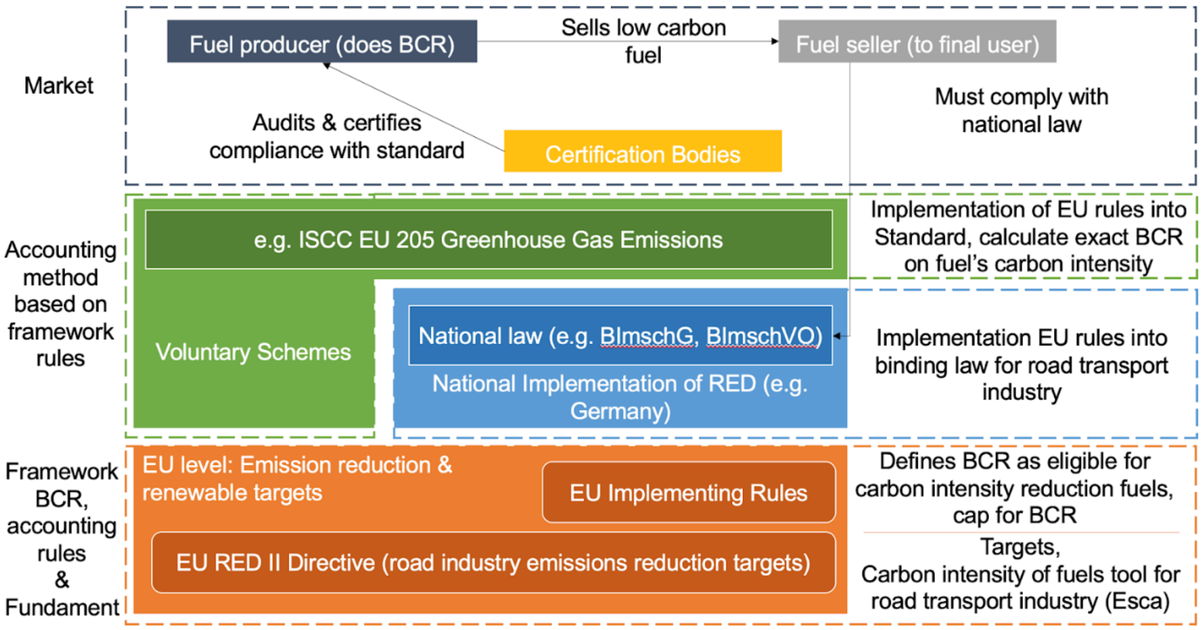

Figure 12: Overview RED Framework with Germany's Implementation
Source: (Commission Implementing regulation 2022/996; EU Directive 2018/2001; BImSchG; ISCC System GmbH, 2024).

The overall system is quite complex. However, the biggest obstacle is the impracticality of verifying biochar application on fields through field measurements, making compliance impossible.

5.2.3 Current Value of BCR on Compliance Market

The current value of BCR in the national compliance market remains undefined. To reach UNFCCC agreements, nations have the flexibility to determine payments through subsidies, purchase programs, or auctions. However, none of those tools have been established in the EU for BCR yet. Denmark is expected to launch the first subsidy scheme soon, but until then, there is no official price benchmark for this compliance market (Klima-, Energi- og Forsyningsministeriet Danmark, 2024). However, for the compliance market based on the RED Directive, a price can be estimated using publicly available data from other carbon intensity (CI) reduction mechanisms than biochar. The fundamental principle governing this market is that lower CI scores make fuels more expensive, as they help companies meet legally mandated emission reduction targets with less amount of fuel.

Germany provides a significant example of a CO_2 displacement market, known as the GHG quota market, which operates under the RED framework. Companies that fail to meet their emission reduction targets must pay substantial penalties—currently set at 600 €/ton CO_2 (BImSchG, 1974, § 37c section 2 No. 1). To avoid these fines, businesses can comply with their GHG quota obligations by investing in various reduction measures across the fuel value chain. One such approach is purchasing low-CI advanced fuels, where BCR could play a role in further reducing CI scores. Another method involves acquiring emission certificates from electric vehicle owners in Germany, who receive financial compensation for selling these CO_2 certificates under the RED framework and finance the purchase of electric vehicles.

Since both BCR and e-car CO_2 certificates are measured in the same unit—€/tCO_2—the e-car market serves as a useful reference for estimating BCR's potential value. However, there is no market data provided by authorities. Some trading platforms publish certificate prices, revealing significant fluctuations in recent years.

Year	**Min (€/t CO_2)**	**Max (€/t CO_2)**	**Average (€/t CO_2)**	**Mode (€/t CO_2)**
2022	na	na	400	na
2023	125	430	239	250
2024 (until week 40)	65	130	105	110

Table 3: Price Development of CI score on the German GHG Quota Market
Datasource: (Schmidt, 2024; Geld für eAuto, 2024; klima-quote.de, n.d.)

As shown in the table, in 2022, prices peaked at around 400 €/tCO_2, while in 2023, they ranged from 125 to 430 €/tCO_2, averaging 239 €/tCO_2. By 2024 (up to week 40), the price range had fallen to

Key points

- BCR accounting is limited but theoretically possible at national and product levels in compliance markets but not used in practice yet.
- National Level: UN-based IPCC rules allow accounting for specific BCR soil sequestration. No country has implemented it yet, though Denmark is planning to.
- Product Level: In the EU fuel market, BCR can be accounted for in biogas-based advanced fuels to lower its carbon footprint (CI score). However, proving sequestration through required field measurement makes it infeasible.
- Prices in the compliance fuel market have dropped significantly in recent years—from 400 €/ton in 2022 to around 105 €/ton, with lows of 65 €/ton—partly due to fraudulent certifications from China.
- After examining current market opportunities, the focus now shifts to exploring future opportunities that are in development.

65–130 €/tCO_2, with an average of 105 €/tCO. This decline in prices is largely attributed to an oversupply of biofuels from China that were misclassified under Germany's RED implementation, leading to market distortions and price dumping (Staude, 2024). If the authorities succeed in preventing the influx of these biofuels by proving that they are falsely certified, the price could return to the 2022 level.

6 Who could account for BCR in the future

This chapter provides an overview of frameworks that are considering the integration of CDR, as well as existing frameworks that, with revision, can create a valuable business opportunity and become a value driver for BCR. Afterward, it explores the legislative landscape around BCR accounting, biochar and climate target claims.

6.1 Evolving Voluntary Frameworks

6.1.1 Revised Corporate Net Zero Standard by SBTi

The SBTi is revising its Corporate Net-Zero Standard to refine how companies should handle residual greenhouse gas emissions. In its revision, the SBTi is exploring the role of environmental attribute certificates, such as carbon removal credits, particularly concerning Scope 3 emissions, which are indirect emissions occurring in a company's value chain (Science Based Targets initiative, 2024). A discussion paper by the SBTi outlines three potential approaches for integrating carbon credits (Carrillo Pineda, et al., 2024):

1. Utilizing credits from mitigation activities within a company's own value chain (does not include CDR, but BCR in some cases).

2. Employing credits to neutralize residual emissions, aligning with the requirement for permanent CO_2 removal.

3. Purchasing and retiring high-quality carbon removal credits or making direct investments to support mitigation beyond the company's value chain.

The SBTi emphasizes that while these approaches are under consideration, direct decarbonization within a company's operations and value chain remains the primary focus.

The SBTi has sparked controversy with its proposal to allow environmental attribute certificates (EACs), including carbon credits, to count toward Scope 3 emissions abatement (Wright, 2024). Critics argue that this move fundamentally undermines the organization's science-based approach by shifting the focus from direct emissions reductions to market-based mechanisms that lack transparency and consistency (Jessop, 2024). Climate experts and some SBTi staff have voiced concerns that relying on carbon credits could dilute corporate accountability, allowing companies to claim progress without making real, measurable reductions in their value chains (Wright, 2024; Jessop, 2024).

An interview with an industry expert on SBTi accounting explained that including carbon removals from outside a company’s value chain can lead to poor accounting. This is because the Greenhouse Gas Protocol follows an attributional approach, linking emissions directly to a company's physical operations. Adding external carbon credits would create a mismatch between reported emissions and actual business activities, weakening the accuracy of emissions accounting.

The upcoming revisions to the SBTi Net-Zero Standard could lead to different scenarios, each with unique implications for BCR. If no CDR is allowed, BCR will remain only relevant for companies with FLAG emissions as it is today. If carbon dioxide removal (CDR) is allowed as long as it occurs within a company's own value chain, BCR could be used to counterbalance more than just FLAG emissions. This would be particularly beneficial for companies with agricultural activities in their Scope 3 emissions or those involved in the production of building materials, such as asphalt or cement, that can be mixed with biochar. However, the extent of its applicability will depend on which methodologies the SBTi recognizes as suitable for validating removals and its final sequestration application. The most expansive scenario would allow CDR credits, regardless of where removals occur, to offset Scope 3 emissions, significantly increasing market demand for all CDR technologies. While the extent of market pull for BCR varies across these scenarios, only the first would maintain the status quo. The final decision timeline is uncertain, but an official outcome is expected in 2026 (Science Based Targets initiative, n.d.).

6.1.2 BCR in Product Environmental Footprint for Food Products

On product level, more frameworks and projects aim to account for BCR in their footprint. A pilot project from Denmark on food explores how BCR can be integrated into a Product Environmental Footprint (PEF) and used as a basis for environmental claims. If it is successful it potentially opens a business opportunity for BCR within the food product category that could drive BCR's value. The project focuses on producing climate-neutral rye bread and rolled oats by incorporating biochar into their value chains. Straw from cereal cultivation undergoes pyrolysis to generate biochar, which is then returned to the field as a stable carbon sink. By demonstrating how BCR can contribute to climate neutrality in food production, the project aims to provide a model for scaling this approach within the industry (SEGES Innovation, n.d.).

To ensure a standardized and credible assessment of the environmental footprint, the project follows the guidelines set by the EU Product Environmental Footprint (PEF), recommended by the European Commission (2021/2279) (European Commission, Environmental Footprint, n.d.). PEF itself is not a methodology but a framework method that guides how to conduct LCAs in a harmonized and comparable way across products and sectors.

Since the PEF method does not currently account for biochar removals, the project proposes an "add-on" approach to include this impact in a structured and transparent way. However, this addition is not yet formally integrated into PEF for food products. To maintain credibility, the LCA undergoes third-party verification both with and without the add-on. While the methodology aligns with general LCA standards such as ISO 14040 and ISO 14044, the proposal of the add-on could be the first step towards a PEF method that allows for BCR as long as it is along its value chain (SEGES Innovation, n.d.).

The project is not concluded yet, but if successful, creates an opportunity for BCR to reduce the climate footprint of food products. Results are expected at the end of 2025 (SEGES Innovation, n.d.). However, there is only a business opportunity if companies can claim those removals towards their product footprint. If not given, companies have no current incentive to do so, because it is impossible to differentiate from market competitors that are not making those extra efforts. Those claims are regulated on national and EU levels with a potential update through the Green Claims Directive in the coming years (EU Energy, Climate change, Environment, n.d.) (further details in chapter 6.3.2).

6.2 Compliance Frameworks with Possible Future BCR Applications

6.2.1 EU ETS

This chapter aims to explain the European Union Emissions Trading System and its connection to BCR. Additionally, it will address key research questions by

- Comparing the scope of the EU ETS with the commonly used scope concept of the voluntary market (scope 1, 2, and 3 as used by SBTi).
- Investigating if biofuels containing biochar negativity are already acknowledged today in the EU ETS system, similar to the REDII regulation.

The EU ETS is a compliance market tool based on a cap-and-trade system designed to reduce greenhouse gas (GHG) emissions within the EU's borders (European Commission, n.d.). It sets a cap on emissions from certain sectors, ensuring alignment with the EU's climate policy objectives, such as the goal to reduce emissions by 55% by 2030. The system applies to energy and industrial sectors, aviation (since 2012), and maritime transport (since 2024) (European Commission, n.d.). A new extension, EU ETS II, will cover CO_2 emissions from fuel combustion in buildings, road transport, and additional sectors, becoming fully operational in 2027.

The mechanism operates through European Union Allowances (EUAs), tradable certificates that companies must buy to match their reported emissions. Some industries receive a proportion of their EUAs for free, based on industry benchmarks, while others must purchase allowances through auctions (EU Directive 2003/87/EC).

The scope of the EU ETS system includes apart from CO_2 six other greenhouse gases as presented in illustration 14.

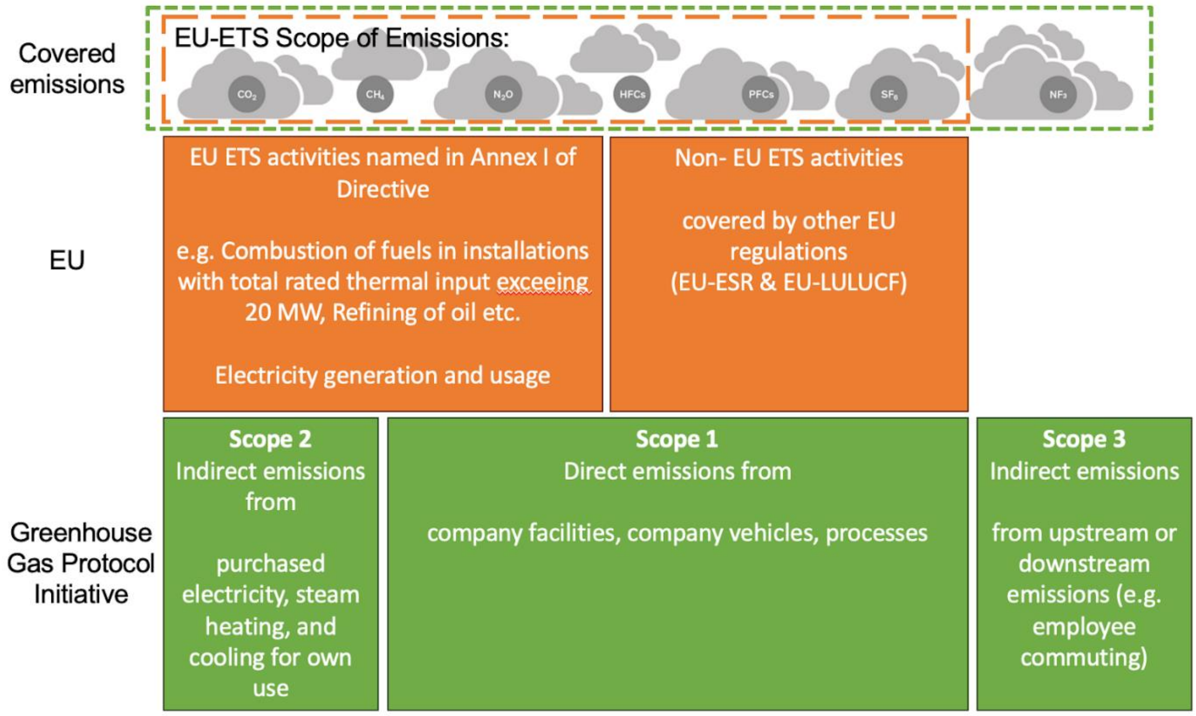

Figure 13: Comparison Scope of EU ETS to Scope 1,2,3 from the Voluntary Market
Source: (EU Directive 2003/87/EC; Roelfsema, Kuramochi, & den Elzen, 2024; Ranganathan, et al., 2015).

The EU ETS does not categorize emissions into Scope 1 (direct emissions), Scope 2 (indirect emissions from purchased electricity), and Scope 3 (other indirect emissions), unlike the most popular voluntary framework (Ranganathan, et al., 2015). However, they have some overlaps. The EU ETS assigns emission regulations based on activity types outlined in Annex I of the EU ETS Directive. Scope 1 emissions from companies involved in electricity generation, energy-intensive industrial processes, and aviation fall under the EU ETS, while others are regulated by another EU regulation, the Effort Sharing Regulation (ESR) (Roelfsema, Kuramochi, & den Elzen, 2024). Scope 2 emissions are indirectly included since the power generation industry falls under the ETS system, thus also its emissions (Roelfsema, Kuramochi, & den Elzen, 2024).

The system allows for CCS and CCUS, provided these activities are covered under the EU ETS Directive Annex I (EU Directive 2003/87/EC). Article 49 of the EU Monitoring and Reporting Regulation 2018/2066 (MRR) permits installations to subtract captured CO_2 from their reported emissions if it is permanently stored in geological formations or used in processes where it is chemically bound, such as in precipitated calcium carbonate production.

While CCS and CCUS are recognized, there is no direct provision for BCR in the EU ETS. The European Commission is set to assess CDR methodologies, including BCR, and provide a report to the European Parliament and Council by the end of 2026 on potential integration pathways (Levina, Blanchard, & Gerrits, 2023).

There is also no indirect integration of BCR into the ETS through biofuels. The system currently assumes a zero-emission factor for biomass-derived fuels that meet sustainability and GHG reduction criteria under the Renewable Energy Directive (RED) (DNV, 2023). However, the emission factor for biochar-containing fuels is not explicitly defined in the EU ETS Directive Annex IV. Since the emission factor for fuels from sustainable biomasses is set to zero, there is no current mechanism to account for additional negative emissions from biochar.

At present, biochar is not accounted for in the EU ETS, either directly as a carbon removal method or indirectly through biofuels with embedded biochar. The existing EU ETS framework recognizes CCS and CCUS but does not yet provide integration rules for BCR. Further policy developments will determine whether biochar can contribute to the EU's carbon reduction goals within the EU ETS framework. The potential for its integration remains open, pending the Commission's 2026 assessment. There are many considerations on how to integrate CDR, like BCR, into the EU ETS. Those will be further in chapter 9.

6.2.2 RED (revised)

The goal of this chapter is to outline how RED (EU Directive 2018/2001) needs to be revised to make BCR a practical and valuable option for companies. Currently, regulatory constraints, particularly field measurement requirements, prevent businesses from utilizing BCR as discussed before. To recap, at present, BCR is classified as a "biological" removal rather than being recognized as an industrial permanent removal within the CCS variable (see figure 12, chapter 5.2.2). To align with broader EU considerations and unlock its full potential, BCR's classification must be reconsidered.

The EU currently is preparing a technology-specific methodology for the certification of BCR on the voluntary market. The regulation is called the Carbon Removal Certification Framework (CRCF) (Regulation (EU) 2024/3012, 2024), which outlines general rules and is the base for each technology-specific methodology. Under the CRCF, the EU COM is handling BCR as an industrial permanent carbon removal (European Commission, 2024). To align the EU CRCF initiative with the RED, a reclassification of BCR in RED is favorable. There are three possible pathways:

1. Reclassify BCR under the CCS variable and replace field measurements with proof of carbon sequestration based on CRCF methodology.

2. Retain its categorization under E_{sca} but modify the field measurement requirements to align with CRCF standards (least aligned option with CRCF).

3. Establish a new variable, E_{CDR}, with its own set of specific rules and implementation guidelines based on the CRCF methodology for BCR.

For BCR to be effectively implemented, regulatory changes must address existing obstacles. This could be achieved in two ways: either by amending RED to introduce a new variable for BCR or by modifying the Implementing Rule 2022/996 to replace field measurements with a more practical method for verifying biochar sequestration.

An industry expert interview highlights key flaws in the RED market and necessary adjustments. According to the interview, a recurring issue is the lack of regulatory understanding of the biogas trade, leading to imprecise and inconsistent guidelines. The vague framework of RED results in fragmented national implementations, causing distrust among EU nations regarding products and certificates. Variations in national tools and handling of proof of origin and sustainability further complicate the market. Audits and certifications differ across countries, creating a trust gap that discourages buyers from participating due to concerns about regulatory compliance and target accounting.

The EU has reacted to some of the named issues by introducing the Union Database (UDB). It was designed to centralize trade records, but practical issues like unclear data transfer processes limit its effectiveness. To improve the system, several recommendations have been suggested:

- Standardizing Proof of Sustainability (PoS) of the biomass used for biogas production and clear definitions across all EU countries.
- Centralizing transactions within the Union Database to ensure immediate, transparent, and accessible trade records with clear rules on how data is collected and transferred.
- Avoid national-level interpretations that hinder standardization and credibility for commodities traded with green certificates.
- Strengthening the link between physical projects and certification to build trust.

In summary, while BCR is included in RED, market opportunities remain inaccessible due to impractical implementing regulations, such as field measurements. This chapter presents potential revisions to RED, based on the author's analysis and insights from an industry player trading biogas and related certificates (PoS).

6.2.3 Danish Industry CO_2 Tax, Green Tripartite Agreement, CO_2 Tax Agriculture & Subsidy for Biochar on Farmland

Denmark is implementing various strategies to reduce greenhouse gas emissions across its industrial and agricultural sectors, many of which could support or integrate BCR as part of the country's climate initiatives. This chapter aims to highlight the most important tools that could help establish a market for BCR in Denmark.

The first tool is CO_2 taxes for various industry sectors, both within and outside the EU ETS. In June 2022, the Danish government, alongside a majority in Parliament, agreed on a green tax reform targeting industrial emissions (State of Green, 2024). Starting in 2025, companies outside the EU ETS will face a CO_2 tax of approximately 100 € per ton, while those within the EU ETS will incur an additional 50 € per ton on top of the existing ETS price (Danish Ministry of Taxation, 2024). Notably, companies employing CCS can deduct captured CO_2 from their taxable emissions (Danish Ministry of Taxation, 2024). This mechanism could be potentially extended to BCR in the future. This approach would assign a clear economic value to CO_2 removals, aligning with the tax rates.

Secondly, Denmark has also introduced a CO_2 tax targeting agricultural emissions, set to commence in 2030. If BCR were implemented similarly to CCS in the industrial CO_2 tax, its values would be the benchmark for BCR's value. This tax differentiates between emission sources, such as livestock, liming, and drained peatlands. For instance, emissions from livestock will be taxed at 300 DKK (~40 €) per ton in 2030, increasing to 750 DKK (~100 €) per ton by 2035 (Quiroz & Dwyer, 2024). This has been part of the Green Tripartite Agreement, a collaborative effort among the government, industry, and environmental groups, that aims to reduce emissions in agriculture, land use, and forestry. Beyond the CO_2 tax, the agreement encompasses initiatives like stricter nitrogen regulations, support for reforestation, and subsidies for biochar storage (Danish Government, 2024; Fraas, Højte, & Johansen, 2024).

Thirdly, in October 2024, Denmark launched its Pyrolysis Strategy and Work Program to promote biochar production and application. The government has allocated over 10 billion DKK (approximately 1,34 € billion) for biochar subsidies, from 2027 extending up to 2045 (Heick, 2024). This funding aims to incentivize biochar production and its use in agriculture, enhancing soil quality and sequestering carbon. The exact subsidy amount per ton of CO_2 sequestrated is not public yet. Some sources estimate an average subsidy of 300 € per ton of biochar-sequestered in soil (Cavallito, 2024). Assuming a CO_2 content of 3 tons of CO_2 per ton of biochar (Fawzy, et al., 2022) this corresponds to a subsidy of 100 € per ton of CO_2. The exact carbon content of biochar depends on the carbon content of the feedstock used for its production. Thus, the final subsidy per ton of biochar could vary. The strategy also includes clear regulations for biochar use in soils, simplified permitting processes for establishing pyrolysis plants, and efforts to integrate biochar's carbon sequestration into Denmark's greenhouse gas inventories (Danish Government, 2024).

While Denmark's policies currently focus on subsidies to promote biochar, discussions are ongoing about integrating carbon removals like BCR into CO_2 tax frameworks as a negative tax (Sørensen, 2023).

Three experts were interviewed on the potential role of carbon taxation and biochar in Denmark's agricultural sector. Two experts pointed out that the subsidy scheme must be designed with the right incentive for farmers to contribute to Danish climate targets. The subsidy must be equal to or higher than the BCR value on the voluntary market, thus farmers sell carbon removal benefits to the Danish state instead of to companies. Both experts expect that the subsidy won't allow farmers to receive subsidies for sequestrating biochar and sell BCR credit on the voluntary market. One highlighted that he favors the Danish approach of keeping subsidies for BCR and CO_2 taxes separately.

In conclusion, Denmark uses different tools to reduce greenhouse gas emissions while supporting carbon removal strategies such as BCR. From 2027 there will be a new market opportunity for BCR players in Denmark that use soil application on agricultural land. The exact value of a BCR is to be defined until 2027 by the Danish government.

6.3 The Policy Landscape Surrounding BCR Accounting

Some regulations and voluntary standards create a market for BCR, while others influence solely accounting, handling of biochar, and defining permissible claims that can be made based on BCR activity. The following chapter highlights key regulations and standards that serve this secondary role.

6.3.1 Carbon Farming and Carbon Removal by the EU

The EU is taking a step toward regulating carbon removal in the voluntary market with the introduction of the CRCF. This framework sets a standard for verifying and certifying carbon removal credits, including technologies like BCR, BECCS and DACCS. The primary goal is to promote trust and transparency in the market while preventing greenwashing, fraud, and unreliable claims (European Commission, n.d.).

The EU's new framework defines clear rules for measuring, reporting, and verifying (MRV) carbon removals, as well as setting rules for permanent storage, assessing the permanence of CDR methods and addressing sustainability concerns of biomass used for BCR and BECCS (EU Regulation 2024/3012). The framework classifies biochar as a permanent carbon removal solution, placing it in the same category as BECCS and DACCS (European Commission, EU Carbon Removal Certification – Biochar Methodology, 2024). By providing standardized criteria, the CRCF helps to lay the groundwork for integrating carbon removal solutions into broader EU policies like the European Green Deal, the EU ETS, or potential public purchasing programs.

6.3.2 Green Claims Directive

The Green Claims Directive is a legislative proposal by the European Commission aimed at ensuring that environmental claims made by companies about their products or services are reliable, comparable, and verifiable across the EU. Its primary objective is to protect consumers from misleading information, commonly known as "greenwashing," and to empower them to make informed purchasing decisions that contribute to a circular and green EU economy (COM/2023/166 final). The directive is intended for companies operating within the EU market that make voluntary environmental claims in business-to-consumer communications.

Regarding claims about carbon-neutral or carbon-negative products or companies, the directive requires that such environmental claims be substantiated using robust, science-based, and verifiable methods (COM/2023/166 final). It does not specifically mention CDR or BCR. However, any environmental claims related to these topics would fall under the general requirements of the directive, necessitating proper verification to ensure their reliability. However, the directive COM/2023/166 final mentions the EU's attempt to develop a certification framework for removals, CRCF, and other existing legislation that tackles the problem of greenwashing and unreliable environmental labels. The Green Claims Directive aims to complement or specify those.

The Green Claims Directive could have significant implications for the voluntary BCR market. It addresses one of its main engines: possible claims on company or product level as drivers for BCR scale and value by limiting claims of carbon negativity or net zero. However, if the draft acknowledges claims based on the CRCF framework, it could also act as a driver for the voluntary BCR market. (Manhart, From greenwashing to green trust: the state of European environmental claims regulation, 2024). The directive creates both challenges and opportunities, driving markets toward credible and standardized practices.

6.3.3 EU ESR & EU LULUCF

The EU uses several key regulatory tools to meet its climate targets, including the Effort Sharing Regulation (ESR) and the EU Land Use, Land Use Change, and Forestry Regulation (EU LULUCF). The main tools to reach its overall target are shown in the illustration below:

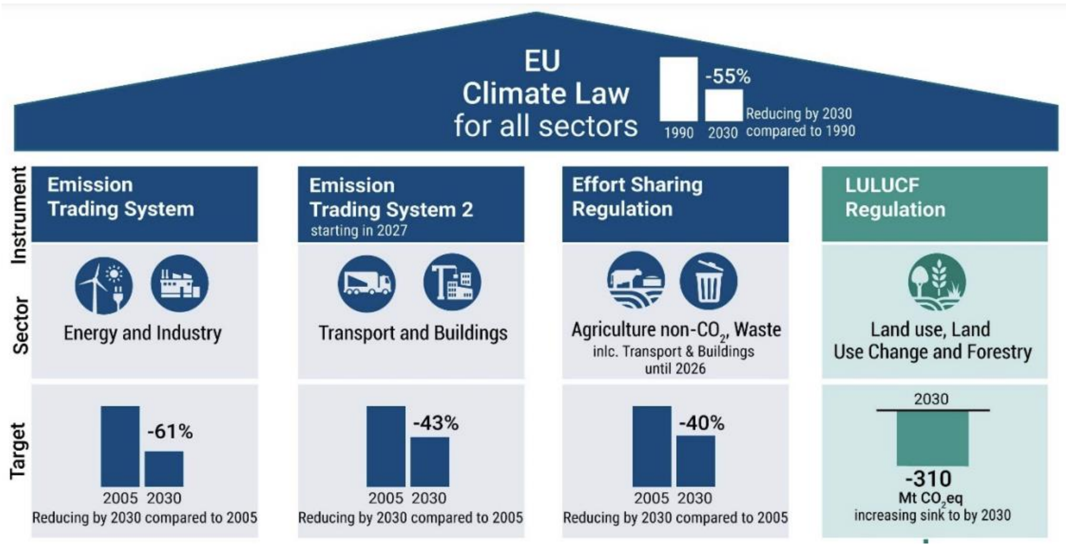

Figure 14: EU Climate Law and its Main Tools (ETS, ESR and LULUCF)
Source: European Environment Agency (2024).

These set binding national targets for greenhouse gas (GHG) reductions in non-ETS sectors (e.g., transport, buildings, agriculture) and the land-use sector (Kujanpää, et al., 2023). The EU LULUCF follows the scope of the LULUCF category in the IPCC's national GHG accounting rules (European Commission, n.d.). Although they share a similar name, they should not be confused with each other. The upcoming ETS 2 will support member states to achieve targets under the ESR obligations (European Commission, n.d.). However, the implementation of measures to meet national targets is mainly left to individual Member States which differs from the EU ETS approach.

Both the ESR and EU LULUCF can have implications for BCR. Some CDR, CCS, and CCUS technologies are recognized in GHG accounting under the ESR and EU LULUCF Regulation, in line with the IPCC guidelines reported to the UNFCCC (Kujanpää, et al., 2023). However, these regulations do not provide incentives for deploying specific technologies and, therefore, do not create a direct market for them. Instead, the implementation and promotion of CDR depend on national policies. The willingness of individual Member States to adopt these technologies is influenced by their GHG reduction commitments.

Key points

- Voluntary Market: SBTi is updating standards to potentially allow CDR to balance Scope 3 emissions by 2026.
- Compliance Market: The EU is assessing by 2026 if CDR should be included in the EU ETS.
- Product Level: Future revisions of the RED could simplify BCR accounting by replacing field measurements with methods from existing regulatory standards.
- Recent Danish initiatives incorporate BCR in the national climate strategy, focusing on agriculture, CO2 taxes, and future subsidies for biochar soil sequestration.
- Policy Landscape: EU voluntary market standards are partly adopted, with BCR-specific rules under development (CRCF). The upcoming Green Claims Directive will regulate claims and recognize CRCF as a quality standard.
- Various frameworks create market opportunities for BCR, though they may overlap. The next chapter assesses the associated risks and opportunities.

7 Overlap of Frameworks: Double Counting, Double Claiming & Double Subsidizing

This chapter assesses the risks that overlapping carbon accounting frameworks pose to achieving global climate targets. Multiple public and private frameworks incentivize GHG reductions across different levels—national, corporate, or product-specific—often resulting in overlaps. These overlaps raise concerns about double counting, double claiming, and double subsidizing, which can create inconsistencies, inefficiencies, and confusion (Kujanpää, et al., 2023; Voysey, 2024; Kammann, 2024). In addition to structural overlaps, the terminology itself creates confusion. As Scherger (2023) notes, "[...] many different terms are used to describe the problem — including double claiming or double use — double counting [...]".

The chapter aims to:

1. Define and contextualize key terms.
2. Evaluate the risks of overlaps across frameworks based on their impact on global climate targets.

7.1 Definitions and First Assessment

Terms such as double counting, double claiming, and double financing are often used interchangeably but lack universally agreed-upon definitions (Guidehouse, 2024; Voysey, 2024). This lack of clarity complicates discussions around overlaps within and across frameworks. To assess the overlap of frameworks effectively, it is crucial to first distinguish what these terms mean within the context of a single framework vs. across several frameworks before evaluating the risks of frameworks overlapping.

The definitions are summarized in figure 16:

	Buyers BCR		Supplier BCR
Entities fall (e.g. companies)…	**Double accounting**	**Double claiming**	**Double financing (double subsidizing*)**
under the same framework: Definition **(e.g. SBTi Net Zero Standard)**	The same removal unit is counted more than once within the same framework	Two entities claim ownership of the same removal unit and claim it as progress toward their own targets under the same framework	The supplier of carbon removals receives financial contributions from multiple entities for the same removal unit.
under different frameworks: Definition **(e.g. RED II and EU ETS)**	The same removal unit is accounted multiple times across different frameworks	Multiple entities claim the same removal unit under different frameworks toward their targets - One entity claims the same removal unit under different frameworks	The supplier receives financial contributions for the same removal unit from different frameworks

*if financial contributions from different public sources

Figure 15: Definition of Double Accounting, Double Claiming, Double Financing

Source: Author's work based on conducted industry expert interviews; Science Based Targets initiative (2024); Scherger (2023); Cullenward, Badgley, & Chay (2023).

The risk of these overlaps can be assessed using two criteria:

1. **Integrity of the Accounting System** – Does the overlap compromise accurate and reliable accounting within a framework? If overlaps undermine the system's integrity, they lead to incorrect results and are unacceptable.

2. **Consistency Across Frameworks** – Are accounting methods aligned across different frameworks to ensure that removals or emissions are treated consistently, such as by geographical territory or sector? If consistency is lacking, it becomes a political decision to balance the risks and benefits—such as public perception and transparency versus funding incentives.

These criteria were selected based on issues raised by interviewees and discussed in the literature (Cullenward, Badgley, & Chay, 2023; Guidehouse, 2024; Scherger, 2023). The final assessment based on the criteria is its impact on the global climate target – does the overlap impede progress toward global climate goal? This assessment is more subjective and requires weighing competing priorities: Should consistency and transparency take precedence, or should frameworks focus on encouraging financial contributions and scaling climate mitigation action?

Two frequent examples illustrate how overlaps occur (Kammann, 2024; Scherger, 2023; Kujanpää, et al., 2023; Cullenward, Badgley, & Chay, 2023):

1. **Company vs. National Claim**: A U.S.-based company purchasing a CDR unit from Denmark may claim it toward its voluntary climate target while Denmark includes it in its national inventory.

2. **Multiple Framework Claims**: A company may claim the same removal under multiple legal frameworks, such as RED II and SBTi FLAG targets, potentially leading to inconsistencies. It is a question of whether the same CO_2 removal unit can be counted for multiple legal acts by the same entity (Voysey, 2024)

	Buyer BCR		Supplier BCR
Entities fall (e.g. companies)…	**Double accounting**	**Double claiming**	**Double subsidizing**
under the same framework: Definition **(e.g. SBTi Net Zero Standard)**	The same removal unit is counted more than once within the same framework	Two entities claim ownership for the same removal unit, often due to financial contributions (e.g., purchasing the unit or subsidizing the action) and often publicly announcing it as progress toward their climate goals	The supplier of carbon removals receives financial contributions from multiple entities for the same removal unit.
Assessment (based on integrity criteria)	✔ Vertical: fine ✖ Horizontal: not allowed due to integrity of accounting	✔ Vertical: fine ✖ Horizontal: not allowed	Political decision, if allowed or not

Figure 16: Assessment Double Accounting, - Claiming, - Subsidizing under One Framework
Source: Author.

In summary, within a single framework, horizontal claiming and accounting are generally not permitted as they compromise the integrity of the system. In the context of the EU CRCF development, this is likely the scope when the legal text refers to "[…] avoiding double counting […]" (EU Regulation 2024/3012). Whether double financing is allowed is ultimately a political decision. A political decision means for the integrity criteria it is not an issue to have this allowed or not, but it is a political decision/evaluation needed whether it is wanted or not. In the voluntary market, this issue is addressed through a financial additionality requirement (Climatetrade, 2023). To register and verify a CDR unit, suppliers must prove that the revenue from the CDR credit is essential for the activity to occur. If a company can carry out the activity without relying on credit revenue, the activity cannot be verified as a carbon removal. Vice versa, if one finance source is not enough to ensure the activity, credits can be registered and verified even if more than one finance source was used.

	Buyer BCR		Supplier BCR
Entities fall (e.g. companies)…	**Double accounting**	**Double claiming**	**Double subsidizing**
under different frameworks: Definition **(RED II and EU ETS)**	The same removal unit is accounted for across different frameworks	One or multiple entities claim the same removal unit under different frameworks toward their targets	The supplier receives financial contributions for the same removal unit from different frameworks
Assessment	✔ No influence on integrity of each system unless summed up, if summed up, correction factor is needed for double-accounted items ⚡ Consistency: results of accounting systems do not align with each other, can be confusing to the public,	✔ Integrity: see double accounting ⚡ Consistency: allowing actions to count toward multiple targets (e.g., ETS & RED), can distort the perceived ambition of overall climate goal plan, political decision	✔ No influence on integrity ⚡ Consistency: can be perceived as ineffective allocation of financial resources from public or demand side

Figure 17: Assessment Double Accounting, - Claiming, - Subsidizing under Several Frameworks
Source: Author.

Figure 18 shows the assessment under several frameworks. While none of the three creates an issue for integrity, all three have advantages and disadvantages regarding the consistency between different frameworks. The question is whether the advantages outweigh its opponents or not. To answer the question, ten industry experts were asked to give their input and opinions and point out risks as well as opportunities. The input is on double accounting, claiming and subsidizing regarding overlaps across different frameworks not within one.

7.2 The Perspectives of Industry Experts

Most experts agree that overlapping frameworks do not threaten the technical integrity of carbon accounting. So double accounting and claiming are permissible. In case different frameworks are summed up, correction factors can be applied. For example, EU greenhouse gas accounting adjusts for double counting emissions from biomass across the EU ETS and LULUCF regulations according to one EU policymaker.

Opinions diverge on how to manage consistency between frameworks:

- Supporters of geographic alignment argue that accounting and claims under voluntary frameworks should match national inventories territorially to avoid discrepancies.
- Proponents of flexibility emphasize the need to attract diverse funding sources to scale the carbon removal industry. Strict alignment, they argue, could limit international collaboration.

A policy advisor pointed out that if entities can use the same removal to meet multiple targets—such as both EU ETS and RED targets—the total level of ambition may be less than initially anticipated by the EU.

Transparency and clear communication are key to maintaining public trust and preventing misunderstandings. Several experts also highlight that double claiming can be permissible if the removal is counted only once in the national inventory, ensuring that both corporate and national actors contribute to climate action. Some suggest dividing claims proportionally or distinguishing between types of claims (e.g., financial contribution vs. reduction target).

None of the experts interviewed support the position found in parts of the academic literature, which argues that only one entity—either the company or the state—should make a claim. According to Scherger (2023), the rationale behind this stricter approach is the belief that the voluntary market should aim to drive additional reductions beyond what governments have pledged. Allowing both corporate and national claims risks undermining that goal.

Double subsidizing is generally seen as essential for scaling carbon removal technologies among the interviewees. Public support and private investments often complement each other, reducing financial risks and accelerating development. However, critics warn of inefficient resource allocation if projects receive excessive public funding while still being eligible for voluntary market credits. Balancing these funding streams requires careful management and transparency.

One expert pointed out, the real-world impact of allowing double or even triple accounting and funding is relatively small compared to the complexity and rules required to prevent it. What matters most is ensuring transparency and clear communication to maintain trust and avoid inefficiencies. If stakeholders understand how funding is distributed and why different streams are necessary, confidence in the system can be preserved.

7.3 Summary of the Overall Assessment

The risks of overlapping frameworks like double accounting, double claiming, and double subsidizing/financing are often misunderstood and discussed out of context. Double accounting across several frameworks is not a threat to the integrity of carbon accounting systems but is frequently misrepresented as one. Different accounting systems mustn't be summed up without their overlaps being corrected. The real debate centers on whether different frameworks should align and if multiple funding channels should be allowed.

Double claiming remains controversial. It is ultimately a political decision about who can claim carbon removals. Proponents argue that it does not compromise accounting integrity and that reaching global climate targets requires cooperation across different levels and entities. Allowing double claiming secures essential incentives to support climate technologies from different actors. Especially when a single income stream is insufficient, or governments cannot finance the industry alone. Critics, however, highlight risks such as inconsistencies between frameworks, public confusion, and inefficient resource allocation.

Double subsidizing raises similar questions. Should public targets for carbon removal be fully backed by government funding, or is it acceptable to use private investment? The conflicting opinions appear to stem from differing interpretations of the purpose of the voluntary market: Can it support government targets, or does it have to go beyond them to achieve additional reductions?

Supporters of combining public and private funding emphasize its necessity for scaling risky, emerging technologies. It's common practice in other industries, like energy, where public funds and private investments are bundled because no single actor—state or market—can bear the full cost and risk alone. On the other hand, critics warn of inefficient resource use and the risk of funding projects that might have happened without additional support. Ultimately, balancing public and private contributions requires careful management, clear communication, and transparency to ensure fairness and public trust.

In summary, whether overlap hinders progress toward global climate goals due to the risks of double accounting, - claiming, and -subsidization/financing depends on how one weighs the associated risks against the potential opportunities.

7.4 Tools to Handle Inconsistencies Across Frameworks

Experts and literature propose several tools to address overlaps between frameworks. These solutions aim to harmonize carbon accounting and reduce inconsistencies, particularly for "company vs. national claims" and "company-level claims across frameworks."

1. Corresponding Adjustments (CAs): Following UN rules, CAs transfer removal units between national inventories to avoid double counting. For instance, if a U.S. company buys a removal unit from Denmark, Denmark applies a CA to transfer it from its inventory to the U.S., ensuring international consistency (Kujanpää, et al., 2023; Cullenward, Badgley, & Chay, 2023).
2. Limiting Voluntary Credits to Non-NDC Activities: Voluntary credits should only apply to removal activities outside a country's Nationally Determined Contribution (NDC) scope. This ensures states cannot claim the same unit as a company. Activities not yet recognized by the UNFCCC or lacking IPCC methodologies would be eligible for voluntary credits (Scherger, 2023). Figure 34 in the annex, shows this option in detail.
3. Transparency Mechanisms: Transparency tools would link removal units to unique IDs and track claims across frameworks. Centralized platforms could verify framework compatibility and prevent duplicate claims by tracking supplier disclosures and buyer usage, an example system is called FarmVault (Voysey, 2024).
4. Correction Factors: Similar to practices at the EU level, correction factors adjust emissions data to prevent inflated totals from overlapping. Correction factors ensure that overlaps do not result in inflated totals.

Key points

- Different types of overlaps exist at vertical (national, company, product) and horizontal (within the same level) levels.
- The lack of a unified vocabulary complicates discussions on overlap types (e.g., accounting, claiming, subsidizing).
- They don't necessarily impose a risk for reaching climate targets.
- While overlap may violate framework integrity in some cases, it is technically allowed in others—ultimately a political decision weighing transparency vs. investment incentives.
- Allowing multiple claims incentivizes investments but risks confusion and inefficient resource allocation.
- This chapter concludes the framework analysis, while the next focuses on identifying bottlenecks in scaling BCR.

8 Bottlenecks for Scaling BCR and its Value Development

This chapter examines the key bottlenecks for scaling BCR and its value development. The chapter has two main parts. First, findings from interviews with experts across different professions highlight the varying perspectives and challenges each group identified. The second part compares these interview insights with observations from recent academic literature.

Experts from diverse fields —policymakers and - advisors, researchers, brokers and BCR suppliers — have been asked to name bottlenecks for the BCR industry (see graph 3, chapter 2.2). Each group identified different critical aspects as bottlenecks. These differences are explored in detail in the following sections.

However, regardless of the group, almost all interviewees agree on one aspect: the voluntary carbon market is not robust enough to support the scaling of BCR activities. The uncertain demand is one of the biggest bottlenecks to attracting required investments into BCR.

Policymakers and policy advisors emphasize that the core barrier lies in the absence of clear and cohesive regulatory frameworks that set targets for all CDR technologies. The main concerns can be summarized as follows:

- The current EU climate law mentions carbon removals but focuses primarily on natural sinks and fails to adequately integrate permanent removal technologies such as BCR, DACCS or BECCS. The law lacks clear definitions for "residual emissions" and the role of different carbon removal technologies in balancing them. This ambiguity prevents the setting of robust policy targets and hinders the development of necessary sub-targets for technologies.
- A key challenge with BCR is its suitability for different accounting categories due to its diverse applications and characteristics:
    - When biochar is applied to agricultural soil, it can be classified under the Land Use, Land Use Change, and Forestry (LULUCF) framework, similar to some nature-based solutions that sequester carbon in soils but with a lower permanence. However, biochar shares characteristics with BECCS and DACCS, particularly in terms of its industrial production process and the permanence of its carbon storage, classifying it as a permanent carbon removal technology.
    - In cases where biochar is used in non-soil applications, classification under LULUCF is not an option.
    - These diverse factors complicate discussions around how BCR should be accounted for and under which EU framework it should be supported, leading to inconsistent messaging from the policy side.
- Current IPCC and EU accounting rules are inadequate for novel removal methods. The adjustment process of IPCC accounting rules is too slow.
- The EU should set rules for the accounting of CDR technologies until it has been agreed on the UN level and set quantifiable sub-targets for different technologies.

Ongoing research on the permanence of BCR without a final result has been mentioned as a bottleneck by researchers as well as interviewees from financial institutions. A clear result is needed to develop monitoring mechanisms for the final sequestration.

Experts from banks and brokers have pointed out that the supply side is presenting a big bottleneck due to the high costs of CDR technologies and limited scale. Although they see BCR as one of the more attractive options for their clients, even for BCR they report a persistent chicken-and-egg dilemma in project financing. Projects need offtake agreements to secure funding, but buyers hesitate without assurances that projects will materialize. This financing gap slows market growth.

High-durability removals are increasingly favored by corporate buyers, but without supportive policy frameworks, the market remains niche.

A recent study by Salo, Weber, Hagner, & Näyhä (2024) asking 72 participants with 43 business actors, 20 researchers, and 9 respondents who were categorized as “others” in the Nordic European region showed partly controversial results.

Respondents were asked about factors limiting the widespread use of biochar, given five specific factors—public awareness, government subsidies, practical experience, scientific research, and market price. The results show that most participants agree these factors pose challenges, with some variation across groups. Researchers emphasize the high market price as the key barrier, while business professionals see limited public awareness and lack of practical experience as the main obstacles to wider adoption (Salo, Weber, Hagner, & Näyhä, 2024). This differs from the interview results, which could be explained by the broader group classifications in Salo’s research compared to the more specific distinctions made during the interviews. Additionally, Salo’s research provided predefined aspects for respondents, whereas interviewees in the interviews conducted were not guided by such predefined categories.

In the same study, when asked what drivers for the biochar market development will be, ultimately as its value, all groups acknowledge the importance of biochar from both environmental and economic perspectives, but their priorities differ slightly. Researchers tend to focus more on its environmental impacts, whereas businesses and other stakeholders adopt a more balanced view, considering both environmental and economic benefits equally. The moderate emphasis on subsidies and funding across all groups, along with biochar’s support for core business activities, indicates a shared recognition of the significant role financial and business factors play in its development and use (Salo, Weber, Hagner, & Näyhä, 2024).

In conclusion, while perspectives on specific bottlenecks for scaling BCR differ among professional groups, a consistent theme emerges: the voluntary carbon market is insufficiently developed to support large-scale BCR activities. Addressing regulatory clarity, financing challenges, and technological scaling will be essential for unlocking BCR’s full potential.

Key points

- The primary bottleneck is uncertain demand—the voluntary market lacks volume and certainty to attract investors.
- Missing political targets for industrial CDR.
- Other bottlenecks include:
    - BCR being associated with natural sinks despite its similarity to DACCS and BECCS.
    - Ongoing research on permanence and monitoring requirements.
    - A chicken-and-egg dilemma in financing: investors want buyer commitments first, and buyers need investor backing.
- The most frequently cited bottleneck, unreliable demand, leads to the next chapter, which explores how policymakers can address it.

9 Driving Demand Through EU ETS Integration

This chapter addresses key questions regarding the strengthening of the BCR market:

1. What steps can be taken to ensure reliable BCR demand?
2. How could BCR be implemented into the political landscape?
3. Which integration approach would be the most favorable?

The previous chapter has shown a significant bottleneck: insufficient and uncertain/unreliable demand for CDR in general, including BCR. The demand for BCR is closely linked to climate targets, which ultimately drive the industry's growth and value. The goal is to generate a compliance-driven demand at the EU level. There are two main approaches to achieving this. The first involves setting specific BCR targets under the EU Climate Law and adjusting existing tools, such as the EU ETS, to ensure these targets are met. The second approach is to integrate BCR into the existing emissions reduction framework without fixed targets, allowing the scale of carbon removal to be determined by ongoing assessments and the market's capacity to deliver.

This chapter will first analyze options to overcome the bottleneck demand, focusing on the ETS as a potential tool. Second, it will develop a concrete framework for integrating BCR into the ETS. Although the focus of this thesis is BCR, the following chapter will investigate an assessment of CDR technologies' integration into ETS in general. Third, the chapter will assess and refine the proposal based on insights from industry experts.

The EU has three major tools to reach its climate targets and ambitions: EU ETS (I & II), LULUCF and ESR (European Environment Agency, 2024). All of them could be used to integrate BCR into a compliance setup aligning with the EU climate targets. However, the ETS emerges as the most suitable option due to its well-established, EU-wide market at the company level (European Commission, n.d.). The ESR sets national-level targets for member states, but enforcement depends solely on national implementation and lacks a unified system to directly incentivize economic operators on EU level (Kujanpää, et al., 2023). The same applies to the EU LULUCF Regulation. In addition, it would only acknowledge biochar applications in soils and does not accommodate other applications or different CDR technologies. The Renewable Energy Directive could support BCR in the transport sector, but the market is highly volatile and faces challenges with fraudulently classified products, for which authorities have yet to provide an effective response as well as finding a substitute to prove biochar sequestration (Staude, 2024).

9.1 Research on Integration Design

The integration of CDR into the EU ETS is gaining attention in policy and academic discussions. This chapter explores different design options, assessing their structure, variations, and impact on the ETS emission cap.

Eleven potential design options for integrating CDR into an ETS have been identified based on literature and policy analysis. The chapter describes each design element and possible add-ons. The options are summarized in the illustration:

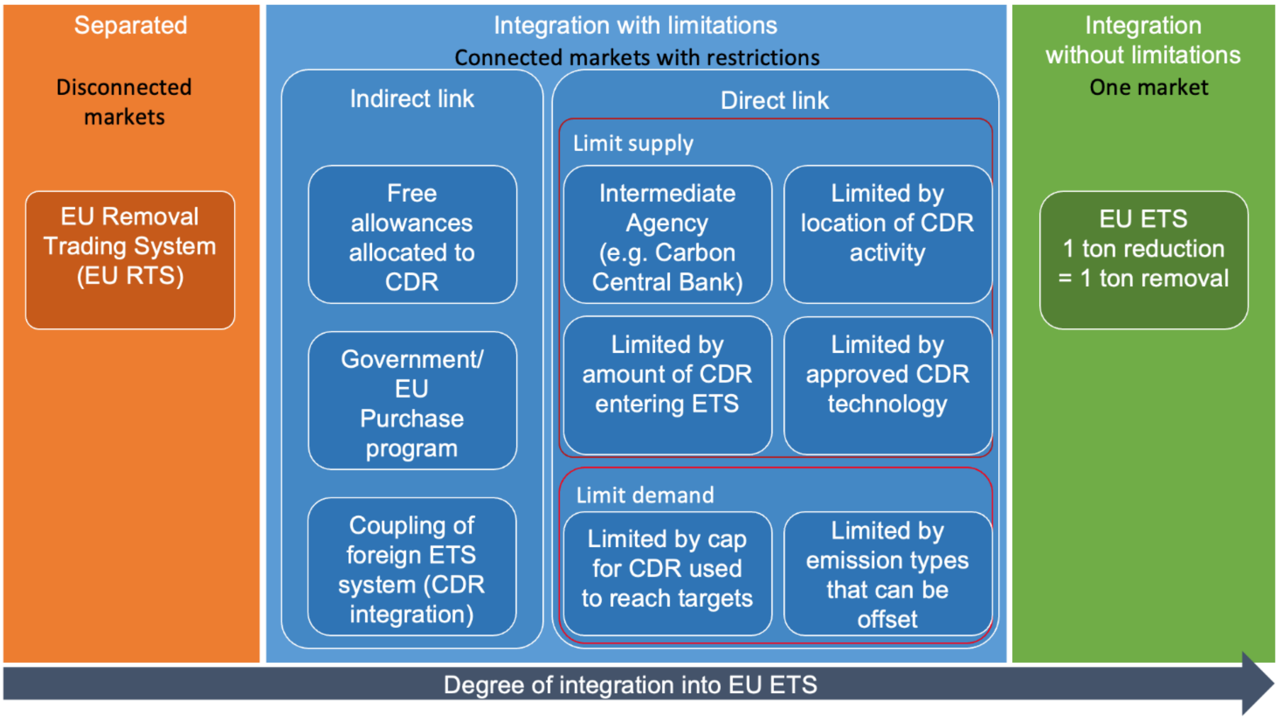

Figure 18: Overview Integration Options CDR into EU ETS
Source: Author's work based on La Hoz Theuer, Doda, Kellner, & Acworth (2021); Meyer-Ohlendorf (2023); emissierechten.nl (2024); Rickels, Fridahl, Rothenstein, & Schenuit (2024).

When integrating CDR into the ETS, a key consideration is whether the cap needs to be adjusted to prevent it from being diluted. Without proper adjustments, there is a risk that CDR integration could reduce the incentive for direct emissions reduction, a phenomenon known as mitigation deterrence. This occurs when attention and investment shift from cutting emissions toward relying on future carbon removal technologies, potentially creating a false sense of security (Lebling, Schumer, & Riedl, 2023).

There is broad scientific consensus that achieving climate goals requires both reducing emissions and scaling up carbon removal (UNEP, 2017). However, the timing and the appropriate balance of investments between these two approaches remain debated. While some CDR design elements—such as a separate removal system, an indirect link through public purchase programs, or free allowances—do not require adjusting the ETS cap, most other options do.

The UK has discussed the impact of CDR on the ETS cap, offering three possible ways to manage it (UK Government, 2024):

1. Gross Cap Increase: Removal credits are issued in addition to the current cap, increasing the overall number of allowances. This approach risks weakening the system by allowing more emissions.
2. Gross Cap Maintenance: Emission allowances (EUAs) are replaced by removal credits after they are issued into the system without increasing the overall cap. This keeps the total supply stable, ensuring the cap remains effective.
3. Reduced Net Cap based on Removal Credits Estimates: A new, lower net cap for EUAs is set that is based on estimates of the future volume of removal credits that will enter the system, ensuring removals do not inflate the total supply.

The UK government recommends starting with the second option—maintaining the gross cap—and later reassessing whether the third option, setting a new cap, would be more suitable once estimates on the volume of available removals are more substantiated.

Experience from New Zealand highlights the risks of unlimited CDR integration without cap adjustments. In the NZ ETS, the unrestricted use of nature-based removals has allowed emitters to meet their obligations at low cost, often avoiding more expensive but necessary emission reduction measures. This approach has conflicted with the broader goal of prioritizing emissions reduction. Therefore, cap adjustments should always be considered to avoid a gross increase that would undermine the system's environmental integrity (Rasmussen, Vermeulen, & Gammelgaard Bøttcher, 2024).

Illustrations 20 and 21 show a detailed description of each design element. It also provides add-ons suggested by literature and clarifies if cap adjustments are needed. Lastly, it indicates if the BCR credit value will be either based on costs or determined by the general ETS price development of EUA.

Option	EU Removal Trading System (RTS)	Free allowances allocated to CDR	Government/EU purchase program	Coupling of foreign ETS that includes CDR credits
Design	obligation on covered entities to remove and store specific minimum amounts of carbon either obliged to remove themselves or buy removal from other companies in additional to ETS	allocate free emission allowances to EU-CDR installations, those can then sell those EUA and receive revenue as financial contribution to removal activities	purchase of CDR credits by the European Commission financed by tax income or ETS revenue streams,	Indirect international link by linking the EU ETS to foreign ETS that include CDR E.g. In 2026, the Japanese ETS system will incorporate J-Credits (CDR credits) and operate as a compliance-based system
Add-ons suggested by literature	• limitations to CDR technologies and amount of each (negative or positive list) • establish a separate target for removals within the EU, aligned with UNFCCC projections for necessary removals • obligation based on historical emissions -> polluters-pay-principle • central purchasing house or marketplace that determines fixed prices to reduce administrative burden and uncertainties prices for obliged entities	-	• purchase by European Investment Bank or by Member States • build up a negative CO2 emissions budget into the Market Stability Reserve (EU ETS reserve) for after 2040 and for residual emissions & exchange CDR credits for emissions allowances after 2040	Design details: • via Art. 25 ETS Directive include CDR in exchange for permits (requirement only they have an absolute cap & signed under Kyoto Protocol) • in combination with Art. 6.2 and 6.4 of UNCCCF transfer of credits according to same mechanism between countries: from host of CDR sequestration to country of buyer
Cap adjustment ETS	• not required because separate system, ETS cap remains untouched	• not required because EUA amount remains unchanged • direct reallocation of ETS income EU to specific removal technologies operator as financial support	• not required because EUA amount remains unchanged	• required but depends coupled system
Value impact	likely: CDR cost-based with preference for cheapest removal technology if all compete on same market	EU ETS price	likely: CDR cost-based	Prices of coupled ETS system (unclear)

Figure 19: Detailed Overview of Integration Options into the ETS (Part 1)

Source: Author's work based on (La Hoz Theuer, Doda, Kellner, & Acworth, 2021; Meyer-Ohlendorf, 2023; emissierechten.nl , 2024; Rickels, Fridahl, Rothenstein, & Schenuit, 2024).

Option	Limit supply through Carbon Central Bank or another intermediary agency	Limited supply by amount of CDR entering ETS, by CDR technology approved or by CDR location	Limit demand by limited emission types allowed to offset or specify max percentage of companies' emissions	Full integration (without limitations)
Design	An intermediary institution, such as a 'European Carbon Central Bank' or 'Carbon Clearing House,' mandated to purchase physical carbon removals, convert them into carbon removal credits, and release them into the EU ETS market. Scope, complexity, and the level of intervention in the EU ETS, ranging from narrow to broad mandates.	Integration of carbon removals into the system can be limited by establishing a maximum cap, which could be defined either as a specific number of tons or as a percentage share of the overall reduction obligations	Use positive or negative lists to specify the types of emissions eligible to counterbalance with CDR removals or Specify percentage of emissions that can be offset	Any type of removal in any quantity -> meet obligations under ETS
Add-ons suggested by literature	• conversion can include discount factor for leakage or non-permanence of specific CDR technology • removal credits establish removal reserve or add to market stability reserve • technology-specific procurement targets established by policymakers through revisions to the EU ETS Directive for entry of removals into ETS • technology-specific tenders for procurement, financing through modernization fund or innovation fund • only auction removals to ETS entities if ETS price surpassed max. price or depending on other conditions (goal to reduce prices to help companies in times of crisis as recessions)	• Limit by location of CDR activity: EU companies purchase CDR credits directly from projects outside EU (compliant with EU law) in combination with Art. 6.2 and 6.4 of UNCCCF to transfer of credits according to same mechanism between countries: from host of CDR sequestration to country of buyer • Limit by approved CDR technology: only specific technologies are allowed to issue EUA or removals unit under the ETS, e.g. only technologies with EU CRCF-approved methodologies	• combination of specific CDR technologies are allowed to counterbalance specific emissions (allocate technologies to specific industry emissions: e.g. DACCS only for aviation emissions)	• conversion can include discount factor (leakage or non-permanence of specific CDR technology) • e.g. 1 tons CO2 (EAU) = 1,1 tons CO2 removal by DACCS
Cap adjustment ETS	•required depending on design • if removal replaces EUA, gross cap remains the same, no adjustment • if removal in addition to EUA, gross cap increases, adjustment required			
Value impact	price = depending on tenders, likely: CDR cost-based	EU ETS price	EU ETS price	EU ETS price

Figure 20: Detailed Overview of Integration Options into the ETS (Part 2)

Source: Author's work based on (La Hoz Theuer, Doda, Kellner, & Acworth, 2021; Meyer-Ohlendorf, 2023; emissierechten.nl , 2024; Rickels, Fridahl, Rothenstein, & Schenuit, 2024).

The value impact is assessed by whether the integration option aligns the value of CDR units with ETS EUAs or with the cost structure of a specific CDR technology. In a direct integration, where both compete at the same price level, the ETS price and its forecasts are assumed to determine the value. In contrast, if the system is tailored specifically to CDR, the cost of CDR technology is assumed to be the key factor. Currently, the costs of BCR, DACCS and BECCS are higher than ETS prices, but this could change over time depending on technological advances and the evolution of the ETS price (BloombergNEF, 2024; Manhart, 2024; Höglund, et al., 2024).

Some authors not only named possible options but presented a proposal on which design option to choose. The most important ones are summarized below. Rickels, Fridahl, Rothenstein, & Schenuit, (2024) proposed a Carbon Removal Reserve with three phases. In Phase 1, a Carbon Central Bank (CCB) procures CDR credits to establish a reserve. In Phase 2, CDR credits are conditionally released alongside the Market Stability Reserve (MSR). When the MSR is depleted, the CDR reserve becomes a market stabilizer, with credits auctioned based on market outcomes and price developments. Phase 3 focuses on managing net-negative emissions, allowing the CCB to adjust the supply of CDR credits depending on market conditions and ultimately cancel credits when removals exceed emissions.

In contrast, Japan's ETS (called JX-League), launched in 2023, integrated CDR into its JX-League in 2024. Initially voluntary, it will become mandatory after 2026. Companies can use CDR to meet up to 5% of their greenhouse gas reduction targets, with eligible technologies certified under the government-administered J-Credit scheme (Ministry of Economy, Trade and Industry Japan, n.d.; Chen, 2024). Approved technologies for the ETS as DACCS, BECCS, coastal blue carbon, and CCU projects (Ghosh & Zulaika Yeong, 2024). Although biochar is part of the J-Credit scheme, it has not yet been approved for the ETS (Chen, 2024). The system has strict geographical limits, with most projects required to be in Japan, except for some approved cases abroad. The total potential volume of credits available for CDR, CCS, and CCUS is estimated at 28 million tons per year, based on Japan's 570 million tons of annual emissions (Chen, 2024).

Manhart (2023) suggests creating a dedicated RTS or an ETS managed by a Carbon Central Bank, focused exclusively on issuing credits for permanent removals like DACCS and BECCS. This approach would ensure long-term reliability and avoid overlaps with temporary storage solutions.

Meyer-Ohlendorf (2023) highlights the potential for direct integration of specific technologies into the ETS. For example, biomass incineration with carbon capture is currently treated as zero-emission, offering no incentive to capture carbon. If the ETS were revised to recognize and reward negative emissions, it could encourage companies to adopt these technologies. Clear rules would be needed to specify sustainable biomass sources and limit impacts of land-use change.

In conclusion, more than ten design options have been identified, with some authors and countries already proposing or implementing certain aspects or combinations of these options. For each design option, it is crucial to determine how to adjust the cap in an ETS system to prevent the integration of CDR credits from diluting it. Various approaches for cap adjustment have also been presented. The next chapter will outline a preliminary proposal for the EU level, accompanied by a justification of its design.

9.2 Initial Proposal for Integration

Based on the review of relevant literature, the author developed a phased integration proposal to guide the adoption of CDR technologies within the EU's climate policy framework. It is not only limited to BCR but in general permanent CDR methods.

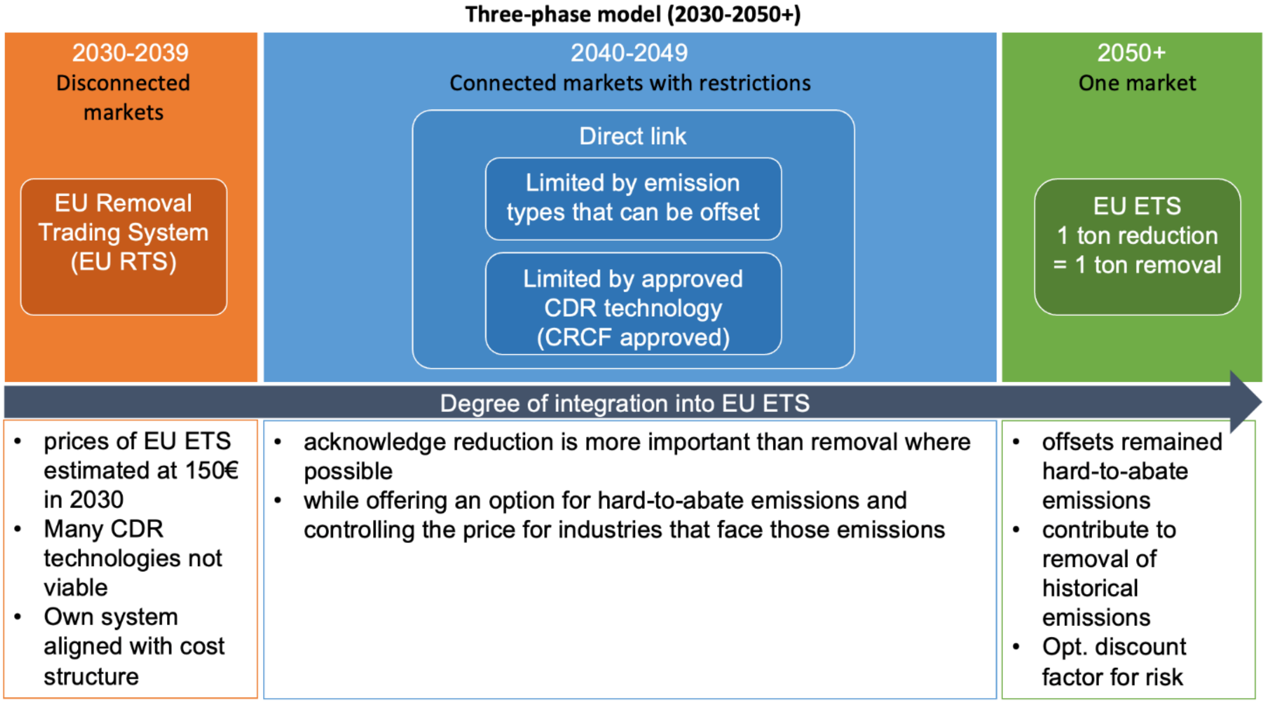

Figure 21: Initial Integration Proposal
Source: Author's work based on La Hoz Theuer, Doda, Kellner, & Acworth (2021); Meyer-Ohlendorf (2023); emissierechten.nl (2024); Rickels, Fridahl, Rothenstein, & Schenuit (2024).

The proposal is structured as a three-phase model, with each phase spanning 10 years. This phased approach aims to test and validate the technologies, their availability, scalability, and long-term performance of different CDR methods and reduce uncertainties about their volumes and economic feasibility.

Phase 1 Removal Trading System (EU RTS)

The first phase starts in 2030 with the establishment of an independent Removal Trading System, which operates separately from the current EU ETS. Under the RTS, entities already covered by EU ETS I and II will face an additional obligation to purchase a specified volume of carbon removals. The exact obligation details are not fully defined, but possible approaches include linking contributions to the industry's share of total EU emissions. Exemptions could be allowed for industries with low financial capacity. No adjustment to the existing EU ETS cap is required during this phase, as the removal targets will be separate from reduction requirements. Member states could implement their national climate strategies by defining at the national level for each technology. These targets can later be substituted with other technologies as they evolve.

One main reason for an RTS was that prices within the RTS would be adjusted based on the cost of different technologies. This pricing mechanism is necessary to promote innovation across the entire spectrum of technologies. The current price of EU ETS allowances is significantly lower than the cost of carbon removals in the voluntary market, making it difficult for carbon removal suppliers to operate profitably (BloombergNEF, 2024; Manhart, 2024; Höglund, et al., 2024; Kujanpää, et al., 2023).

Current prices on the voluntary market suggest that BCR and BECCS could become available before DACCS (Höglund, et al., 2024), but fluctuating prices of energy co-products, uncertain costs from quality standards under ETS, and potential rising costs of biomass and energy make predictions more challenging. This highlights the importance of aligning obligations with the cost structure of different technologies to derisk investments while maintaining flexibility.

Phase 2 EU ETS Integration with Limitations (on Supply and Demand)

The second phase, beginning in 2040, marks the gradual integration of the CDR into the EU ETS. However, integration will be subject to limitations on both supply and demand. The exact cap adjustment has not been considered in the first proposal. Supply will be limited to technologies that meet strict quality criteria, including proven availability, permanence, and neglectable negative effects on biodiversity. Demand will be restricted to hard-to-abate sectors—such as aviation—where achieving zero emissions solely through reductions is not feasible. During this phase, removals will primarily be used for these sectors, ensuring that only essential needs are met while avoiding over-reliance on carbon removals.

Phase 3 Direct integration of CDR with ETS

In the third phase, after 2050, the goal is to reach and maintain a zero-emissions or negative state. Full integration of removals into a broader system—potentially beyond the scope of the EU ETS—will take place. This expanded system will include all prior emitters and economic operators across the EU. Entities that continue to emit will be required to offset their emissions through removals, while those that have reached zero emissions may no longer be obligated to do so. The volume and scope of removals required will depend on future political targets. This phase is closely aligned with the polluter-pay principle, ensuring that entities with historical responsibility for emissions contribute to the long-term effort of carbon removal.

The decision for the initial proposal is based on three key criteria:

1. Creating sufficient incentives for permanent carbon removals in the RTS, as current prices show that most CDR technologies won’t be viable for ETS integration without subsidies in 2030.
2. Ensuring cost-effectiveness and a clear signal for investors during ETS integration with limitations to encourage removals.
3. By 2050, the proposal aims for policy coherence, supporting an EU target of at least climate neutrality—or even becoming net-negative.

The arguments have been refined based on assessment criteria provided by Rasmussen, Vermeulen, & Gammelgaard Bøttcher (2024). They identified seven criteria and 10 indicators for their assessment of four integration design options (criteria are in table 9 in annex I). The sheer amount of assessment criteria shows that there are many feedback areas that experts could comment on. The following chapter presents feedback and opinions from ten industry experts who evaluated the initial proposal.

9.3 Experts’ Opinion on Integration and Proposal

The chapter includes two main aspects. One, feedback from ten experts on the author’s proposal. Two, an overview of areas where experts agreed or disagreed on key elements of integrating CDR into the EU ETS. It also introduces new suggestions from industry experts that were not part of the original proposal.

General Feedback on the Proposal

Experts found the proposed integration of CDR into compliance markets good. While no expert agreed with everything in the proposal, none rejected the idea outright, but opinions varied on the details. Some supported creating a separate market for removals (EU RTS), while others favored integrating CDR into the existing EU ETS.

Separate System for CDR (EU-RTS)

The idea of a separate system for removals received mixed reactions. Although it could avoid mitigation deterrence and allow pricing tailored to new technologies, most experts believed it would be politically difficult to implement and overly complex administratively. A policymaker noted that the administrative burden would be too great for a 10-year period. A policy advisor argued that higher prices in a separate market might contradict the principle of prioritizing emissions reductions over removals.

Integration into the Emissions Trading System (ETS)

Opinions on ETS integration were also mixed. Four experts preferred integrating CDR into the ETS because it would provide clear signals to investors, require less administrative effort, and leverage existing ETS regulations. Three mentioned that ETS would be a tool they consider, but maybe not for all permanent CDR technologies. Some noted that certain ETS articles could potentially be repurposed to manage removals.

However, other experts expressed concerns about the ETS price level, which is currently too low to make many CDR technologies viable without subsidies. There was a broad agreement to adjust the ETS cap to prevent market dilution caused by removals. One expert mentioned that removals should be treated differently from emissions allowances, with a separate name and unit for easier monitoring under the ETS.

Timeframes, Transitions and Stability for Investments

A key concern raised by many experts was the importance of regulatory stability. Private investors need certainty and reduced risk to unlock funding for CDR projects. Changing regulations and incentives too frequently could discourage investment. One expert proposed using key performance indicators —such as cost and permanence targets—as conditions for allowing the integration of specific CDR technologies into the ETS between phases one and two of the proposal. If these targets are met, the technologies could be gradually integrated into the ETS.

Geographical Allocation of Projects

Most experts did not elaborate on geographical allocation. The opinions provided were divided. Some experts supported sourcing the lowest-cost removals globally, emphasizing cost efficiency. Others argued that European projects should be prioritized to avoid risks such as fraud and to support local job creation.

Compliance Targets

Most experts agree that setting clear EU-level targets is essential for creating demand and scaling CDR. Some advocated separate targets for emissions reductions and removals, believing this would ensure clear priorities and allow for better policy adjustments. Others preferred a flexible target system that could adapt to advances in removal technology.

Funding and Cost Allocation

The question of who should pay for removals sparked significant discussion. In the near term, most experts agreed that current ETS participants should bear the cost. Sectors with hard-to-abate emissions—such as aviation, shipping, cement, and heavy industry—were seen as key long-term buyers.

Opinions on long-term funding were varied (last phase from 2050 on). Some suggested a general carbon tax after 2050 to finance all removals, while others argued that removals should be treated as a public service funded by tax revenue, or similar to waste management with a general fee for everyone. Historical emissions as proposed for after 2050 were deemed as difficult by several policy advisors. It is unclear if the companies are still existing by then and how to calculate them fairly.

There was a general agreement that combining public and private funding is required to accelerate scaling. Most supported allowing claims in different accounting systems, provided that each removal was registered in only one national system. Some experts warned that it could confuse the public and undermine overall climate ambition, as private funding should support activities beyond state climate targets.

Additional Regulatory Considerations

Several experts raised the need for further regulation around CDR regarding the permanence and leakage of stored CO2 and highlighted it as one of the most important quality criteria for CDR. Biomass use for technologies like BECCS and BCR was also a recurring topic.

There were differing views on how to regulate BCR. Some experts believe BCR has an unfair advantage due to lighter monitoring requirements after it is sequestrated compared to BECCS and DACCS on EU level. They fall under the CCS Directive, which requires continuous monitoring while BCR does not. Others argue that BCR’s final sequestration has lower risks than geological storage has and this flexibility makes biochar valuable, as it offers similar permanence at a lower cost and requires less regulatory work.

Consensus and Disagreements

Despite differing views on certain details, there was broad agreement that industries, such as aviation, waste incineration, and cement, should adopt removal technologies early. Also, compliance targets are needed. The main point of divergence was on the timeline and framework details for integration. Some experts favored linking removals to the ETS for efficiency and signal to investors, while others recommended a more cautious approach with an RTS system to avoid undermining reduction targets.

9.4 Revised Policy Proposal: Integration of CDR into EU ETS

The proposal has been revised based on the experts' input. The new proposal is summarized in illustration 23.

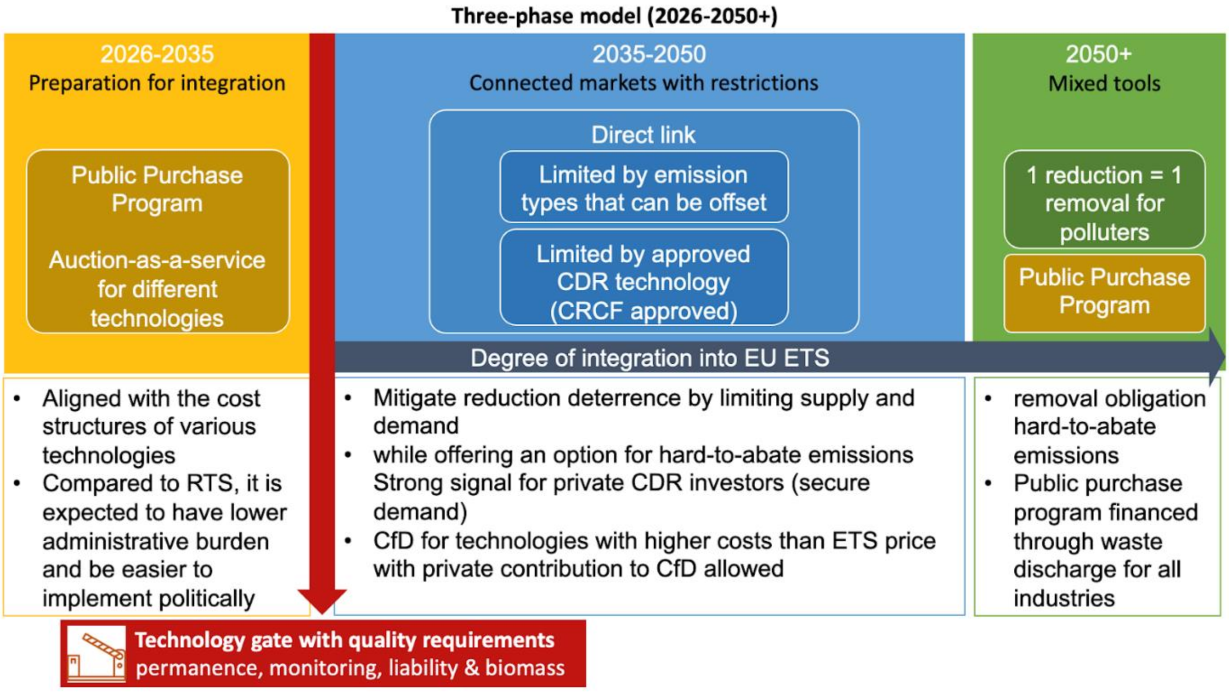

Figure 22: Revised Integration Proposal

Source: Author's work based on La Hoz Theuer, Doda, Kellner, & Acworth (2021); Meyer-Ohlendorf (2023); emissierechten.nl (2024); Rickels, Fridahl, Rothenstein, & Schenuit (2024).

There are two general changes in the full system based on two important expert inputs:

1. **Extended Timelines to Ensure Investor Assurance**: The public purchase program will start earlier to accelerate removals. A 9-year period is set for industries to adapt to the auction mechanism and for the EU to gather insights on CDR technologies before starting the integration. The ETS timeline is extended by 15 years, aligning with longer investment and return periods to offer greater certainty for investors. Clear communication to investors about integrating CDR into ETS by 2035, with strict requirements on technology quality (e.g., permanence, monitoring) as a market signal.
2. **Cap Management**: Ensure the gross cap for the EU ETS remains consistent with EU climate law, avoiding uncontrolled increases as happened in New Zealand. Integration of removals into ETS must follow the 1:1 principle, each removal replaces one emissions allowance.

The three phases are described in detail in the following:

Phase 1 Public Purchase Program instead of EU RTS

In response to expert feedback, the separate RTS system is replaced by a centralized public purchase program. This approach is considered more efficient and realistic, reducing administrative complexity and minimizing political resistance. A public purchase program provides cost-specific incentives to scale CDR technologies, avoiding the volatility of ETS prices. The RTS system is viewed as burdensome due to complex processes and the involvement of multiple member states, which increase administrative and political challenges.

A unified EU auction platform is suggested over multiple national programs. The EU would conduct auctions for various technologies, while individual nations could add their own funding to support projects within their borders. For example, if the EU funds the top 10 projects, the 11th project—if Danish—could receive funding from Denmark based on the same criteria. Private companies could also contribute funds through this mechanism. Small and medium companies may face challenges due to the administrative complexity of auctions. Lessons from the EU Innovation Fund and similar schemes should be applied to improve the auction design and make them also accessible for smaller companies.

During the first phase, a clear signal on how CDR will be integrated into ETS should be sent to the market, emphasizing high-quality standards for technologies (e.g., monitoring, permanence, liability for reversals, biomass use).

Phase 2 Results-Based Milestones

In this phase, only mature technologies that meet the previously defined strict standards (e.g., monitoring, permanence, liability) will be integrated into ETS. Results-based milestones will ensure that only CDR technologies pass that cover a certain quality standard.

There are no other changes to the design of the second phase. The integration of removals will be carefully capped on both supply and demand sides to avoid reducing incentives for emissions mitigation. Although fully excluding CDR is seen as too restrictive, tools will be introduced to mitigate risks.

In addition, price and support mechanisms are proposed. Some technologies, such as DACCS may have costs above the ETS prices. To address this and price fluctuations, Contracts for Difference (CfD) are proposed. These contracts, allowed to be co-funded by public and private sectors, would stabilize supplier revenues. To attract private funds, private contributors (e.g. companies) can claim voluntary market credits towards their targets also for credits that are partly funded by public money.

Periodic reviews will update the program based on new insights to keep the cap aligned with climate goals, as suggested by Rasmussen, Vermeulen, & Gammelgaard Bøttcher (2024). Adjustments may also be made for permanence issues, such as applying discount factors where necessary. In case permanence is not sufficient enough, the ratio of 1 removal unit = 1 emission allowance could be changed to accommodate for that (e.g. 1,1 removal unit = 1 emission allowance).

Phase 3 Mixed Tools and Waste Disposal Fee

The final phase includes multiple tools, assuming few emitters remain (hard to abate industries). These companies must offset their emissions, while additional removals are needed to meet climate targets. The EU or aligned governments purchase these removals, funded by a general waste disposal fee for all industries.

Certain areas require further investigation beyond the current scope of this proposal. In the short term, ensuring fairness in the auction-as-a-service model is crucial. Further research is needed to refine milestone parameters, such as biomass limits, permanence evidence, liability measures, and monitoring requirements for different technologies. Another key area for investigation is defining which emissions should be prioritized for removal eligibility (hard-to-abate emissions), with aviation emissions identified as a critical focus due to limited alternatives. In the long term, cost-effective financing options for CDR must be explored, such as sector-specific taxes, a comprehensive ETS system, or a waste discharge fee. Additionally, post-2050 removal targets must be clarified, determining whether the long-term goal is net-zero or net-negative emissions and the role of removals in achieving these targets.

In summary, integrating CDR into the EU ETS offers a promising path to create compliance-driven demand and unlock required funding and financing. This chapter outlined key design options and a phased approach to integration, ensuring that CDR contributes effectively to climate targets without compromising the system integrity or causing mitigation deterrence.

Key points

- Integrating BCR into the EU ETS is considered the most promising way to address uncertain demand.
- Eleven design elements for integration were identified, with the key challenge being how to adjust the overall cap.
- **Three-Phase Proposal:**
    - **2026–2035:** Public purchase program.
    - **2035–2050:** Limited ETS integration with quality-based KPI gateways.
    - **2050 Onward:** A removal obligation for polluters and a public purchase program financed through a general waste disposal fee.
- The next chapter will explore BCR's future value projection and apply the author's assessment to the proposed three-phase model.

10 Projections and Key Drivers for the Future Value of BCR

1. Will the value of BCR credits increase or decrease?
2. What future value could BCR have under the proposed framework?

This chapter explores the potential future value of BCR. It aims to determine whether the value of BCR will increase or decrease and at what approximate level it might stabilize in the future. Key assumptions and expert insights are combined with survey data and literature to outline likely trends and drivers of value for BCR. It begins with demand-side expectations for CDR in general, followed by supply-side cost assessments to explore what might be feasible. The literature review focuses on BCR-specific aspects. The chapter highlights the difficulties of value projections between two categories of biochar, artisanal biochar and biochar produced with an emphasis on permanence. Expert input on both demand and supply for BCR provides valuable insights into key value drivers. The chapter concludes with the author's stance on the value will develop, which is applied to the policy proposal.

Demand-side projections are based on surveys such as those conducted by Guzzardi, et al. (2024). Although they are not BCR-specific, they provide a useful reference for general price expectations.

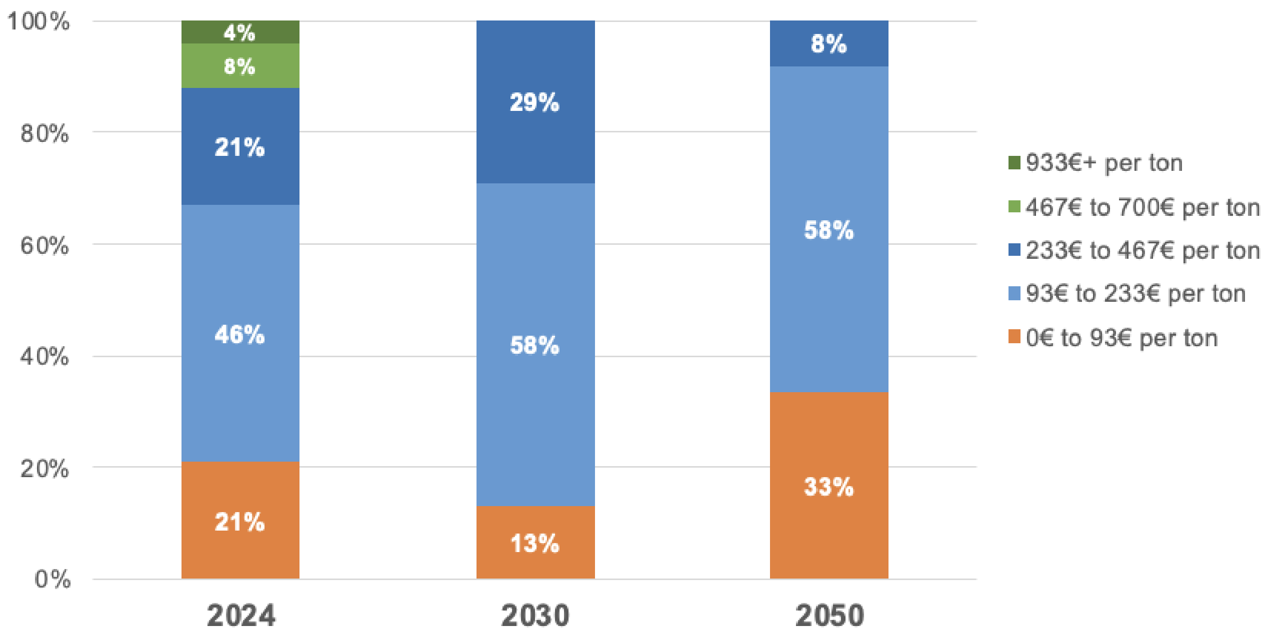

Figure 23: Average Price Purchasers are Budgeting to Pay for a Ton of durable CDR
Source: Guzzardi et al. (2024).

Survey insights indicate a clear shift toward lower prices, with an increasing number of purchasers expecting long-term CDR prices to range between 93 € and 233 € per ton (100–250 $). The willingness to pay prices above 467 € per ton (500 $) is projected to decline significantly by 2030. Looking further ahead, 33% of survey respondents anticipate prices dropping below 93 € per ton (100 $) by 2050. This suggests that demand-side expectations are moving toward greater affordability over time, with most buyers projecting costs to stabilize in the 93–233 € range. The source does not clarify the price base, but it is assumed to be given in real prices with the base year of 2023 when the underlying survey was conducted.

The supplier side shows similar expectations.

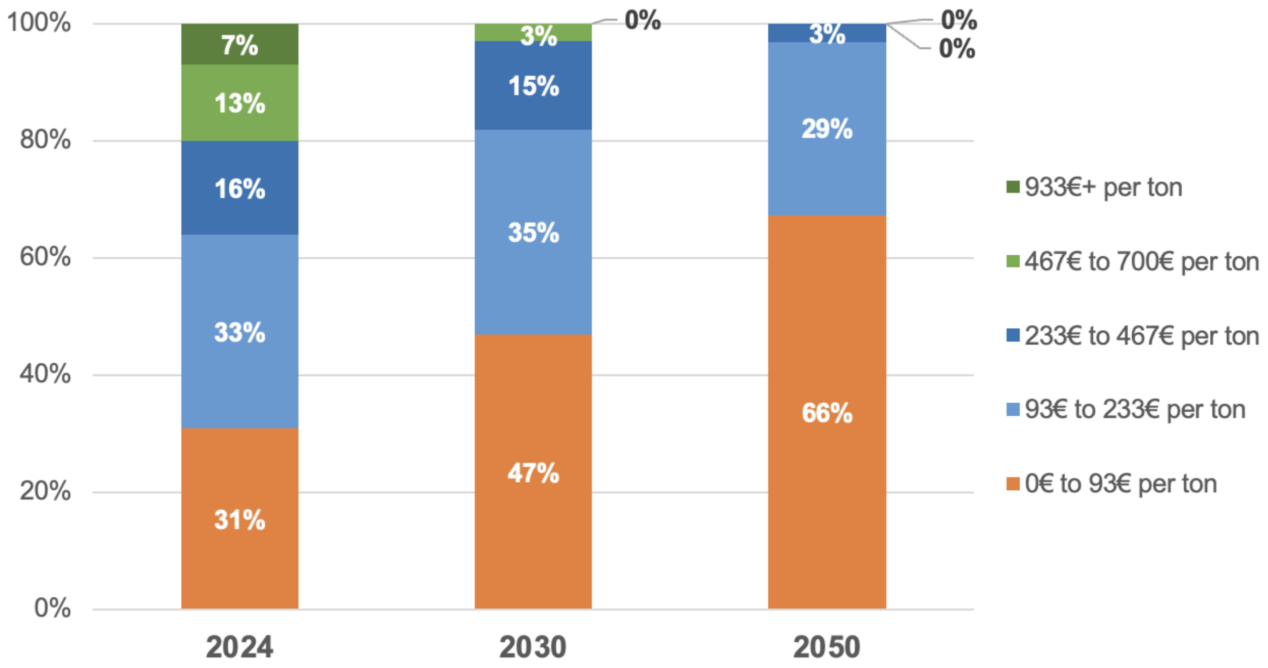

Figure 24: Average Production Cost per Metric Ton Suppliers expect to Achieve
Source: Guzzardi et al. (2024).

The overall trend shows a clear expectation of declining costs over time. By 2050, most suppliers anticipate costs to range between 0 € and 93 € (0 $ to 100 $) per ton, with higher cost brackets above 468 € (501 $) expected to disappear. It is important to note that these projections refer to costs, not the selling price of CDR.

A recent survey from 2025 highlights a significant gap between the prices purchasers are willing to pay and the amounts suppliers need for a reasonable profit. For instance, biochar providers require 174 € (187 $) per metric ton in 2025 and 168 € (180 $) in 2030 to achieve a reasonable profit. However, buyers perceive prices of 145 € (155 $) in 2025 and 121 € (130 $) in 2030 as "expensive" (CDR.fyi, 2025).

An interesting pattern emerges when comparing responses from those with market experience—"veterans" who have already bought or sold credits—versus newcomers who have yet to close a deal. In some sectors, such as BECCS or DACCS, experienced suppliers reported lower breakeven prices than new entrants, possibly due to operational efficiencies or a more refined understanding of actual costs. However, for biochar, the opposite trend appears: veterans cited significantly higher breakeven prices for 2025 than those who have not yet sold biochar credits. This suggests that production costs are higher than new entrants anticipate. On the buyer side, veterans generally expected higher price ranges than newcomers, except in the case of DACCS, where new buyers anticipated paying more (CDR.fyi, 2025).

Academic literature sources show low-cost estimates for biochar, partly around 50-75 € on the lower end, while others report costs up to 185 €. An overview of different sources and prices based on the work of Rasmussen, Vermeulen, & Gammelgaard Bøttcher (2024):

- Saharudin, Jeswani, & Azapagic (2024): 55–185 € per ton.
- Buss, et al. (2022): 75–135 € per tonne.
- Fawzy, Osman, Yang, Doran, & Rooney (2021): 65–160 € per ton.
- Deng, et al. (2024): 53–129€ per ton (average ~80 € per ton).

- Kujanpää, et al. (2023): 110-150 € per tonne

There are different possible explanations for the differences in cost estimates. One, the cost estimates are specific for geographical regions, e.g. Deng et al. (2024) is based on Chinese biochar, while Saharudin et al. (2024) is Malaysian biochar. Second, it could be the underlying definition of biochar used for CDR. There is a variety of biochar “types” especially regarding production methods and quality standards that influence the cost. In the voluntary carbon market, a distinction is made between artisanal and industrial biochar (Klimate.co, n.d.). Artisanal biochar is produced on a small scale using basic, easily accessible technology, offering only limited control over production parameters and is usually not eligible to be certified as CDR but used for other purposes (Malins, Pereira, & Popstoyanova, 2024). On the other hand, industrial biochar is produced with advanced technology, which allows for greater control of key factors like production temperature—crucial for ensuring high carbon removal performance and permanence (Klimate.co, n.d.). Industrial processes also ensure compliance with biomass quality standards. This lack of a clear definition creates uncertainty in estimating baseline costs, as it is often unclear whether the data refers to artisanal or industrial biochar production. Artisan(al) biochar could artificially lower cost expectations and give a false impression of what is feasible under CDR quality requirements. In addition, assumptions on the value of biochar’s co-products on the energy market can influence the price up or down since they can co-finance the activity (Rasmussen, Vermeulen, & Gammelgaard Bøttcher, 2024).

According to input from expert interviews, only a gave specific future prices or costs. Only one expert considered 100 € a realistic estimate, with another one describing it as the minimum, though likely higher. A third expert suggested prices would either increase or remain within a range of 150 to 200 €. Most of the experts focused on identifying key value drivers that they believe will shape future demand and supply.

An extensive list of potential key drivers for the value was developed based on the interviews:

Source	**Increase value**	**Decrease value**
Expert interviews	Demand • More use cases for biochar increase demand (e.g. asphalt, cement) • Co-benefits drive demand and value (e.g. texture of end-product, soil improvements) although considered limited • Integration into a compliance market Supply • Delay of other CDR (DACCS and BECCS) • Delay in BCR mega-projects Regulatory constraints • Sustainable criteria biomass, monitoring and liability rules Biomass • Biomass availability is reduced, increasing costs for BCR Permanence • BCR same permanence proven by academia, permanence	Demand • Increased availability of other permanent CDRs lowers the demand for BCR due to the preference for geological storage • Mature buyers and more available knowledge Supply • First large-scale projects become operational Improvements in technology • Industrialized scale as a driver for lower costs Cost-based approach • Transition from storyline to BCR cost as an anchor for price

becomes anker price (thus DACCS bottom-line)	

Table 4: Key Drivers BCR Value Based on Interviews

More factors indicate an increase in the price of BCR than those that decrease it. However, this does not match the expectations of academic literature and the majority of suppliers from surveys in 2024. Production costs for BCR could align with lower estimates in studies and surveys if factors like permanence, controlled production parameters, sustainable biomass sourcing, value chain monitoring, and geographical location are ignored. Alternatively, if high-value assumptions for biochar by-products are considered, costs may still reach the levels suggested in the literature. Interviewees, however, indicate this is unlikely for European projects that must fulfill certain quality criteria.

The author follows the assumption that high-quality, durable, and regulated biochar for BCR purposes is expected to maintain or increase in value, starting from around 150 € per ton, and will apply this to her proposal. This estimate partially aligns with survey data from 2025 and supports the assumption that BCR's baseline cost will act as a price anchor. While technological advancements may reduce costs, the author thinks those are offset by increasing costs from strict quality requirements and biomass prices, keeping prices higher.

The previous estimates are applied as value projections on the proposal. The author projects the following values:

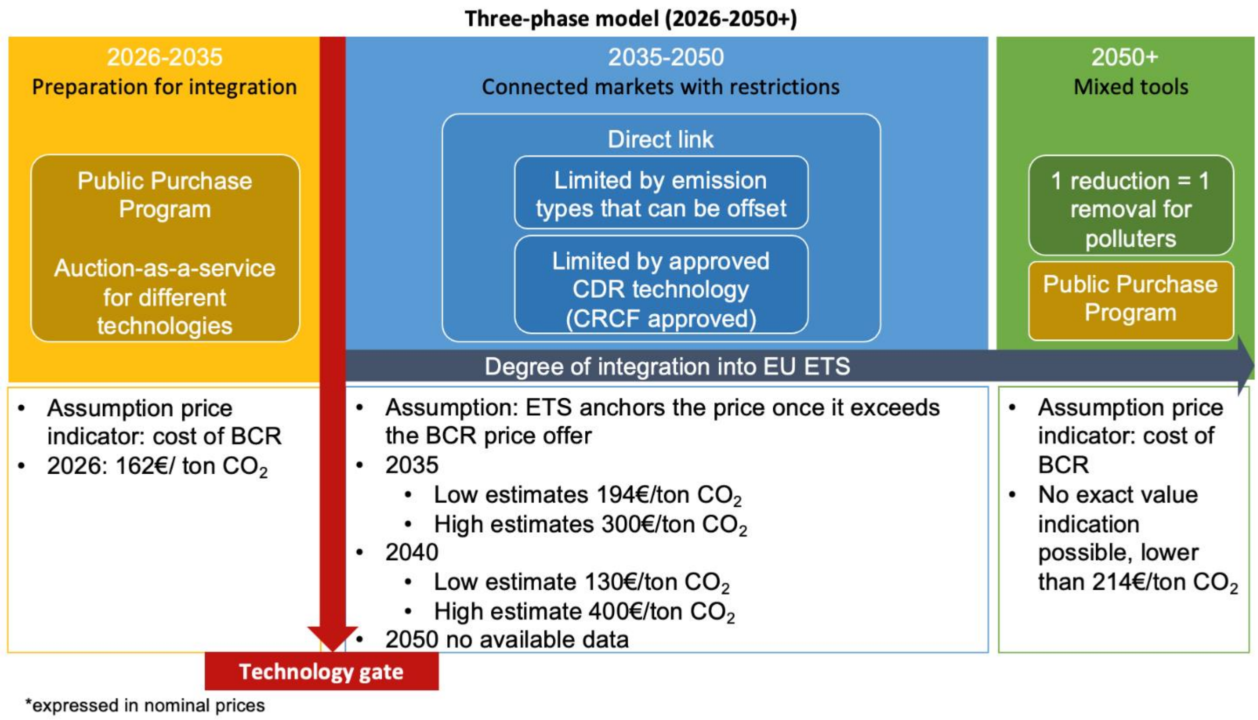

Figure 25: Final Proposal with Value Projections

Source: Carla Soleta based on expert interviews; (Mantulet, Peffen, & Cail, 2023; BloombergNEF, 2024; Manhart, 2024); CDR.fyi data analytics.

The author established specific assumptions for her proposal based on insights from literature, expert interviews, her data analysis (CDR.fyi dataset), and the limited publicly available data on the EU ETS price forecast. In the first and final phases of the model, it is assumed that the baseline price of biochar, produced according to a certain BCR standard, will set the price. Therefore, today's voluntary average market price for BCR is used as a reference— set at 156 €/ton of CO_2 for 2024. A 2% annual inflation adjustment is applied for projections in the first and last phases to create nominal prices.

In the second phase of the model, it is anticipated that BCR unit prices will be driven by the overall ETS market price rather than by actual production costs. Forecasts suggest prices between 194-300 €/ton of CO_2 in 2035, while other sources estimate for 2040 prices between 130-400 €/ton CO_2. These predictions are based on limited public data, with some sources not specifying whether the values are nominal or real (Mantulet, Peffen, & Cail, 2023; BloombergNEF, 2024; Manhart, 2024). The lower minimum price estimate for 2040 compared to 2035 is due to the use of different data sources. Since neither source provides data for both years, one was selected for 2035 (BloombergNEF, 2024) and the other for 2040 (Mantulet, Peffen, & Cail, 2023).

In the second phase, it is assumed that each removal unit will replace an emissions allowance, keeping the total emissions cap unchanged. Therefore, no significant price reduction due to removals is expected in the model. If removals were added to existing allowances, thus increasing the overall gross cap, prices would likely decrease, as suggested by research (Sultani, 2024).

In conclusion, estimating the future value of BCR is challenging due to conflicting views in literature and among experts. Unclear criteria for biochar production, quality standards and carbon sequestration in cost assumptions could easily distort future value projections. To meet the requirements for permanent CDR, biochar must fulfill specific quality criteria. In addition, inexperienced buyers and suppliers appear to underestimate costs and expect lower prices than experienced buyers, skewing price expectations towards a lower value.

While literature and surveys generally expect CDR costs to decline due to technological advancements and scaling, expert interviews highlight cost drivers. Price reductions may be offset by rising biomass costs, stricter regulations, permanence requirements, and delays in large CDR projects. Industry surveys suggest that CDR prices could fall to around 100 € per ton, but numerous cost drivers create an unpredictable outlook. Experts from interviews generally agree that the extremely high price outliers for BCR seen in the early market will decline as large-scale projects develop and buyers gain a clearer understanding of production costs.

Key points

- Industry surveys from CDR.fyi and literature expect falling BCR costs and prices, but the assumptions around biomass costs, assumed co-product values and quality standards are unclear.
- Surveys reveal that inexperienced buyers and suppliers tend to underestimate costs, leading to lower price expectations than “veterans”.
- Expert interviews identify more cost drivers for BCR credits in the future that could counterbalance cost reductions from scale and technology improvements.
- They expect prices to remain below DACCS but possibly equal to or higher than the voluntary market average today (156 €/ton BCR).
- Price Projections for proposal (in €/ton BCR):
    - 2026: Around 160 under the public purchase program.
    - 2035–2050: ETS prices likely to determine BCR prices (130–400).
    - 2050: Approximately 215, factoring in inflation and cost projections.
- This chapter addressed the 2nd and 3rd research questions on future value projection and policy support. The next chapter will summarize key takeaways.

11 Key Takeaways

The objective of this thesis is to assess the current and future value development of carbon removal credits, with a focus on scaling biochar carbon removal in the European Union. It explores both voluntary and compliance markets, providing insights for key stakeholders. The market assessment is designed to help BCR industry players better understand market opportunities and current and future price trends, while the regulatory analysis offers guidance for policymakers providing helpful incentives for the industry to scale. These included answering three specific research questions:

1. What are the market opportunities for BCR?
2. What is the current value of BCR credits, and what are its future projections?
3. How can policymakers, particularly in the EU, create effective incentives and market conditions to support the large-scale deployment of BCR and help close the gap toward achieving the global climate target of within 1,5°C temperature rise?

This chapter is structured to provide an overview of key takeaways, highlighting practical implications for different target audiences— industry players and policymakers. It concludes by discussing the study's limitations and suggesting areas for future research. By combining market data, expert interviews, and regulatory developments, this work aims to contribute to the ongoing conversation around scaling BCR as part of Europe's climate change strategy.

11.1 Overview of Results

Market Opportunities

The market for BCR can be primarily categorized into two segments: the voluntary market and the compliance market. Companies purchase BCR units either to meet self-imposed climate targets (voluntary market) or to comply with regulatory requirements and national targets (compliance market). These market segments drive the demand for BCR and determine its value from the demand side.

Voluntary Market for BCR and Current Value of BCR

The voluntary market for BCR is still developing, driven by corporate sustainability strategies and frameworks such as SBTi's Net Zero Corporate Standard. While CDR methods are generally not permissible under the SBTi standard, BCR plays a limited but unique role for agriculture-related industries under SBTi's framework. Currently, BCR is only allowed at the corporate level in very specific cases (FLAG emissions), while for other sectors, CDR (including BCR) purchases are only recommended by SBTi without being counted toward official targets (referred to as Beyond Value Chain Mitigation activities). Other industries, such as the banking sector developed their own target-setting guideline that acknowledges CDR credits today for their sector. Banks are among the common buyers in the CDR market.

Market data from CDR.fyi reveals that the voluntary BCR market is young, with limited transaction data and a low share of reported transaction prices. The majority of transactions over the three years fall within the range of 120 € to 190 € per ton of CO_2 removal. High-value outliers significantly impact the average price, which initially declined before experiencing a moderate recovery. Expert interviews suggest that these outliers were driven by philanthropic buyers and inexperienced market participants in the past. However, the median price, which is less affected by outliers, shows an overall increase from 93 €/ton BCR in 2021 to 149 €/ton BCR in 2024, despite a dip in 2023.

Compliance Market for BCR and Current Value of BCR

In the compliance market, the accounting of BCR is highly restricted at the national and product levels. At the national level, accounting is based on IPCC guidelines, which allow countries to account for biochar sequestration but only in agricultural and grassland soils. However, no country has fully implemented these accounting methods yet, although Denmark is planning to do so. These removals could theoretically be traded between countries once national methods are approved by the UN.

On the product level, BCR can contribute to the carbon intensity (CI) score of advanced fuels within the EU biogas transport market. Regulations in this sector are forcing fuel distributors to reduce their emissions and distribute fuels with low carbon intensity. BCR offers them the opportunity to achieve a reduction in the CI score. However, practical challenges exist, particularly the difficulty of proving BCR sequestration with field measurements, making this market opportunity inaccessible to the industry.

The current value of BCR on a national level remains unclear due to the lack of actual transactions between nations. If the field measurements were replaced, BCR could gain a revenue stream in the fuel market by lowering the CI score. In the fuel market, prices have fallen significantly from an average of 400 € per ton of CO_2 in 2022 to as low as 65 €, partly due to fraudulent certifications from China. Despite this drop, the market is expected to recover once the authorities stop all frauds.

Future Business Opportunities for BCR

Several future developments could expand the market and increase demand for BCR across different levels—national, corporate, and product. For the voluntary market, SBTi is updating its standards to explore how CDR can offset companies' Scope 3 emissions. The updated standards are controversial in its community but are expected to be concluded in 2026.

On the compliance market, the European Commission is assessing until 2026 whether to integrate CDR into the EU Emissions Trading System after 2030. Revisions to the Renewable Energy Directive could address current regulatory hurdles, enabling BCR to be used in advanced fuel production without impractical field measurement requirements. However, there is no clear timeline for a revision set yet. In Denmark, political initiatives are incorporating BCR into national climate strategies, including the introduction of future subsidy schemes focused on BCR in agriculture.

Policy Landscape and Framework Overlap

The evolving policy landscape presents both opportunities and challenges for the BCR market. Quality standards for voluntary markets are being developed, with the Carbon Removal Certification Framework as a potential quality and accounting benchmark. Meanwhile, the proposed Green Claims Directive could regulate BCR-related claims in the future either increasing the legal certainty for buyers or limiting their incentives by prohibiting any kind of claims towards consumers based on BCR.

One of the most controversial topics in the regulatory environment is the overlap between different frameworks at the national, corporate, and product levels. The concepts of double counting, double claiming, and double subsidizing often create confusion due to inconsistent terminology and definitions. While such overlaps do not always pose a risk to reaching climate targets, they pose a political question: should multiple actors be allowed to claim the same removal credit under different frameworks? It would provide greater incentives for investment, but it also raises concerns about potential fraud, transparency, and the risk of inefficient use of financial resources. Following a comprehensive assessment, the author's position is that all three should be permitted across different frameworks, provided the integrity of each framework remains intact and each removal unit is recorded in only one national accounting inventory—the primary framework for tracking and ensuring progress toward global climate targets. The author believes that the integrity of each accounting system is sufficiently protected while it offers incentives for investments into BCR.

Bottlenecks for Scaling the BCR Market

The primary bottleneck for scaling BCR and increasing its value is the lack of reliable demand according to expert interviews. The voluntary market does not provide the stability or volume needed for investors to commit to financing large-scale projects. The market is trapped in a "chicken and egg" dilemma: investors require offtake agreements from buyers to finance projects, while buyers hesitate to commit without secured investment. This dynamic results in higher demand than supply but insufficient market signals to trigger investments in suppliers.

Other barriers include the complexity of BCR's classification at the national accounting level, where it is grouped with natural sink methods due to one application option of biochar in soils despite sharing more similarities with permanent CDR technologies like DACCS and BECCS. Additionally, research on BCR's permanence is still evolving, making it challenging to establish reliable monitoring requirements.

Policy Proposal and Future Value Development of BCR Credits

The integration of BCR into the EU ETS is identified as the most promising solution for removing uncertainty from the demand side. Various design options for integration are being discussed, involving different stages of implementation. The initial proposal suggests a phased approach starting in 2030 with a separate Removal Trading System (RTS), followed by limited integration into the ETS and, eventually, full integration by 2050. However, after receiving feedback from industry experts on the proposal, it was refined. The first phase has been replaced with a Public Purchase Program that starts already in 2026 and the last phase with mixed tools combining removal obligation for remaining polluters as well a general "waste" fee for cleaning the atmosphere for all companies to finance public purchases of removals. The period for the individual phases has been extended to create greater legal certainty for longer investment payback periods.

In the first phase (2026–2035), the estimated price for BCR credits is expected to be around 160 € per ton of CO_2. During the second phase (2035–2050), the ETS market price will determine the credit value, with projections ranging between 130 € and 400 € per ton. After 2050, the price is likely to be projected at around 215 €, reflecting inflation-adjusted costs.

The most contradictory finding is that academic literature and industry surveys expect a decline in future costs and prices of BCR. In contradiction, interviews and survey results from experienced buyers and suppliers indicate that BCR credits may need to maintain a current or higher price to attract investment and reduce investment risk. According to the interviews, this is because cost reductions from technological improvements and scale will be offset by rising biomass costs and uncertainty around the value of co-products and costs from increasing quality requirements.

Practical Implications for Industry Players and Policymakers

The key-take ways are summarized as short sentences filtered for each target group in the following illustration

Industry Players

Why is BCR demand today and how are frameworks related to it?
Achieving climate targets is the primary driver of BCR demand. Frameworks guide companies and nations on setting and meeting these targets, thereby introducing or restricting BCR as a tool to achieve them.

What are market opportunities for BCR based on who can account for it today?
BCR is already recognized in various voluntary (mainly company level) and compliance frameworks (national and product level), though with significant limitations. In practice it creates only market opportunities on voluntary market so far.

What are new market opportunities based on who could account for BCR in the future?
A lot is evolving. Voluntary and compliance frameworks are being revised to explore the integration of CDR. SBTi as a driver for the voluntary market (from 2026 on) and the EU ETS for the compliance market (beyond 2030) represent the most interesting market opportunities.

What is the value projection for BCR? Will prices increase or decrease?
Forecasting future value is challenging. While literature and industry surveys predict lower costs and prices, interviews reveal numerous potential cost drivers. The author expects similar or higher future prices due to rising costs, aligning with survey findings from experienced buyers and sellers.

Figure 26: Overview Key Takeaways for Industry Players
Source: Author.

Industry Players

What is the biggest obstacle for the BCR industry to scale to a level that helps to keep global temperature well below 2°C?
Unreliable demand is the industry's biggest obstacle to scaling and required support from policymakers.

What does double counting, double claiming, and double subsidizing mean and are overlapping frameworks an issue for reaching the global climate target?
They are widely debated in the context of overlapping frameworks but are not necessarily a risk. Politicians must decide what should be allowed while balancing enough incentives for investments vs. transparency.

What options are out there to integrate BCR into EU law?
Options would be integration of BCR into LULUCF, ESR or ETS of the EU.
Integrating BCR into the EU ETS has been identified as the most suitable policy option to support BCR scaling. This requires also an adjustment of cap of the EU ETS. Eleven design options for integrating BCR into the ETS were identified.

What is the "best" option to integrate it? How do industry expert evaluate the proposal?
A proposed integration design was developed and refined with input from ten industry voices. The proposal suggests a three-stage system consisting of a Public Purchase Program, integration into the ETS with certain limitations, and mixed tools financed by a waste fee for all industry after 2050.

Figure 27: Overview Key Takeaways for Policymakers
Source: Author.

11.2 Limitations

The study faces limitations related to data constraints, limited access to documents from evolving frameworks (e.g. SBTi revision, EU's assessment on integrating CDR into the EU ETS), methodological choices, and the scope of stakeholder perspectives.

The study's ability to assess current market prices was constrained by limited data availability and representation. The primary dataset, sourced from CDR.fyi, covers only four years (2021–2024), making it difficult to identify long-term trends. The representativeness of the data was confirmed by different industry experts. However, there were no buyers among the interviewees, only brokers, bankers and suppliers. It excludes an important perspective and industry voice.

A limitation is the lack of a deeper investigation into supply-side factors. While biomass costs are a key determinant of future BCR prices according to several expert interviews, the study did not fully explore how biomass availability and pricing in the EU may have developed or could develop in the future. Similarly, interviews with companies that sold BCR at very low prices could have helped clarify whether price differences stem from variations in biomass costs or additional revenue streams from co-products.

Regarding future price projections, a significant discrepancy emerged between industry expectations about future cost drivers and findings from surveys and literature, which generally predict declining prices. Due to time constraints, the study was unable to investigate further the reasons behind this divergence, making it difficult to provide a definitive answer to this research question. However, it provides some hypotheses like inexperienced buyers and suppliers, the value of co-products, geographical location, or a missing standard of biochar characteristics.

Another limitation in addressing the research questions is the reliance on unpublished or evolving regulatory frameworks. The assessment of future BCR accounting frameworks remains limited, as key initiatives—such as the Science-Based Targets initiative (SBTi) and the EU Commission's evaluation of CDR within the ETS system—are still undergoing revision. Consequently, future market opportunity analyses rely on working group materials and expert interviews rather than finalized regulatory texts, offering less certainty for industry players and future researchers, as some details remain subject to change.

The study also relied heavily on grey literature, as crucial information on BCR's role in climate strategy is primarily found in policy documents, industry reports, and regulatory assessments rather than peer-reviewed academic studies. While this was necessary to capture the latest developments, it limits the academic quality of this work.

Additionally, the study's qualitative analysis faced methodological constraints. AI-based transcription software was used to transcribe interviews, which may have introduced transcription errors. Moreover, qualitative research software, which is commonly used to analyze wording patterns, was not applied due to the long and diverse nature of the interviews. Since interviewees came from different professional backgrounds and the terminology within the BCR industry is still evolving, a strict word-based analysis was not feasible. Instead, the study relied on interpretative categorization, which, while necessary, introduces a level of subjectivity and risk of biases. In the future, as definitions and terminology become more standardized across industry groups, interviews combined with word-based analysis could provide valuable insights.

Finally, the study's interview sampling strategy predominantly included stakeholders who support the development of CDR. It ensures interviewees with expertise in CDR or BCR markets, regulations, or policy development. However, while this approach ensures relevant insights, it limits diversity and selects mainly favoring voices of CDR by focusing primarily on industry stakeholders, policymakers, and market analysts (see graph 3). The diversity among those voices and their position on a specific CDR method, BCR, is presented but not opponents of CDR in general. A more balanced approach—

incorporating critical voices that question whether removals should play a role in the EU's climate strategy—could have provided a broader perspective. Additionally, a structured survey (instead of open-ended interviews) could have helped quantify different viewpoints, but ensuring the representativeness of such data would have remained a challenge.

11.3 Future Research

Future research opportunities based on this thesis could explore several areas in more depth. Although this work primarily targets a non-academic audience, some findings provide a basis for further academic investigation.

The data analysis of the voluntary BCR market revealed high-value outliers with no clear trend. Expert interviews offered potential explanations for these outliers, which could serve as a foundation for developing and testing new hypotheses. Additionally, the interviews identified bottlenecks in scaling BCR, some of which contradict previous research. These findings could be refined by focusing on specific stakeholder groups.

The most surprising finding was the discrepancy between industry expectations about increased future cost drivers in interviews and findings from surveys and literature, which generally predict declining prices. Further research regarding research question 2 and future prices is required. This thesis developed the hypothesis that the geographical location of projects that were used as a baseline but also unclear assumptions behind those expectations are possible reasons for the discrepancy. Further research could help to validate those.

As previously noted, the study's focus on the demand side leaves significant opportunities for further research that integrates supply-side factors with its findings. Future studies could explore aspects such as biomass prices, co-product pricing, cost reductions driven by technological advancements, as well as CAPEX and OPEX costs. Additionally, investigating potential future projections of these factors and their impact on BCR pricing would provide a more comprehensive understanding of market dynamics.

Another promising area for research is a comprehensive evaluation of the 11 design elements for integrating BCR into the EU ETS. While this thesis could not fully develop an assessment framework for these elements, a future study could build on existing methodologies, such as the report from Rasmussen, Vermeulen, & Gammelgaard Bøttcher (2024), to create weighted criteria and conduct a detailed analysis.

This thesis contributes to understanding its current and future market opportunities and value development for market players. It provides insights into future growth projections, while for policymakers, it highlights the role of regulatory integration in creating reliable demand and market stability. Together, these efforts can position BCR as a pivotal solution for achieving Europe's climate targets and scaling industry.

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Annex I Further Graphs and Illustrations

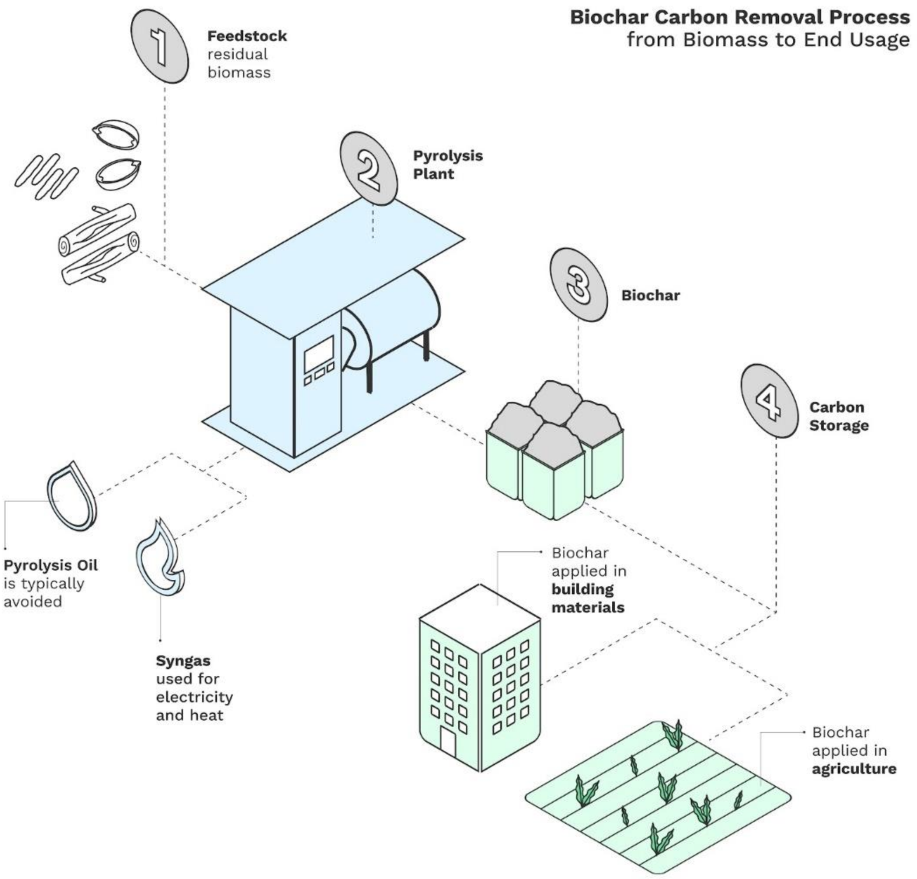


Figure 28: Overview Value Chain Biochar
Source: (Carbonfuture, n.d.)

Year	Total Tons Purchased	Average Tons Purchased	Median Tons Purchased	Min Tons Purchased	Max Tons Purchased	Transaction Count
2019	273	46	36	1	100	6
2020	3.595	95	19	1	1.100	38
2021	37.195	225	63	0	4.760	165
2022	97.534	252	39	0	9.100	387
2023	489.344	754	36	0	193.125	649
2024	706.961	1.633	65	0	95.000	433
Total	1.334.900					1.678

Table 5: Volume Analysis Voluntary Market (in tons BCR)

Source: Author’s Analysis (CDR.fyi’s dataset).

	Price (€/ton BCR)
count	173
mean	160
std	74
min	83
25%	117
50%	140
75%	187
max	560
Median	140
mode	140

Table 6: Statistical Summary dataset (CDR.fyi)
Source: Author’s Analysis (CDR.fyi’s dataset).

Metric	Value
R^2	-0,08114*
Mean Squared Error	2325,51

Table 7: Parameters Linear Regression Model (R Squared)
Source: Author’s Analysis (CDR.fyi’s dataset).

*A negative R2 indicates that the model performs worse than using the mean and is not suitable.

Metric	Value
Spearman's Rank Correlation Coefficient (-1 and 1)	0,527*
p-value (at 5% significance)	0.52749

Table 8: Results Spearman's Rank Correlation
Source: Author’s Analysis (CDR.fyi’s dataset).

***Non-linear Correlation and Price Prediction tests on the dataset**

The data is right-skewed, not normally distributed and has several extreme outliers. The linear regression model is not significant and suitable. A model that can handle non-normal distributed data and the presence of outliers is Spearman’s Rank Correlation. It investigates the correlation that assesses how well the relationship between two variables can be described using a monotonic function (meaning there is a general trend, up or down, not necessarily at a constant rate/straight-line pattern). The results of the Spearman test are in table 8. If it were a perfect positive monotonic relationship the coefficient would be close to 1, -1 if it was negative (Chattamvelli, 2024). The coefficient is close to 0 indicating no monotonic relationship. In addition, the p-value is much higher than 0,05 (the assumed significance level), thus the relationship is statistically not significant. A price prediction is difficult based on any correlation between price and time.

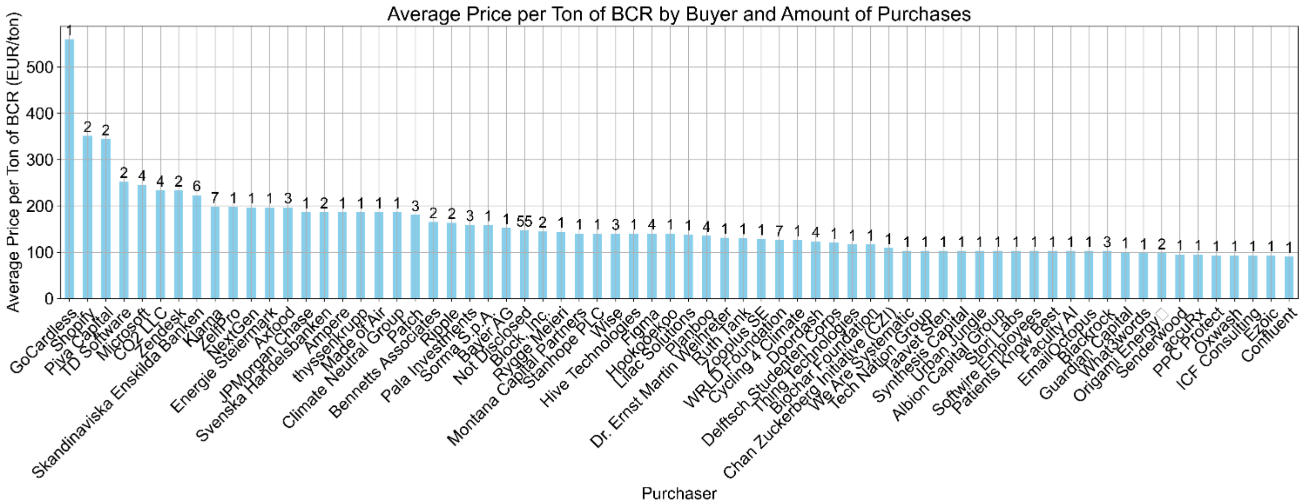


Figure 29: Buyer Pattern Analysis
Source: Author’s Analysis (CDR.fyi’s dataset).

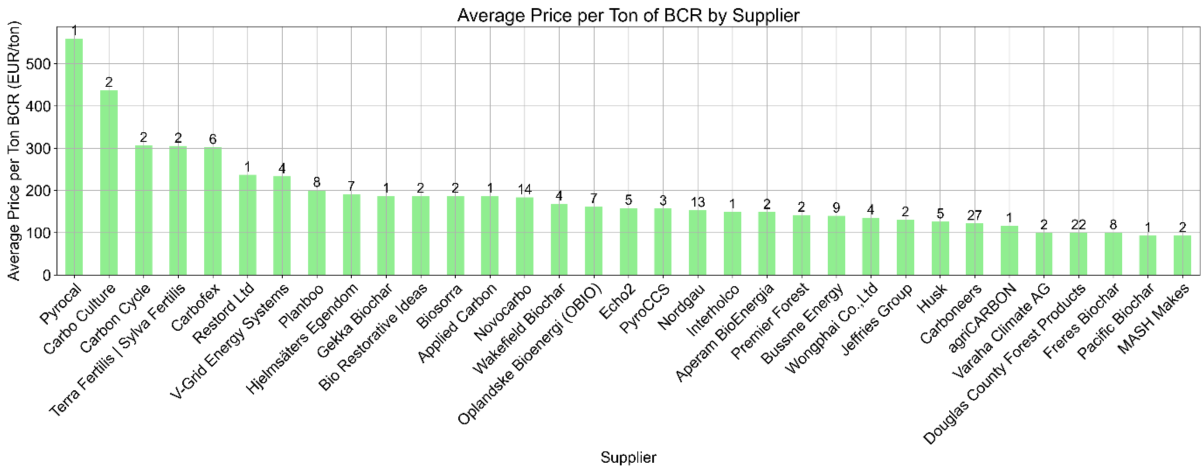


Figure 30: Supplier Pattern Analysis
Source: Author’s Analysis (CDR.fyi’s dataset).

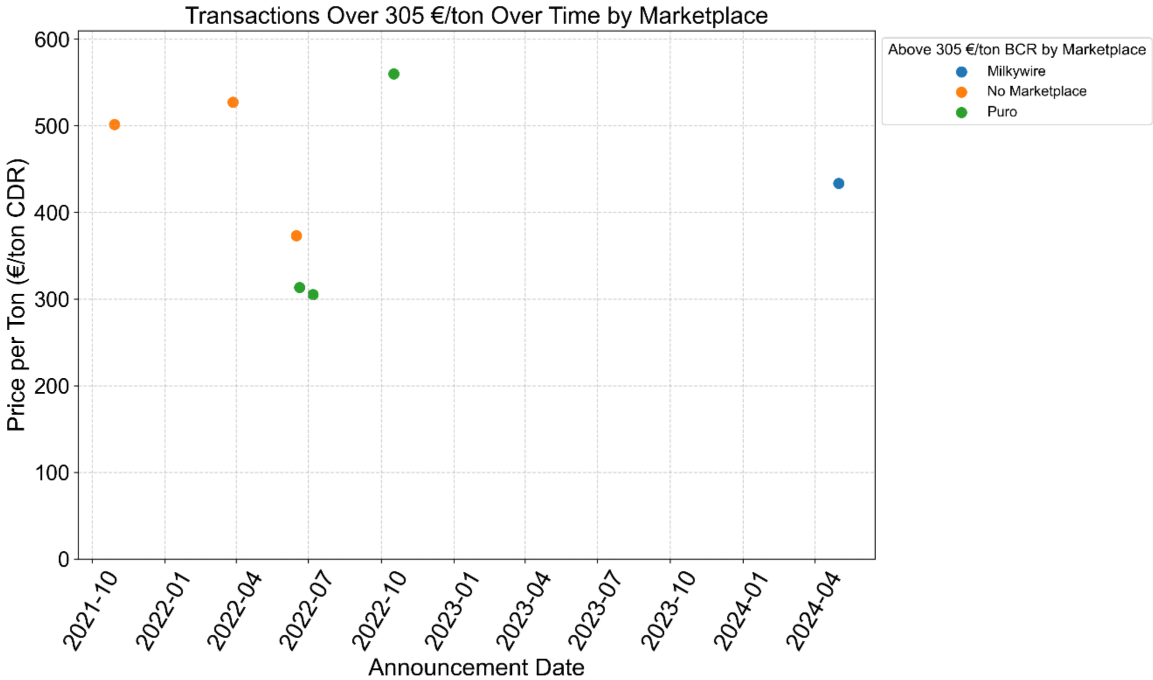


Figure 31: Transaction Over 305 €/ton BCR by Marketplace
Source: Author's Analysis (CDR.fyi's dataset).

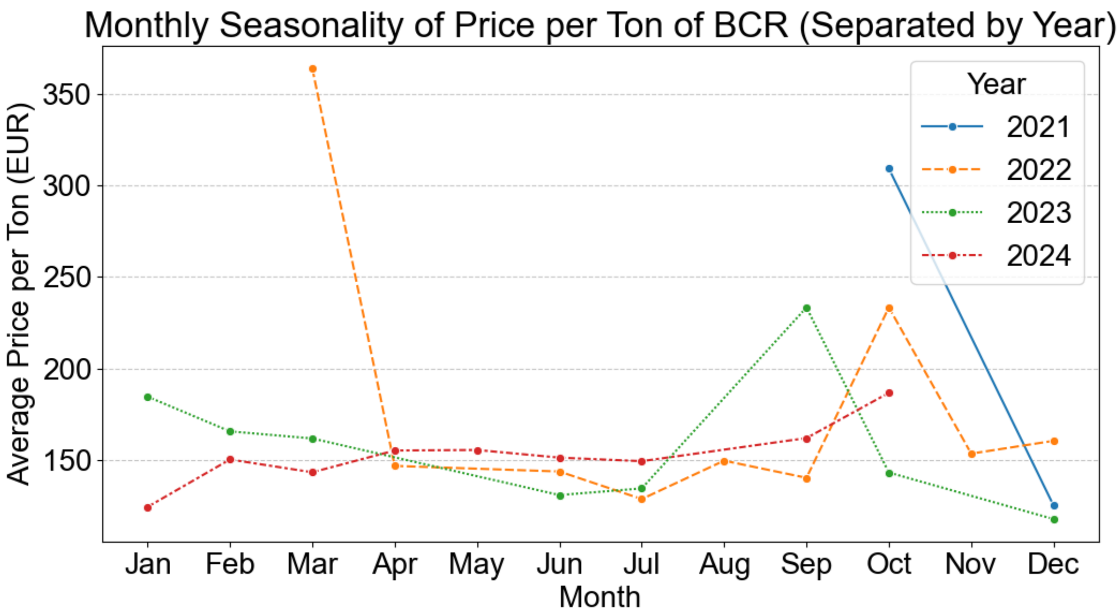
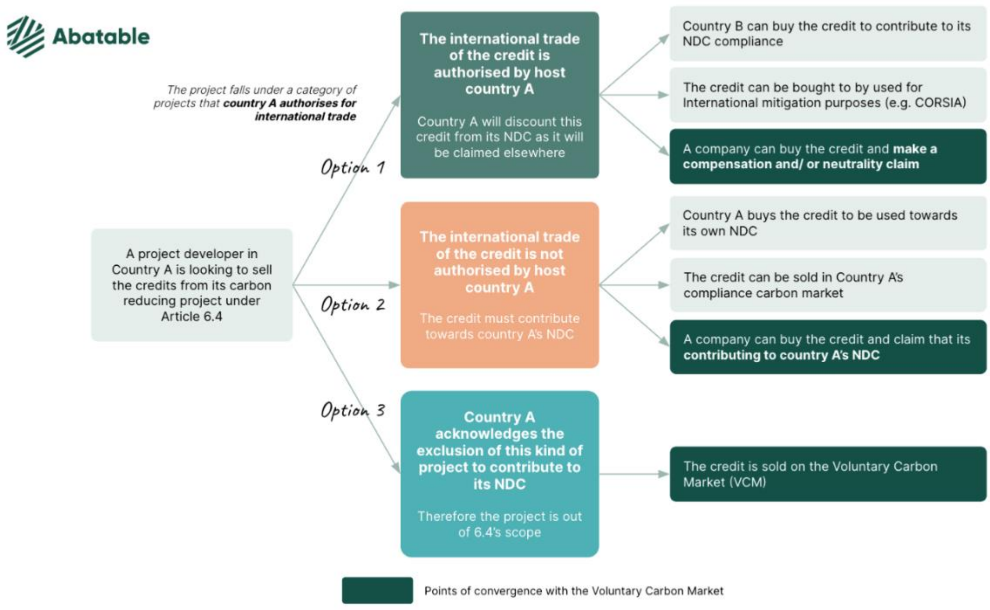


Figure 32: Monthly Value Pattern for Each Year
Source: Author's Analysis (CDR.fyi's dataset).



Source: Abatable

Figure 33: Proposal to Limit Voluntary Credits
Source: Scherger (2023) based on Abatable.

Criteria	Indicators	Description
Incentive for permanent carbon removals	Deployment of permanent carbon removals	Interventions should create appropriate demand for deployment of high-quality permanent carbon removals in line with EU climate targets.
Maintain incentives for emissions reduction	Abatement deterrence	Interventions should address risks of abatement deterrence (often referred to as 'mitigation deterrence' elsewhere in public debates and literature). Abatement deterrence is understood as the prospects of reduced or delayed emissions reductions due to the introduction or expectation of carbon removals, i.e. when carbon removals substitute for otherwise expected emissions reductions.
Cost-effectiveness	Mitigation at lowest economic cost	Integration should work towards establishing a framework that ensures a cost-effective mix between reducing emissions and using permanent carbon removals, enabling compliance entities to achieve abatement at the lowest cost to meet climate targets.
Market functioning	Volatility	Interventions should consider the effects on volatility. Volatility in allowance prices is not necessarily a negative outcome, but high volatility can be undesirable for compliance entities, as they need a reliable price signal on which to base long-term investment decisions.
	Liquidity	Interventions should take into account market liquidity, i.e. traded volumes, since a liquid market can improve market functioning.
Sustainability	Land sector risks	Interventions should be designed to take into account associated risks for climate (potential negative impact on land carbon sinks) and the environment (biodiversity and food production through direct and indirect land use change) of biomass resource use for BioCCS and possibly biochar. The main issue is the current lack of pricing of environmental externalities in the land use sector potentially leading to arbitrage.
Implementability	Administrative costs	Interventions should aim to limit additional administrative complexity and burdens on regulated entities and regulators.
	Speed/ease of implementation	Interventions should consider speed/ease of implementation such that it is operationally feasible in timescales relevant for EU climate targets.
	Fiscal impact	Interventions should maximise the value of auctioning revenues and take into account impacts on

		distribution of revenues (e.g. among Member States and EU funds).
Policy coherence	Deliverability of a net-zero and net-negative EU	Interventions should be coherent with EU climate targets of reaching climate neutrality and net-negative emissions hereafter.

Table 9: Overview Assessment Criteria Integration ETS
Source: (Rasmussen, Vermeulen, & Gammelgaard Bøttcher, 2024).

GitHub Repository: https://github.com/CarlitaCPH/masterThesis

Link 1: GitHub Repository

Annex II Interview Guides 1 and 2

Interview Guide 1: Voluntary Market, Price Analysis CDR.fyi, Future Price Projections

Purpose:

- validation of CDR.fyi data results for current value
- forecast for projection future prices

1. Current Value of Biochar Carbon Credits (BCR)

- How would you describe the current market value of biochar carbon credits (BCR) compared to other carbon credits?
- In your experience, how have you seen BCR values change over recent years, and what might explain these changes?
- What factors do you believe currently influence the price of BCR in the voluntary carbon market?

2. Reasons for Price Discrepancies

- How representative is the data reported at CDR.fyi regarding prices (report higher, lower etc.)
- What are the main factors, in your opinion, that lead to price variations for biochar carbon credits on the voluntary market?
- How does the quality or verification of BCR influence its pricing, if at all?
- What role do you think
    - geographic location,
    - supplier practices, or
    - marketplace
    - location supplier or buyer
    - certification play in these price differences?
- Have you observed any patterns in buyer behavior that might explain why prices vary widely for similar BCR offerings?

3. Future Value Potential of BCR

- Where do you see the value of biochar carbon credits heading in the next 5 to 10 years? (up or down)
- What potential market or policy changes could positively or negatively impact the future value of BCR?
- How could advancements in technology or sustainability practices affect the demand for and value of BCR?

4. Drivers of Value Development for BCR

- What do you believe are the main drivers that will affect the future value of BCR in the market?
- How might changes in environmental regulations or climate policy influence BCR valuation trends?
- In your view, how do supply chain factors, such as production costs or availability, impact the value of BCR?
- What role do you think public awareness and corporate responsibility initiatives play in influencing the demand for BCR?
- 5. Potential Bottlenecks to Value Growth

- What do you consider the biggest potential bottleneck in the development of the BCR market?
- Are there any regulatory, technological, or market-based constraints you believe could limit the growth of BCR value?
- How do you think certification or standardization issues could impact BCR's future value and acceptance?
- In your opinion, are there any supply chain or production limitations that could restrict BCR's scalability?

Closing question of that part

- Are there any aspects of BCR and voluntary market developments that you think are overlooked in the current discussion?

Interview Guide 2: Compliance Markets, Double Counting & Proposal Evaluation

Section 1: Integrating BCR into Co2 tax/ EU ETS Frameworks

- What role do you think BCR could play specifically within the CO2 tax (Agri and industrial)/ EU ETS climate mitigation goals?
- How do you see the option of integrating BCR into EU ETS or other compliance frameworks?
    - What do you envision as the primary pathways for integrating BCR into EU ETS or other compliance frameworks?
- In your opinion, what modifications or new mechanisms would need to be introduced within the EU ETS to accommodate BCR effectively?
- How could BCR credits be accounted for alongside other forms of carbon credits in CO2 tax/ EU ETS to ensure environmental integrity?
    - who can claim Co2 reduction in their accounts? (voluntary and compliance market)
    - The farmer's opportunities and limitations for using the carbon credits from the biochar that is spread

Section 2: Risks of Double Claiming and Overlap Concerns

- What risks, if any, do you perceive related to double counting when integrating removals within existing frameworks such as the EU ETS, RED, CO2 tax or IPCC GHG accounting?
- How do you see the alignment of private companies' CO_2 removal purchases with nations' territorial carbon accounting under frameworks like Article 6.4 of the Paris Agreement?
    - How do you see BCR credits potentially overlapping with credits or accounting practices in other compliance mechanisms?
    - "Double claiming": When can you double count the climate effect of biochar and when can you not?
- What approaches do you suggest addressing these overlaps and mitigate the risks of double counting across different systems?
- In your view, are there any existing precedents or examples of managing such overlaps that could apply to BCR?

Section 3: Optimal Framework and Integration Strategy for BCR

- If BCR were to be integrated into compliance markets, would you prefer to see it incorporated directly into the EU ETS or another specific framework? Why?
    - What would be the most effective or favorable way to integrate BCR into the CO2 tax/ EU ETS or other frameworks?

- How do you believe including BCR could impact the perceived and actual value of carbon credits within compliance markets?
- If you were to suggest alternative options for BCR integration, which frameworks or mechanisms would you recommend, and why?

Section 4: Anticipated Impacts and Future Outlook

- What challenges or bottlenecks do you foresee in integrating BCR into compliance markets like the EU ETS?
- How do you expect the value of BCR to evolve if integrated into the EU ETS or other compliance frameworks?
- What potential long-term benefits or drawbacks could arise from integrating BCR within compliance markets?

5. Proposal evaluation

- Refers to
    - How might changes in environmental regulations or climate policy influence BCR valuation trends?

Initial Reaction/ Overall Feedback

- What are your initial thoughts on the proposal? What stands out to you as its main strengths and weaknesses?
- Is there anything in the proposal that you find unclear or need further clarification on?

Feasibility and Practicality

- How feasible do you think this proposal is, given the current regulatory, technological, and market conditions?
    - What specific aspects of the proposal might be challenging?

6. Alignment with Existing Frameworks and Standards

- To what extent do you think this proposal aligns with existing frameworks like the EU ETS, RED, or IPCC GHG accounting standards?
- Do you see any areas of conflict or potential overlap with current regulations or practices?
- What would you suggest to ensure this proposal is better integrated or harmonized with existing systems?

7. Potential Risks and Mitigation Strategies

- What risks do you associate with the implementation of this proposal, if any?
- What mitigation strategy would you recommend?
- Improvements:
- What aspects of the proposal do you think could be improved or expanded upon?
- Is there anything you believe is missing from the proposal that should be included?

8. Closing Questions

- Are there any aspects of BCR integration or compliance markets that you think are overlooked in the current discussion?
- If you had the opportunity to advise policymakers on this integration, what would be your top recommendations?
- What aspects of the proposal do you think could be improved or expanded upon?
- Is there anything you believe is missing from the proposal that should be included?