



Germany's potential to deploy CDR at scale and speed

Background report

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A collaboration between

carbon

gap

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About the Carbon Removal Readiness Assessment project

Many governments have committed to net-zero; moreover, the IPCC forecasts the need for hundreds of billions of tonnes of carbon dioxide removal (CDR) to stabilise global temperatures well below 2°C. Yet, few, if any, countries currently have a robust plan to develop and deploy atmospheric CDR at the capacity required to counteract remaining emissions at the point of net-zero. Forecasted CDR needs are typically global in scope and do not inform CDR planning and policy design at the country level.

The Carbon Removal Readiness Assessments (CRRA) aim to fill this information gap and to support national policymakers in complementing their climate strategies with ambitious yet realistic CDR goals. The CRRA estimates the extent to which CDR countries can realistically deploy CDR using a bottom-up approach and provides country-specific roadmaps, developed in consultation with local stakeholders, to assist decision-makers in understanding the opportunities and the actions needed to realise them.

Acknowledgments

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Disclaimer

This document presents a quantified estimate of Germany's potential for deploying CDR methods. Because most of the methods assessed in this report are still in early stages of development, the assessment is subject to significant uncertainty. Some methods may not prove viable, while others excluded from this report may develop more quickly than expected. CRRA assess the technical and physical feasibility of CDR deployment at the country level, and is not a substitute for project-level feasibility studies or techno-economic assessments.

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Executive summary

Germany has set a target of greenhouse gas (GHG) neutrality by 2045 and net-negative emissions by 2050, in line with the Paris Agreement. Meeting this legally binding goal will require not only rapid emissions reductions across all sectors, but also a significant scale-up of carbon dioxide removal (CDR) to counterbalance residual emissions, particularly in hard-to-abate sectors, and to enable net-negative emissions, removing historical emissions and addressing a likely temperature overshoot.

Germany was selected for the Carbon Removal Readiness Assessment (CRRA) project due to its substantial theoretical CDR potential, its actively emerging national dialogue on the topic, and the need for tailored strategies that reflect its distinct socio-economic and geographic conditions. At the same time, Germany's land-sink outlook has become significantly more uncertain, necessitating a close look at how a balanced, diverse CDR portfolio may emerge.

Moreover, regarding Germany's net-negative ambition post-2050, Carbon Gap's CARE (Coordinated Allocation of Removal Efforts) Calculator¹ – a burden-sharing tool that translates Paris-aligned global CDR needs into indicative national contributions using different equity principles – suggests Germany's implied contribution could be on the order of several hundred MtCO₂e per year (~300–345 MtCO₂e/yr under illustrative allocation settings). Understanding how much of such a contribution can realistically be realised domestically is therefore essential.

This report provides quantified insights into Germany's potential to deploy CDR in support of ambitious yet grounded CDR goals. Based on a bottom-up analysis of Germany's available key resources, this study estimates both (a) theoretical and (b) realistic potentials for implementing a wide spectrum of CDR methods for 2035 and 2045. Recognising that CDR deployment is not solely a technical challenge, the report also analyses the 'social geography' of the issue, capturing perspectives through stakeholder interviews, a survey, and a citizen panel discussion.

The assessment follows six key steps:

1. Identification and selection of relevant CDR methods;
2. Mapping of available resources for CDR, including renewable electricity, waste heat, biomass, land, water, and geological storage capacity;
3. Estimation of the maximum theoretical CDR potential;
4. Evaluation of Germany's regulatory, economic, and political landscape;
5. Analysis of societal attitudes toward CDR deployment in Germany, based on stakeholder interviews and a citizen panel;
6. Estimation of realistic CDR potential for 2035 and 2045 based on three scenarios.

Main results on Germany's CDR potential

The report reviews a range of CDR methods – grouped into ecosystem management, biomass conversion, geochemical, and synthetic methods.

In the first step, the theoretical potential for CDR is assessed using domestic resources. This "maximalist" assessment yields a **theoretical CDR potential of ~258 MtCO₂/year in Germany by 2045**, assuming all available resources (after priority uses) are directed entirely to CDR – an assumption unattainable in real-world conditions. This potential is dominated by agroforestry, BECCS with combustion, and afforestation. While natural forest carbon sinks are not classified as CDR under strict definitions (because they are not human-induced or additional), they are still accounted for in Germany's CDR potential due to their influence on harvesting levels. Managed forest dynamics significantly shape net removals, making them a relevant component in national accounting and scenario modelling.

Next, **three realistic scenarios** were developed: a **low ambition** CDR scenario (referred to as 'Scenario A') and **two high ambition** CDR scenarios: **energy-efficiency focused** (referred to as 'Scenario B') and **reduced-BECCS** (referred to as 'Scenario C'). All scenarios are modelled for the short term (2035) and the longer term (2045) - Germany's net-zero target year. The results of these scenarios are shown in Figure 1 and are compared to a range of estimated residual emissions in Germany in 2045 (in grey). Compared with the theoretical scenario, the realistic scenarios account for socioeconomic constraints and employ conservative assumptions about available resources that could be utilised for CDR, thereby making them implementable with higher confidence without deviating significantly from current conditions.

Scenario A: Low ambition depicts a situation close to the status quo, in which only limited efforts are made to deploy CDR, and the resources are assumed to be primarily used for purposes other than CDR. The most distinctive differences from other scenarios are the wood-based biomass derived from Thünen's WEHAM BAU scenario, the electricity volumes and their availability for CDR, based on Fraunhofer's Persistence electricity scenario, and the natural sink informed by the BBioNET projections.

In this low-ambition scenario, the CDR potential for Germany is **~26 MtCO₂ in 2035 and ~47 MtCO₂ in 2045** (including the natural sink; see Figure 1). The capacity of the portfolio of CDR methods deployed remains lower than that of natural carbon sinks in forests, which constitute a significant share of the carbon sequestration potential (16 MtCO₂).

Scenario A also entails significantly lower deployment of BECCS and DACCS than Scenarios B and C, primarily because CO₂ storage capacity has not been developed. While BECCS has potential given biomass availability, its expansion is constrained by the availability of geological CO₂ storage. Of the available storage capacity for BECCS, 90% was allocated to combustion and 10% to anaerobic digestion, reflecting the greater feasibility of retrofitting large wood-combustion facilities than smaller, dispersed biogas plants. Durable bio-based products (such as wood and bio-composites used in construction) contribute a small potential to the overall picture, as do enhanced rock weathering and ocean alkalinity enhancement.

Scenarios B: High ambition, energy-efficiency focused and **Scenario C: High ambition, reduced-BECCS**, assume significant efforts to deploy CDR, allocating more resources to the various CDR

methods. In Scenario B, the realistic CDR potential amounts to **~42 MtCO₂ in 2035 and ~91 MtCO₂ in 2045**; and Scenario C calculates **~42 MtCO₂ in 2035 and ~95 MtCO₂ in 2045**.

The key difference between *Scenario B: High ambition, energy-efficiency focused* and *Scenario C: High ambition, reduced-BECCS* is that Scenario C assumes a political preference to limit the use of biomass for BECCS, and thus most CO₂ storage capacity is allocated to DACCS instead of BECCS. In *Scenario C: High ambition, reduced-BECCS*, reduced biomass use – particularly energy wood – results in lower harvesting levels and a greater share of wood is directed to products, thereby reducing BECCS potential compared to *Scenario B: High ambition, energy-efficiency focused*. By contrast, DACCS retains significant potential in *Scenario C: High ambition, reduced BECCS*, and natural carbon sinks are also expected to increase.

Key takeaways

- 1. The realistic CDR potential in Germany shows that CDR could make a meaningful contribution to Germany's climate targets.** By 2045, *Scenarios B: High ambition, energy-efficiency focused* and *Scenario C: High ambition, reduced-BECCS* reveal CDR volumes that could enable net-zero within range of expected residual emissions and may allow Germany to go net negative slightly earlier than planned.
- 2. Most CDR methods are possible in Germany.** Mobilising a diversified portfolio of CDR methods distributes risk and resource pressure. It also provides flexibility to offtake markets and governance structures. However, a diversified CDR portfolio requires significant coordination between public and private actors to ensure that all potential methods are developed to their full potential.
- 3. The limited geological storage capacity constraints DACCS and BECCS.** In all scenarios, geological storage capacity emerges as the limiting factor for BECCS and DACCS. Accelerated, large-scale industrial policy interventions and market investment are needed to ensure that CO₂ transport and storage capacity align with Germany's capture potential.
- 4. Interviews with experts and a citizen panel demonstrated support for CDR, but scepticism and uncertainty persist regarding scaling novel CDR methods.** Stakeholders across academia,

industry, government, and civil society agree on scaling a CDR portfolio, though insufficient policies and infrastructure investments were noted. The citizen panel was more aware - and favoured - conventional nature-based CDR methods, though positive attitudes towards all methods increased after a detailed discussion on CDR. Citizens were less aware and more critical of novel, technical solutions. Expert stakeholders and citizen panels agreed on the need for regulation and oversight to prevent greenwashing and ensure transparent, sustainable practices.

5. Germany cannot risk “low ambition”, as it lands at ~47 MtCO₂ by 2045 – likely not enough margin for resilience. In Scenario A, the pathway offers limited room against real-world uncertainties – especially given the recent volatility of land sinks – and increases the risk of missing the net-zero and net-negative targets.

6. Portfolio choices have real consequences: less BECCS can mean more DACCS. Scenario C reflects a potential political preference to constrain BECCS biomass use; as a result, a larger share of geological storage capacity is available for DACCS, and the pathway also delivers higher natural-sink outcomes than Scenario B. This illustrates that Germany can shape its CDR mix through explicit choices, such as biomass allocation and the prioritisation of transport and storage infrastructure, but must acknowledge and manage the associated trade-offs.

7. There is no viable business case yet – CDR deployment still depends on public support and market design. Stakeholders emphasise that early CDR deployment still hinges on public support programs, such as financial incentives, establishing standards, and public procurement, alongside nascent voluntary demand. Stakeholders point to the need for investment in

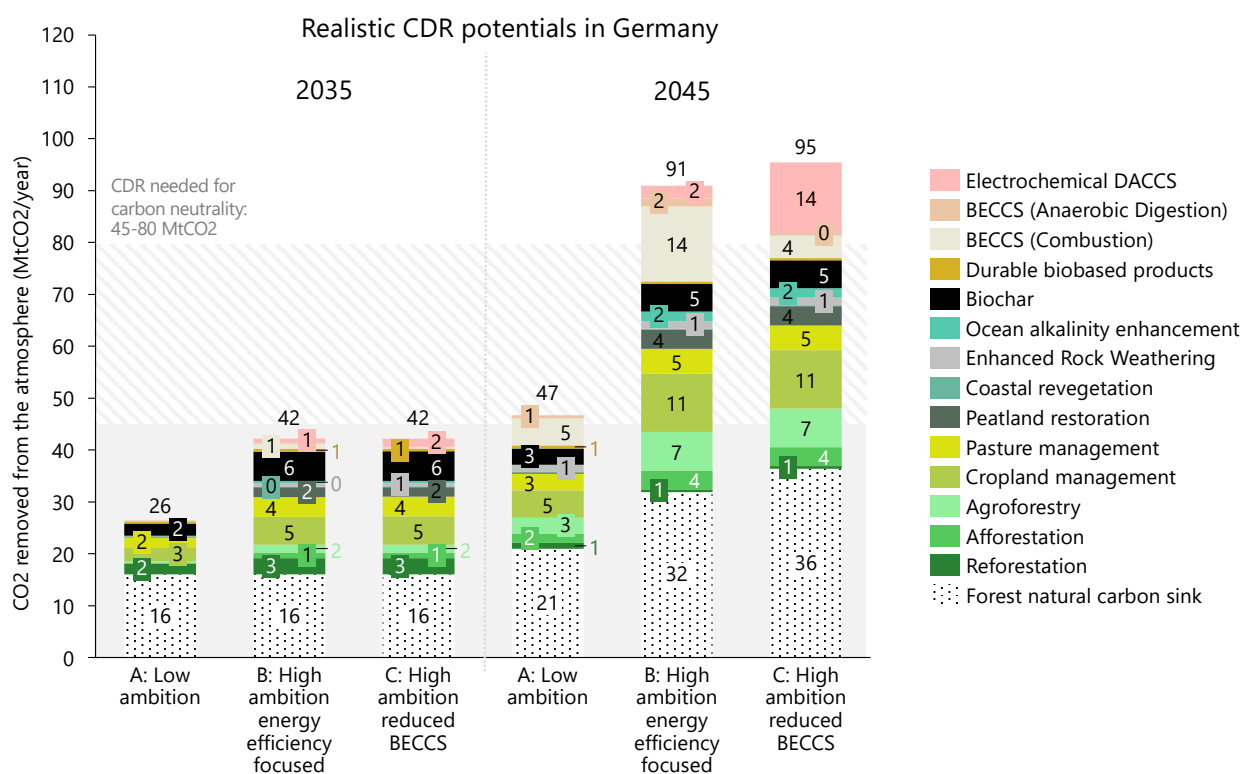


Figure 1. Germany's realistic CDR potential for the three scenarios in 2035 and 2045, compared with an expected carbon gap (residual emissions) in 2045. The potential of improved forest management is captured in the WEHAM scenarios and has not been included as a separate CDR method to avoid double-counting.

CO₂ transport and storage infrastructure, as well as clearer market incentives to unlock private capital and create a durable business case.

8. Net-zero is not the finish line, and substantial theoretical potential remains to be unlocked in the second half of this century, beyond 2050. Germany's stated objective of becoming net-negative after 2050 means continued scaling beyond the ~100 MtCO₂/year level in 2045 pathways, potentially toward the domestic upper threshold (~258 MtCO₂/year under maximalist assumptions). This is essential for addressing historical emissions and reversing a likely temperature overshoot.

In sum, the realistic CDR potential scenarios presented in this report should not be interpreted as forecasts but as illustrative pathways, given

sensitivities around land sinks and availability of CO₂ infrastructure, as well as the lack of a full techno-economic assessment. The actual level of CDR achieved in Germany will depend on public and private investment levels, strategic choices, and the evolution of relevant markets.

The concrete actions required to realise Germany's CDR potential are outlined in a separate *Roadmap* that builds on the findings of this background report.



List of abbreviations

BAU	Business as usual
bcm	Billion cubic meters
BECCS	Bioenergy with carbon capture and storage
CAPEX	Capital expenses
CCS	Carbon capture and storage
CCUS	Carbon capture, utilisation and storage
CDR	Carbon dioxide removal
CL	Carbon Limits
CO₂	Carbon dioxide
CO₂e	Carbon dioxide equivalents
COP	Conference of the Parties
CRCF	Carbon Removal Certification Framework
DAC	Direct air capture
DACCS	Direct air carbon capture and storage
DIHK	German Chamber of Commerce and Industry
DOCCS	Direct ocean carbon capture and storage
EEA	European Environmental Agency
EEZ	European Economic Zone
EIB	European Investment Bank
ESR	Effort Sharing Regulation
ETS	Emission Trading System
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gases
Gt	Giga-tonne
GW	Gigawatts
HWP	Harvested wood product
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change

LCA	Life cycle assessment
LULUCF	Land use, land use change, and forestry
mcm	Million cubic meters
mm	Milli-meter
Mm³	Million cubic metres
MMdt	Million dry tons
MRV	Monitoring, reporting, and verification
Mt	Million tonnes
MtCO₂	million tonnes of carbon dioxide
Mtpa	Million tonnes per annum
MW	Megawatts
NATO	North Atlantic Treaty Organization
NDC	Nationally determined contribution
NECP	National Energy and Climate Plan
NTC	Net Transfer Capacity
OAE	Ocean alkalinity enhancement
OECD	Organisation for Economic Co-operation and Development
OPEX	Operational expenses
pH	Potential of Hydrogen
QGIS	Quantum Geographic Information System
R&D&I / RDI	Research, development and innovation
S-DAC	Solid sorbent direct air capture
STEM	Science, technology, engineering, and mathematics
t	Tonnes (metric)
tha	Thousand hectares
TRL	Technology readiness level
TSO	Transmission system operator
TWh	Terawatt-hour
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar (\$)
VCM	Voluntary carbon market
WEHAM	Die Waldentwicklungs- und Holzaufkommensmodellierung

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1. Introduction

Climate change is one of the most significant challenges of the 21st century, endangering ecosystems, human health, economies, and global security. In response, the 2015 Paris Agreement committed signatories to

Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change.²

Meeting these targets requires not only rapid and deep emissions reductions across all sectors, but also the removal of carbon dioxide (CO₂) from the atmosphere to offset residual emissions.³ With a 70% likelihood that the 1.5°C threshold will be temporarily exceeded between 2025 and 2029⁴, CDR is increasingly a critical tool - not just for balancing emissions, but also for actively reversing temperature overshoot. Its role will be essential throughout the remainder of this century in helping to bring global temperatures back within safe limits.

CDR refers to anthropogenic processes used to remove CO₂ from the atmosphere and durably store it to prevent further warming. CDR is not an alternative to emissions reductions, but it is a necessary addition, particularly in hard-to-decarbonise sectors such as agriculture, aviation, and heavy industry and net-negative emissions.⁵ CDR methods range from biological and nature-based solutions to technological processes that physically and chemically separate CO₂ directly from the air and store it durably in underground geological formations.

Despite growing recognition, CDR faces significant uncertainties around technical maturity, economic feasibility, environmental risks, and public acceptance. Country-specific assessments are crucial for tailoring solutions to local socio-economic and geographical contexts, thereby enhancing their feasibility and effectiveness.

Germany, the EU's largest economy, has set ambitious climate targets: net-zero greenhouse gas (GHG) emissions by 2045 and net-negative emissions by 2050. In support of these legally-binding goals, Germany is beginning to put in place key building blocks for carbon dioxide removal (CDR), including public research and innovation programmes such as CDRterra and CDRmare, preparation of a dedicated national CDR strategy (the "Long-term Strategy for Negative Emissions", LNe – currently under development), passing a formative CO₂ transport and storage act (KSpTG), and public financial support for early deployment, with €500 million committed for CDR over the period 2026 to 2033, over €100M of which is to be spent in 2026.

At the same time, Germany's current trajectory remains highly dependent on nature-based sinks, which have shown clear signs of weakening in recent years. Reducing this exposure requires portfolio diversification across conventional and novel CDR approaches, making the next few years critical for setting direction, establishing rules, and developing the enabling infrastructure to support the first wave of CDR projects mature and scale.

Regarding Germany's residual emissions at the point of net-zero by 2045, various studies estimate that between **45 and 80 Mt CO₂e** need to be counterbalanced by CDR to achieve net-zero. Residual emissions are largely biogenic, with agriculture and waste contributing an estimated 27–50 MtCO₂e across studies, primarily as methane and nitrous oxide. Non-biogenic sources are smaller: industry accounts for 8–23 MtCO₂e, primarily from process emissions and fossil feedstocks, whereas energy, buildings, and transport together contribute only 0–9 MtCO₂e as marginal residues.⁶

Moreover, after targeting net-zero by 2045, Germany has set the objective of becoming net-negative after 2050, but has not specified quantified targets. Carbon Gap's CARE calculator¹ provides a burden-sharing perspective: it translates Paris-aligned global CDR needs into indicative country contributions under alternative equity principles (polluter-pays, ability-to-pay, equality). Under several illustrative settings, Germany's implied contribution reaches the hundreds of MtCO₂e per year (around ~300–345 MtCO₂e/yr in the tool's comparison table). These figures are not a domestic feasibility estimate; they provide an order-of-magnitude indication, making it important to assess Germany's realisable potential and constraints.

This report was prepared using a bottom-up approach that included desk research and the development of CDR scenario models, interviews with relevant national stakeholders, and public engagement through a citizen panel. Following this introduction, Chapter 2 outlines the relevant CDR methods and those selected for this study. Chapter 3 then describes Germany's geographical landscape, including current and prospective resources and feedstocks needed to deploy the selected CDR methods. In Chapter 4, a preliminary estimation of CDR potential is presented based only on the

physical resources – the so-called “theoretical” potential. Following this, Chapters 5 and 6 outline Germany's social geography by analysing the socio-economic, regulatory, and political landscape, and by discussing the results of the stakeholder interviews and the citizen panel. Finally, Chapter 7 presents the CDR potentials across three scenarios, accounting for both physical and social geography. Chapter 8 concludes with a set of targeted recommendations, based on the main findings, for policymakers, researchers, and stakeholders seeking to scale CDR to climate-meaningful levels.



2. CDR pathways and their resource requirements

Following the IPCC definition of CDR, all the methods assessed in this report must follow three key principles:

1. The CO₂ captured must come from the atmosphere (or oceans), not from fossil sources;
2. The subsequent storage must be durable over climate-relevant timescales (typically decades to centuries or millennia), in either geological, terrestrial, oceanic, or durable products;
3. The removal must be the result of human intervention, additional to the Earth's natural carbon cycling;⁷

Importantly, while carbon capture and utilisation (CCU) and carbon capture and storage (CCS) are valuable tools for climate mitigation and share components with certain CDR methods, they do not achieve durable removal of CO₂ from the atmosphere, as illustrated in Figure 2.

2.1 Diversity of CDR methods

The effectiveness of CDR methods depends not only on the amount of CO₂ removed, but also, among other factors, on the durability of storage, scalability towards climate-meaningful volumes, measurability, additionality, and social acceptability. CDR methods can be classified into four main categories: enhanced ecosystem management, biomass conversion or preservation, geochemical and synthetic CDR, as illustrated in Figure 3.

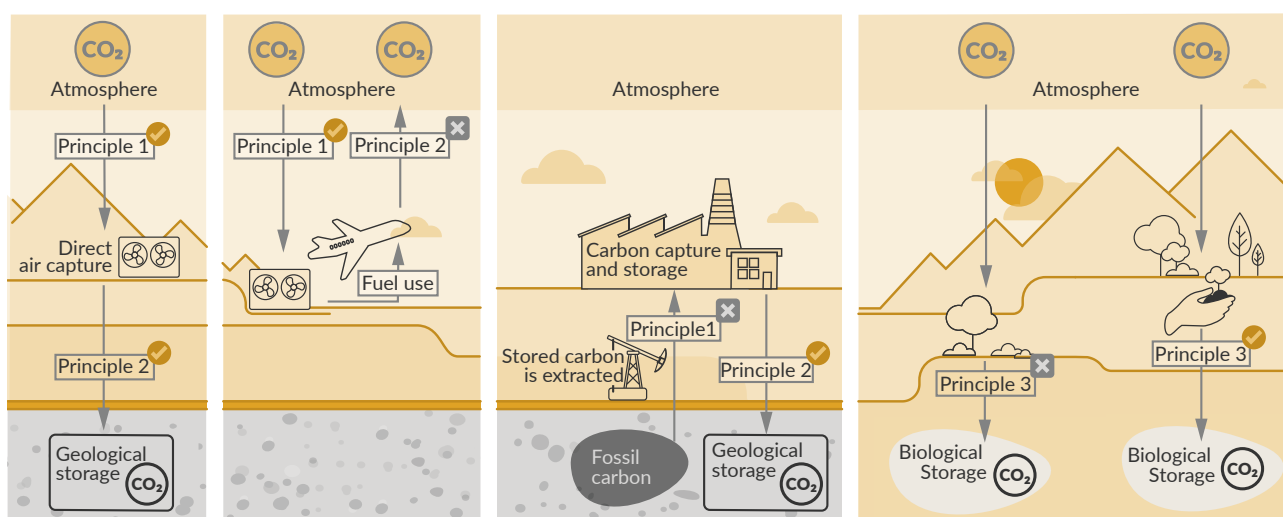


Figure 2. Section A illustrates direct air capture (DAC) with permanent geological storage, a configuration that satisfies all three core principles of carbon dioxide removal. In contrast, section B depicts DAC, in which captured CO₂ is used to produce short-lived products such as fuels, thereby failing to meet Principle 2 on durability. Section C depicts the capture and geological storage of fossil-derived CO₂, which does not meet Principle 1 because it does not remove carbon already in the atmosphere. Section D presents natural processes, such as tree growth, that fall short of Principle 3 unless actively enhanced by human intervention (Figure from the State of CDR report, 2024).

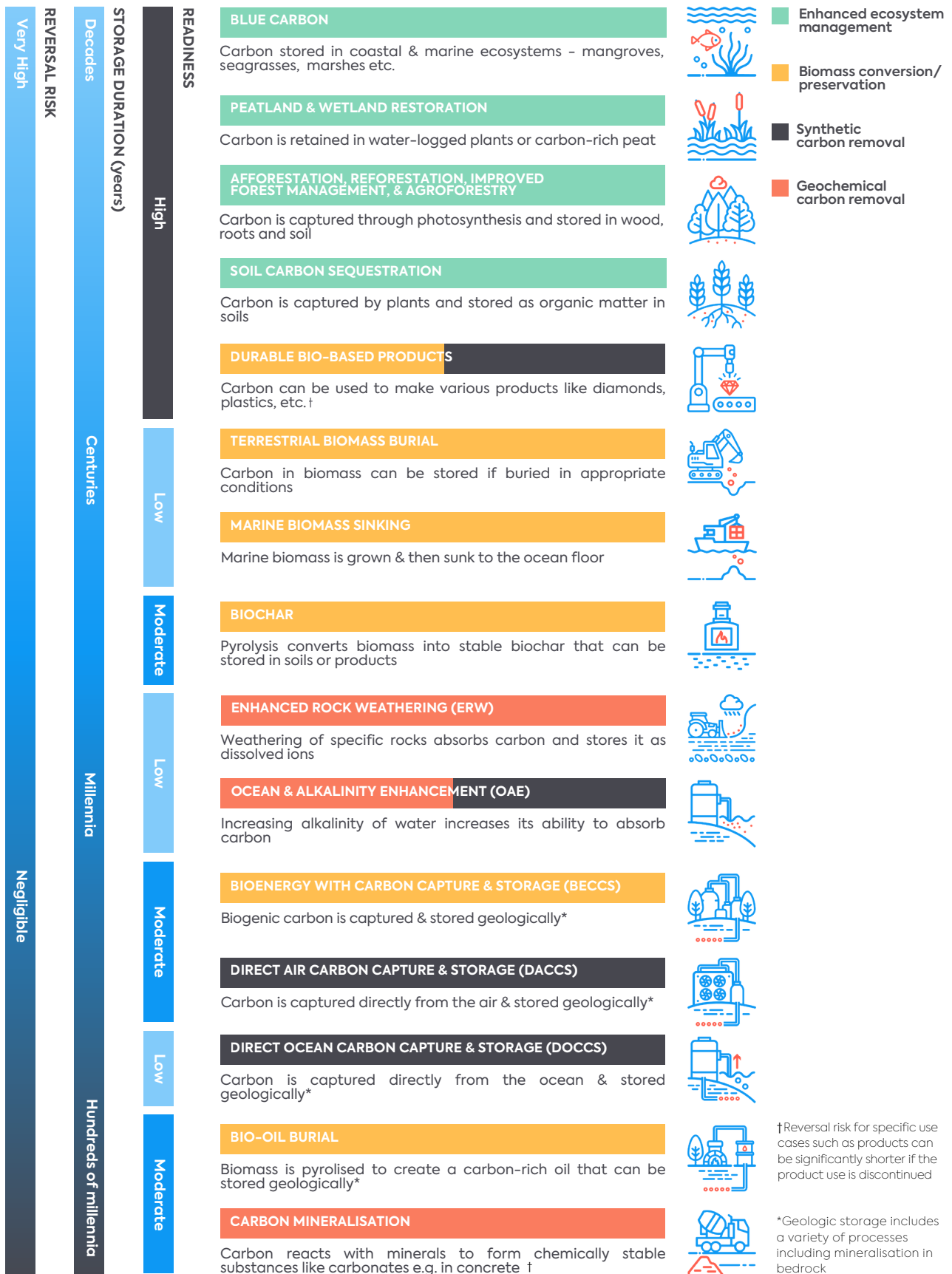


Figure 3. CDR Methods with their respective storage duration and deployment readiness (Carbon Gap).

2.1.1 Enhanced ecosystem management

CDR methods based on enhanced ecosystem management increase the amount of CO₂ sequestered and retained across both natural and managed ecosystems. By optimising land use or restoring degraded or altered ecosystems, these approaches strengthen the capacity of natural ecosystems to operate as carbon sinks. Landscapes' capacity to act as carbon sinks. Methods within this category include:

1. **Afforestation** creates new forests by planting trees on land that previously lacked forest cover, often targeting degraded farmland, grasslands, or other open areas.
2. **Reforestation** restores tree cover on land that has been deforested or ecologically degraded, helping to restore ecosystem function and carbon storage.
3. **Improved forest management (IFM)** enhances forestry practices to increase carbon sequestration within forest ecosystems, including extended rotation periods, reduced harvesting, and conservation of old-growth stands.
4. **Agroforestry** integrates trees and shrubs into agricultural systems, combining crop and livestock production with perennial vegetation to improve resilience, biodiversity, productivity and carbon storage.
5. **Soil carbon sequestration** enhances soil organic carbon through regenerative practices in cropland and pasture management, including no-till farming, cover cropping, compost application, and crop rotations, thereby reducing emissions and improving soil health.
6. **Peatland restoration** aims to restore the natural capacity of peatlands to store carbon.
7. **Blue Carbon** focuses on the restoration and conservation of coastal ecosystems – like mangroves, salt marshes, and seagrasses – that naturally capture and store large amounts of carbon in biomass and sediments.

2.1.2 Biomass conversion/preservation

Biomass-based CDR methods harness the natural ability of plants to absorb atmospheric CO₂ through photosynthesis, storing it in their biomass – leaves, stems, roots, and other organic tissues. To prevent

CO₂ from returning to the atmosphere via natural decomposition or combustion, these approaches deliberately intervene in this carbon cycle. Biomass is intentionally processed in ways that stabilise or durably sequester the captured carbon, ensuring long-term storage. Methods included in this category are:

1. **Durable bio-based products** refer to carbon stored in materials such as timber and bioplastics. These products delay carbon release by extending the lifecycle of biomass-derived carbon.
2. **Biochar (carbon removal)** is produced by pyrolysing biomass under low-oxygen conditions, resulting in a stable, carbon-rich material. When applied to soils or other materials, biochar resists decomposition and can store carbon for decades to millennia.
3. **Bio-oil storage** converts biomass via pyrolysis and injects the resulting bio-oil into stable geological formations. This method sequesters liquid carbon underground for hundreds to thousands of years.
4. **Bioenergy with carbon capture and storage (BECCS)** integrates biomass utilisation with CO₂ capture and geological storage. It prevents the release of CO₂ from biomass combustion or processing, thereby enabling net-negative emissions.
 - a. **BECCS with combustion** captures CO₂ from biomass combustion in power or industrial plants and stores it underground, while generating usable energy.
 - b. **BECCS with anaerobic digestion/fermentation** captures CO₂ released during biomass breakdown for biogas or ethanol production, diverting it to secure geological storage.
5. **Marine biomass sinking** refers to the cultivation or collection of seaweed and other marine biomass, which is deposited in deep ocean layers (greater than 1000 m). This accelerates the natural carbon pump and sequesters carbon for centuries to millennia.
6. **Terrestrial biomass burial** involves harvesting plant biomass and burying it in engineered, low-oxygen environments to prevent decomposition. This method locks carbon absorbed via photosynthesis into stable storage for extended timescales.

2.1.3 Geochemical carbon removal

Geochemical and ocean-based methods accelerate or enhance naturally occurring chemical interactions between CO₂ and reactive rocks or minerals. In nature, such reactions unfold slowly over geological timescales. However, by increasing the surface area of reactive materials - typically through grinding - and applying them to terrestrial or marine environments, the rate of CO₂ conversion and storage can be significantly enhanced. Key methods include:

- 1. Enhanced rock weathering (ERW)** involves the application of finely ground silicate minerals to soils, where they react with CO₂ to form stable carbonates, thereby sequestering carbon over long timescales.
- 2. Ocean alkalinity enhancement (OAE)** increases seawater alkalinity to accelerate the natural absorption of CO₂, converting it into stable bicarbonate and carbonate ions.
 - a. Mineral OAE** involves dissolving alkaline minerals (e.g., olivine, lime) into seawater to boost alkalinity and enhance CO₂ uptake.
 - b. Electrochemical OAE** uses electricity to modify seawater chemistry, increasing its alkalinity and, therefore, its capacity to absorb and retain CO₂.
- 3. Carbon mineralisation** facilitates the reaction of CO₂ with calcium- or magnesium-rich rocks to form solid carbonates. This can occur in separate plants (ex situ) or within porous rock formations (in situ), enabling permanent carbon storage.
- 4. Ocean fertilisation** adds nutrients to ocean regions to stimulate phytoplankton growth and CO₂ uptake. It can be done with iron, nitrogen/phosphorus, or artificial upwelling. Overall, results are variable and may involve ecological risks and rapid carbon re-release.

2.1.4 Synthetic carbon removal

Synthetic carbon removal encompasses engineered systems designed to extract CO₂ from the atmosphere or oceans and store it permanently. Two principal approaches in this category are direct air carbon capture and storage (DACCS) and direct ocean carbon capture and storage (DOCCS). Both offer the advantage of long-term, measurable carbon sequestration.

- 1. Direct air carbon capture and storage (DACCS)** involves capturing CO₂ directly from ambient air using solid sorbents or liquid solvents. Once captured, the CO₂ is released by heating, pressurising, or undergoing chemical reactions, yielding a purified CO₂ stream. This concentrated CO₂ is then compressed and stored in geological formations or other long-term sequestration sites.

- a. Electrochemical DACCS** utilises electrochemical reactions to capture and release CO₂ selectively.
- b. Moisture-swing DACCS** employs sorbents that adsorb CO₂ under dry conditions and release it upon exposure to moisture.
- c. Mineral-looping DACCS** captures CO₂ by reacting it with Ca- or Mg-rich minerals, thereby forming stable carbonates such as calcite or magnesite.
- d. Low-temperature DACCS** (<100 °C) uses solid amine sorbents or alkaline solutions, often powered by low-grade or waste heat, to capture CO₂.
- e. High-temperature DACCS** (>400 °C) and techniques like calcium looping operate at elevated temperatures, enabling rapid CO₂ capture.

- 2. Direct ocean carbon capture and storage (DOCCS)** targets CO₂ dissolved in seawater, where it exists in large quantities as part of the ocean's inorganic carbon pool. The pH swing method alters chemical equilibria to release CO₂ from solution, enabling its capture and permanent storage.

2.2 Selected CDR methods

Germany's natural conditions and geography offer favourable conditions for implementing most ecosystem management methods. However, two key limitations constrain this potential: the scarcity of land available for reforestation and the relatively short coastline. In this report, Improved Forest Management (IFM) is not treated as a separate CDR category to prevent double-counting since it is already incorporated into the WEHAM (Die Waldentwicklungs- und Holzaufkommensmodellierung) scenarios.

Given the substantial volumes of residual biomass generated by Germany's forestry sector, biomass conversion methods are particularly relevant.

The most promising biomass-based methods in Germany are biochar, BECCS, and durable bio-based products, all of which align with Germany's industrial base, research capacity, and circular bioeconomy strategies. Bio-oil storage, due to its low TLR, was excluded from this report, as were terrestrial biomass burial and marine biomass sinking. Both were excluded due to insufficient research and land-use constraints.

For Germany, geochemical CDR pathways show potential due to compatible geology, industrial integration and ongoing research activities. Methods such as enhanced rock weathering and carbon mineralisation could provide durable, verifiable carbon storage with relatively low land competition. In this report, carbon mineralisation was considered a storage option (both in situ and ex situ).

By contrast, ocean fertilisation was excluded due to the lack of demonstrated efficacy and its unsuitability for German national waters. While ocean alkalinity enhancement remains to be developed and demonstrated, it was deemed relevant for Germany on the considered timescale; however, open-sea applications may be constrained by the shallow, sensitive ecosystems of the North and Baltic Seas.⁸

As for synthetic CDR, DOCCS was excluded from the study due to its low TRL and limited research, particularly regarding its suitability for the specific conditions of the Baltic and North Seas.

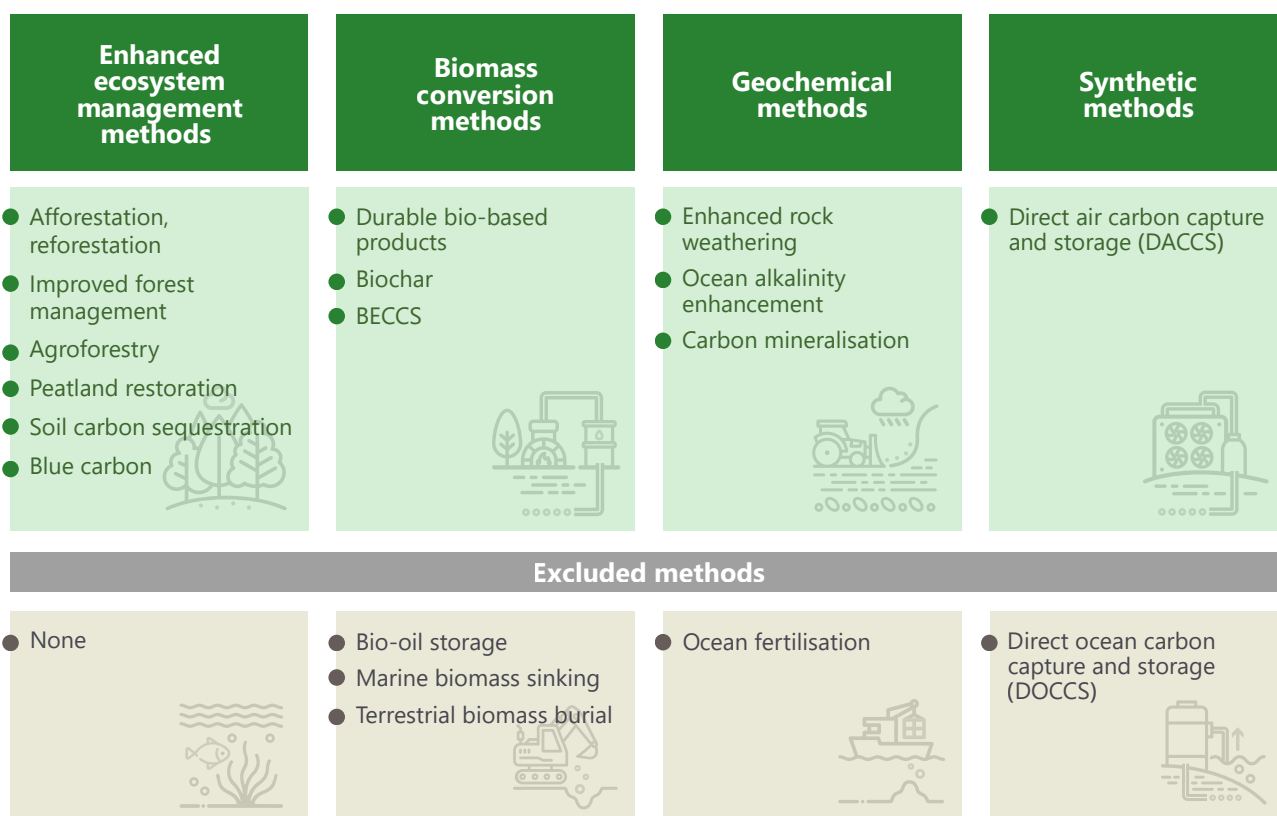


Figure 4. Summary of the CDR Methods included and excluded from the study. Please note that improved forest management is included in the natural carbon sink and not treated as a separate CDR method to avoid double-counting.

2.3 Resource requirements for selected CDR methods

To assess the deployment potential of each CDR method, it is essential to understand their resource requirements – such as water usage, land area, and energy consumption – per net tonne of CO₂ removed. However, accurately quantifying these inputs presents two key challenges:

- The diversity of CDR methods, each with multiple variants that differ significantly in design, scale, and operational parameters.
- Limited availability of reliable data, as most methods remain in early stages of development and lack robust field-based evidence.

Moreover, comparing methods requires a consistent basis. Since all CDR approaches generate GHG emissions during operation, resource requirements must be evaluated on a per-tonne-of-CO₂-removed basis, accounting for emissions subtracted from gross removal volumes. This makes life cycle analysis (LCA) a crucial tool for generating reliable and meaningful data.

The scientific literature offers valuable insights, particularly due to its methodological transparency and rigorous peer review. However, most studies rely on laboratory-scale experiments or modelling, often based on limited datasets. As a result, their applicability to real-world conditions remains uncertain, and few include comprehensive LCAs.

Operational data from companies – those developing pilot projects or commercial-scale deployments – is rare but increasingly available. For

instance, application files submitted to the Frontier fund provide performance metrics from actual projects. While these figures more accurately reflect current technological capabilities, they are often self-reported and lack peer review, making them “declarative” in nature.

To overcome these limitations and build a robust database of resource requirements, Carbon Gap partnered with RMI. The resulting dataset is grounded in three complementary sources: peer-reviewed scientific literature, publicly available Frontier fund applications (across three cohorts), and direct surveys conducted with active CDR operators.

The database will continue to evolve after the publication of this report, but at the time of publication, it includes:

- 442 data points obtained from 129 scientific articles;
- 200 data points obtained from 113 Frontier files;
- 330 data points obtained from 57 survey responses.

The database is accessible on the [CRRA website](#).

The data were compiled to produce consolidated values for each resource required for CDR methods. These values are used throughout the remainder of the report to estimate the potential of CDR methods based on available resource feedstocks. When values are unavailable in the database, or alternative values are more relevant to the national context, they are explicitly reported, along with their sources.



3. Germany's resources and feedstocks

Germany's physical resources present both opportunities and challenges for deploying CDR methods. A robust electricity grid, abundant renewables, and widespread waste heat support energy-intensive approaches such as DACCS. Water availability from rivers and lakes, along with extensive forestland, enables biomass-based methods such as BECCS and biochar. However, limited geological CO₂ storage capacity, despite recent legal adjustments to authorise storage, and intense land competition, coupled with strict environmental regulations, constrain CCS-based methods and large-scale land-based solutions such as afforestation, reforestation, and peatland restoration. This chapter assesses the availability and future potential of key resources for CDR, estimating the share realistically accessible for implementing CDR methods.

3.1 Energy

Germany has a highly developed energy system characterised by a reliable electricity grid, strong interconnections with neighbouring countries, and a rapidly growing share of renewable energy, especially wind and solar. The country has undergone a full nuclear phase-out in 2023 and is gradually phasing out coal, making renewables the backbone of its future electricity system.^c Germany is currently a net importer of electricity on a yearly basis. By 2030, renewable electricity is targeted to cover 80% of demand, with significant surpluses in periods of high renewable generation providing potential for CDR methods.⁹

3.1.1 Electricity

In 2024, the **total electricity production** was approximately **438.4 TWh**, including an import balance of 26.3 TWh.¹⁰ In 2024, the average carbon intensity of electricity produced in Germany was

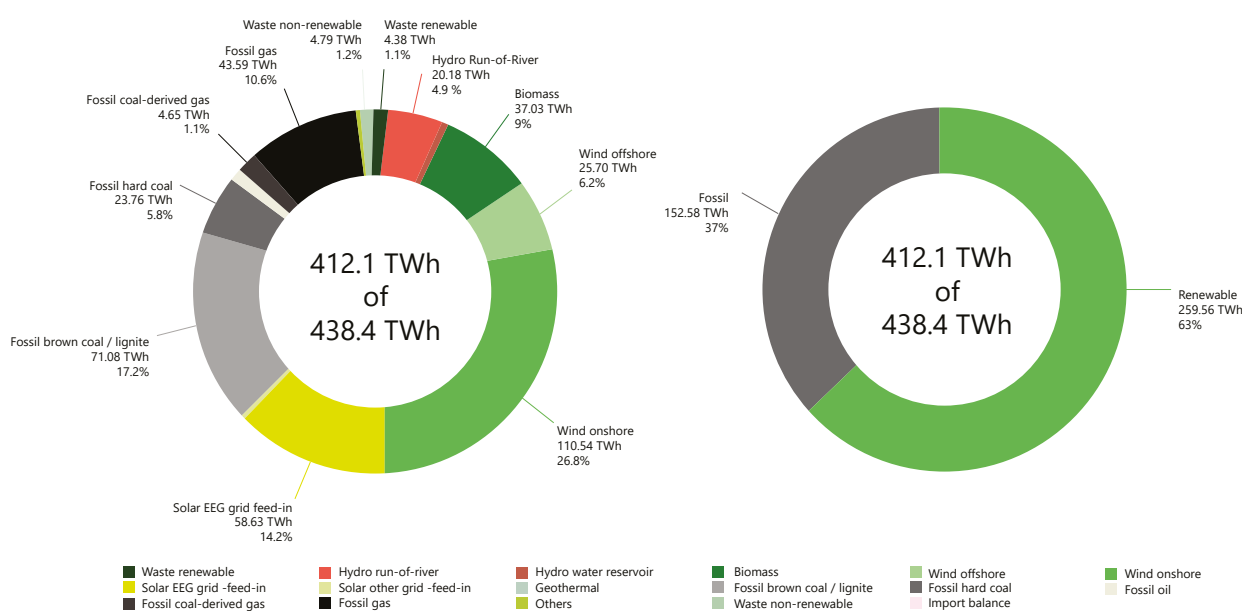


Figure 5. Public net electricity generation in Germany in 2024.⁹ Please note that domestic electricity generation amounted to 412.1 TWh in 2024. Imports were 26.3 TWh for a total available electricity of 438.4 TWh.

c. Despite a recently proposed stronger reliance on "H₂-ready" gas power plants under the new Federal Minister for Economic Affairs and Energy, the German government remains committed to the climate and energy targets enshrined in the Renewable Energy Sources Act (EEG 2023), which mandates at least 80% of electricity consumption to be covered by renewable sources by 2030.

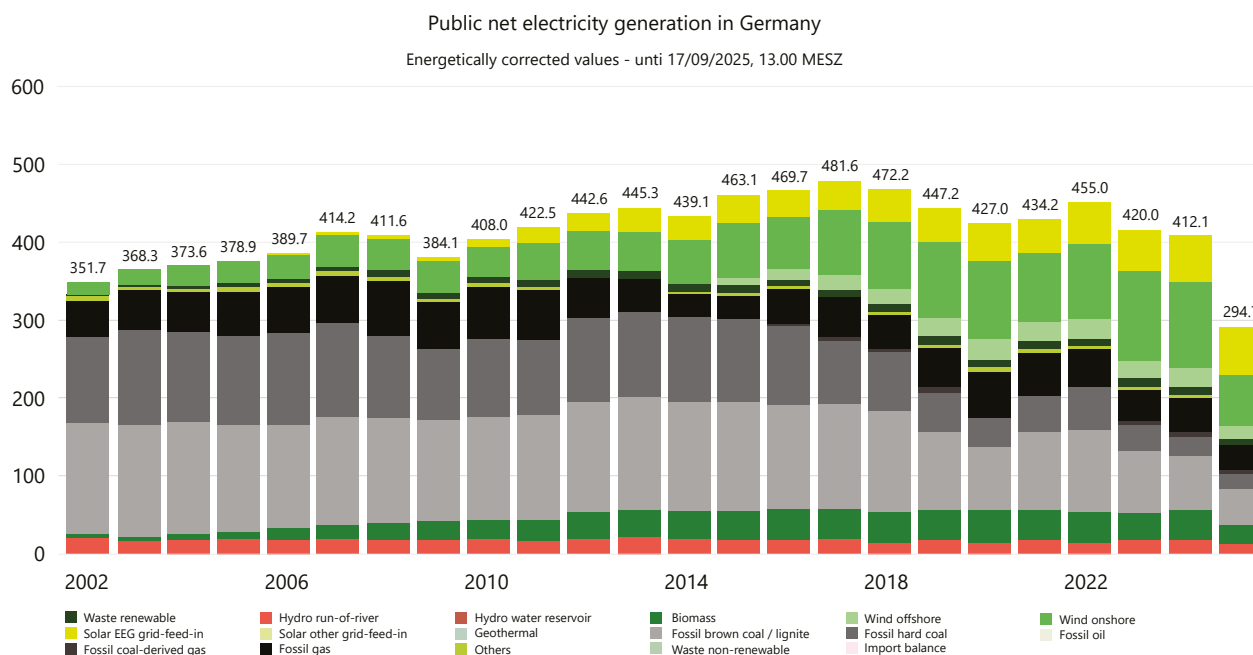


Figure 6. Development of shares of energy sources (2002-2025).³ Please note that 2025 is only covered until mid-September.

321 gCO₂e/kWh.¹¹ Onshore wind produces the largest share of electricity, contributing about 25.2% of total generation. When offshore wind is included, **wind power** accounts for **33.1%** of overall electricity production. Other significant forms of production include fossil brown coal (16.1%), solar (13.4%), fossil gas (9.9%), and biomass (8.5).² Conventional generation from coal and gas is above the EU average, but it is declining, and following the nuclear phase-out in 2023, Germany now relies heavily on renewables, with fossil backup capacity. The share of **renewable energy sources** in public net electricity generation was **63%** in 2024.⁹ The distribution of different production methods is shown in Figure 5, while Figure 6 illustrates the development of energy sources' shares in electricity generation from 2002 to 2024.⁹

Electricity generation from renewables is expected to grow substantially over the coming decades as Germany aims to achieve carbon neutrality by 2045. The "Energy scenarios" section below describes the expected development of electricity production.

Germany's **total electricity consumption** rose from 454 TWh in 2023 to **465.5 TWh** in 2024,¹² exceeding annual production. Figure 7 shows the historical development of final electricity consumption by consumer group: in 2023, industry accounted for

about 41.4%, households 28.6%, trade and services 26.65%, and transport 3.3%.¹³

Germany's gross electricity demand in 2045 is projected to range from **1396 to 1737 TWh**, depending on the scenario.¹⁴ The expected growth in electricity consumption is primarily attributable to electrification in industry and transport, and to power-to-X (PtX) technologies (such as electrolysis, methanation, and synthetic fuels).

Germany's electricity system consists of large-scale power plants, a dense high-voltage transmission network, and extensive regional distribution systems. Four transmission system operators - Amprion, 50Hertz, TenneT, and TransnetBW - manage a grid of more than 35,000 km of high-voltage lines, while several hundred distribution system operators ensure local supply. Germany is part of the Continental European synchronous area, providing additional stability and supply security.

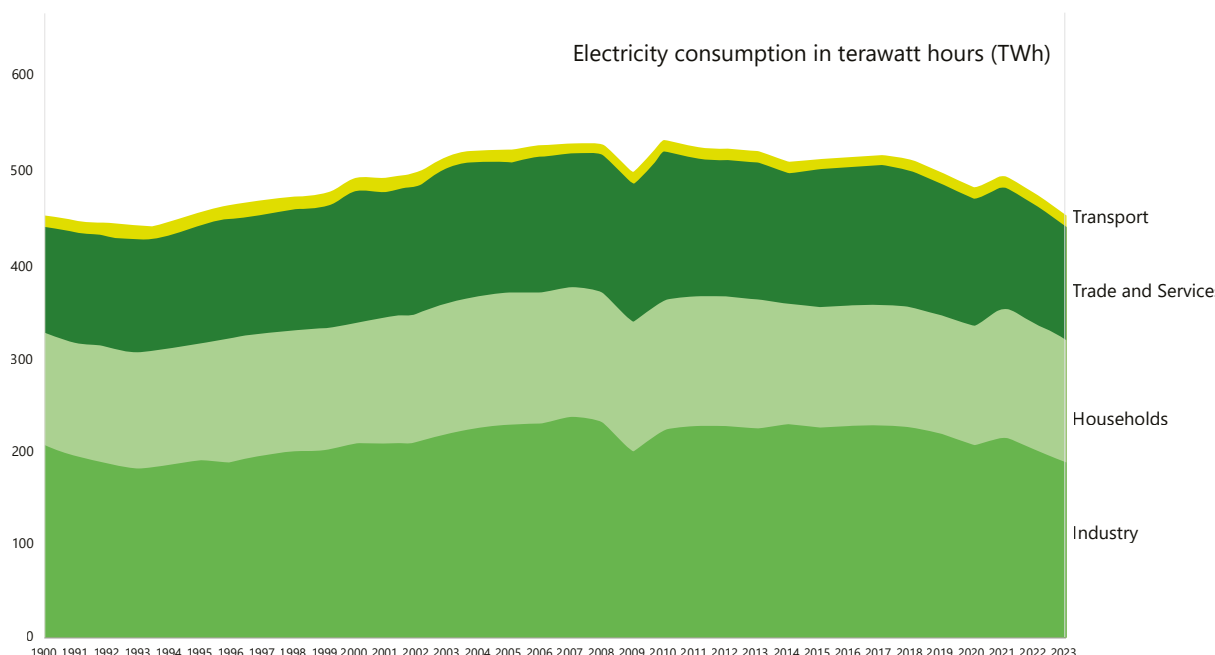


Figure 7. Historical final energy consumption by consumer group (1990-2023). Source: Clean Energy Wire, data: AGEF 2024.

Germany's power system is undergoing a significant transformation. The nuclear phase-out was completed in 2023, and coal is scheduled to be phased out by 2038, with ongoing debate about accelerating the deadline to 2030. To integrate increasing renewable energy, grid operators are expanding north-south transmission corridors to transport wind power from northern regions to industrial demand centres in the south.¹⁵ At the same time, large-scale investments in battery storage,¹⁶ demand-side flexibility, and hydrogen infrastructure¹⁷ are underway to ensure a secure, resilient, and decarbonised energy system.

3.1.2 Electricity scenarios

The Fraunhofer Institute has developed different electricity transformation paths for Germany from 2025 to 2045, differentiated by ambition level.¹⁸ These scenarios evaluate expected electricity production and consumption, enabling estimation of electricity availability for CDR. The scenarios were selected for their alignment with Germany's current political context, in which rapid growth in renewables such as wind and solar is expected by 2045.

Box 1. Electricity scenarios in the realistic CDR potential scenarios

The Fraunhofer '**Persistence**' scenario was selected to reflect the realistic availability of CDR in *Scenario A: Low ambition*. *Scenarios B: High ambition, energy efficiency focused* and *Scenario C: High ambition, reduced-BECCS* are instead based on the Fraunhofer '**Technology Open**' scenario, which expects the sharpest decline in fossil energy sources and thus accelerated actions towards green transition and climate targets. Counterintuitively, in this scenario a lower share is reserved for methods like DACCS and there is less surplus electricity available for CDR. This is justified by the decline in fossil fuels requiring more electricity for electrification.

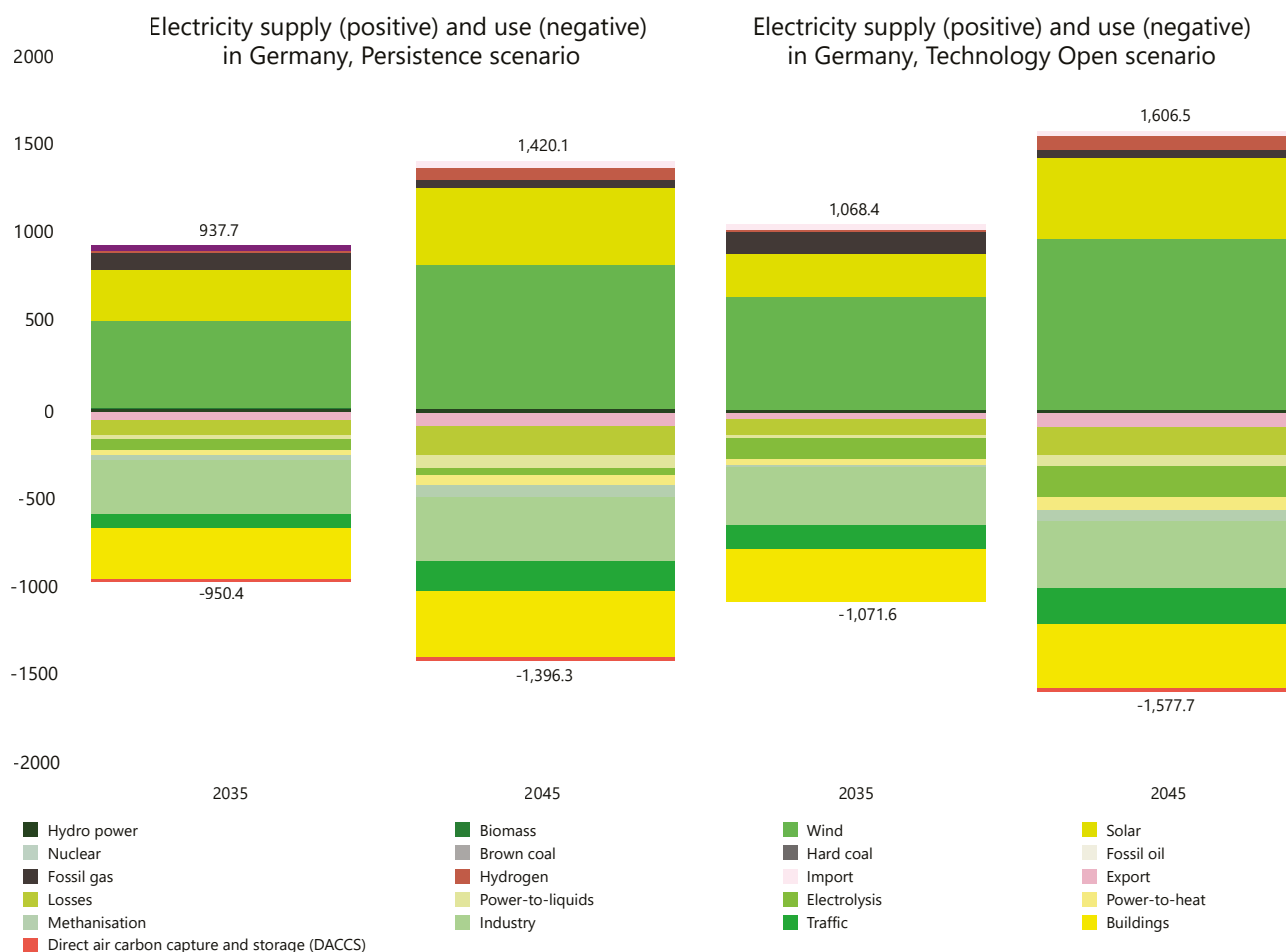


Figure 8. Electricity supply and use in 2035 and 2045 according to the Fraunhofer Persistence and Technology Open scenarios.⁹

Across the Fraunhofer scenarios (Figure 8), wind and solar power are expected to grow the most, whilst biomass is expected to decline in absolute volumes. The share of renewables will need to increase steadily to replace primary fossil fuels, with full near-substitution by 2045. Depending on the level of ambition, **electricity production is projected to range from 1420 TWh to 1760 TWh in 2045. Electricity consumption is projected to increase from 570 TWh in 2025 to 590 TWh in 2035 and from 1396 TWh in 2025 to 1737 TWh in 2045.**¹⁹ These transformation scenarios have been used to evaluate the theoretical potential of CDR methods to estimate resource availability.

The Fraunhofer 'Persistence' scenario presented in Figure 8 (left side) depicts stronger resistance

to energy transition technologies: gas heating and boilers remain in use longer, combustion engines remain popular, and wind expansion faces opposition. In the Persistence scenario, 7 TWh in 2035 and 16.6 TWh in 2045 are reserved for DACCS. The total electricity balance is negative in 2035, requiring imported electricity. Therefore, only the electricity allocated to DACCS in the Fraunhofer scenarios is assumed to be available for CDR. By 2045, the electricity balance is expected to become positive.

The 'Technology Open' scenario (Figure 8, right side) instead outlines the most cost-effective pathway to transform the energy system and achieve climate neutrality by 2045. This scenario reserves 0.7 TWh for DACCS in 2035, rising to 12.5 TWh in 2045.^d In

d. The allocation to DACCS is lower than in the Persistence scenario because a sharper decline in fossil fuel use is expected. With reduced fossil fuel consumption and lower fossil CO₂ emissions, the need for DACCS decreases.

addition, it reserves 13.1 TWh and 55.1 TWh for CCU and Power-to-X, of which 10% was assumed to be reallocated to CDR. The total electricity balance is negative in 2035, but it shifts to a surplus of 28.7 TWh by 2045, which is assumed to be available for CDR. Thus, the **total electricity availability for CDR** in realistic Scenarios B and C is assumed to be **~2 TWh** in 2035, rising to **~46.7 TWh** in 2045. **For the theoretical scenario**, electricity consumption is assumed to be further reduced in other sectors, and a higher share (25% of the amount consumed in Power-to-X) is directed to DACCS, resulting in **55 TWh in 2045** (assuming total electricity production volumes as in the realistic Scenarios B and C).

In summary, Germany's electricity production remains reliant on fossil fuels, primarily natural gas, and the negative electricity balance limits the deployment of energy-intensive CDR methods in the short term due to the limited availability of renewable electricity. By 2045, however, rapid growth in renewables - especially wind and solar - and a positive electricity balance are expected to create favourable conditions for wider CDR deployment.

3.1.3 Thermal energy

Thermal energy is central to Germany's decarbonisation pathways and is directly relevant to CDR deployment. Currently, heat demand is largely covered with fossil energy, yet scaling of district heating and low-carbon heat sources (including geothermal, large heat pumps, solar thermal, waste heat recovery, and power-to-heat, alongside thermal storage systems such as pit and aquifer solutions) is proceeding rapidly.²⁰

In 2025, Germany launched a continuously updated national waste heat platform to map industrial and commercial waste heat sources, currently totalling 21,987 sources with an annual potential of **223.7 TWh**.²¹ This considerable potential contrasts sharply with current use: in 2024, only **9.6 TWh** (4.3%) were integrated into district heating networks, highlighting a vast untapped resource for both heat decarbonisation and CDR. However, as waste heat generation is expected to decline as technical solutions in both industry and the energy sector evolve toward greater energy efficiency, it is projected to decrease to **64 TWh** by 2045.²² As waste heat can be efficiently utilised in district heating to reduce emissions, such systems are expected to be the primary use case for waste heat - especially waste heat with higher qualities such as consistency and temperature profile, which is also the most

suitable resource for CDR - and thus, reducing the availability for CDR.

In conclusion, Germany has relatively high waste heat availability, and the current utilisation rate is low, resulting in substantial theoretical potential for CDR. In the theoretical potential, it is assumed that 75% of the projected 64 TWh of waste heat in 2045 - equivalent to **48 TWh** - could be available for CDR, on the basis that most, though not all, of the waste heat is recoverable.

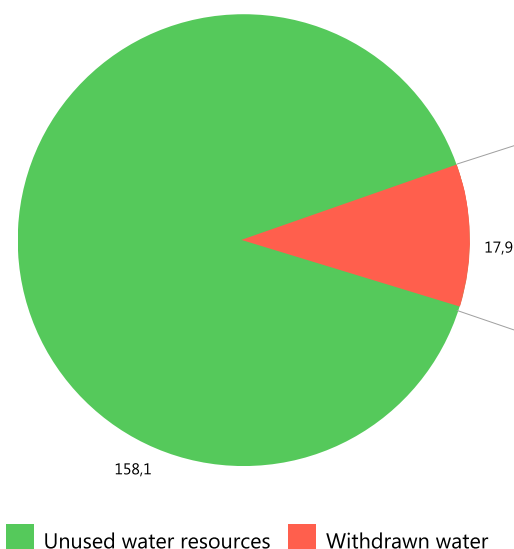
3.2 Water

Germany is considered a water-rich country, with a diverse mix of groundwater, surface water, and precipitation contributing to its freshwater availability. The country has a dense network of rivers and lakes, including major river systems such as the Rhine, Elbe, Danube, and Weser. Groundwater is the primary source of drinking water, supplying nearly 70% of the public water supply, while surface water is widely used for industrial and energy purposes.²³

According to long-term hydrological assessments, Germany has a potential renewable water availability of approximately **176 billion cubic metres (bcm) per year**, based on the period 1991–2020.²⁴ This figure represents the average amount of water that can be used from both groundwater and surface water sources. Compared with the previous reference period (1961–1990), long-term potential water availability has declined by 12 bcm (6.4%), reflecting the impacts of climate change, increased evapotranspiration, and changing precipitation patterns.²⁵ Due to climate change, this trend is expected to continue over the next decades, leading to a reduction in water availability. Renewable water resources vary widely with climate, shaping both short-term management and long-term planning. Snowpack, soil moisture, and groundwater can buffer or intensify these shifts. Between 1991 and 2020, water resources ranged from 102 bcm (2003) to 276 bcm (2001), with an average of 176 bcm.²⁶

In 2022, Germany's total water abstraction amounted to approximately **17.9 bcm** from groundwater and surface water sources - only 10% of the country's average water availability (1991–2020).²⁷ As shown in Figure 9, water use is split across four main sectors:²⁸ energy supply accounted for the largest share at 6.9 bcm (38.6%), mainly for cooling), public water supply withdrew 5.3 bcm (29.8%) for household and municipal use, mining and manufacturing used 5.2 bcm (29.1%), and agriculture used 0.5 bcm (2.5% of total abstraction).

Distribution of freshwater resources (billion m³)



Water use in Germany by sector (billion m³)

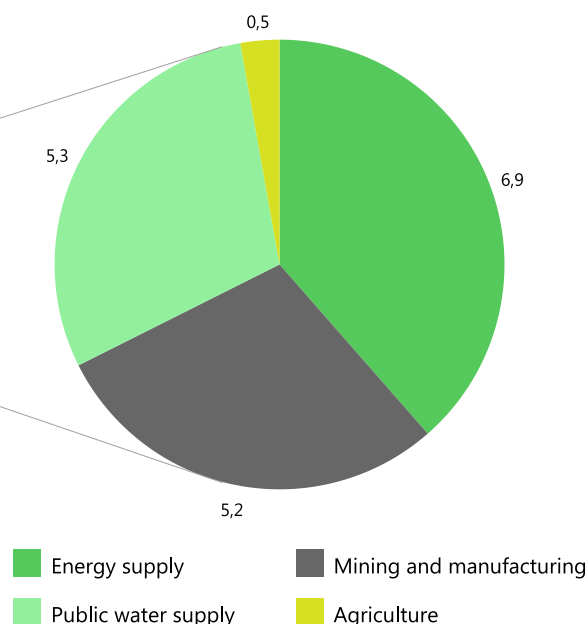


Figure 9. Distribution and use of freshwater in Germany in 2022.

Since 2013, energy water use has declined, while industrial abstraction has gradually fallen since 1991.²⁹ Public supply rose slightly in 2013–2019 but dipped again in 2022. Agricultural use more than doubled since 2020, reflecting climate pressures, though it remains a small share overall.

In 2022, Germany's 8,659 public wastewater treatment plants processed about 8.3 bcm - equivalent to sewage from 115 million people.³⁰ This extensive infrastructure ensures high efficiency and coverage, supporting environmental protection and public health through advanced treatment and monitoring. These facilities also produce sewage sludge and sludge ashes, which can be valorised through mineralisation or as supplementary cementitious materials.

Although climate change may reduce water availability, it is unlikely to constrain the deployment of CDR in Germany. Water use has fallen sharply, with withdrawals well below the international stress threshold^e since 2007. In 2022, only 10.1% of the renewable supply was used, largely due to declines in the energy, mining, and manufacturing sectors. Current consumption trends suggest over **17 bcm** could be **available for CDR**, though regional droughts in the east and northeast of the country warrant consideration. Overall, Germany's

infrastructure and efficient water management provide a strong foundation, making water availability an unlikely limiting factor for CDR.

In conclusion, while climate-induced changes in precipitation patterns and evapotranspiration rates necessitate vigilant monitoring and adaptive planning, Germany's water management infrastructure and resource availability provide a robust foundation, making water availability an unlikely limiting factor for CDR.

3.3. Land

Germany's land area is approximately **35.8 Mha** (357,683 km²), of which over 83% is vegetated, including agricultural areas, forests, and natural landscapes.³¹ This extensive coverage of biologically active land provides a strong foundation for land-based CDR strategies, such as afforestation, peatland restoration, and soil carbon sequestration.

Projections for 2045 indicate that settlement and transport areas in Germany are expected to expand, particularly around metropolitan regions, whereas rural areas are expected to change only slightly. Agricultural land is projected to decline, whereas forests and near-natural areas are projected to remain stable or slightly increase. These trends

e. Defined as withdrawing more than 20% of available water resources.

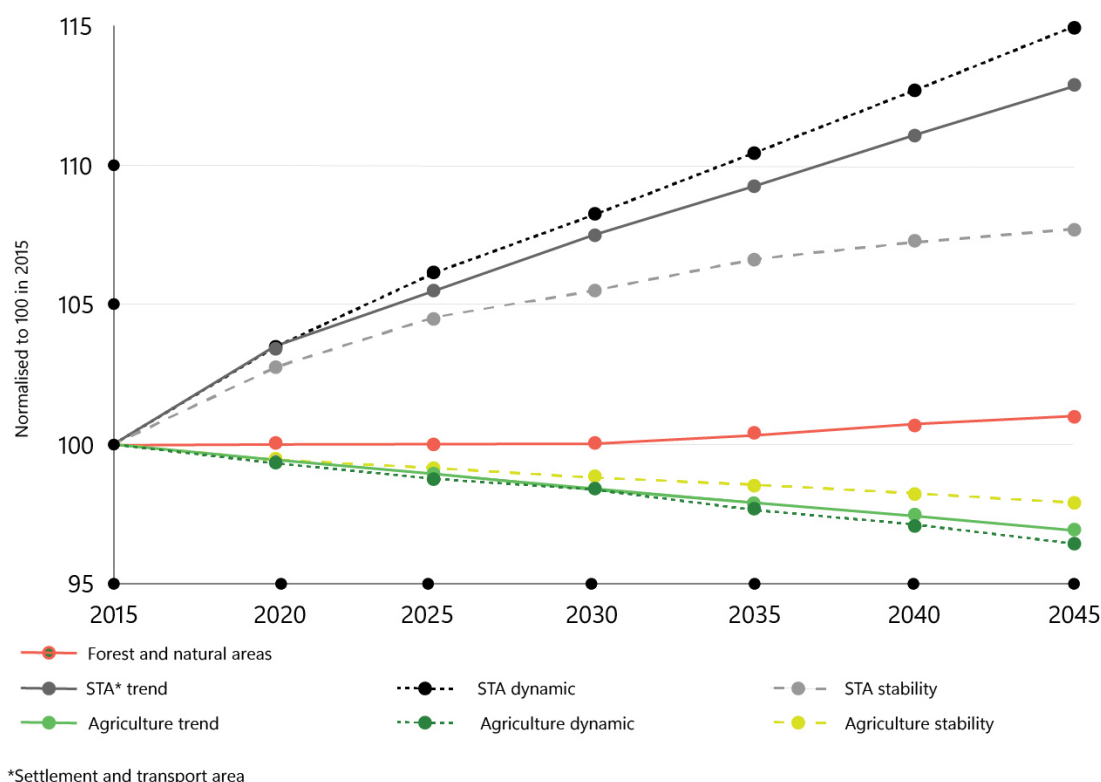


Figure 10. Projections of land development between 2015-2045.³³ "STA" refers to settlement and transport area. "Trend" reflects continuation of current demographic and economic trends. "Dynamic" assumes higher population growth and stronger economic activity, leading to more land use pressure. "Stability" assumes low population growth and restrained economic development.

align with the official Settlement Area Projection 2045, developed in Germany's climate impact and vulnerability analysis by UBA and BMUV.³² The study models three socioeconomic scenarios, as illustrated in Figure 10: Trend, Dynamic, and Stability.

Germany's high population density (~233/km²), urbanisation, and land sealing reduce space for nature-based CDR. Competing demands from agriculture, infrastructure, renewable energy, and conservation further constrain land allocation. Despite these constraints, Germany's existing forest cover, agricultural soils, and wetlands still offer significant potential for CDR, provided that integrated land-use planning and climate policy frameworks support their sustainable use.

3.3.1 Forestland

Germany's forests cover about **11.5 Mha** (30% of the national land area)³⁴ and are a cornerstone of the national environmental and climate policy, serving as carbon sinks, biodiversity reservoirs, and renewable resource bases. The National Forest Inventory, coordinated by the Thünen Institute, provides comprehensive data on forest composition,

age structure, timber stock, and land-use changes every 10 years, as mandated by §41a of the Federal Forest Act.³⁵ German forests are predominantly composed of conifers (spruce and pine, particularly in commercial forestry) and deciduous species (beech and oak, particularly in mixed and natural forests).

In Germany, 48% of forest land is privately owned, 29% is owned by federal states, 20% is owned and managed by corporate and institutional entities, and 3% is owned by the federal government (Figure 11).³⁶ This ownership structure influences forest management practices: private forests are often managed for timber production, whereas public forests may prioritise conservation, recreation, and climate adaptation.

The age structure of forests is shifting, with older stands becoming more common, which affects growth rates and carbon sequestration potential.³⁷ Germany's forests, increasingly impacted by drought, storms, and pests have shifted **since 2017 from a net carbon sink to a carbon source** due to declining growth and increased rising tree mortality and forest damage.^{38,39}

Germany's forests currently hold about **3,700 Mm³** of timber stock (335 m³/ha), down 220 Mm³ (18%) from 2017, returning to 2012 Forest Inventory levels.⁴¹ This decline is largely due to severe droughts since 2018 and bark beetle damage, with spruce stands losing 190 Mm³ since 2012. Annual timber growth fallen 20% to 9.4 m³/ha, while annual timber use remains stable at around 6.7 m³/ha.⁴² Young trees in reforested areas contribute little to carbon storage in the early decades, and mature trees show signs of stress and reduced vitality, leading to reduced carbon stocks and shifting forests from a net sink to a net CO₂ source.⁴³

According to the WEHAM model (*Forest Development and Timber Supply*), developed by the Thünen Institute with BMEL (Federal Ministry of Food and Agriculture), **Germany's forest area is expected to remain stable at ~10.7 Mha** through the early 2050s⁴⁴ (excluding non-productive or inaccessible forest segments such as roads, clearings, and mountainous terrain). Tree species composition will shift significantly due to climate impacts and forest policy: deciduous tree cover is projected to rise from ~47% of forest area in 2052 to ~56% in 2062, while conifers decline correspondingly.⁴⁵ This transition reflects efforts to enhance forest resilience and biodiversity.

Ownership structure of forest land in Germany (% of total forest area)

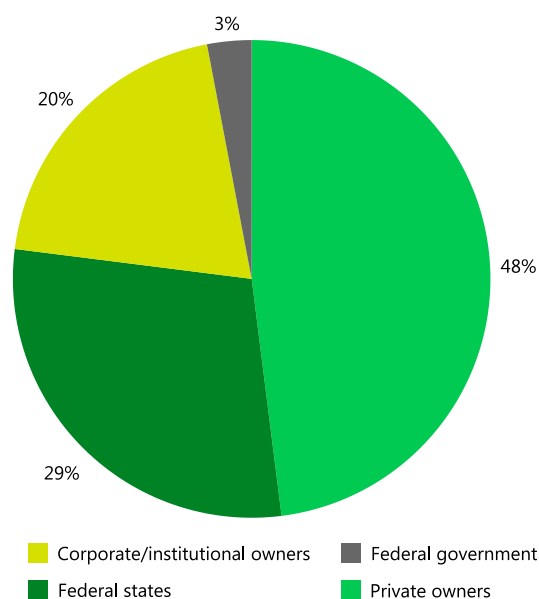


Figure 11. Ownership structure of forestland in Germany.

Greenhouse gas emissions from forests (including biomass, deadwood, soils, and wood products)

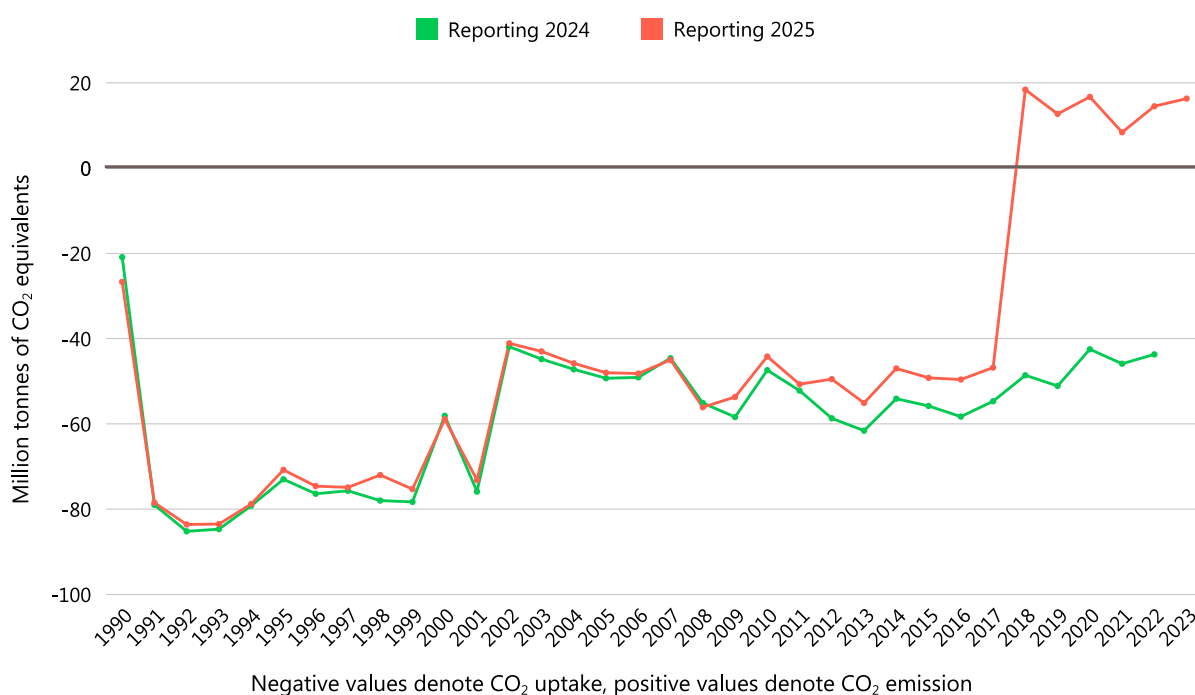


Figure 12. GHG emissions from forests (including biomass, deadwood, soils and wood products).⁴⁰

Box 2. Germany's forest sink projections data

The CDR potential of forests depends on both their natural carbon sink function and wood biomass production. **WEHAM** data (based on the 2012 National Forest Inventory, published in 2017) was utilised for forest biomass data.⁴⁶ Three main scenarios were modelled: Business as Usual (BAU), Wood Preference, and Nature Preference Scenario (NPS).⁴⁷ All scenarios indicate a gradual replacement of vulnerable conifers (e.g., spruce, pine) with more climate-resilient deciduous species (e.g., beech, oak).⁴⁸ For this study, **the BAU and NPS projections were selected to represent two alternative futures of wood biomass availability.** The BAU scenario assumes current forest management practices and policies continue along the same track, while the NPS prioritises nature preservation, biodiversity, and forest resilience with lower harvests than the other two WEHAM scenarios. According to the WEHAM scenarios, by 2035/2045, the forest sink is projected at ~20/21 MtCO₂ under BAU and ~31/33 MtCO₂ under NPS. However, because the WEHAM projections are based on data from before the forest disruptions (starting in 2018), their sink estimate may be overstated. Germany's environmental protection agency (UBA) warns that medium disturbances could reduce sink capacity by 17-20 MtCO₂/year, and severe ones by up to 35 MtCO₂/year.⁴⁹ The potential sink reduction constitutes a large proportion of the total sink. In 2021, according to Germany's National GHG Inventory, forests emitted ~40 MtCO₂,⁵⁰ highlighting the scale of potential losses. UBA notes that current forest projections do not fully account for increasing disturbances, and further research is needed.

The more recent **BioNET** study (2024) – which evaluates the negative emission potential of biomass-based methods in Germany – suggests offsetting losses by setting aside commercial land for enhanced carbon sequestration. It estimates that this could lead to a natural sink of **16 MtCO₂/year** in 2035 and **32 MtCO₂ in 2045**.⁵¹ This more recent and conservative estimates have been used for the **realistic CDR potentials**.

Therefore, in this study, the realistic scenarios do not rely on the WEHAM projections for the natural sink capacity as only part of it could be realised. Instead, purposely set aside surfaces are included to secure the sink capacity proposed in the BioNET projection (16 MtCO₂/year in 2035 and 32 MtCO₂ in 2045) after validating that the corresponding missing biomass fits in the unused volumes of wood biomass.

Germany's forests face ecological stress, shifting species composition, and evolving management priorities. While climate-related disturbances have weakened their role as carbon sinks, ongoing efforts to enhance forest resilience and biodiversity signal a strategic reorientation. Around **500 kha** of dead and deforested land require extensive reforestation efforts, which could be considered as **theoretical potential for reforestation**.⁵² The national restoration plan outlines a phased approach to reforestation, prioritising the most severely affected areas first and gradually expanding efforts to restore the whole area.⁵³ In sum, the theoretical maximum of the **forest's natural carbon sink is assumed to be 33 MtCO₂ in 2045**, as per the WEHAM NPS scenario, supported by the more recent BioNET projection.

3.3.2 Agricultural land

Germany's agricultural landscape is characterised by a high proportion of arable land and permanent grassland, which together form the backbone of the country's food production system and rural

economy. As of 2024, approximately **11.6 Mha** are used as **arable land**, while **4.7 Mha** are classified as **grassland** (Figure 13).⁵⁴ Land-use figures indicate a long-term trend of a gradual decline in arable land, primarily due to urban expansion, infrastructure development, and shifts in agricultural policy. Conversely, grassland areas have remained relatively stable since 2010, supported by conservation measures and agri-environmental schemes.⁵⁵

According to the Thünen Trend Scenario, the arable land area is projected to decrease further to 11.32 Mha by 2034, while grassland may slightly expand to 4.77 Mha.⁵⁶ These projections are based on observed trends from 2000 to 2034 and assume a continuation of current policy and market dynamics. It is assumed that this trend will continue in the following years, leading to a further reduction in arable land and a modest increase in grassland.

If current developments persist beyond 2035, the **arable land** area could decline even further, reaching approximately **11 Mha by 2045**, while **grassland** may continue to grow slightly, stabilising at around

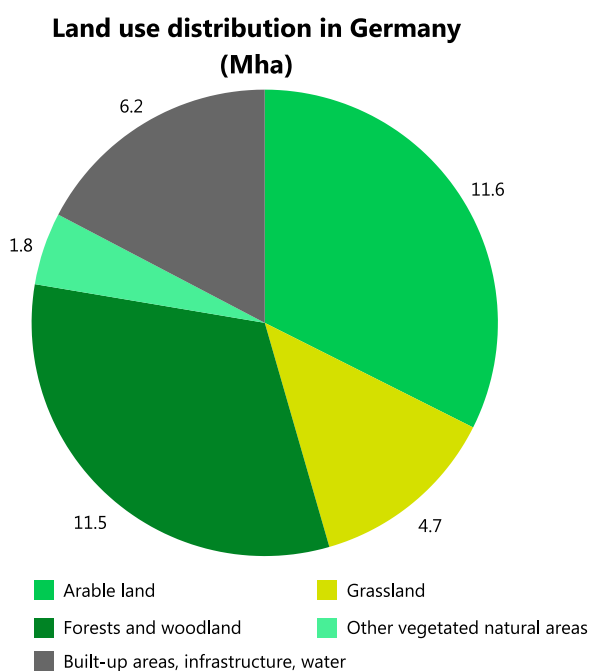


Figure 13. Land use distribution in Germany in 2024.

4.8 Mha by 2045.⁵⁷ The decline in arable land is largely attributable to reduced livestock production, lower demand for feed crops, and increased land allocation for biodiversity and climate protection. To calculate the theoretical CDR potential of agricultural land, we assumed that most of the areas (**9.6 Mha in 2045**) would be available for carbon sequestration alongside existing farming practices, while recognising that some land is unsuitable for CDR methods due to factors such as soil properties.

This evolving land use pattern has significant implications for climate change mitigation strategies, particularly for soil carbon sequestration, afforestation, and enhanced rock weathering. As land becomes increasingly allocated to ecological functions, the potential for implementing land-based CDR methods - such as afforestation, peatland restoration, and agroforestry - grows. For the theoretical potential of **afforestation**, studies estimate that around **1 Mha** of marginal or underutilised land could be made available, primarily outside of productive agricultural zones.⁵⁸ For drained organic soils in agricultural use, approximately **400 kha** has been identified as **suitable for peatland restoration** under national climate strategies.^{59,60}

Based on the *Deutscher Fachverband für Agroforstwirtschaft* (DeFAF) estimate,⁶¹ up to 90 % of the agricultural land could in principle be used for agroforestry. However, to calculate the theoretical

potential of agroforestry, a conservative assumption of **2.4 Mha** was applied.⁶² While some methods may be implemented simultaneously, the extent of such overlaps could not be reliably evaluated, and therefore the calculation reflects only the standalone potential of agroforestry.

To conclude, in Germany, the realistic arable land availability (as described in section 7.4.2) for CDR methods is significantly lower than the theoretical potential due to competing land uses and ecological constraints, such as biodiversity protection (e.g., Natura 2000 sites), soil conservation and erosion prevention, water protection zones, peatland restoration under the National Climate Protection Program, and the preservation of landscape elements for climate adaptation.

3.3.3 Peatlands and wetlands

Wetlands, including floodplains, peatlands, and coastal marshes, are among the most effective natural carbon sinks because they store large quantities of organic carbon in saturated soils and biomass. In Germany, water bodies, including rivers, lakes, reservoirs, and floodplains, cover approximately **0.82 Mha**, accounting for 2.3% of the national land area.⁶³ While these aquatic systems are not directly applicable for land-based CDR methods, they play a pivotal role in nature-based solutions, particularly through wetland restoration and hydrological management.

Floodplains and other wetland types contribute to long-term carbon sequestration, especially when restored to near-natural hydrological conditions.⁶⁴ Restoration enhances carbon storage while improving biodiversity, water retention, and resilience to climate extremes. In Germany, floodplain degradation has reduced the landscape's capacity to buffer floods and droughts, highlighting the need for integrated restoration strategies. One key initiative is the Blue Belt Programme (*Blaues Band Deutschland*), led by the Federal Ministries of Environment and Transport, which aims to reconnect rivers with floodplains, supporting ecological restoration and carbon accumulation in wet soils and riparian vegetation.⁶⁵ Germany also hosts 35 Ramsar sites covering ~869 kha; 80% of these are water bodies, which contribute significantly to carbon storage and climate resilience.⁶⁶

Peatlands are among the most carbon-rich ecosystems in Germany. Initially, they covered over 5% of the country's land area, but due to centuries of drainage and land conversion, only about **1.28 Mha** remain - roughly 3.6% of Germany's

surface.⁶⁷ Peatlands today are used primarily for⁶⁸ agriculture (72%), forestry (14%), infrastructure (7%), peat extraction (1.5%), and for other uses (1.5%). Only about 4% (51.2 kha) of the peatland area is under nature protection. More than 70% of Germany's peat soils are used for agriculture, especially as grassland and arable land. The resulting drainage introduces oxygen into the peat, accelerating peat decomposition and releasing CO₂ and N₂O, potent GHGs. Emissions from drained peatlands contribute approximately 7% to Germany's total GHG emissions, and over 40% of emissions from agriculture and agricultural soils.⁶⁹

Germany has set **ambitious goals for peatland restoration**. The *Bund-Länder-Zielvereinbarung* aims to rewet **250 kha by 2030**; however, the current rate is only 2 kha per year, well below the required rate.⁷⁰ To meet climate targets, experts estimate that 50 kha per year must be rewetted. This would not only sequester carbon but also restore biodiversity, water retention, and other ecosystem services.

Germany's climate and biodiversity strategies prioritise peatland protection and restoration, alongside afforestation on degraded farmland. Former peat-extraction and intensively farmed areas are targeted for rewetting and ecological conversion, supported by federal and state programmes, and are integrated into the LULUCF sector for GHG reporting.

To calculate the theoretical CDR potential of peatland restoration, we assumed that all peatland area under agricultural, forestry and peat extraction use (**1.12 Mha**) would be rewetted **by 2045**. This would mean approximately **56,000 ha** of peatland rewetted annually. For the low-ambition realistic potential, we used the current rate of rewetting (2 kha/year) to estimate the 2035 (20 kha) and 2045 (40 kha) potentials, and for the high-ambition realistic potential, we assumed that the *Bund-Länder-Zielvereinbarung* restoration goals would be met by 2035.

3.3.4 Coastal areas

Germany's coastline stretches approximately 2,389 km along the North and Baltic Seas, encompassing a wide range of landscapes, including sandy beaches, cliffs, estuaries, tidal flats, and salt marshes.⁷¹ Coastal wetlands store carbon in waterlogged sediments, where anaerobic conditions slow decomposition and allow organic matter to accumulate over long periods. However, many of these habitats have been significantly altered by human activities, including land reclamation, pollution, and hydrological

changes, thereby reducing their ecological integrity and carbon storage capacity. To address this, Germany has launched targeted restoration efforts under the Federal Action Programme for Natural Climate Protection (*Aktionsprogramm Natürlicher Klimaschutz*, ANK).⁷² Measures include replanting seagrass meadows through seeding and transplantation, restoring tidal dynamics in salt marshes and coastal floodplains, reducing nutrient inputs into the North and Baltic Seas, and protecting carbon-rich marine sediments from disturbance.

A landmark study by Schubert et al. (2015) mapped and modelled the distribution of eelgrass (*Zostera marina*) in the western Baltic Sea, revealing that it covers approximately **14 kha** (80% of the study region), as shown in Figure 11. Using species distribution models (SDMs), the study identified depth, wave exposure, and slope as key predictors of eelgrass presence. These meadows act as natural carbon sinks, storing CO₂ in both biomass and sediments. The predictive modelling approach supports targeted restoration by identifying optimal sites for expansion.⁷³

The CDRmare research mission, coordinated by the German Marine Research Alliance (DAM), is currently investigating the feasibility and scalability of ocean-based CDR methods - including alkalisation, blue carbon, and artificial upwelling - in German waters. The mission emphasises the importance of monitoring, governance, and ecological safeguards in the deployment of these methods.⁷⁵ A recent study published by CDRmare researchers highlights that Germany's North Sea and Baltic Sea offer limited potential for large-scale marine CDR due to site-specific constraints.⁷⁶ These include limited availability of suitable geological formations for CO₂ storage, high energy and material requirements for alkalisation, environmental risks associated with artificial upwelling, and infrastructure and logistical challenges for deployment.

Germany's marine CDR potential lies primarily in restoring and protecting coastal ecosystems, especially seagrass meadows, which offer scalable, scientifically validated carbon-sequestration benefits. While technological methods such as artificial upwelling are being explored, their feasibility is constrained by local environmental and logistical factors. For example, eutrophication – the increase in growth and the supply of organic matter due to excessive nutrient availability – is a key environmental problem in the Baltic Sea and a central goal of the HELCOM Ministerial Declaration and the Baltic Sea Action Plan, likely limiting the possibilities for artificial upwelling.⁷⁷ There

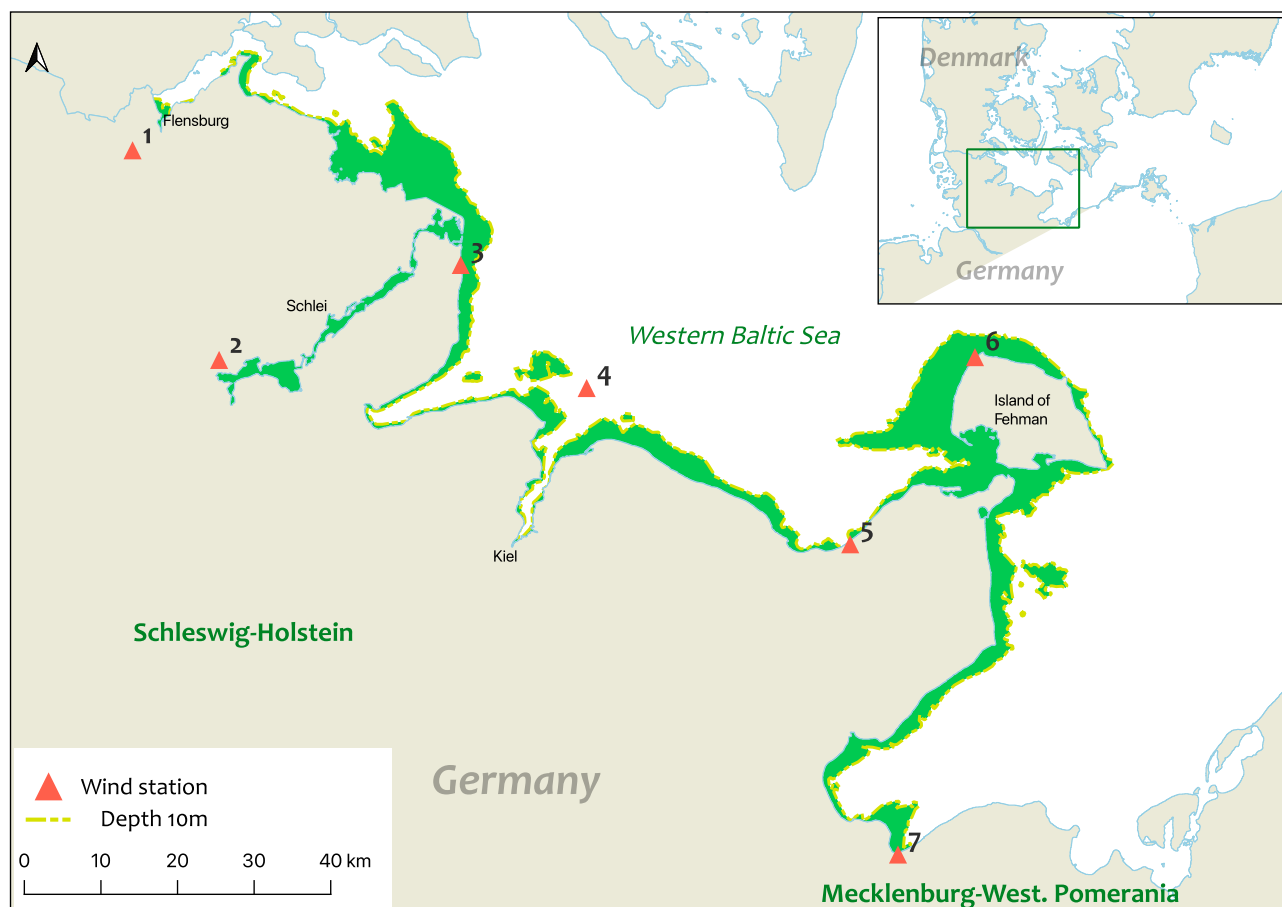


Figure 14. Potentially habitable depth zone for eelgrass in green.⁷⁴

is evidence that, from a techno-environmental feasibility perspective, some technological CDR approaches could reach a significant scale, but further assessments are needed.⁷⁸ Therefore, nature-based solutions currently represent the most promising path for marine CDR in Germany.

For the theoretical CDR potential of coastal revegetation, including salt marshes and seagrass meadows, we used an estimate based on a study by the Helmholtz Centre for Environmental Research.⁷⁹ Assuming that the entire area that can potentially sustain seagrass beds in the Baltic Sea (**97.8 kha**) is vegetated by natural expansion and active restoration by **2045^f**, and that the area and condition of the salt marshes stay the same as in 2022, a total of 200 kt CO₂/year in 2045 could be removed. Human activities to both enhance existing salt marsh and seagrass meadow habitats in the

North Sea coast, and to expand Baltic Sea seagrass meadows, are assumed for theoretical potential. They include activities such as regulating fertilisation in agriculture, improving wastewater treatment, and actively restoring seagrass habitats. For seagrass meadows, increasing the area and achieving the required carbon-reduction functionality takes nearly 20 years, so restoration activities would need to begin immediately to increase the sink by 2045.

In conclusion, Germany's coastal ecosystems offer tangible potential for nature-based marine CDR. While technological approaches face ecological and logistical constraints, restoring seagrass meadows and salt marshes provides a feasible, scalable, and ecologically sound pathway for long-term carbon sequestration.

^f In the original study this estimate was for 2050, but we assume that the same CDR potential could be achieved for 2045 if the measures are implemented more rapidly.

3.3.5 Built environment

Built-up areas - including settlements, infrastructure, and transport networks - cover approximately **5.2 Mha** (52,074 km²), or 14.6% of Germany's total land area as of 2024. Of this, 9.5% is allocated to residential and commercial uses, reflecting the country's dense urban structure and highly developed economy. The remaining 5.1% is allocated to transport infrastructure, including roads, railways, and associated facilities.⁸⁰

Urbanisation continues to increase, particularly around major metropolitan regions. This expansion often occurs at the expense of agricultural land, forests, and natural habitats, contributing to land-use conflicts and ecosystem degradation.

The expansion of built-up areas in Germany intensifies competition for land, limiting the feasibility of land-intensive CDR methods. While urbanisation constrains the large-scale deployment of approaches such as afforestation, it also creates incentives for multifunctional land use and for the policy-driven integration of CDR into broader sustainability strategies. Effective land-use planning and nature-based solutions will be essential to reconcile climate mitigation goals with ongoing urban development.

3.4 Biomass feedstocks

Biomass is a cornerstone of Germany's climate and energy policy. It serves not only as a renewable energy source but also plays a key role in the circular economy and in CDR methods such as BECCS or biochar. Germany's main biomass resources can be categorised into forest, agricultural, and waste biomass. Biomass is used mainly for food, heat and electricity production, biogas, transportation fuels, and wood products. The **current theoretical maximum availability of forest biomass ranges from 70 to 118 Mm³ per year**,²¹⁷ and the **residual biomass potential is estimated at about 90 Mt dry tonne per year**.^{99,218} About half of German bioenergy is used as solid fuels, especially in residential heating, and Germany also has some of the highest biogas consumption globally.⁸¹

Agricultural biomass is undergoing a transformation. The cultivation of energy crops such as silage maize is projected to decline by 50–70% by 2045, driven by biodiversity and climate goals. Simultaneously, livestock reduction will lower demand for feed crops, freeing up land for food production and ecological restoration.⁸² Additionally, climate change will affect availability: regions such as Brandenburg and Saxony-Anhalt are particularly

vulnerable to drought and water scarcity, which will reduce agricultural productivity and the generation of residual biomass.⁸³

3.4.1 Forest biomass

Germany's forests provide CDR potential through both harvested biomass and natural carbon sinks. Maximising harvests undermines carbon storage, so optimal levels must balance political, economic, and ecological goals. National forest policy stresses sustainable harvesting, with the Federal Environment Agency (UBA) warning that intensive extraction threatens biodiversity, resilience, and carbon sink capacity. The strategy prioritises material use over energy use, cascading utilisation, and restrained extraction to safeguard the integrity of forest ecosystems.⁸⁴

Despite contributing only modestly to national GDP, the forest industry is economically significant, particularly to private owners.⁸⁵ Yet, as confirmed by the fourth Federal Forest Inventory published in 2024, the LULUCF sector has been a net source since 2021, highlighting the urgency of strengthening natural sinks.^{86,87} Climate impacts and calamities have reduced the forest growth rate by 16% compared to 2012 and cut the forest carbon stock by 41.5 Mt (3%) since 2017. These disruptions make the CDR potential of the forest more unpredictable and may lead to a smaller natural sink and less woody biomass availability than predicted.

The current theoretical availability of roundwood (Derbholz) from sustainable forest management ranges from **70 to 118 Mm³ per year**, depending on forest management scenarios. According to the most recent forest inventory, there is a slight decreasing trend in the amount of wood used, with the most recent average being 72.6 Mm³ of raw wood (Rohholz) per year.⁸⁸ Spruce wood contributes the most (41%) to the raw wood potential, followed by beech (31%), pine (20%), and oak (9%).⁸⁹

Wood biomass, once a significant energy source, is increasingly used for material production. The BioSINK study warns that increased hardwood extraction undermines forests' carbon-sink capacity, thereby conflicting with natural climate-protection goals.⁹⁰ Although incentives for renewable heating may briefly boost energy wood demand, efficiency gains and ecological targets are expected to drive a long-term decline, with **energy use of wood falling to 44.5 Mm³ by 2050**, more than 50% below current levels. Meanwhile, **demand for wood in construction** is expected to rise significantly, reaching about **80 Mm³** annually and potentially

Forest harvest projections: present, 2035, and 2045

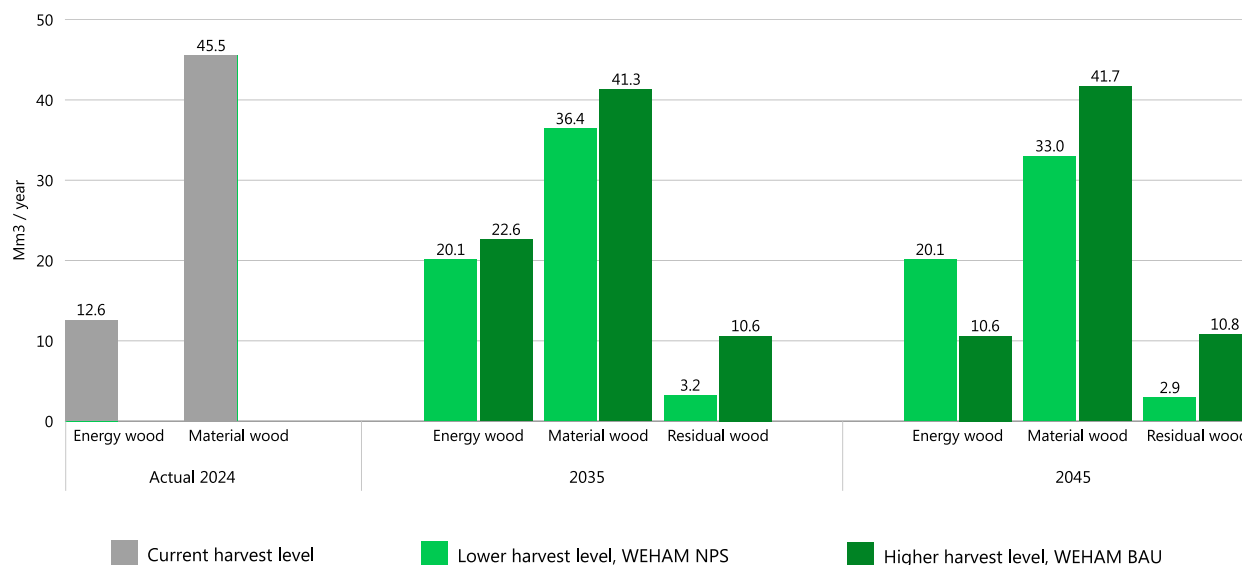


Figure 15. Forest harvest volumes for 2024⁹² and future projections for 2035 and 2045.⁹³ Present amounts and projections are not directly comparable, as current figures are purely harvest amounts, whereas the projections are harvest amounts adjusted to be compatible with wood market modelling, e.g., by accounting for deadwood left in the forest. The methodology is explained in the data source.²²¹

exceeding domestic softwood supply.⁹¹ Wood use forecasts remain uncertain; however, national WEHAM projections do not anticipate significant reductions in domestic energy wood demand.²¹⁹

As described in Section 3.3.1, Box 2, the WEHAM BAU and NPS scenarios were used to generate biomass availability data. Figure 15 shows current harvest levels alongside projections under both scenarios. Although current harvest data and WEHAM scenarios in Figure 15 are not fully comparable due to differences in data format and uncertainties in future projections, the energy use of wood is expected to rise from current levels. The apparent gap stems from older WEHAM projections that overestimate present-day energy wood use. Harvest levels in Germany have also fluctuated by ~30 Mm³ over the past decade, adding variability to both data and projections.²²⁰

As noted previously, WEHAM scenarios, based on the 2012 forest inventory, are partly outdated due to updates to calculation methods and disturbances documented in the 2024 forest inventory. Forest disturbances may reduce wood supply, and future wood availability may be lower than WEHAM estimates if disturbances continue. Since the **WEHAM** scenarios do not account for forest disturbances from the most recent forest inventory, the forest sink

projections may be overly optimistic. Therefore, this study used **BioNET projections** to estimate the **natural sink** in 2035 and 2045 expected from purposely set-aside forest surfaces.

In summary, Germany's forests offer significant CDR potential both as natural carbon sinks and through forest-based biomass. While energy wood's role is likely to decrease in the future, it still provides moderate potential for CDR: ~40% is used in households (therefore unavailable for CDR)⁹⁴, ~40% is combusted in industrial facilities (over 1 MW in size) which could be retrofitted with BECCS. Of wood intended for material use, less than half is used for pulp and its derivative products, with a growing share directed to long term uses like construction. Residual wood, now mostly combusted, could support CDR via BECCS or biochar. Table 1 outlines projected total wood biomass in 2035 and 2045 as m³ (the original unit) and tons (used for the CDR calculation) with descriptions of the amounts that could be theoretically available for CDR.

Type of biomass	Total projected amount (2035)	Total projected amount (2045)	Assumptions on maximum theoretical availability
Energy wood	12.1-13.5 MtDt 20.1-22.6 Mm ³ ²²¹	12.1-13.5 MtDt 20.1-22.6 Mm ³ ²²¹	About 40% used in households and excluded from CDR.
Residual wood	1.8-6.1 MtDt 3.2-10.5 Mm ³ ²²¹	2.9-6.2 MtDt 5-10.8 Mm ³ ²²¹	About 40% used in households and excluded from CDR.
Pulp wood	2.9-5 MtDt 6.5-10.2 Mm ³	2.7-10 MtDt 5.9-20.6 Mm ³	Pulp wood fraction of material wood estimated based on wood use data. ²²¹ Estimated 60% of pulp production ends in end products and the rest as black liquor. Due to lower wood availability in NPS scenario, estimated all needed for households and unavailable for CDR
Sawmilling and plywood	5.7-6.2 MtDt 12.7-12.8 Mm ³	5.2-8.3 MtDt 11.6-17.1 Mm ³	Sawmilling and plywood fraction of material wood estimated based on wood use data. ²²² Assumed half of raw wood mass end up in end-products and the rest as side products. Some already used for long-term products so this amount assumed to be possible to increase. A small amount assumed to be directed to biochar. Assumed 60% in total could be used for CDR.
Side products from wood industry	5.7-6.2 MtDt 12.7-12.8 Mm ³	5.2-8.3 MtDt 11.6-17.1 Mm ³	Assumed half of raw wood mass end up in end-products and the rest as side products. Assumed all available for CDR because used in industry.
Black liquor	2-3.3 MtDt 4.4-6.8 Mm ³	1.8-6.7 MtDt 4-13.7 Mm ³	Estimated 60% of pulp production ends in end products and the rest as black liquor. Assumed all available for CDR because used in industry.
Totals	30.3-40.3 MtDt 59.6-76 Mm ³	29.8-61.4 MtDt 58.1-102.5 Mm ³	

Table 1. Projected wood biomass amounts for 2035 and 2045 and assumptions on their availability for CDR. The lower amounts are from the WEHAM NPS Scenario and the higher amounts from the WEHAM BAU Scenario. M³ were converted to dry tons using the conversion factors 0.45 t/m³ for softwood and 0.7 t/m³ for hardwood.⁹⁵ When the type of wood was unknown, an average of the two was used. Amounts in MtDt (million dry tons) and Mm³ (million cubic metres).

3.4.2 Waste and Residual Biomass

In this section, only waste and residual biomass, excluding other priority uses such as food, were considered, consistent with the recent BECCS potential assessment commissioned by BioNET.⁹⁶ **Energy crops were excluded from this assessment because their cultivation is projected to decrease dramatically.** There is also growing competition for residual and energy biomass, particularly in novel areas where it has not typically been utilised, such as the chemical and aviation industries.^{95,97,98}

Biomass presents significant CDR potential for Germany. Residual and waste biomass will play an increasingly important role, while competition for

agricultural land will require strategic governance. The top 15 waste and residual biomass types add up to more than **65 Mt (dry) of biomass in 2045**, of which **about 50%** - based on averages of the datapoints in Table 2 - **is theoretically available for CDR** when assuming energy use is compatible with CDR. However, demand for residual biomass is likely to increase in other fields, such as the chemical and aviation industries, in the future, which may lead to competition. Because the market for these novel biomass-based products is immature, more research is needed to determine the biomass resource needs for them. Therefore, estimations for realistic CDR potential must account for a portion of biomass being prioritised for these novel industries.

Box 3. Methodology and data sources to estimate waste and residual biomass available for CDR

The German BIOSTRAT report compiles several biomass projections from the BioRest study and the BEPASO scenarios.⁹⁹ For this study, the **BEPASO baseline scenario** (BAU, Bioökonomie am Tropf) was chosen as the primary data source, as it combines historical data with future trends and is considered more reliable than BioRest projections, which relies solely on past data. Originally based on 2015, the dataset was updated to 2020 as the reference year for the BIOSTRAT report. The top 15 biomass feedstocks evaluated in this study are listed in Table 1, with 2020 values closely matching those reported in the DBFZ Biomass Monitor.⁹⁹

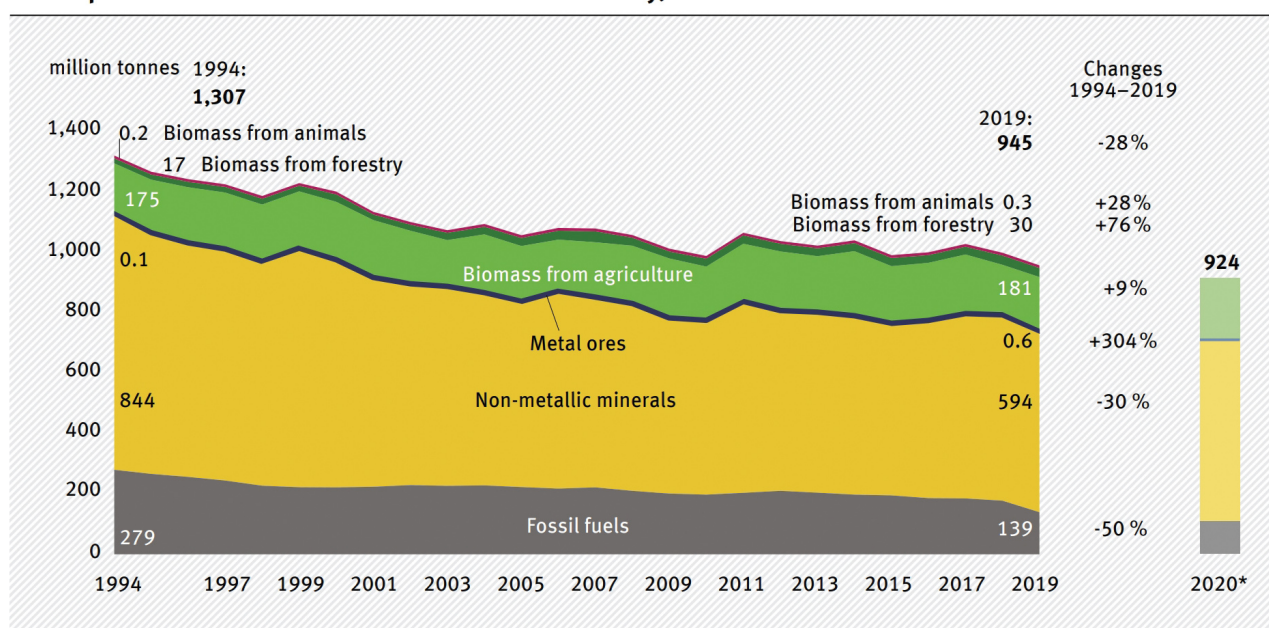
Estimates of biomass availability for CDR were derived from the **DBFZ Biomass Monitor**,¹⁰⁰ which tracks 77 waste and residual biomass types from 2010-2020. The database provides estimates of theoretical and technical potential across material and energy uses. The share of technically available biomass not currently utilised – termed “mobilisable technical potential” – was assumed to be available for CDR. Energy uses, mainly biogas or biofuels, were considered compatible with CDR via anaerobic digestion (AD) with BECCS and thus included in the CDR potential. Although usage data is from 2020, it was assumed to reflect future uses due to the absence of projections for 2035 and 2045. Yet competition for waste biomass is expected to increase. Hence, in realistic scenarios, only a fraction of the available biomass was used to account for emerging uses.

3.5 Mineral feedstocks

Germany possesses a diverse geological and industrial resource base that supports the deployment of mineral-based CDR methods.

These feedstocks can be categorised into **primary minerals**, which are naturally occurring, and **secondary materials**, which are industrial by-products and waste streams. Both offer relevant potential for scalable CDR methods.

Development of used raw material extraction in Germany, 1994–2020



Data based upon revised version of the economy-wide material balance of November 2021.
Values in this figure are not directly comparable to the previous Resources Reports (UBA, 2016 a; UBA, 2018).
* Estimate based on trends of domestic extraction as reported by Eurostat, 2021.

Source: Destatis, 2021 h

Figure 16. Raw material extraction in Germany (1994-2019).¹⁰¹

Type of biomass	Total amount (2020) ⁹⁸	Total amount (2035) ⁹⁸	Total amount (2045) ⁹⁸	Current uses according to DBFZ ⁹⁹	Assumptions on maximum theoretical availability for CDR
Waste paper	14.47	14.53	14.33	91% in material use	Unavailable for CDR because prioritised for material use
Cereal straw	12.22	11.99	11.92	About 53% of technical potential in material use and rest unused	Unused amount (47%) available for CDR
Green waste	8.50	8.23	8.16	29% in material use and 14% in energy use, 5% in both, 50% unused	Energy use assumed to be compatible with BECCS via AD. Unused potential available for CDR. In total 65% available.
Cattle slurry	8.24	8.26	8.19	60% of technical potential in energy use and 40% unused	Energy use assumed to be compatible with BECCS via AD. Unused potential available for CDR. In total all technical potential available.
Residues from oil production	6.79	5.99	6.09	100% of technical potential in material use	Unavailable for CDR because prioritised for material use.
Cattle solid manure	5.91	5.93	5.88	31% of technical potential in energy use and 69% unused	Energy use assumed to be compatible with BECCS via AD. Unused potential available for CDR. In total all technical potential available.
Biogenic share of wastewater	3.24	3.75	3.67	85% of technical potential in energy use and 15% unused	Energy use assumed to be compatible with BECCS via AD. Unused potential available for CDR. In total all technical potential available.
Municipal organic waste	2.82	2.68	2.65	34% of technical potential in energy use, 22% in material use, 17% in both, and 22% unused	Energy use assumed to be compatible with BECCS via AD. Unused potential available for CDR. In total 56% available.
Wood from landscaping	2.08	2.08	2.08	30% of technical potential in energy use and 70% unused	Energy use assumed to be compatible with BECCS. Unused potential available for either biochar or BECCS. In total all technical potential available.
Pig slurry	1.00	1.04	1.07	61% of technical potential in energy use and 39% unused	Energy use assumed to be compatible with BECCS via AD. Unused potential available for CDR. In total all technical potential available.
Chicken solid manure	0.63	0.64	0.65	100% of technical potential in energy use	Energy use assumed to be compatible with BECCS via AD so all assumed available for CDR.
Pig manure	0.18	0.19	0.19	52% of technical potential in energy use and 48% unused	Energy use assumed to be compatible with BECCS via AD. Unused potential available for CDR. In total all technical potential available.
Cattle liquid manure	0.20	0.20	0.20	100% of technical potential in use that is not differentiable.	Assumed 50% of technical potential available for CDR.
Chicken liquid manure	0.08	0.08	0.08	100% of technical potential in use that is not differentiable.	Assumed 50% of technical potential available for CDR.
Pig liquid manure	0.01	0.01	0.01	100% of technical potential in use that is not differentiable.	Assumed 50% of technical potential available for CDR.
Total	51.9	65.6	65.17		

Table 2. Top 15 residual and waste biomass amounts, projections, and assumptions on availability for CDR (Mt dry).

g. Percentages of 2020 technical potential, mean value. Mobilisable technical potential considered to be unused quantity available for CDR.

3.5.1 Primary Mineral Resources

Germany's mineral extraction has declined by 30% since 1994, reflecting improved efficiency and stricter environmental regulation. Protected geological formations (e.g., serpentine zones) limit access to some high-potential minerals. However, Germany's Federal Environment Agency (UBA) and the Federal Institute for Geosciences and Natural Resources (BGR) emphasise the strategic importance of mineral-based CDR methods within a circular-economy framework.

Germany has substantial reserves of limestone and dolomite. According to the 2023 Raw Materials Report by the Federal Institute for Geosciences and Natural Resources (BGR), around **44.7 Mt of limestone and dolomite** were extracted in 2023. Widely used in the cement, steel, and chemical industries, they are also suitable for ocean alkalisation and surface mineralisation.¹⁰²

Basalt, a silicate-rich volcanic rock, is found in regions such as the Eifel, Vogelsberg, Rhön, Swabian Jura, and Westerwald. It is particularly well-suited to terrestrial and coastal enhanced weathering. Although basalt production is not separately recorded, estimates indicate that approximately **32.5 Mt** of basalt and lava are extracted annually.¹⁰³

Magnesium silicates such as olivine and serpentine are highly effective for CO₂ sequestration; however, Germany has limited deposits.¹⁰⁴ Olivine is mainly imported from Norway and used domestically as a blasting abrasive, in foundry sands for steel and aluminium casting, and increasingly as a sustainable binder alternative in cement production.^{105,106} Serpentine occurs in small amounts in regions such as the Erzgebirge, though extraction is constrained by environmental protection regulations.

Due to limited data on mineral consumption, it is assumed that nearly all current mineral production is used for primary applications. In the future, the production of basalt and carbonate minerals - primarily limestone and dolomite - is expected to decline due to reduced demand,¹⁰⁷ driven by improved raw material efficiency in construction and increased use of secondary materials.

In assessing the **theoretical maximum availability** of minerals for CDR, it was assumed that current uses would decline significantly, particularly in the construction sector, where alternative materials are

increasingly used. However, reduced consumption does not translate into lower production, as demand shifts to carbon removals. Under this assumption, up to **~14 Mt of basalt** and up to **~13 Mt of limestone and dolomite** could be available for CDR by 2045.

3.5.2 Secondary Raw Materials and Industrial by-products

Germany produces large volumes of mineral-rich industrial waste, which are increasingly recognised as viable feedstocks for CDR through mineralisation. These materials originate from steel production, cement manufacturing, construction and demolition, and energy generation. In Germany, approximately 220 Mt of mineral construction waste are generated annually. 90% of these mineral construction wastes are currently reused, though partially for low-value applications such as landfill construction.¹⁸ Therefore, a relatively high volume could potentially be utilised for CDR. However, due to the lack of precise information on the percentage of mineral construction waste suitable for CO₂ mineralisation, a **theoretical available volume** of 5% of the annual mineral construction waste (**~11 Mt in 2045**) has been assumed.

According to the Steel Action Plan of the Federal Ministry for Economic Affairs and Energy (BMWi) and the German Steel Federation (WV Stahl), Germany's steel production is approximately 37 Mt per year.¹⁰⁹ This results in an annual steel slag volume of approximately 11 Mt, assuming 0.35 t of slag per ton of steel produced. It was assumed, however, that this volume is not available for CDR, as it is largely used in the building sector, cement production, and fertiliser production. For cement kiln dust, no reliable volume data are available to assess its availability for CDR; it was therefore excluded from the CDR potential calculations.

3.6 Marine resources

The country's Exclusive Economic Zone (EEZ) covers approximately 32,982 km², providing a legal and spatial framework for marine resource utilisation and the potential deployment of ocean-based CDR methods.¹¹⁰ Despite this access, the technical and ecological potential for marine CDR in German waters is limited.^h

According to the national CDRmare research initiative, five CO₂ removal methods could potentially be implemented in the German North

h. Please note that CDR methods related to artificial upwelling and coastal revegetation, including seagrass meadows, are covered in section 3.3.5 Coastal areas.

and Baltic seas: ocean alkalinity enhancement (OAE) via (i) silicates in shallow coastal zones, (ii) lime along shipping routes, (iii) basalt spreading, or (iv) sodium hydroxide discharge from desalination plants, (v) BECCS with fermentation through macroalgae cultivation (e.g., kelp farming) near Heligoland for biomethane production with CO₂ storage in saline aquifers. These methods are constrained by spatial competition, environmental regulation, and Germany's relatively small marine territory.¹¹¹

Technologies such as DOCCS or large-scale kelp farming are not yet viable in Germany due to the lack of deep-sea access, limited infrastructure, and ecological concerns. The feasibility of marine CDR deployment is highly dependent on site-specific factors, including the availability of suitable mineral feedstocks, energy requirements, transport logistics, and environmental impact assessments.¹¹²

Unlike the North Sea, the Baltic Sea is a shallow inland sea experiencing severe eutrophication.¹¹³ Weak water circulation exacerbates eutrophication, and limited connections to other seas restrict the inflow of saline water. Instead, the sea receives continuous freshwater input from rivers and rainfall, resulting in low-salinity brackish conditions. Studies collectively indicate that further research is necessary to understand the localised effects of methods such as OAE and to ensure environmentally safe implementation.¹¹⁴

In conclusion, while Germany's seas offer potential for CDR, its implementation is constrained by environmental regulations (e.g., the *Hohe-See-Einbringungsgesetz*) and limited research on marine CDR.

3.7 CO₂ Storage

While Germany's geological formations offer substantial potential for CO₂ storage, they currently impose significant constraints on the deployment of CDR methods such as BECCS and DACCS. Despite recent legislative changes enabling CO₂ storage in Germany, rapid and effective action is crucial to ensure that storage capacity keeps pace with carbon capture potential. Estimates of Germany's potential geological storage capacity for CDR vary with resource availability, regulatory development, and social acceptance, ranging from **9 to 15 GtCO₂** depending on the level of ambition.¹¹⁵

Early project initiation is essential, as the development of CO₂ storage infrastructure typically takes seven to ten years.¹¹⁶ Some of the capacity must be operational by the early 2030s to meet

Germany's climate targets. As an example, according to the DENA's (Deutsche Energie-Agentur) study "*Aufbruch Klimaneutralität*", the central scenario (KN100) projects that Germany will need to capture and store around 34 MtCO₂ annually by 2045 to achieve climate neutrality, with 24 Mt destined for geological storage (the remaining part is to be reached with other carbon removal or utilisation pathways). The study outlines a gradual ramp-up in CCS deployment, with only limited volumes (2-4 Mt CO₂/year) expected by 2030, followed by a significant scale-up over the subsequent 15 years. These figures are based on sector-specific transformation pathways and modelled energy system scenarios, with particular emphasis on hard-to-abate emissions in industry, waste management, and other sectors.¹¹⁷

3.7.1 Geological Reservoirs

Germany's geological formations offer significant storage potential, particularly in saline aquifers and depleted gas fields. According to the Federal Institute for Geosciences and Natural Resources (BGR, n.d.), the total theoretical storage capacity in **deep saline aquifers** across Germany's three major sedimentary basins - both onshore and offshore - is estimated at **6.3 to 12.8 GtCO₂**. Of this, 3.6 to 10.4 Gt are located beneath the North Sea.¹¹⁸

In addition, **depleted natural gas fields** offer a technically proven option for geological CO₂ storage, with an estimated capacity in Germany of **2.75 GtCO₂**, while **former oil reservoirs** contribute a much smaller capacity of around **130 Mt**. These formations are considered reliable due to their historical ability to trap hydrocarbons over millions of years.¹¹⁹

The depth of suitable formations typically ranges between 800m and 4,500m, ensuring separation from groundwater resources. Offshore formations in the North Sea are particularly attractive due to their scale and lower public resistance, although they face competition from wind farms, shipping routes, and marine protected areas where CO₂ injection is prohibited.¹²⁰

Onshore storage, while technically feasible in regions such as Lower Saxony, Brandenburg, and Schleswig-Holstein, is subject to legal restrictions and low public acceptance, making large-scale deployment in the short term unlikely.

Strategically, Germany's offshore geological formations - particularly sandstone layers beneath the EEZ of the North Sea - offer multi-gigatonne CO₂

storage potential. This capacity could play a decisive role in achieving the country's net-zero emissions target by 2045, especially for residual emissions from hard-to-abate sectors such as cement, steel, and waste management.¹²¹

To calculate the theoretical domestic geological storage capacity in Germany, we assumed a total storage capacity of **~15 Gt**. If Germany realises 2-3 Mt of that capacity by 2030 and starts to ramp up the capacity with linear growth until 2070, the annual capacity increase in 2045 would be **392 Mt of CO₂** stored.

3.7.2 Exports

Despite Germany's considerable CO₂ geological reservoirs, the country should at least in the short term utilise the availability of storage sites located abroad. The closest geological storage sites to Germany are in Norway and the Netherlands, and, in the future, in Denmark and the UK once injection capacity is developed.

In addition to bilateral storage agreements between countries, the volume of CO₂ exports is constrained by the availability of CO₂ transport infrastructure (both pipelines and ports) and the amount of CO₂ that can be captured. By 2045, a significant share of captured CO₂ may still be of fossil origin. The EU aims to have an injection capacity of at least 50 Mt per year by 2030, as outlined in the Net-Zero Industry Act (NZIA). There is no target for further years, but the European Commission estimates that the EU will need to capture and permanently store approximately 250 Mt of CO₂ each year from 2040 onwards to achieve climate neutrality by 2050.¹²²

For 2030, estimates indicate that the available geological storage capacity in Northern Europe will be approximately 10 MtCO₂.¹²³ The storage capacity is likely to grow strongly by 2045, but given the constraints of the transportation infrastructure and the expected share of fossil CO₂, the **export capacity** has been estimated to be **10 MtCO₂ per year by 2045**, which has been used as the assumed export capacity in the calculation of Germany's theoretical CDR potential.ⁱ Transport and storage assumptions and sources are summarised in Section 7.4.4.

3.7.3 Timber Use in Long-Lasting Buildings

Timber use in construction provides a temporary carbon sink, with storage lasting decades, depending on the building's lifespan. Germany has a robust timber construction sector, strong demand, and the capacity to support significant annual CO₂ storage, provided there is a consistent and sustainable supply of high-quality wood. Replacing carbon-intensive materials such as concrete and steel offers significant opportunities, but challenges include competing timber uses, reliance on imports to meet increased demand, and adherence to sustainable forest management.

UBA estimates that increased timber use could store 5-10 MtCO₂ annually by 2030, depending on substitution rates and building lifespans – an estimate of the gross annual inflow of biogenic carbon into long-lived harvested wood products (HWP) in buildings under comparatively ambitious uptake and lifetime assumptions, rather than a directly comparable estimate of net economy-wide GHG mitigation.¹²⁴ In another study, Hafner (2017) modelled Germany's net GHG impacts in the residential new-build segment (EZFH/MFH) under defined wood-construction share scenarios and BBSR-based projections of future housing demand, and reports results that vary strongly depending on how quickly higher wood shares are achieved and which period is averaged. Hafner finds annual average mitigation from ~0.38 MtCO₂e/year under modest uptake assumptions up to ~1.8 MtCO₂e/year in the most ambitious early-deployment case, with an additional ~1.6 MtCO₂/year from increased HWP storage in the first five years, and hence a combined order of magnitude consistent with ~0.3–2.4 MtCO₂e/year depending on scenario and reporting convention.¹²⁵

As described in Section 3.4.1, in 2023, 70.6 Mm³ of roundwood were harvested (Holzeinschlag) in Germany. Only a portion enters long-lived harvested wood products (e.g., construction timber), while other shares are used in short-lived products and energy use.¹²⁶ According to the Thünen Institute, harvested wood products contributed a net carbon sink of –4.6 MtCO₂e in 2023, based on Germany's GHG inventory using the production approach, which accounts for domestically produced wood products, regardless of their export destination.¹²⁷ With reliable life-cycle data, the construction sector is currently the most suitable domain for assessing wood's GHG mitigation potential.

i. These areas have protection potential but are constrained by fragmentation, intensive land use, and poor connectivity. However, no legal restrictions apply to measures in them.

3.8 CO₂ Infrastructure

Germany currently lacks a dedicated national CO₂ pipeline network. However, the country is actively planning a significant expansion of CO₂ transport infrastructure as part of its broader decarbonisation strategy. This includes the development of pipeline corridors linked to industrial clusters and offshore storage sites in the North Sea.

Pipeline Infrastructure and Capacity

Germany's plans for a national CO₂ transport infrastructure have gained significant momentum following the Federal Cabinet's and Parliament's adoption of the amended Carbon Dioxide Storage and Transport Act (KSpTG). A Carbon Management Strategy was developed but not published by the previous government, and will likely continue to be developed, as the BMWi has indicated.¹²⁸ It will likely outline the vision for a CO₂ backbone network connecting industrial hubs such as North Rhine-Westphalia, Hamburg, and eastern Germany to offshore storage sites in the North Sea. The new legislation provides a binding legal framework for implementing these plans.¹²⁹

Authorities are now empowered to expropriate private land, with compensation, for the construction of pipelines. Additionally, easements are anticipated for CO₂ pipelines adjacent to planned hydrogen pipelines, and permitting authorities are encouraged to prioritise processing. Judicial review procedures have also been streamlined to reduce delays.

The infrastructure is projected to remain operational by the early 2030s and to be integrated into European CO₂ transport systems, including those in the Netherlands, Denmark, and Norway.¹³⁰

In addition to pipeline infrastructure, there are plans to enable CO₂ export by ship to countries with operational offshore storage facilities, such as Norway. Export terminals were proposed in Wilhelmshaven, Brunsbüttel, and Hamburg, leveraging existing energy infrastructure to facilitate the transport of liquefied CO₂ to storage hubs like Northern Lights.¹³¹

Concrete pipeline projects are being developed. Open Grid Europe (OGE), in partnership with Tree Energy Solutions (TES), is developing a 1,000 km **CO₂ transport network** with a **projected annual capacity of 50 MtCO₂**, excluding transit.¹³² The network will connect industrial sites across Germany to a green energy hub in Wilhelmshaven, enabling both CO₂ storage and reuse within a circular economy model.¹³³

Furthermore, OGE, ONTRAS, and Fluxys have received regulatory approval for **two export-oriented pipeline projects**, linking German industrial regions to offshore storage sites in the North Sea and Denmark, and to Belgium's Zeebrugge port for maritime CO₂ export.¹³⁴

These plans are part of a broader strategy to support hard-to-abate industrial sectors and align Germany with European CCS developments. During the initial phases of CCS deployment, truck and rail transport may be used for short distances, particularly between industrial sites and interim storage or compression facilities. These modes are considered transitional solutions, as they are less efficient and more costly than pipelines or maritime transport.

Germany is laying the groundwork for a future-ready CO₂ transport infrastructure, backed by new legislation and strategic planning. With pipeline and shipping projects underway, the country aims to connect industrial regions to offshore storage and integrate into European CCS networks.

3.9 Natural Conditions

Germany lies in Central Europe's temperate zone, shaped by both maritime and continental air masses. The climate is moderate, with mild winters, warm summers, and evenly distributed precipitation throughout the year. Average annual temperatures range from ~5 °C in mountainous areas to ~10 °C in lowlands, with summer values of 16–20 °C and winter values of –1 to 3 °C. The southwest (e.g., Upper Rhine Valley) is the warmest, while the Bavarian Alps and eastern regions are the coldest.¹³⁵

Since 1881, Germany has warmed by ~1.7 °C, with projections of an additional 3–4.7 °C by 2100.¹³⁶ This regime supports diverse ecosystems and agriculture, enabling mitigation strategies such as afforestation, biochar, and enhanced weathering.

Annual precipitation in Germany averages 700–1,200 mm (Figure 17), but climate change is shifting patterns: wetter winters, drier summers in central and eastern regions, and more frequent extreme events, with impacts on groundwater recharge, river flows, and water availability - especially in vulnerable areas such as Brandenburg and Saxony-Anhalt.¹³⁷ Climate projections indicate up to 15% more winter rainfall and reduced summer precipitation in eastern Germany, heightening drought risk and affecting soil moisture, vegetation, and mineral dissolution, all critical for carbon sequestration and enhanced

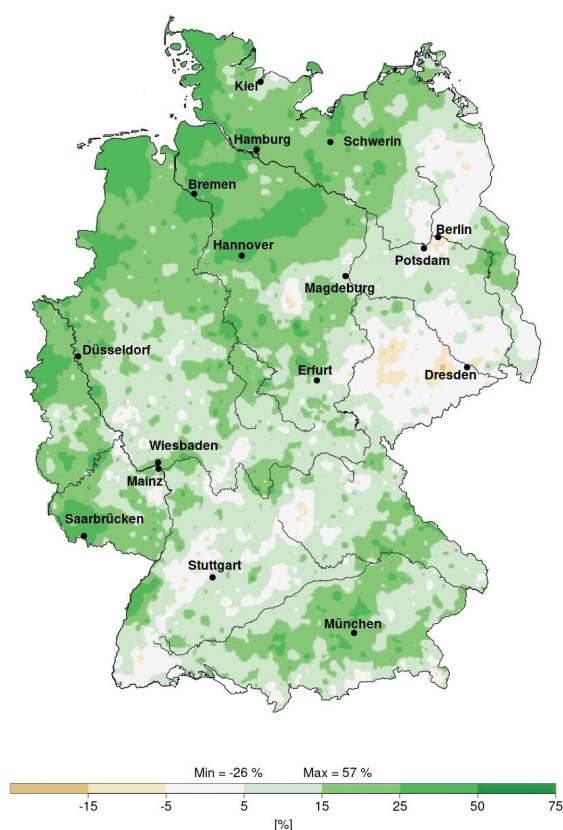


Figure 17. Change in annual precipitation in Germany in 2024 (%).¹⁴⁰

rock weathering.¹³⁸ Germany's relatively high humidity (70–85% in winter, 60–75% in summer) supports microbial activity, chemical weathering, and vegetation growth, enhancing biomass-based CDR methods.¹³⁹

Overall, Germany's temperate climate remains favourable for various CDR methods, but climate change introduces both opportunities and constraints: wetter winters enhance biochar and weathering potential, while drier summers may limit afforestation and soil carbon storage. Effective adaptation and planning will be essential to optimise CDR under evolving conditions.

3.10 Restrictions

The deployment of CDR infrastructure in Germany is constrained to spatial limitations arising from environmental protection, land-use regulations, and societal considerations. These constraints affect both surface and subsurface land availability and must be integrated into national planning efforts. A national landscape assessment classifies 54.7% of land as ecologically, culturally, or scenically valuable - 12.3% as particularly worthy of protection, 10.8% as worthy, and 31.6% as worthy with deficits^j - leaving 45.3% with lower conservation value or urbanised.

While all areas may host important habitats and species, the protected landscapes are prioritised for preserving characteristic features and biodiversity, in line with Germany's National Strategy on Biological Diversity.¹⁴¹ Urban areas account for 14.2% of the land. While not entirely excluded, buffer zones of 300–500 m are required between residential areas and industrial installations.¹⁴² Military zones (1% of the territory) are generally excluded from public land-use planning and are not available for infrastructure development.¹⁴³ Groundwater protection zones (over 10%) restrict subsurface activities, including CO₂ injection.¹⁴⁴

The deployment of CDR infrastructure in Germany is significantly constrained by land-use limitations, environmental protection zones, and societal considerations. With over half of the country's land classified as ecologically or culturally valuable, and additional restrictions in urban, military, and groundwater-protection areas, the available space for CDR technologies is limited. Effective national planning must account for these spatial challenges to ensure sustainable and socially acceptable implementation. The assumptions used to assess land area potential are explained in greater detail in Chapter 7.

j. These areas have protection potential but are constrained by fragmentation, intensive land use, and poor connectivity. However, no legal restrictions apply to measures in them.

4. CDR theoretical potential (Could do)

To estimate Germany's theoretical CDR potential, the analysis first assesses the maximum availability of relevant resources – such as biomass, land, and energy – while preserving their essential priority uses. This hypothetical scenario assumes full mobilisation of all suitable resources for CDR, without factoring in real-world constraints, competing demands from other sectors, or societal readiness. While not practically feasible, this upper-bound estimate serves as a benchmark for understanding what could be achieved under extraordinary circumstances, akin to a nationwide mobilisation effort to address climate change. This theoretical maximum helps frame the more realistic estimates presented in Chapter 7.

4.1 Methodology

To assess the theoretical potential, it is necessary to estimate the resource availability of each CDR method. Most CDR methods rely on multiple inputs – such as electricity, water or heat – and therefore compete for the same resources. The calculation of theoretical potential is based on a bottom-up approach of assessing how the physical resources (described in Chapter 3) should be used optimally allocated to maximise overall removal potential. For each CDR method it is firstly defined what is the primary resource – or resources – needed, and resources are then secondly allocated optimally to the different methods based on which method requires the less resources per net ton of CO₂. The methodology and database used for this optimisation is described in section 2.3. Based on this allocation, it is then calculated how much CO₂ could be used with existing resources using the portfolio of methods in the most optimal way.

In the German context, **the most contested and limiting resources among different CDR methods are geological storage capacity and energy**. Additionally, various CDR methods compete for similar types of biomasses, particularly wood-based biomass. Alongside energy efficiency, current uses and economic feasibility were also considered in the resource allocation process to a reasonable extent, i.e. on a qualitative level – no economic variables were factored in the calculation. For example, despite biochar's technical efficiency, allocating the majority of wood-based biomass to its production is not justifiable due to limited market demand compared to other CDR pathways. For CDR methods where biomass feedstocks can be clearly assigned without competition from other

CDR methods, the CDR potential was calculated by applying conversion factors to translate available biomass into equivalent tons of CO₂.

The theoretical CDR potential was calculated through a bottom-up assessment, quantifying the amount of carbon dioxide that Germany could remove by mobilising available resources across various CDR pathways. Annex A lists the assumptions and values for biomass availability.

4.2 Theoretical CDR potential in Germany

The **theoretical CDR potential** for Germany in 2050 is **~258 MtCO₂** (incl. the forest natural sink). This potential is dominated by electrochemical DACCS (~70 MtCO₂), agroforestry (~37 MtCO₂), BECCS with combustion (~24 MtCO₂), BECCS with anaerobic digestion (~19 MtCO₂) and afforestation (~11 MtCO₂). The forest carbon sink estimate is based on the WEHAM NPS scenario (see Box 2 for details). Other methods contributing to the theoretical CDR potential and their method-specific potential can be found in Table 3.

It is important to remember that this potential is a **purely theoretical estimate**. It is achieved, for instance, if all German biomass remaining after allocation to priority uses is assigned to CDR methods. A significant factor contributing to the theoretical CDR potential is the assumption that ample storage capacity is available in Germany and elsewhere where Germany could export carbon dioxide. **Geological storage is assumed to be available for 402 MtCO₂ per year**, of which 392 Mt is Germany's domestic capacity and 10 Mt is export capacity. Allocation of geologic CO₂ storage was prioritised for BECCS over DACCS, as it is more efficient to capture CO₂ from flue gases than from air. The combustion of biomass is projected to continue in Germany over the coming decades, based on national WEHAM wood-use scenarios, thereby ensuring ample biogenic CO₂ availability. Thermal energy was not considered a limiting resource for BECCS. Instead, an additional 7% of biomass feedstock was included to account for the additional resources required for integrating BECCS into an incineration process.¹⁴⁹ While a substantial share of geological CO₂ storage was allocated to DACCS after accounting for BECCS, electricity availability emerged as a limiting factor for DACCS deployment.

The theoretical potential was calculated under the assumption that ample land is available for agroforestry, based on the assumed technical potential for agroforestry, which is considered not realistically feasible. That, together with the uncertainty

about the suitability of the conversion factor used for German agricultural conditions, leads to the conclusion that the estimated contribution of agroforestry is likely overstated.

CDR method	CDR potential by 2045 (MtCO ₂ /year)	Notes
DACCS (electrochemical)	70	The CO ₂ storage left after BECCS was fully deployed was allocated to DACCS.
Agroforestry	37	The theoretical potential land area on which agroforestry can be deployed is 2.4 Mha . ¹⁴⁵ This is likely an overestimate, due to lack of data on how the conversion factors apply to German agricultural conditions.
BECCS with combustion	24	The figure is based on the current total volumes of biomass suitable for BECCS with combustion, after biomass has been allocated to priority uses. BECCS was prioritised over DACCS (in terms of limited storage capacity) because of energy efficiency and availability of biogenic CO ₂ .
BECCS with anaerobic digestion	19	The figure is based on the current total volumes of biomasses suitable for BECCS with anaerobic digestion, after biomass has been allocated to priority uses.
Cropland management	18	The figure assumes that most of Germany's cropland area (70%) is available for CDR methods, i.e. 7.7 kha .
Afforestation	11	The figure is based on the estimated, theoretical potential of 1 Mha hectares of land available for afforestation. ¹⁴⁶
Peatland restoration	9	The figure assumes that total area of drained peatlands in Germany is rewetted, at the steady annual pace of 56 kha .
Pasture management	8	The figure assumes that 40% of the total pasture area in Germany is available for carbon removals, i.e. 1.9 kha .
Biochar	8	The figure assumes that most side products from wood industry and black liquor (and other relevant inputs) are available for CDR, as those are used industrially. Most of those resources (80%) are allocated to BECCS with combustion, and 20% to biochar.
Ocean alkalinity enhancement	8	The figure assumes that the current uses of mineral feedstocks are reduced drastically (e.g. construction industry applies alternative materials) and that leaves available resources for CDR.
Enhanced rock weathering	7	The figure assumes that the current uses of mineral feedstocks are reduced drastically (e.g. construction industry applies alternative materials) and that leaves available resources for CDR.
Reforestation	5	The figure is drawn from the total forest area damaged because of natural disturbances, and which needs to be reforested, i.e. 500 kha . ¹⁴⁷
Durable bio-based products	0.7	The figure is based on current total volumes of wood-based biomass already used for these products, and an assumption about the extent to which this could be increased.
Coastal revegetation	0.2	Existing salt marshes and seagrass meadows on both North Sea and Baltic Sea coasts are expected to remain, and Baltic Sea seagrass meadows are expected to expand by both natural expansion and active restoration, while also improving in quality.
Forest natural carbon sink (based on assumed harvesting levels)	33	The figure is based on WEHAM NPS scenario. ¹⁴⁸
Total	258 MtCO₂e	The most limiting factor for technical methods such as BECCS and DACCS is geological storage capacity and energy.

Table 3. Germany's theoretical CDR potential by 2045.

5. Existing policy

Kick-started by the previous coalition government in 2021, particularly under the Federal Minister for Economic Affairs and Climate Action, Robert Habeck, Germany has been evolving its legal frameworks and strategic approach to CDR. This chapter aims to present the current status and anticipated future of Germany's CDR policy and to analyse how these factors enable or constrain the potential for CDR deployment.

5.1 CDR within Germany's climate strategy

Germany targets GHG neutrality by 2045 and net-negative emissions from 2050 onwards, as specified in its **Federal Climate Change Act** (KSG).¹⁵⁰ Nonetheless, in mainstream policy, CDR remains relatively unknown and considered a less certain and more contested climate pillar. However, significant momentum toward a more mature and comprehensive discussion can be noted, as well as active regulatory development of CDR policy.

Germany accounts for 23.7% of the EU's net GHG emissions and reduced its net emissions by 30.7% between 2005 and 2023, slightly above the EU average of 30.5%.¹⁵² Key actions outlined in

Germany's national energy and climate strategies focus on increasing the share of renewable energy, phasing out coal, and investing in sustainable transport infrastructure.

The **Federal Climate Action Act** sets specific targets for the LULUCF sector – which is expected to contribute CDR volumes of 25, 35, and 40 MtCO₂e per year by 2030, 2040, and 2045, respectively – and additionally emphasises the importance of novel “technical sinks”.¹⁵³ Natural sinks, particularly in the LULUCF sector, are integral to German climate policy. CDR methods such as afforestation, peatland restoration and sustainable land use, which store carbon dioxide in soil and vegetation, are key components of these efforts.

A pivotal moment for CDR came in 2021 with the formation of the “traffic light coalition”, a governing alliance composed of the Social Democratic Party (SPD), the Greens, and the Free Democratic Party (FDP). In their coalition agreement, the government recognised natural and technical sinks as necessary to achieve national climate goals and committed to developing targets for technical sinks and to developing both a **Carbon Management Strategy** for CCUS and a **Long-Term Strategy for**

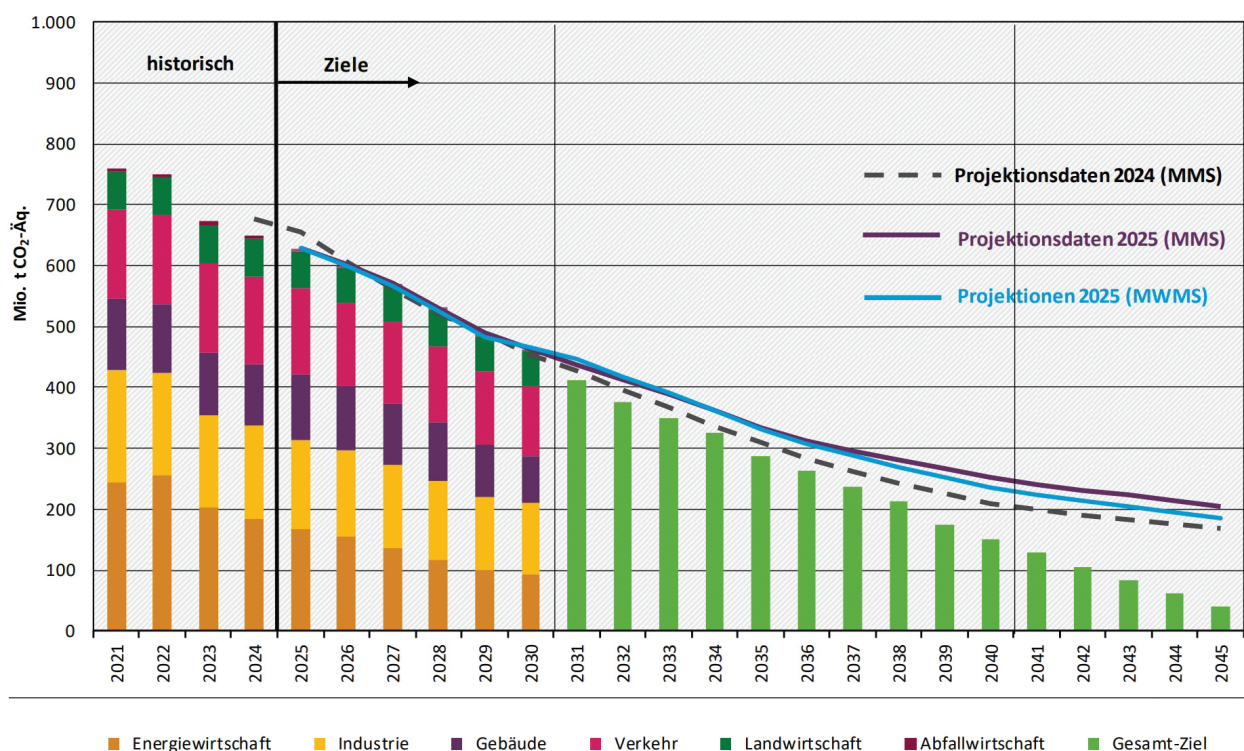


Figure 18. Germany's path to carbon neutrality by 2045.¹⁵¹

Negative Emissions (German: *Langfriststrategie Negativemissionen*; **LNe**) for CDR. Additionally, the coalition promoted cross-border cooperation initiatives, such as signing the Aalborg Declaration in 2023, which aims to accelerate the development of a unified European market for CCUS and to establish a joint working group with Denmark, Sweden, the Netherlands, and France to implement the declaration.¹⁵⁴

Following the 2025 change of government to a coalition of the Christian Democratic Union/Christian Social Union (CDU/CSU) and the SPD, there is now a more pronounced focus on economic and industrial policy objectives within climate policy. The new government coalition agreement explicitly highlights the importance of “permanent and sustainable negative emissions”. A new **dedicated team for CDR** was also established in the Federal Ministry for the Environment, Climate Action, Nature Conservation and Nuclear Safety (**BMUKN**), named *NK I 5 Negativemissionen*.¹⁵⁵

Furthermore, the **Carbon Dioxide Storage and Transport Act** (*Kohlendioxid-Speicherung-und-Transport-Gesetz – KSpTG*), a foundational legislative package to enable CCS for industrial sectors with hard-to-avoid emissions, was approved by Parliament in November 2025.¹⁵⁶ Geological onshore storage is allowed via an opt-in clause at the state level. The government also plans to establish new bilateral agreements with neighbouring countries to advance CO₂ transport infrastructure. The ratification of the **London Protocol** is also marked as a priority; it is an international maritime treaty that regulates ocean dumping and is crucial for CDR because it currently constrains (and could enable, if amended) activities such as CO₂ sub-seabed storage and certain marine CDR approaches.

Germany currently offers no large-scale financial instruments tailored to high-permanence CDR. Nature-based programs, particularly the **Aktionsprogramm Natürlicher Klimaschutz (ANK)**,¹⁵⁷ place significant emphasis on restoring and stabilising ecosystems (moors, forests, soils, wetlands) and can strengthen the natural carbon sink, but are not designed to deliver durable negative emissions at scale and do not substitute for high-permanence CDR.

Crucially, Germany's state budget 2026 now includes €98m of project funding for CDR projects, €11.5m for the purchase of CDR certificates, and €44.6m reserved to enhance soil sequestration.¹⁵⁸ Details on how this funding support will be operationalised are pending.

Despite progress in CDR policy, challenges and areas of conflict remain. Central issues debated among policymakers and policy influencers include land competition, high energy consumption, low TRLs and environmental impacts of CDR methods. A central debate concerns the appropriate balance between emission reduction and the deployment of CDR to avoid mitigation deterrence. Moreover, historical public resistance to CCS and onshore storage continues to shape today's political choices. Lastly, integrating CDR into various policy regimes, including environmental protection and biodiversity policy, adds complexity.

In sum, Germany's climate strategy demonstrates a comprehensive approach to achieving climate neutrality and has begun developing CDR policies. However, crucial details remain unclear, as key policy documents are outstanding, including the national CDR strategy (LNe). Other prominent contemporary issues, such as budgetary constraints, a weakening economy, and declining public support for climate action, add pressure on the advancement of CDR.

5.2 Support for R&D and Innovation

Germany has begun to lay the groundwork for a viable CDR ecosystem through a combination of research investment, innovation funding, and early market-shaping policy instruments.

The most prominent programmes in this field are **CDRterra**¹⁵⁹ and **CDRmare**,¹⁶⁰ supported by the Federal Ministry of Research, Technology and Space (BMFTR). The programmes aim to enhance scientific understanding of terrestrial and marine CDR methods, including their environmental benefits and risks, to develop monitoring and policy frameworks, and to estimate potential. CDRterra was granted funding of EUR 21 M for the period 2021–2025, and CDRmare EUR 27 M for the period 2021–2024, with programmes continuing with CDRterra II 2024–2028¹⁶¹ and a second phase of CDRmare from 2024–2027.¹⁶²

Germany promotes innovation in CDR through a mix of grants, public R&D funding, and tax incentives. Startups and research consortia can access funding for technology development and deployment from agencies such as the project sponsor Jülich and the former Federal Ministry for Economic Affairs and Climate Action (BMWK). Relevant programs include the Central Innovation program for SMEs (ZIM) and the GO-Bio initiative. In June 2020, Germany temporarily expanded the R&D tax incentive ('Forschungszulage') by increasing the annual maximum assessment base from €2m to €4m for eligible R&D expenditure

(effective for expenditure incurred after 30 June 2020), strengthening incentives for investment in novel technologies, including CDR.^{163,164}

Although Germany offers substantial funding for basic and applied research, support for innovation beyond the lab remains fragmented. There is **limited continuity of financing**, especially for long-term stakeholder engagement and transitioning from research to demonstration. To attract private investment and reduce development risks, the government is exploring financial instruments, such as public-private funding models and guarantee schemes, to support pilot projects and demonstration facilities, which can also be applied to CDR. The EU Innovation Fund also co-finances large-scale low-carbon technologies. Currently, there is **no structured de-risking mechanism or guarantee framework for private investors in CDR**. High upfront costs and regulatory uncertainty may deter private-sector participation, as may unclear business models, especially for marine-based methods such as blue carbon projects.

Pilot projects are crucial for the maturation of CDR solutions. **Germany supports early-stage demonstrations**, including DACCS, enhanced weathering trials, and carbon-storing building materials. These pilots often involve interdisciplinary networks that combine technical, regulatory, and public-engagement expertise. However, regulatory environments hinder real-world pilot projects, especially in the marine domain. Prohibitions under international and national law, such as the London Protocol, prevent testing ocean interventions in open waters.

There is emerging corporate demand for high-durability CDR in Germany and several early project activities, but in the absence of clear domestic rules, certifications, and market instruments, this nascent demand remains fragile.



6. Germany's social geography

This section aims to describe the social geography of Germany, identifying the main enablers and limitations to the deployment of CDR. Section 6.1 provides a high-level description of Germany from economic and political perspectives, followed by analyses of stakeholder interviews in Section 6.2 and of the citizen panel in Section 6.3. More detailed results are provided in Annexe B.

6.1 Overview

6.1.1 Economic

According to the European Commission's macroeconomic forecast,¹⁶⁵ Germany is experiencing economic stagnation, with persistent challenges in exports and investment. While private consumption has shown modest improvement, a rebound to 1.1% growth is projected for 2026, driven by strengthening domestic demand and a gradual recovery in investment. Nonetheless, substantial concerns remain over the government's deficit and rising debt levels. Given the scale and structural pressures on Germany's economy, these fiscal constraints could limit federal budget allocations for climate and CDR initiatives, particularly those requiring substantial investment support.

6.1.2 Political and public landscape

Prior to the current coalition, political cycles have shifted toward greater environmental awareness, with the 2021 elections yielding a coalition government with the Green Party, reflecting growing public demand for more decisive climate action. However, in 2025, the election results marked a major political upheaval with the far-right Alternative für Deutschland (AfD) gaining support while centrist parties lost support. The coalition led by the chancellor, *Friedrich Merz*, was formed by the CDU/CSU and the SPD, thereby blocking the AfD from entering government and marking a shift toward conservatism away from the more left-leaning policies of the previous government.

Structure of the Political Landscape

Germany's political landscape is dominated by the Christian Democratic Union (CDU), the Social Democratic Party (SPD), the Greens, the Free Democratic Party (FDP), and the Alternative for Germany (AfD). The CDU and SPD traditionally hold centrist positions, while the Greens advocate for progressive environmental policies. The FDP is economically liberal, emphasising market-based solutions, whereas the AfD is sceptical of climate change policies and often opposes large-scale environmental initiatives. In 2025, the FDP did not enter the Bundestag, whilst the far-right party AfD and the left-wing party "die Linke" are gaining national momentum in the opposition.

GDP (billion USD)	1,092.2 ¹⁶⁶
Growth 2025	0.3 ¹⁶⁷
Productivity	\$93.81 USD per hour worked ¹⁶⁸
Unemployment 2025	3.9% ¹⁶⁹
Main Sectors	70.6% Services, 23.1% Industry (Automotive & Manufacturing, Machinery & Equipment, Chemicals & Pharmaceuticals, renewable energy), 5.4% Construction ¹⁷⁰
Trends	Germany's economy faces challenges such as trade tensions, elevated uncertainty, and demographic changes, but there are positive signs of recovery driven by domestic demand, public investment, and productivity improvements.
Carbon intensity	Moderate (below EU average 0,22): 0,20 kg/per e (greenhouse gas emissions intensity of gross value added) ¹⁷¹
GDP per capita (Current USD, 2024)	54,343.2 ¹⁷²
HDI (2022)	0.95 ¹⁷³
CO₂ emissions (megatons) in 2023	582.95 ¹⁷⁴

Table 4. Germany's key economic indicators.

State of the Public Conversation on CDR

There is a strong consensus in Germany's political and societal spheres on the necessity of achieving net-zero emissions. This consensus is driven by a widespread recognition of the climate crisis and Germany's historical leadership in environmental policy. All major political parties, except the AfD, endorse net-zero emissions, although they differ in their methods and timelines for achieving it. However, given the country's ongoing economic struggles, voices across the political, industrial, and social spectrum are increasingly concerned about climate efforts undermining economic competitiveness.

While CDR is growing quickly, public debate remains early and niche, characterised by diverse positions. Recognising important nuances across the facets of CDR under discussion (e.g., natural versus technical sinks), the proponents include environmental organisations and scientific communities that advocate the urgent implementation of CDR technologies as crucial to meeting climate targets. All political factions are concerned about the feasibility, costs, and potential environmental impacts of large-scale CDR projects. Critics often argue for prioritising immediate emission-reduction strategies and caution against relying too heavily on future technological solutions.

6.1.3 Relationship to ecology

Germans generally hold strong pro-environment and pro-climate action attitudes, with broad recognition of climate change and its impacts, and a majority wanting Germany to be a leader in tackling the crisis, albeit support is wavering. While there's high awareness of the urgency and potential harms of climate change, views on the effectiveness and economic impact of green policies show some scepticism, and support for national action is strong but less so for personal responsibility. National surveys, such as those by the German Environment Agency,¹⁷⁵ European Investment Bank,¹⁷⁶ and the Federal Agency for Nature Conservation,¹⁷⁷ provide data on these attitudes.

According to the European Investment Bank's (EIB) annual Climate Survey (2024), 92% of German respondents say it is important for their country to adapt to climate change, while 40% say it needs to be prioritised.¹⁷⁸ According to the survey, German respondents report less impact from extreme weather events than respondents in other EU countries. Even after the catastrophic flooding caused by Storm Boris in the Baden-Württemberg

and Bavaria regions, only 32% think they will have to move to a less climate-vulnerable place to avoid floods, forest fires, or other extreme weather events. German respondents of the survey say that climate change is the third-biggest challenge facing their country, after large-scale migration and the rising cost of living, but only 40% (compared to 50% for the EU) regard that climate adaptation should be a priority for Germany in the coming years.

Regarding new technologies, large-scale projects, and the risk of inaction, German public attitudes are generally supportive but cautious. A significant segment of the population values innovation and recognises the necessity of bold action to combat climate change.¹⁷⁹

6.1.4 Human Resources

Although Germany has a highly educated population and a comprehensive education system, a recent study by the German Chamber of Commerce and Industry (DIHK) indicates that it will face a deficit of more than 500,000 skilled workers across 250 key professions crucial to the green transition. For instance, the solar, wind, and hydrogen sectors alone might require at least 300,000 additional skilled workers over the next ten years.¹⁸⁰ DIHK emphasises that the shortage is not only about highly specialised and skilled workers; professions such as truck drivers and other vocational school-level workers are also needed to ensure the full value chain.¹⁸¹

Based on recent KOFA data (June 2025), the overall workforce gap—the shortage of qualified workers—remains significant, with around 391,600 positions across Germany that cannot be filled due to a lack of suitably skilled candidates. This highlights structural constraints that would also affect the large-scale deployment of CDR technologies.

While Germany has a relatively strong academic and industrial base in relevant disciplines, such as engineering, geology, environmental sciences, and economics, the KOFA findings indicate acute shortages of technical professionals critical to CDR implementation. For instance, there are over 236,000 unfilled positions for a trained workforce, including strong increases in construction, transport, and technical trades, which are essential for infrastructure, plant operation, and material handling. These shortages suggest that while foundational expertise exists, the available human resources are insufficient to meet future CDR deployment needs at scale without targeted training and workforce expansion.¹⁸²

6.1.5 Cultural, aesthetic, religious and ethical considerations

Germany has a strong culture of environmental awareness, partly rooted in the anti-nuclear and anti-coal movements of the 1970s–1990s. This tradition often translates into scepticism toward large-scale technological “fixes,” including geoengineering and subsurface CO₂ storage. On the other hand, Germany is also traditionally a highly engineering-oriented society that tends to favour technical solutions. Therefore, the duality of these two sections of society can cause friction in advancing CDR.

A distinctive feature of the German energy transition (*Energiewende*) is the strong involvement of communities (energy cooperatives and municipal utilities). Germany has a strong tradition of protecting its cultural landscapes (e.g., vineyards, forested regions, and historic towns). Wind turbines have already triggered debates about visual intrusion; similar concerns could arise for visible DAC plants, CO₂ pipelines, or storage sites near iconic landscapes. Conversely, CDR integrated into the built environment (e.g., low-carbon concrete, green façades, biochar in urban soils) may be considered to *enhance* aesthetics when carefully designed, as Germany places high standards on architecture and urban design.

Germany is largely secular, and mainstream Christian denominations (Catholic, Protestant) have not issued specific positions on CDR. Ethical debates in Germany often centre on who bears the costs and who benefits. For instance, will rural regions host

infrastructure for urban/industrial emissions? Strong cultural emphasis on leaving a liveable environment for future generations underpins both support for aggressive climate action and suspicion toward solutions that may defer rather than prevent harm.

6.2 Stakeholder interviews

This chapter synthesises insights from a series of interviews conducted with experts across sectors on CDR methods in Germany between April and June 2025. The interviews encompass perspectives from academia, industry, government agencies, and non-governmental organisations. The goal is to present a coherent overview of the current state, challenges, and future directions for CDR in Germany.

6.2.1 Awareness and views of stakeholders on Germany's existing climate policy

The interviews revealed mixed sentiment regarding Germany's climate ambitions and the specific role of CDR within them. Several experts noted that while Germany has set ambitious climate goals aligned with EU targets, such as achieving net-zero emissions by 2045, the explicit targets for CDR are limited and somewhat unclear. There is concern that the current policy framework does not sufficiently distinguish between traditional emission reduction measures and CDR methods, potentially leading to confusion and inefficiencies in achieving climate goals.

Most interviewed organisations noted that including CDR in the new government coalition agreement is a major step in the right direction and emphasised

Ministries	Ministerium für Landwirtschaft und Verbraucherschutz des Landes Nordrhein-Westfalen
Public Agencies & Implementation Bodies	- Umweltbundesamt - NRW.Energy4Climate - Deutsche Energie-Agentur GmbH (dena)
Knowledge Institutes & Research Programs	- Fraunhofer Institut 'UMSICHT' - Forschungszentrum Jülich - CDRterra - CDRmare - Potsdam-Institut für Klimafolgenforschung - Wuppertal Institut
Civil Society	WWF
Industry Organisations	Deutscher Verband für negative Emissionen e.V. (DVNE)
Private Sector (Companies)	- Climeworks AG - eva - ecosystem value alliance

Table 5. Interviewed organisations.

that the policy environment for all climate policy, including CDR, is currently undergoing big changes. CDR is considered a viable instrument for achieving Germany's climate targets. Germany has formally acknowledged the role of CDR in its climate strategy, with references in the coalition agreement and the pending Long-Term Strategy for Negative Emissions (LNE). However, many interviewees noted that operational clarity is lacking, and some said CDR is still a secondary, low-priority tool in the federal government's climate policy. The interviews highlighted legal barriers, such as current restrictions on CO₂ storage (KSpTG), which passed Parliament shortly after the interviews were conducted, and on marine research (High Seas Dumping Law), which impede deployment, but noted that the legal framework around CDR is developing rapidly. Fragmented governance across ministries (BMWE, BMUKN, BMELH) further complicates coordination and reduces implementation effectiveness.

Interviewed **ministries** were aware of the policies and commended the ambitious targets of the Federal Climate Action Act (KSG). Still, they see a lack of measures to achieve long-term emission reductions by 2045 and regret the insufficient political priority given to climate change in the coalition agreement. A noted risk is that fossil CCS technologies may dominate the discussion, thereby hindering the development of more comprehensive and sustainable climate policy. More integration and cooperation among various political sectors and actors, including scientists, are required to implement effective and sustainable climate protection measures.

Knowledge institutions are well informed about Germany's climate policy and recognise its positive aspects, such as international agreements and frameworks that support emissions reductions and the inclusion of CDR in the coalition agreement. However, they emphasise significant challenges, including fragmented governance, land use conflicts, and insufficient public awareness and engagement. Addressing these issues through better communication and integrated policies is crucial for the effective deployment and acceptance of CDR methods in Germany.

Industry and civil society organisations viewed the current policy as having significant potential to support climate goals through various methods, including CDR. They stressed the importance of prioritising emissions reductions and implementing substantial decarbonisation efforts rather than relying solely on certificate trading. Additionally, they emphasised the necessity for clear policies,

supportive conditions, improved communication strategies, and coordinated efforts to develop and implement effective CDR solutions. Civil society organisations viewed Germany's current climate policy and actions to achieve its climate goal more negatively, emphasising that both the ambition levels and the actions to match them are insufficient. Overall, these groups see the need for more robust frameworks to fully leverage Germany's climate policy potential.

6.2.2 Awareness and knowledge of CDR and the different methods

The interviewed stakeholders were generally familiar with CDR methods, but ocean-based approaches - DOCCS, blue carbon, and biomass sinking - were less well-known, except among knowledge institutions specialised in ocean CDR.

The interviewed **ministries highlighted nature-based methods**, such as afforestation, reforestation, and peatland rewetting, as the most familiar and promising, due to their co-benefits and cost-efficiency. However, novel solutions such as DACCS and BECCS, despite unresolved storage and transport issues, were considered important because they can provide permanent CO₂ storage. In addition to ocean-based methods, ministry actors were largely unaware of enhanced rock weathering and CO₂ mineralisation and were unable to provide insights into their deployability.

Among the interviewed **industry organisations**, the best-known CDR method was DACCS, whereas the less well-known were enhanced rock weathering and various ocean CDR methods. For Germany, forest management, peatland rewetting, and BECCS were identified as particularly relevant, with their implementation dependent on legal and economic frameworks.

Civil society organisations were generally aware of CDR methods but less familiar with novel ones, such as DACCS and BECCS, and with marine approaches, such as ocean alkalisation, due to uncertainties and complexities surrounding their implementation and impacts. They emphasised prioritising natural sinks (forests and ecosystems) and developing technical sinks with clear regulatory frameworks and target definitions. Additionally, they noted that harnessing agriculture, forestry, and circular-economy practices will be crucial for reducing and sequestering CO₂.

Interviewed Knowledge institutions had varying levels of knowledge and understanding of the methods based on what their specific focus was, and

What is your level of understanding of how methods work (technically)?

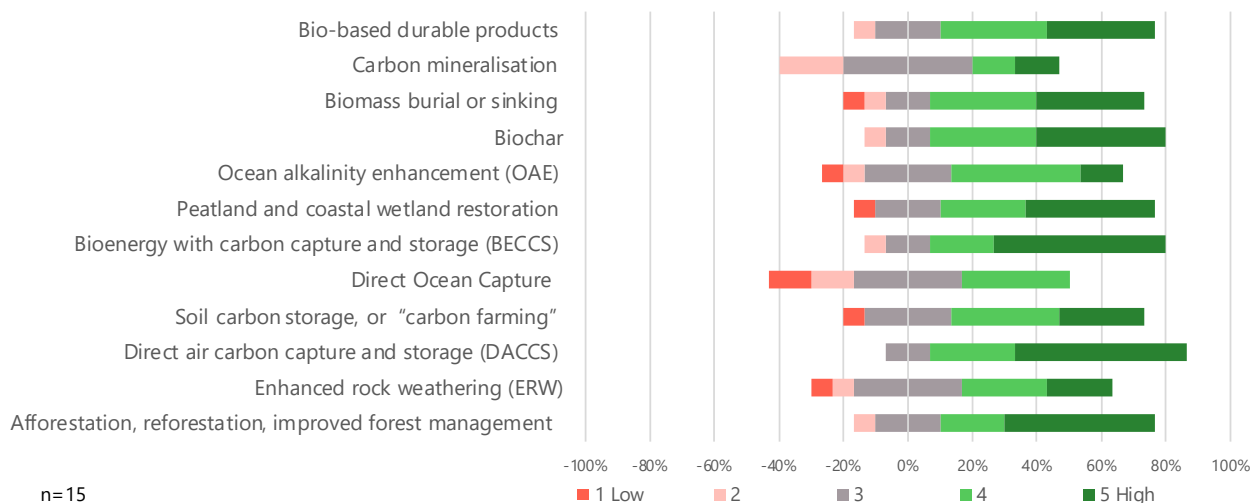


Figure 19. How well the interviewed stakeholders knew the various methods. Generally, all methods were relatively well known.

thus, it cannot be generalised that some methods would be lesser known than others. Generally, the interviewees were less familiar with DOCCS and carbon mineralisation, while afforestation and peatland protection were considered particularly relevant for Germany due to their ecological benefits and ease of integration into existing landscapes. DACCS and BECCS were noted as potentially significant contributors to the CDR portfolio.

Based on all the interviews, the following sentiment can be provided about each method covered in the interviews:

Direct Air Capture (DACCS) was seen by some as a wild card that could be a scalable, permanent solution, yet its high energy demands and costs invoked scepticism. Many recognised its current political favouritism, and the potential for DACCS was seen as high. Infrastructure needs, high electricity demand, high costs, and societal resistance were repeatedly noted as barriers to DACCS. Overall, stakeholders across all groups rated DACCS as highly promising, although the current deployment and capacity to deploy were considered limited.

Bioenergy with Carbon Capture and Storage (BECCS) was generally viewed positively in the interviews for its technical feasibility and cost-effectiveness, with dual benefits in energy production and CO₂ removal. While the potential for BECCS was considered high, challenges, including biomass availability, land-use conflicts, and limited CO₂ storage infrastructure, were noted that could

significantly hinder deployment, fuelling ongoing societal debate.

Biochar garnered favourable opinions for its cost-effectiveness, flexibility, and potential for decentralised deployment and soil improvement. However, competition for biomass and the uncertain permanence of sequestration were noted as concerns.

Enhanced rock weathering was seen as a cautiously optimistic, promising yet under-researched method. It was considered viable in Germany due to the availability of mineral resources and low resource conflict. Slow reaction rates and a need for further research were recognised challenges.

Marine CDR Methods, while theoretically potent (e.g., ocean alkalinity enhancement), were identified by most interviewees as the least familiar, and many expressed doubts about them. The methods were reported to face substantial legal restrictions and developmental barriers in Germany, although regulatory changes to enhance the deployability of marine-based CDR were expected in the near future. It was also noted that Germany is conducting studies on these methods that could alter their deployment.

Peatland restoration received strong support for its immediate actionability and potential to mitigate a share of Germany's emissions from drained peatlands, although its capacity for long-term CDR remains limited and slow to materialise. Key challenges mentioned included land ownership,

What is your appreciation of the relative balance between the benefits and potential risks/negative impacts of the method?

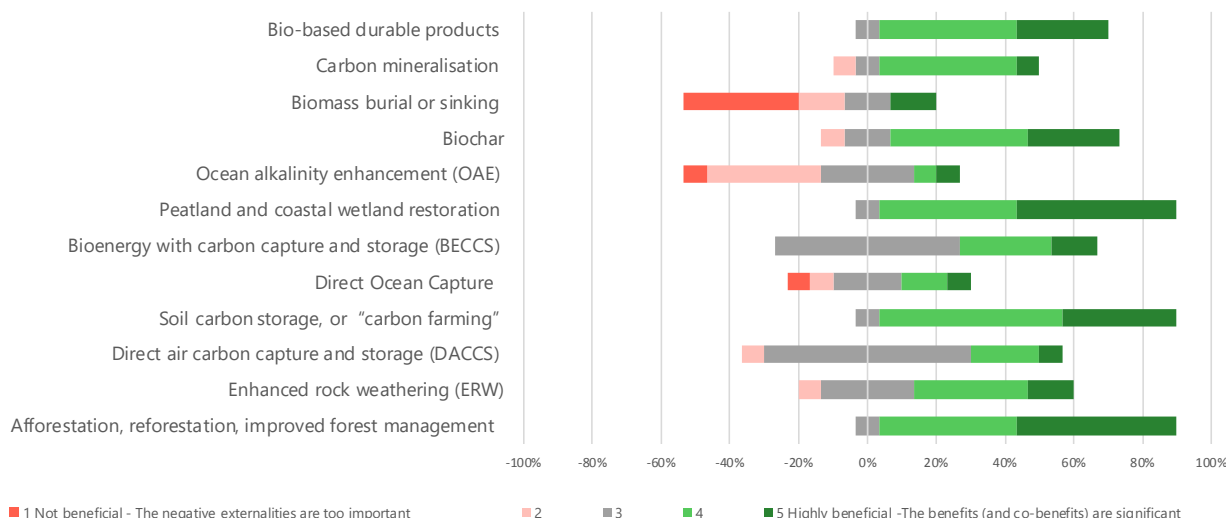


Figure 20. What the interviewed stakeholders thought about the impacts of the various methods.

water availability, and lengthy implementation timelines.

Forest Management & Afforestation evoked mixed views. Despite recognised co-benefits and public acceptance, concerns about climate stress, such as the recent forest fires and other forest losses that have become irreversible, have been repeatedly noted, with recent inventories suggesting that forests in Germany may currently emit rather than absorb CO₂. However, enhanced forest management and afforestation were the most familiar methods among all interviewees, and most considered them essential.

Carbon Farming views were strongly positive, with significant co-benefits anticipated, including biodiversity enhancement, improved soil health, and climate resilience. However, its slow impact and MRV challenges were considered barriers that needed to be addressed.

6.2.3 Views on CDR deployment in Germany and its use to fight climate change

The interviewed stakeholders identified several barriers to deploying CDR in Germany, noting that it remains a rapidly evolving field, with current obstacles being actively addressed through policy incentives as of spring 2025. At the time of the interviews, legal uncertainty and insufficient infrastructure were highlighted as major concerns, potentially limiting investment and large-scale deployment. The distinction between CDR and emission reductions was noted not as a barrier in

itself, but as a complicating factor if the broader public fails to grasp the difference. Compared to CCU and CCS, which benefit from longer histories and greater economic activity, making a compelling case for CDR was considered more challenging.

This can increase societal scepticism about the effectiveness and safety of CDR methods. Interviewed civil society actors and ministries noted that this necessitates improved communication and public engagement regarding what CDR is.

Generally, the most prominent factor noted by interviewees across ministries, industry, civil society, and knowledge institutions as causing societal resistance to CDR is the energy intensity of certain technical methods, such as BECCS, DACCS, and biochar. In addition to energy-related questions, concerns were raised about the environmental impacts of ocean alkalisation and artificial upwelling, given the limited research on their long-term effects.

Methods such as BECCS and DACCS may face resistance due to uncertainties and limited knowledge. Both methods are highly debated in Germany for various reasons. Additionally, land-use questions and biodiversity issues were identified as key areas to monitor when deciding to scale up CDR activities closely. Clear communication, thorough research, robust regulatory frameworks, procedural fairness, and public engagement were noted as essential to address these concerns and gain public acceptance. Storing CO₂, especially in geological formations on land or at sea, was noted as an important topic that requires much more attention to ensure that DACCS or BECCS can be

viable ways to combat climate change. According to the interviewees, no viable business case exists for CDR in Germany at present, with deployment relying heavily on public subsidies, tax incentives, and voluntary commitments. This was noted as one of the key barriers to deployment, since the economic situation in Germany and, more widely, in Europe is tight. Thus, public funding for initiatives like CDR is lacking. Integration into the EU Emissions Trading System (EU ETS) was debated in some interviews. Those interviewed stakeholders who brought ETS up saw it both as a potentially advancing mechanism for CDR, but also voiced concerns over additionality, permanence, and double counting.

Some interviews also highlighted several instruments to support CDR, including:

- Carbon pricing: for example, WWF recommends €180 per ton of CO₂.
- Contracts for Difference (CfD) providing financial stability and incentives for CDR projects.
- Biodiversity-linked payments rewarding projects that deliver both carbon removal and biodiversity benefits.
- Consumer labelling of CDR-enhanced products enabling informed choices and potentially driving market demand.

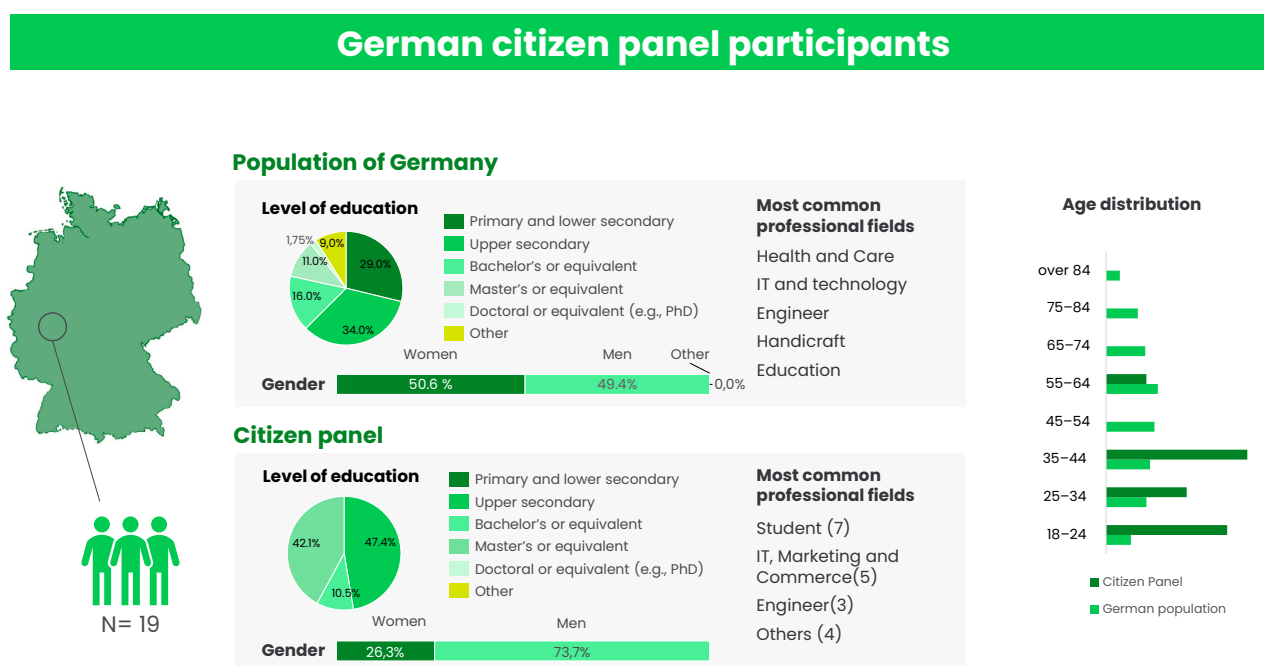
6.2.4 Conclusions on the stakeholder interviews

Interviewees share the sentiment that CDR is not a substitute for emissions reduction but a necessary complement to Germany's climate policy. Germany's leadership in climate science and engineering gives it a unique opportunity to shape a credible, equitable, and scalable CDR pathway. However, there is a shared concern that political ambition, regulatory clarity, and public awareness are currently insufficient to unlock the full potential of CDR methods. Interviewees agree that unlocking their potential requires legal reform, infrastructure investment, market incentives, and public engagement.

Recommendations emphasise the need to finalise a national CDR strategy and pursue legal reforms to create a supportive regulatory environment. Stakeholders advocate for a multi-method approach tailored to regional contexts and stress the alignment of research with regulatory needs, proposing the establishment of expert advisory boards. Importantly, CDR is viewed as a complement to emissions reduction efforts, not a substitute, underscoring the need for a holistic climate strategy.

6.3 Citizen panel

The German citizen panel was held in June 2025 in Cologne, with 19 participants from varying backgrounds (see Figure 21).



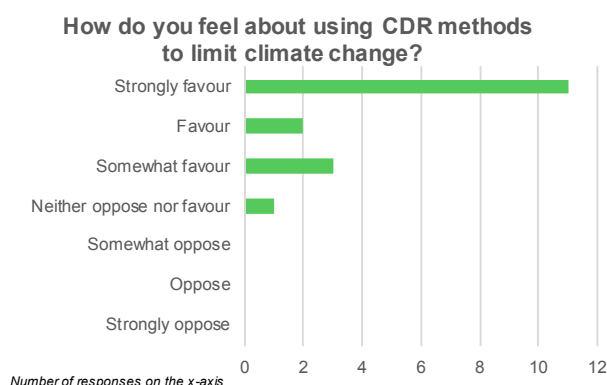


Figure 22. Answers of the citizen panel participants in the pre-survey question "How do you feel about using CDR methods to limit climate change?"

The citizen panel results closely align with the findings from the stakeholder interviews. However, the composition of the German citizen panel did not reflect a representative sample of the broader population and, therefore, cannot be considered indicative of national sentiment; instead, it should be viewed as a singular qualitative data point from a group discussion and not statistically significant.

Before the panel, participants received one-page summaries outlining each CDR method, including their advantages and drawbacks, as well as the broader context of CDR, including its definition and relevance. This material was provided in both written and webinar formats, which could be either attended live or viewed later as an on-demand recording. Participants completed a pre-panel survey capturing their initial views on the methods; the graphs presented in this chapter are based on those responses. The three-hour live panel featured small-group discussions followed by a plenary session. Citizen panel participants were encouraged to share their perspectives openly and request additional information as needed. The dialogue was structured method-by-method, beginning with perceived benefits and concerns, and culminating in a synthesis of preferred CDR approaches for Germany.

6.3.1 Awareness and views of citizen panel participants on the existing climate policy and CDR methods

The survey results reveal significant general awareness of various CDR methods and their importance in tackling climate change. Participants demonstrate a comprehensive understanding that climate change requires a multifaceted approach

How important do you think climate action is, meaning all efforts to reduce the warming of the planet?

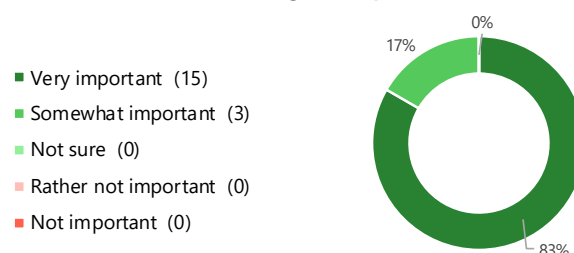


Figure 23. Answers of citizen panel participants to the pre-survey question: "How important do you think climate action is, meaning all efforts to reduce the warming of the planet?"

combining diverse CDR strategies. It became clear that many stakeholders expanded their knowledge during the survey process. It must be mentioned that, since the panel was formed by self-selection, it can be estimated that the panellists may have been more in tune with climate issues than the average German.

Panellists generally acknowledged Germany's ambitious climate targets, including the goal of substantially reducing GHG emissions and achieving climate neutrality by 2045. Nonetheless, panellists also pointed out significant failures, especially in meeting interim targets and dealing with sectors resistant to change. There was a perception that while some advances have been made, they are not enough to meet the overarching climate goals. They recognised the urgency of implementing effective measures to meet these targets and the necessity of a comprehensive approach that could also involve multiple CDR methods, whilst maintaining a focus on reducing emissions.

Regarding policy incentives, the panellists reached consensus that climate action should be based on fairness. Participants preferred a mix of funding through CO₂-intensive companies, publicly financed services via CO₂ taxes, and contributions from high-income countries to support the implementation of CDR technologies in lower-income nations. Some participants appreciate the existing incentives for renewable energy development, such as subsidies for solar and wind power, as well as initiatives to promote energy efficiency in buildings and industries. These incentives were viewed positively for catalysing growth in the renewables and reducing reliance on fossil fuels.

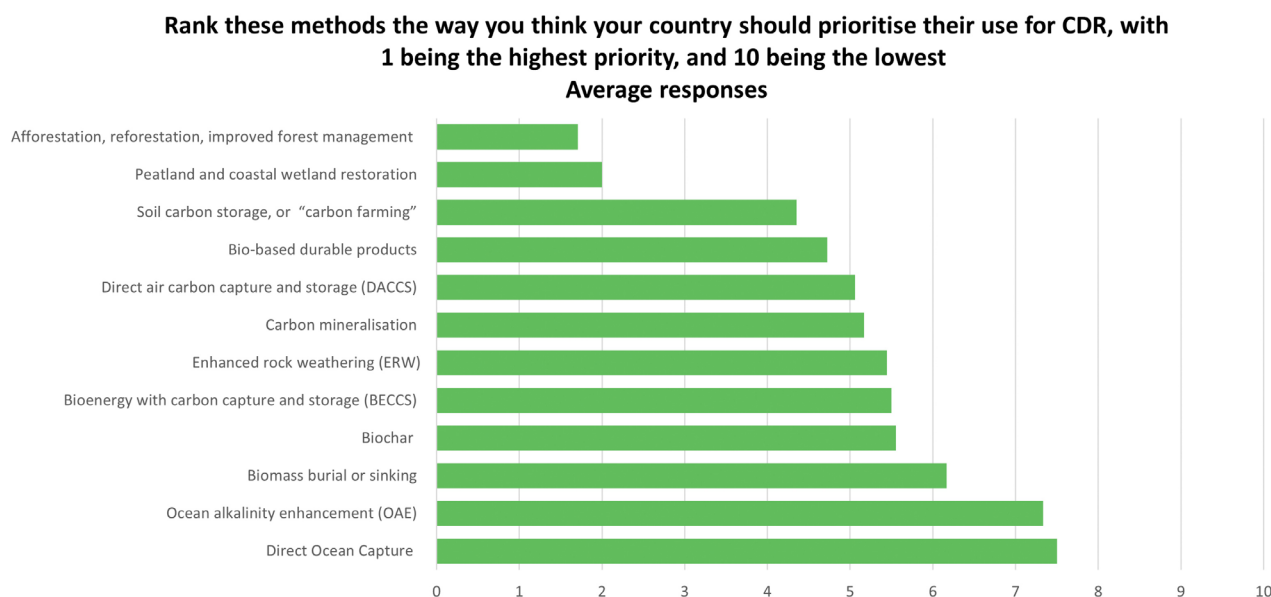


Figure 24. Preferred combination of CDR methods based on the responses of citizen panel participants to the pre-survey.

However, significant criticisms were raised on the adequacy and implementation of these policies. Questions were raised regarding the effectiveness of current incentives, with concerns that they may not be sufficiently effective or widespread to drive the necessary large-scale changes. It was noted that certain policies may be overly bureaucratic, complicating access to benefits for smaller entities and individuals, thus limiting broader participation. Failures were identified in insufficient support for innovative technologies such as DACCS and carbon farming, which were seen as vital to meeting long-term climate goals. There was an emphasised need for transparent, stringent monitoring to prevent greenwashing and ensure the genuine sustainability of practices such as afforestation and biochar use. Some panellists retained their scepticism about the true environmental benefits of CDR methods, but agreed that with rigorous standards and regulations, CDR could be a viable part of Germany's climate action.

The citizen panel discussions underscored the essential role of the government in both regulating and incentivising CDR and other climate initiatives. Participants called for a balanced approach in which emission reductions remain a fundamental priority, complemented by effective CDR strategies. There was a shared belief that climate policy should be inclusive, ensuring all societal sectors can contribute to the common goal, and adaptive, integrating emerging solutions promptly and efficiently.

The responses collectively indicate that Germany's climate policy requires comprehensive evolution,

building on the variety of available methods and involving all stakeholders to ensure sustainable and effective climate protection.

6.3.2 Awareness and knowledge of CDR and the different methods

The panellists emphasised that they generally lack knowledge of CDR and especially of technical CDR methods. Nature-based CDR methods were more familiar with the participants than technical ones.

Survey results and citizen panel discussions revealed varied levels of awareness and understanding about CDR methods. The differences in understanding transferred into general support or distrust in the methods. These insights highlight both well-known techniques and those that remain obscure or misunderstood.

Most preferred CDR methods:

- **Afforestation, reforestation, and improved forest management:** citizen panel participants were generally highly familiar with these methods before the live discussion and recognised their importance for carbon sequestration, biodiversity enhancement, and temperature regulation. These methods were widely supported due to their multiple environmental benefits. However, concerns about potential greenwashing and the necessity for rigorous standards to prevent monoculture practices were prevalent in small group discussions and in the panel discussion.

• **Soil carbon storage / carbon farming:**

awareness of these methods among participants was moderate. While many were familiar with the concept, fewer grasped the technical details. The methods were generally viewed positively for co-benefits to agricultural practices and soil health, yet scepticism persisted over monitoring challenges and scalability, underscoring the need for robust and transparent verification systems. Concerns were also raised about the financial implications for farmers, with calls for support mechanisms help farmers adopt carbon farming.

- **Biochar:** knowledge of biochar was moderate to high. Citizen panel participants acknowledged its benefits for soil improvement and carbon sequestration, yet some noted lack of understanding of how biochar impacts soil. Concerns about resource competition for biomass and potential misuse and even greenwashing in the discussion highlighted the need for balanced implementation strategies.

- **Direct Air Capture and Storage (DACCS):** panellists were moderately to highly familiar with DACCS, reflecting stronger engagement with climate policy and technology than the general German population. They viewed the method favourably for its scalability and large CO₂ removal potential, though concerns arose over energy use, water demands, logistical hurdles, and costs. Despite these issues, participants showed readiness to engage with recent DACCS advancements.

- **Carbon Mineralisation:** participants had moderate awareness of carbon mineralisation. The method was viewed favourably for its permanent CO₂ storage capability, with calls for more research to ensure its efficiency and applicability.

- **Peatland and Coastal Wetland Restoration:** participants exhibited moderate to high awareness these methods, which were praised for their co-benefits, including biodiversity enhancement and ecosystem restoration. However, the potential for land-use competition necessitates strategic planning to ensure balanced implementation.

Least preferred CDR methods:

- **Bioenergy with Carbon Capture and Storage (BECCS):**

panellists were moderately familiar with BECCS and expressed mixed views. While seen as sensible in combination with other methods, concerns centred on high costs and significant energy demands. Technological complexity and potential negative environmental impacts were mentioned in all small groups. This scepticism mirrors broader societal discussion on BECCS in Germany.

- **Enhanced Rock Weathering (ERW):**

panellists had low to moderate awareness of ERW and felt unable to judge its suitability in Germany. Still, they saw it as a promising method – especially when leveraging industrial byproducts – while noting technical demands, high transport costs, and potential environmental risks. They stressed the need for thorough evaluation before large-scale deployment, particularly regarding air quality, heavy metal accumulation, and soil salinisation.

- **Ocean Alkalinity Enhancement (OAE):**

panellists had low to moderate awareness of OAE and met the method with scepticism, largely due to uncertainties around its effectiveness, the scale of mineral inputs required, and potential ecological impacts. Some participants acknowledged that their reservations stemmed from limited understanding and suggested that clearer information on how OAE affects marine environments might shift their perspectives.

- **Biomass Sinking and Burial:**

panellists had low to moderate awareness of this method, and they generally perceived it negatively due to concerns about sustainability, resource competition, and CO₂ resurfacing risk. Some of these concerns were debunked during the small group discussions and some changed their views on the method from negative to neutral. Overall, the panellists felt that further investigation into its long-term viability and environmental impacts would be needed before being comfortable with either sinking or burial methods.

Did the information provided on the CDR methods change your perception towards any of them?

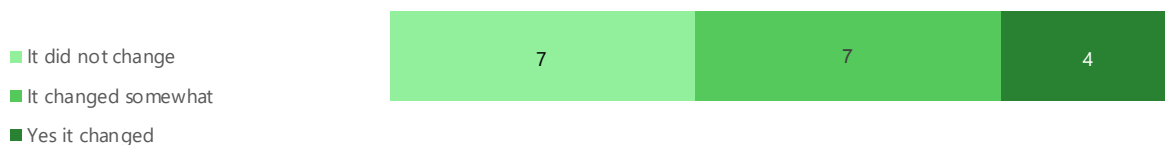


Figure 25. Answers of citizen panel participants to the pre-survey question "Did the information provided on the CDR methods change your perception towards any of them?" Number of responses.

- **Durable biobased products:** participants demonstrated moderate awareness of this method, especially within industries related to construction and manufacturing. They recognised the potential of embedding carbon in products but questioned storage durability, certification, and market mechanisms. Concerns over energy intensity and costs of producing carbon-based materials highlighted the need for transparent standards and supportive policies.
- **Direct Ocean Capture (DOCCS):** participants showed mixed awareness and views on DOCCS. They supported its potential, especially with integration of renewable energy, but questioned the current level of research and the unknown impacts on the ocean. The complexity of marine ecosystems and questions around the cost-benefit ratio emerged as key points of contention, highlighting the need for comprehensive research and cautious, evidence-based evaluation.

Overall, insights from the pre-panel survey and live discussions - both in small groups and plenary - indicate that panellists tended to favour carbon removal methods they were already familiar with over more novel approaches. Nature-based methods emerged as the most preferred, reflecting their perceived co-benefits and accessibility. However, DACCS was also frequently mentioned as a preferred option, likely influenced by its prominent role in public discourse in Germany during the spring and summer of 2025.

6.3.3 Views on CDR deployment in Germany and its use to fight climate change

The German citizen panel participants generally favoured the deployment of CDR methods to combat climate change and recognised many of the proposed methods as possible additions to the national climate policy alongside emission reduction strategies, even though most participants highlighted that their lack of deep understanding of how the methods work hindered their capacity to fully evaluate them. The most prominent positive and negative views about CDR deployment can be categorised as follows:

Positive Views:

1. **Support for Implementation:** the participants had strong consensus that CDR methods need to be implemented quickly to address Germany's climate targets effectively as the current actions were seen insufficient. Participants emphasised the urgency of combining various CDR methods to enhance their cumulative impact on carbon reduction and were unable to pinpoint any one CDR method that should be preferred over others.
2. **Integration with renewable energy:** methods such as DACCS and BECCS were supported when powered by renewable energy sources but concerns about the availability of energy was brought up.
3. **Support for natural methods:** natural methods like afforestation, peatland restoration, and carbon farming received widespread approval due to their positive co-benefits like biodiversity enhancement and ecosystem services. These techniques were preferred for their immediate applicability and potential for long-term CO₂ storage and due to them being most familiar topics to all participants.

Concerns and Challenges:

- 1. Cost and energy consumption:** high costs and energy demands, particularly for methods like DACCS and BECCS, raised concerns about feasibility and scalability of those methods. There was apprehension about the potential need for extensive infrastructure and the associated risks, such as CO₂ leakage during transport and storage among the participants.
- 2. Regulatory and monitoring needs:** panellists stressed the importance of strict regulations and monitoring to prevent misuse and ensure genuine sustainability. Many saw that CDR can cause biodiversity and climate issues elsewhere, if the activities are not fully analysed. Effective oversight by government bodies was deemed necessary to mitigate risks like greenwashing, particularly in afforestation and biochar and CO₂ based products.
- 3. Potential land use conflicts:** methods involving significant land use, such as enhanced rock weathering and biomass sinking, were viewed with caution due to potential conflicts with agricultural land and energy production. Balancing land use for CDR and other essential activities remained a critical concern throughout the discussion.

The citizen panellist discussed also ways to enhance deployment of CDR methods in Germany and what kinds of policy actions they would like to see happen. While the panellist noted that they don't have adequate understanding of policy measures, some had more views on suggestions on policy interventions than others:

- 1. Taxation and Funding Mechanisms:** a popular view is that CO₂-intensive companies should be taxed based on emissions to fund CDR infrastructure and incentivise technology deployment. Government-driven initiatives, supported by private partnership and transparent funding models, were advocated to ensure equitable and effective implementation.
- 2. Incentives for Diverse Approaches:** panellists called for a mix of incentives to promote both high-tech methods and accessible, low-tech solutions. Policies should encourage innovative CDR technologies while supporting traditional methods through subsidies and educational programs.

- 3. Holistic Approach to Climate Policy:** integrating CDR methods within broader climate policies, such as promoting a circular economy and reducing emissions, was seen as essential. Panellists emphasised the need for inclusive and adaptive strategies that encompass a wide range of solutions to address climate change comprehensively.

6.3.4 Conclusions on the citizen panel

In summary, German citizen panel participants demonstrated strong awareness of the various CDR methods and their importance in combating climate change. There was a general understanding that a multi-layered approach combining different CDR strategies with emissions reduction measures is needed.

While Germany's ambitious target of climate neutrality by 2045 was acknowledged, participants expressed concerns about delays in meeting interim goals and the uneven pace of progress across sectors. Participants highlighted the need for a comprehensive climate policy that offers fair and well-structured incentives while integrating both carbon removal and emissions reduction methods. Natural CDR approaches, such as afforestation and soil carbon storage, received positive evaluations, being seen as readily applicable and environmentally beneficial. In contrast, technical methods like DACCS and BECCS were viewed more critically due to their higher costs and energy demands.

Participants called for stronger regulation and oversight to prevent greenwashing and to ensure genuine sustainability of implemented practices. Overall, respondents emphasised that Germany's climate policy requires evolutionary adaptation, involving all sectors of society to ensure sustainable and effective climate protection.

7. Today's realistic potential to deploy CDR (Can do)

Building on the resources described in chapter 3 and the theoretical CDR potential outlined in chapter 4, this chapter revises assumptions around resource availability and selected CDR methods to incorporate stakeholder perspectives, public sentiment, and the legal and socio-economic considerations discussed in chapters 5 and 6. Based on this integrated analysis, we estimate the realistic potential – defined as the volumes of CDR that can be deployed with high confidence in the near future. Within this framework, multiple scenarios emerge, mainly shaped by Germany's level of ambition. This chapter examines those pathways in detail.

7.1 Background

To contextualise Germany's realistic CDR potential and the scenarios representing varying levels of ambition in CDR deployment, we consider (i) Germany's climate targets and (ii) the expected residual emissions gap that must be balanced by carbon dioxide removal (CDR). Germany aims to reduce GHG emissions by at least 65% relative to 1990 levels, achieve climate neutrality by 2045, and transition to net negative emissions thereafter. Between 2005 and 2023, Germany reduced its net emissions by 30.7%, slightly outperforming the EU average reduction of 30.5%.¹⁸³

In March 2025, the German Environment Agency (UBA) reported that Germany's emissions are declining and that the 2030 target of reducing emissions by 65% relative to 1990 levels remains achievable. At the same time, UBA warned that Germany risks missing its EU Effort Sharing Regulation (ESR) targets for 2021–2030, with a projected gap of 226 MtCO₂e. Longer-term projections indicate that current measures would deliver approximately an 80% reduction by 2040 relative to 1990 levels, implying that additional measures would be required to align all sectors with the 2045 climate-neutrality target.¹⁸⁴

Climate-neutrality studies for Germany estimate residual emissions in 2045 in the range of 45–80 MtCO₂e, which would need to be counterbalanced by CDR to achieve net-zero.¹⁸⁵ By contrast, based on UBA's 2025 GHG projections under currently adopted policies and measures, Germany is expected to emit around 204 MtCO₂e in 2045 (excluding LULUCF); the LULUCF balance in that projection is expected to be around +37 MtCO₂e. The Agora Energiewende study *Klimaneutrales Deutschland*

2045 (updated 2024) provides a detailed roadmap for achieving climate neutrality by 2045 and projects 58 MtCO₂e of residual GHG emissions in 2045 in its KN2045 scenario. While the Agora study illustrates what is technically and economically feasible with ambitious climate action, the contrast with current-policy projections highlights the scale of Germany's carbon removal challenge and the need to rapidly scale CDR capacity. **This assessment, therefore, benchmarks realistic CDR potential against a residual emissions gap of 45–80 MtCO₂e in 2045.**

7.2. Methodology for the realistic CDR potential

The calculation of the realistic CDR potential in Germany employed the same methodology as that used for the theoretical potential presented in Chapter 4. However, it incorporates additional constraints, including the regulatory and economic contexts, as well as public support. The assessment of public support is based on the views gathered through the stakeholder interviews and the citizen panel described in Chapter 6.

The estimated resource availability for CDR under realistic potential is more conservative than that in the theoretical assessment presented in Chapter 4. While the theoretical potential assumes that all available resources are allocated to CDR, the realistic potential accounts for competing demands and constraints, resulting in lower projected CDR volumes. These more cautious estimates are based on the following considerations:

- **Techno-economic feasibility:** in addition to physical constraints, resource use was evaluated in terms of what is reasonably feasible from a techno-economic perspective – particularly for resources that are contested among multiple CDR methods. However, macroeconomic variables such as GDP growth, cost levels, interest rates, and existing financial support mechanisms were not included as dynamic inputs.
- **Technological deployment:** the pace and scope of technology rollout were adjusted to reflect realistic expectations. For example, adoption rates for technologies such as BECCS and DACCS were estimated for 2035 and 2045 based on plausible deployment trajectories.
- **Legislative constraints:** legal limitations were incorporated where they clearly and significantly limit the availability of certain resources.

- Social acceptance was assessed through public support, as determined by input from stakeholder interviews and results from the citizen panel.

7.3 Realistic CDR potential scenarios

Three scenarios were developed to illustrate different pathways to CDR deployment in Germany:

- **Scenario A:** a low ambition CDR scenario,
- **Scenario B:** a high ambition CDR energy efficient scenario,
- **Scenario C:** a high ambition CDR policy-preferred scenario (reduced-BECCS).

All scenarios were modelled for 2035 and 2045, aligned with Germany's climate targets. They outline different carbon removal pathways informed by the number of resources allocated to carbon removal. Ambition levels vary mainly in the availability of clean electricity drawing from Fraunhofer's electricity scenarios,¹⁸⁶ the use of wood-based biomass derived from the Thünen's WEHAM forest scenarios,¹⁸⁷ and on the natural sink estimates based on BioNET. Other resource availability for carbon removal and CDR deployment were assessed using collected data, detailed in section 7.4.

Scenario A reflects a context in which limited efforts are made to deploy CDR, with resources largely directed toward non-CDR purposes or only partially available for carbon removal. Availability of electricity was modelled based on the estimations from Fraunhofer's 'Persistence' scenario, as described in section 3.1.2 (Box 1). For availability and use of wood-based biomass, **Scenario A** draws on Thünen's WEHAM-BAU scenario, which assumes forest management will continue mostly unchanged, and on BioNET for the natural sink estimates. (see section 3.3.1, Box 2 for more details). For other resources a very conservative availability for CDR was estimated considering what is technically, economically and socially possible.

Scenario B and **Scenario C**, both reflect a higher ambition context in which significant and deliberate efforts are made to deploy CDR. The clean electricity available is based on Fraunhofer's 'Technology open' scenario, which assumes a cost-optimal pathway to achieve climate neutrality by 2045, allowing broad flexibility in technology choices without considering additional, fixed boundary limitations (section 3.1.2 for details). The availability and use of wood-based biomass are derived from Thünen's WEHAM

Nature-Preference Scenario (NPS), which promotes forest biodiversity and prioritises improved forest management, protected areas, and usage limits – reducing harvest volumes and wood biomass potential compared to WEHAM BAU but enhancing natural carbon sinks (see section 3.3.1, Box 2 for more details). The natural sink estimates are based on BioNET also in **Scenario B** and **C**. Despite lower wood-based biomass availability in the WEHAM NPS scenario, it is assumed that a larger share of existing resources is prioritised for CDR compared to Scenario A. For other resources we have assumed greater availability for CDR compared to Scenario A, within technical, economic and social feasibility (see details in section 7.4).

For all scenarios, the performance of the natural sink (mostly forests) was first based on the WEHAM scenarios but then reduced to more conservative levels in line with the more recent BioNET scenarios. Indeed, WEHAM are based on data that do not account for the large reduction of the forest sink after 2018. As a result, in all scenarios the natural sink was capped at ~16 MtCO₂/year in 2035. For 2045, the projection of the BioNET scenario (~32 MtCO₂/year) was used as a basis and **scenario C** goes slightly beyond given the reduced levels of BECCS and associated lower demand for biomass. The BioNET projections rely on "set-aside" translating into volumes of biomass not entering the market (approximately 2.5 Mt of dry biomass). In all three scenarios, the amounts of biomass unused due to the limitations on geologic storage exceeded the volumes restricted by set-asides, confirming the viability for implementing them.

Scenarios B and **C** share the same underlying assumptions regarding resource availability for CDR, except for wood biomass. They also differ in how CO₂ storage capacity is allocated between BECCS and DACCS. **Scenario B**: ("energy-efficiency focused") prioritises storage capacity for BECCS, given its superior energy efficiency compared to DACCS. In contrast, **Scenario C** ("reduced-BECCS") reflects a context where political constraints limit biomass utilisation, resulting in the majority of CO₂ storage capacity being allocated to DACCS instead. Because less biomass is needed for CDR, it is assumed that half of the unused biomass for CDR is used for non-CDR material uses and half is translated into lower forest harvests.

The resource scenarios – Fraunhofer's energy scenario and WEHAM scenarios for forest-based biomass – that were the basis for the CDR scenarios diverge on how the energy wood and its usage is expected to develop. The 'Technology open' energy scenario used for **Scenarios B** and **C** assumes

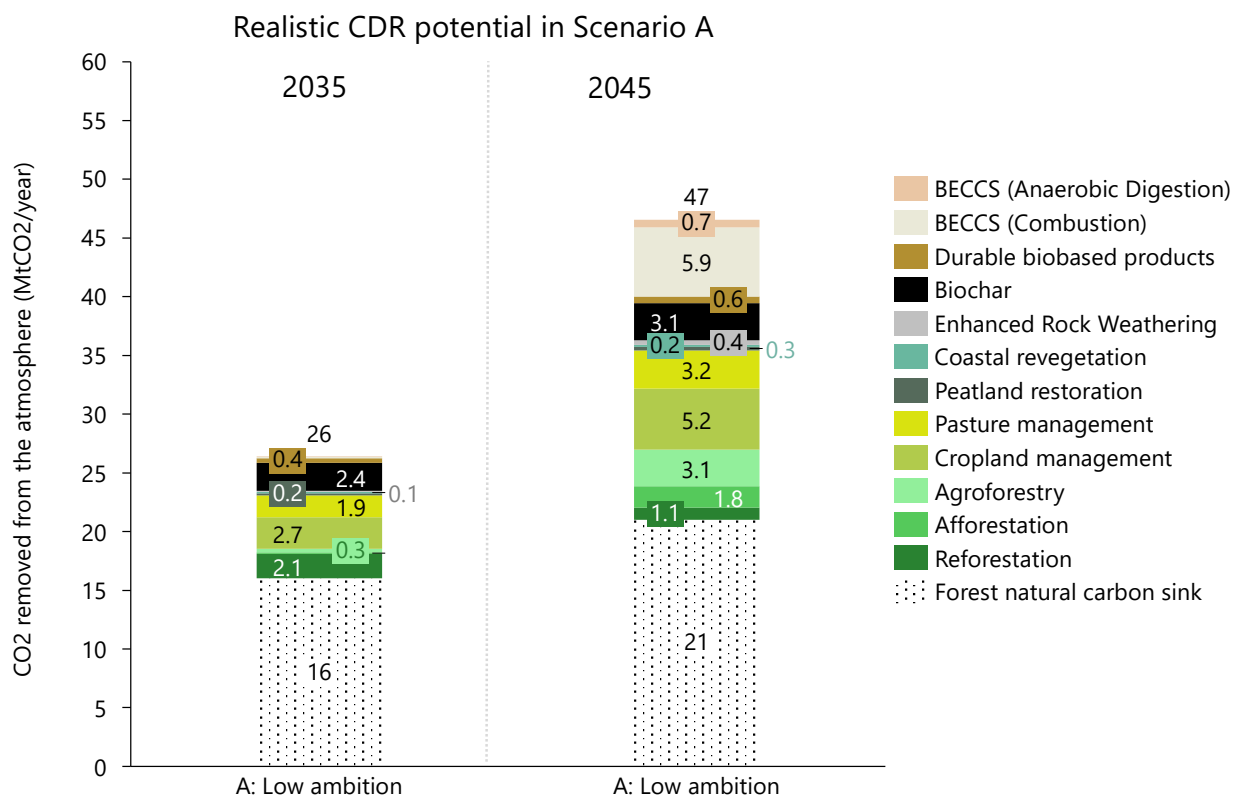


Figure 26. CDR potential in Scenario A: Low ambition in 2035 and 2045.

that use of energy wood will decrease drastically, whereas the WEHAM scenarios don't indicate a clear decreasing trend. Thus, in **Scenario C** it was assumed that the use of energy wood would decrease beyond the WEHAM scenarios. It was assumed that reduced energy wood demand leads to partially reduced harvesting levels and partially more material use of wood – while there is still enough electricity for CDR.

7.3.1 Scenario A: low ambition

In scenario A the annual CDR potential (excl. natural sink) for Germany is ~10 MtCO₂ in 2035 and ~26 MtCO₂ in 2045. Adding the capacity of the projected natural sink (which also includes improved forest management), Germany could remove ~26 MtCO₂ in 2035 and ~47 MtCO₂ in 2045. The potential of each CDR method is summarised in Figure 26.

The natural carbon sinks in forests, which are influenced by both harvesting levels and different forest management practices, constitute a major part of the carbon sequestration potential in Scenario A with ~16 MtCO₂ in 2035 based on BioNET scenario, and ~21 MtCO₂ in 2045, below BioNET and aligned with WEHAM BAU scenario.¹⁸⁸ Additionally, reforestation could remove ~2 MtCO₂

in 2035 and ~1 MtCO₂ in 2045, while afforestation grows from ~0.1 MtCO₂ in 2035 to ~2 MtCO₂ in 2045. Afforestation potential is assumed to be limited due to its slow progress so far¹⁸⁹ and modest expectations for it,¹⁹⁰ whereas reforestation is supported by a national plan to implement EU nature restoration law.¹⁹¹ Peatland restoration contributes ~0.2 MtCO₂ in 2035 and ~0.3 MtCO₂ in 2045, assuming the current rewetting pace of 2 kha/year through 2035 and 2045. Coastal revegetation has very limited potential with ~0.1 MtCO₂ in 2035 and ~0.2 MtCO₂ in 2045.

The most significant carbon removal methods in **scenario A** in 2035 and 2045 are cropland and pasture management, with a combined potential of ~5 MtCO₂ in 2035 and more than ~8 MtCO₂ in 2045. Agroforestry holds limited potential in 2035 (~0.3 MtCO₂) reflecting its current modest deployment pace, but its potential is estimated to grow to ~3 MtCO₂ by 2045.

Amongst biomass conversion methods, biochar holds the most potential in **Scenario A**, deployed with ~2 MtCO₂ in 2035 and ~3 MtCO₂ in 2045. Durable bio-based products have a modest potential of ~0.4 MtCO₂ in 2035, rising to ~0.6 MtCO₂ in 2045. BECCS has potential in terms of biomass

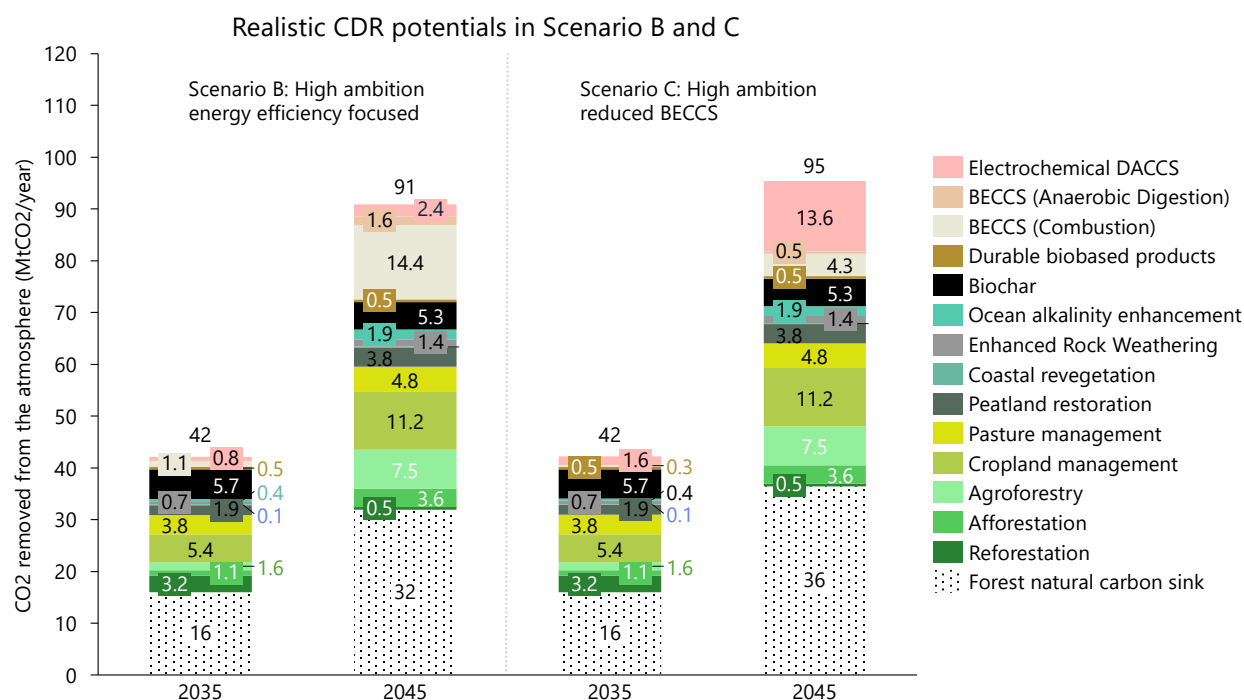


Figure 27. CDR potential for Scenario B: High ambition energy efficiency focused and Scenario C: High ambition Policy preferred for 2035 and 2045.

availability, but its role is constrained by CO₂ storage capacity, which is scarce and prioritised for CCS. BECCS with combustion contributes ~0.1 MtCO₂ in 2035 and ~5.9 MtCO₂ in 2045, while BECCS with anaerobic digestion is deployed with a smaller ~0.02 MtCO₂ in 2035 and ~0.7 MtCO₂ in 2045. To reflect feasibility, 90% of storage capacity for BECCS was allocated to combustion and 10% for anaerobic digestion, as wood combustion facilities are in general larger and more feasible for BECCS retrofits than smaller scattered biogas plants.¹⁹²

In **Scenario A**, ocean alkalinity enhancement is not deployed reflecting the results from the social geography analysis described in sections 6.2.2 and 6.3.2 which reported legal restrictions, developmental barriers, and overall scepticism towards this method also due to potential ecological risks. Enhanced rock weathering is deployed with ~0.07 MtCO₂ in 2035 rising to ~0.4 MtCO₂ in 2045. Although DACCS was included in the scenario, it ultimately had no deployment potential in Scenario A due to the optimal allocation of resources. The limited CO₂ storage capacity was prioritised for BECCS, given its higher energy efficiency relative to DACCS.

Scenario A can be considered realistic, as it is based on modest efforts on carbon removals, and for many methods – such as afforestation and agroforestry as an example – the potential follows the current

pace of deployment. Also, in this scenario, the potential is concentrated on nature-based methods, particularly cropland and pasture management and reforestation, which are cost-effective carbon removal methods. In the scenario the major uncertainty is related to the natural carbon sinks in forests, which is a significant contributor to the overall CDR potential. As forests have shifted from being a carbon sink to a carbon source, the scenario does include set-asides, as described in the BioNET scenario to meet the sink levels projected.

7.3.2 Scenario B & C: High ambition – energy-efficiency focused & policy-preferred

In **Scenario B** the CDR potential for Germany is ~26 MtCO₂ in 2035 and ~59 MtCO₂ in 2045. If the natural carbon sink projections are considered, the CDR potential is ~42 MtCO₂ in 2035 and ~91 MtCO₂ in 2045. In Scenario C the CDR potential for Germany is ~26 MtCO₂ in 2035 and ~59 MtCO₂ in 2045. If the projections for the natural carbon sinks are also included, the potential for carbon removals are ~42 MtCO₂ in 2035 and ~95 MtCO₂ in 2045. The carbon removal capacities are summarised in Figure 27.

In both **Scenario B** and **C**, the natural carbon sink is a significant contributor to the total CDR potential, due to enhanced forest management practices and set asides. The forest natural carbon sink in **scenario B**

is ~16 MtCO₂ in 2035 and ~32 MtCO₂ in 2045, based on the BioNET scenario.¹⁹³ **Scenario C** depicts a situation in which less energy wood is available, leading partially to reduced harvesting levels. Thus, in **scenario C** the natural carbon sink is ~15 MtCO₂ in 2035 and ~36 MtCO₂ in 2045.

Otherwise, the potential of forest-related methods are the same in the **Scenarios B** and **C**. Reforestation is assumed to remove ~3 MtCO₂ in 2035, decreasing to ~0.5 MtCO₂ in 2045. Afforestation holds more potential compared to **Scenario A**, as its potential is ~1 MtCO₂ in 2035 and ~3 MtCO₂ in 2045. Peatland restoration also holds more potential than in **Scenario A**, contributing to ~2 MtCO₂ in 2035 and ~4 MtCO₂ in 2045. The rewetting rate for peatland restoration assumed in **Scenario B** and **C** is derived from The *Bund-Länder-Zielvereinbarung's* objectives (250 kha by 2035 and 500 kha by 2045), and the yearly rewetting area is assumed to be 25 kha both in 2035 and 2045. As peatland is gradually rewetted over the years, the amount of CDR through this method grows significantly by 2045. On the other hand, the potential of coastal revegetation remains minimal also in these scenarios (~0.1 MtCO₂ in 2035 and ~0.2 MtCO₂ in 2045).

Similarly to **Scenario A**, also in **Scenario B** and **C** the different agricultural land-use practices hold significant CDR potential. Cropland and pasture management are deployed with ~9 MtCO₂ in 2035 and ~16 MtCO₂ in 2045. Agroforestry is expected to sequester significantly more than in **Scenario A** (~2 MtCO₂ in 2035 and ~7 MtCO₂ in 2045), as a faster adoption rate is assumed.

In **Scenario B**: High ambition energy efficiency focused, biochar is estimated to remove ~6 MtCO₂ in 2035, declining to ~5 MtCO₂ in 2045, as biomass is increasingly directed to BECCS given the more available CO₂ storage. BECCS total potential rises from ~1 MtCO₂ in 2035 to ~16 MtCO₂ in 2045, ~14 MtCO₂ of which is through combustion reflecting the same prioritisation of BECCS storage as in **Scenario A**. DACCS is deployed in small amounts with ~0.8 MtCO₂ in 2035 and 2.4 MtCO₂ in 2045. Durable bio-based products hold ~0.5 MtCO₂ both in 2035 and 2045.

In **Scenario C**: High ambition, reduced BECCS the dominant biomass-based method is biochar, with the potential of ~6 MtCO₂ in 2030 and ~5 MtCO₂ in 2045 – the assumption for the declining amounts is the same as in **scenario B**. Total BECCS potential is significantly lower than Scenario B with ~0.4 MtCO₂ estimated for 2035, and ~5 MtCO₂ for 2045. Out of the total BECCS potential in 2045, ~4 MtCO₂ is

expected to be achieved with combustion, which is significantly less than in the **Scenario B**, due to policy preference for reducing the use of energy wood and the CO₂ storage capacity being prioritised for DACCS over BECCS. DACCS is therefore deployed in higher amounts, 1.6 MtCO₂ in 2035 and 13.6 MtCO₂ in 2045. Durable bio-based products hold the same modest potential as in the **Scenario B**, with ~0.5 MtCO₂ both in 2035 and 2045.

In both **scenarios B** and **C**, mineral ocean alkalinity enhancement is also limited by technological maturity and low public acceptance but still deployed to higher amounts than in **scenario A**, with ~0.4 MtCO₂ in 2035, and ~1.9 MtCO₂ in 2045. Enhanced rock weathering mostly leverages silicate rocks like basalt and contributes to the CDR potential with ~0.7 MtCO₂ in 2035 and ~1.4 MtCO₂ in 2045.

The most limiting resource is the CO₂ storage capacity, which requires determined and strong scale up by 2045. In **Scenario B**, most of the storage capacity was allocated to BECCS for its higher energy-efficiency compared to DACCS, while in **Scenario C** most of the capacity was allocated to DACCS, reflecting the conscious preference of using less wood-based biomass. Considering the challenges of Germany's land-use sector emissions, it is likely that **Scenario C** showcases a more likely pathway of synthetic removal methods.

Overall, **Scenarios B** and **C** depict a high ambition approach to deploying CDR, and the deployment of the assessed potential requires decisive actions in many industries. Considering that some of the methods – for example the geochemical ones – are today deployed in a very limited manner, some of the potential especially in the short term (i.e. by 2035) will be challenging to realise with the current rate of change in policy making for CDR.

7.4 Resource Allocation

Key assumptions on the resource amounts available for CDR are presented in Table 6, and the more detailed assumptions per resource and scenario are explained later in this chapter. For biomass, the assumptions are presented in Table 9 in section 7.4.2. The more detailed description and background for different resources can be found in Chapter 3.

Resource (unit)	Amount available for CDR	Key assumptions
Electricity (TWh)	2035: 2-7 2045: 16.6–46.7	In Scenario A, CDR electricity availability in 2035 and 2045 reflects DACCS reservations from the Fraunhofer's 'Persistence' scenario. In the more ambitious Scenarios B and C, surplus electricity is also allocated to CDR in addition to the DACCS reservations.
Thermal energy (TWh)	2035: 12.8-32 2045: 16–32	It was assumed that 5-50% of waste heat is available for CDR as currently low utilisation rate is unlikely to significantly increase quickly. The ambition level rises towards 2050 but as waste heat generation declines, the total availability is assumed to remain on the same level until 2045 (32 TWh in Scenario B and C).
Agricultural land (Mha)	2035: 1.6–3.3 2045: 3.2–6.4	Out of the total land areas, the assumed land availability was derived from current deployment rate of CDR and related methods.
Other land areas (kha)	2035: 200–400 2045: 270–390	Other land areas for afforestation and reforestation were identified through assessments of degraded areas suitable for reforestation and estimates of afforestation potential.
Areas for peatland restoration (kha)	2035: 20-250 2045: 40-500	The assumptions are based on the current rate of rewetting (for Scenario A), and the objectives of The <i>Bund-Länder-Zielvereinbarung</i> to rewet peatlands (for Scenarios B & C). ¹⁹⁴
Areas for coastal revegetation		Salt marshes and seagrass meadows in the North Sea are expected to remain stable due to protected areas. In the Baltic Sea, seagrass coverage and quality are assumed to increase to areas previously habited by seagrass through restoration efforts and improved marine conditions.
Mineral feedstock (Mt)	2035: 5-12 2045: 13–23	Basalt, limestone, and dolomite production is expected to decline due to lower demand. For realistic CDR estimates, it is assumed production stays constant, with the surplus redirected to carbon removal. Basalt is assumed to be used for ERW, while limestone and dolomite are used for OAE.
Storage capacity (Mt)	2035: 0.15-1.2 2045: 5.7–16	to-abate fossil CO ₂ emissions until 2045, leaving modest allocations for CDR. ¹⁹⁵ Export assumptions are based on known projects such as Porthos, Northern Lights, Greensand and Aramis. ¹⁹⁶

In Scenario A, **domestic** storage capacity is assumed to be 2 MtCO₂ in 2035, with 5% (0.1 Mt) available for CDR, after CCS allocation. In 2045, the capacity is assumed to be 20 Mt, with 25% (5 Mt) for CDR after allocation to CCS.

Export capacity for the European market is expected to be 5 MtCO₂ in 2035, of which Germany could claim 20% (1 Mt); after CCS allocation, 5% of that claimed amount, 0.05 MtCO₂ remain for CDR. By 2045 export capacity for the European market grows to 15 Mt, of which Germany is assumed to claim 20% (3 Mt). With the assumption that the allocation of that amount becomes more favourable to CDR with 25% of that amount, 0.75 MtCO₂ would be available for CDR after CCS.

Additionally, the potential for ex-situ **mineralisation** is assumed to grow from 0 in 2035 to 0.8MtCO₂ in 2045, leveraging a small share of the existing feedstocks of demolition concrete.

In Scenario B and C, **domestic** storage capacity is expected to be 3 MtCO₂ in 2035, with 15% (0.45 Mt) available for CDR, after CCS allocation. In 2045 the capacity rises to 20 Mt, with 50% (10 Mt) assumed to be available for CDR after CCS allocation.

Export capacity is projected at 12 MtCO₂ in 2035, with Germany claiming 40% of it (4.8 MtCO₂); after CCS allocation, 15% of that amount, 0.72 MtCO₂ is assumed available for CDR. By 2045, export capacity is expected to reach 30 Mt, of which Germany claims 40% (12 Mt). After CCS allocation, the assumed available capacity for CDR is 50% (6 Mt).

Finally, in these two scenarios, ex-situ **mineralisation** is assumed to deploy more quickly and to allow for an additional storage capacity of 2.2 MtCO₂ in 2035 and 6.6 MtCO₂ in 2045, leveraging 1% and 3% of the theoretical potential respectively.

Table 6. Key assumptions for allocating energy, land, mineral feedstocks, and CO₂ storage capacities.

Resource (unit)	2035			2045		
	A	B	C	A	B	C
Mineral feedstock						
Basalt	100%	100%	100%	100%	100%	100%
Limestone, dolomite,	0%	10%	10%	0%	30%	30%
Mineral construction waste	0%	20%	20%	20%	60%	60%
Biomass	17%	15%	16%	46%	50%	27%
Land						
Arable land	100%	100%	100%	100%	100%	100%
Unspecified land (afforestation, reforestation)	100%	100%	100%	100%	100%	100%
Energy						
Electrical energy	not material	not material	not material	not material	not material	23%
Thermal energy	31%	19%	23%	44%	28%	28%
CO₂ storage						
Domestic storage	100%	100%	100%	100%	100%	100%
Exports	100%	100%	100%	100%	100%	100%

Table 7. Share of available resources used for CDR methods in each scenario. All resources available for CDR are used at their maximum except biomass and energy, that are constrained by insufficient CO₂ storage capacity. The percentages refer to the share of resource used for CDR in the realistic scenarios out of the total resource available for CDR.

Although Table 6 presented the assumptions of the resource amounts available for CDR, not all these resources are needed if the resources are optimally allocated across different CDR methods and resource constraints are considered. For example, the applied allocation model assumes that DACCS methods needs both electricity and CO₂ storage. The storage is needed in larger extent than electricity and thus acts as the limiting resource. As a result, not all electricity available for DACCS is required. Table 7 shows the shares of resources used in the scenarios from those estimated to be available for CDR, as summarised in Table 6. These shares do not represent utilisation rates of the total resource amounts, which have been described in Chapter 3.

7.4.1 Allocation of energy resources

As described in section 3.1.2, the assessment of energy availability was based on scenarios published by the Fraunhofer institute. Electricity availability was assumed to correspond to the estimated DACCS reservation and, in scenarios with positive electricity balance, to surplus electricity in the balance, amounting to 2-7 TWh in 2035 and 16.6-46.7 TWh in 2050. In addition, in high ambition scenarios B and C, it was assumed that 10% of the PtX reservation was reallocated for CCS.

In the realistic scenarios, thermal energy availability for CDR was assumed to be limited to low grade

waste heat. Few suitable high-temperature heat sources exist for high-temperature DACCS, but since production is optimised to match demand (especially from industry), only low-grade waste heat is considered available for CDR. It was assumed that in 2035, 5-15% of the waste heat generated could be directed to CDR and in 2045 25-50% depending on the ambition level and assuming improvement in technical readiness level of utilising waste heat. The ambition level is increasing towards 2050 but as the generation of waste heat declines, the total availability is assumed to remain on the same level (32 TWh in both realistic scenarios with higher ambition level).

The results indicate that **neither electricity nor heat constitutes a limiting factor for CDR potential**. Instead, as mentioned above, a broader deployment of electricity- and heat-consuming CDR methods, namely DACCS, would require significant expansion of the available CO₂ storage capacity. As a result, not all projected energy resources available for CDR are consumed. In the resource allocation model applied, electricity consumption is considered only for DACCS (electricity required to deploy BECCS in combustion power plants is covered with additional biomass consumption). Thus, ~4% of the available electricity is consumed in Scenario B and about 23% in scenario C which sees significantly more DACCS deployed.

Land type and allocation	Scenario A		Scenarios B and C	
	2035	2045	2035	2045
Arable land for cropland and pasture management	1.6 Mha	3.2 Mha	3 Mha	5.6 Mha
Land allocated to agroforestry	2 kha	2 kha	25 kha	25 kha
Land for reforestation	200 kha	100 kha	300 kha	50 kha
Land for afforestation	10 kha	170 kha	100 kha	340 kha
Land for peatland restoration	2 kha	2 kha	25 kha	25 kha

Table 8. Summary of land available for CDR annually in the realistic scenarios.

7.4.2 Allocation of agricultural land and other land areas

To assess the availability of arable land for the realistic CDR potential, both projected development of agricultural areas and current deployment rates of CDR or related methods were considered.

In Scenario A, **10% of total arable land** - ~1.6 Mha in 2035 and **~3.2 Mha** in 2045 - **is assumed to be available for CDR**. These areas were allocated to cropland management and pasture management. The extent to which these carbon sequestration methods are currently applied in these areas remains unclear. However, since roughly 10% of arable land is under organic farming, it was assumed that at minimum these areas are suitable for CDR.¹⁹⁷ The land allocated for agroforestry (2 kha) was based on the estimate that only 1.7 kha¹⁹⁸ is deployed for it currently. In Scenarios B and C, **20% of total arable land** - about ~3 Mha in 2035 and **~5.9 Mha** in 2045 - is assumed available for cropland management and pasture management, and 25 kha allocated to agroforestry.^{199,200}

In Scenario A, the available **land for reforestation** is assumed to be 200 kha in 2035, and 100 kha remains available in 2045. In Scenarios B & C the land for reforestation is assumed to be 300 kha in 2035, and as per high ambition scenario for deploying CDR, only 50 kha remains available for reforestation in 2045. The assumptions are based on the estimates by *Deutscher Bundestag*²⁰¹ and the reforestation targets set by the council of European Union.²⁰² For **afforestation**, in Scenario A it is assumed that in 2035 there are 10 kha available, and in 2045 170 kha. In Scenarios B and C, it is assumed that there could be 100 kha for afforestation in 2035, and up to 340 kha in 2045. The assumptions are based on the current pace of afforestation²⁰³ and study by UBA.²⁰⁴

For **peatland** areas, in the theoretical potential it was assumed that 56 kha of peatland are rewetted every year. In the realistic potential this was drastically reduced. The current pace for rewetting is 2 kha per year, and this was the assumption used in the Scenario A, both in 2035 and 2045. In Scenario B and C, the available areas for peatland restoration are based on the rate of The *Bund-Länder-Zielvereinbarung's* objectives for rewetting (250 kha by 2035 and 500 kha by 2045), and the yearly rewetting area is assumed to be 25 kha both in 2035 and in 2045.

For **coastal revegetation**, the theoretical CDR potential was based on a *Helmholtz* Centre study estimating the CDR potential of salt marshes and seagrass meadows in German coastal areas. In 2022, salt marshes covered 23.25 kha and seagrass meadows 46.5 kha. For salt marshes growing in the protected coastline in the North Sea, no area changes were assumed in any scenario due to protection. Similarly, seagrass CDR potential was held constant to 2035, since it would take nearly 20 years for a new seagrass meadow to function as a carbon sink. For 2045, realistic scenarios scaled down the theoretical maximum potential of the seagrass meadows. In Scenario A, Baltic Sea seagrass meadows are assumed to increase (5,627 kha) and quality improves under EU nutrient reduction targets, while North Sea seagrass meadows maintain the same area, but quality improves leading to increased carbon uptake (19,1 kt CO₂ uptake increase). In Scenarios B and C, seagrass meadows carbon sink is assumed to increase to 75% of the theoretical maximum through habitat improvement and increase of the area following active restoration.

7.4.3 Allocation of biomass resources

For the realistic CDR potential, the availability of biomass resources was estimated to be lower than in the theoretical potential due to competing uses and practical and financial feasibility constraints. Across all scenarios, **geological CO₂ storage was allocated 10% to BECCS with anaerobic digestion and 90% to BECCS with combustion**. Biomass feedstocks allocated to combustion are energy wood, used in retrofits to existing facilities regardless of BECCS. In contrast, a significant portion of the non-forest biomass allocated to CDR is currently unused and its utilisation for BECCS would require construction of new anaerobic digestion facilities. Implementing BECCS for combustion is therefore the more resource-efficient option and Germany's larger, centralised wood combustion facilities offer

greater CDR potential than its smaller, dispersed biogas plants. Table 9 lists the total biomass figures and their availability for CDR across Scenario A and B, alongside the key assumptions.

In **Scenario A: low ambition** it was assumed that only a fraction of the theoretical maximum biomass feedstock is available due to prioritisation to other uses, financial, and political constraints. Overall, in Scenario A about **20% of the theoretical maximum availability for CDR was assumed to be used**. Wood biomass availability followed the WEHAM BAU scenario for harvests and wood use (see Box 2 for details), with a **forest carbon sink of ~20 MtCO₂²⁰⁵**. BECCS was assumed to be installed in 20% of energy wood combustion sites. For wood used for pulp, about half of the exported quantity was assumed to be diverted to CDR. For sawmilling

Type of biomass	Total projected amount (2035)	Amount available for CDR (2035)	Total projected amount (2045)	Amount available for CDR (2045)	Allocation to CDR methods	Key assumptions
Cereal straw	12	Scenario A: 1.1 Scenario B: 2.8	11.9	Scenario A: 1.1 Scenario B: 2.8	BECCS with anaerobic digestion (AD)	Of theoretical scenario availability as described in Annex A, 20% assumed available for Scenario A. In Scenario B, 50% assumed available.
Green waste	8.2	A: 1.1 B: 2.7	8.2	A: 1.1 B: 2.7		
Cattle slurry	8.3	A: 1.7 B: 4.1	8.2	A: 1.6 B: 4.1		
Cattle solid manure	5.9	A: 1.2 B: 3	5.9	A: 1.2 B: 2.9		
Biogenic share of wastewater	3.8	A: 0.8 B: 1.9	3.7	A: 0.7 B: 1.8		
Municipal organic waste	2.7	A: 0.3 B: 0.8	2.7	A: 0.3 B: 0.7		
Wood from landscaping	2.1	A: 0.4 B: 1.04	2.1	A: 0.4 B: 1.04	BECCS (combustion), biochar	Of theoretical scenario availability, 20% assumed available in Scenario A, while 50% in Scenario B. Due to storage limitations, all allocated to biochar.
Pig slurry	1	A: 0.2 B: 0.5	1.1	A: 0.2 B: 0.5	BECCS with AD	Of theoretical scenario availability, 20% assumed available in Scenario A, while 50% in Scenario B.
Chicken solid manure	0.6	A: 0.1 B: 0.3	0.7	A: 0.1 B: 0.3		
Pig manure	0.2	A: 0.04 B: 0.1	0.2	A: 0.04 B: 0.1		
Cattle liquid manure	0.2	A: 0.02 B: 0.05	0.2	A: 0.02 B: 0.05		
Chicken liquid manure	0.1	A: 0.01 B: 0.02	0.1	A: 0.01 B: 0.02		
Pig liquid manure	0.01	A and B: 0	0.01	A and B: 0		

continued>

Type of biomass	Total projected amount (2035)	Amount available for CDR (2035)	Total projected amount (2045)	Amount available for CDR (2045)	Allocation to CDR methods	Key assumptions
Energy wood	NPS: 12.1 BAU: 13.5	A: 2.7 B: 4.8	NPS: 12.1 BAU: 13.5	A: 2.7 B: 4.8	BECCS (combustion)	Only largest facilities assumed for BECCS, so 20% of energy wood counted for CDR in Scenario A, while 40% counted in Scenario B (40% of energy wood combustion happens in over 1MW facilities so half of these were included).
Residual wood	NPS: 1.8 BAU: 6.1	A: 1.2 B: 0.7	NPS: 2.9 BAU: 6.2	A: 1.2 B: 1.15		Assumed 20% would be available for CDR in Scenario A, while 40% in Scenario B.
Pulp wood	NPS: 2.9 BAU: 5	A: 0.5 B: 0	NPS: 2.7 BAU: 10	A: 1 B: 0	Scenario A: 80% products, 20% biochar	In Scenario A, the total pulp figure assumes 60% becomes end products, with the rest as black liquor. Per the WEHAM report, surplus wood is largely exported – about 25% of domestic production – rather than used domestically. Assumed 10% of total production could be directed to CDR in Scenario A, while in Scenario B, due to low wood available in NPS scenario, all is assumed for households and therefore not available for CDR.
Sawmilling and plywood	NPS: 5.7 BAU: 6.2	A: 1.2 B: 2.3	NPS: 5.2 BAU: 8.3	A: 1.7 B: 2.1	80% products, 20% biochar	Assumed half of raw wood mass end up in end-products and the rest as side products. Of theoretical scenario availability, 20% assumed available in Scenario A, while 40% in Scenario B.
Side products from wood industry	NPS: 5.7 BAU: 6.2	A: 1.2 B: 4.6	NPS: 5.2 BAU: 8.3	A: 1.7 B: 4.2	80% BECCS (combustion), 20% biochar	Assuming 40% of pulp production becomes black liquor, with 20% of theoretical potential considered available in Scenario A. In Scenario B, estimated 60% of pulp production ends in end products and the rest as black liquor. Of theoretical scenario availability, 80% assumed available.
Black liquor	NPS: 2 BAU: 3.3	A: 0.6 B: 1.6	NPS: 1.8 BAU: 6.7	A: 1.2 B: 1.4	BECCS (combustion)	
Totals	Scenario A: 126.6 Scenario B: 112.21	Scenario A: 14.4 Scenario B: 31.26	Scenario A: 159.9 Scenario B: 109.85	Scenario A: 16.3 Scenario B: 30.8		

Table 9. Biomass availability for CDR in **Scenario A** and **B** (Mt dry). Wood biomass values have been converted from m³ in original source to dry tons for the CDR calculation as in Table 1, section 3.4.1. **Non-wood biomass availability is expressed as a share of theoretical maximum availability**, which can be found in Annex A. Whereas, **wood availability is expressed as a percentage of total biomass**. This distinction reflects the fact that the underlying data came from different sources. Non-wood biomass total figures are from BIOSTRAT⁹⁸ and wood biomass total figures based on are from WEHAM.²²⁴ Pulpwood, sawmilling, and plywood are considered material wood as described in Chapter 3.

and plywood wood types, 20% was assumed to be available for CDR, most of which for durable products, with a small portion diverted to biochar. The wood availability was estimated low enough to allow also for possible reductions in harvest levels in line with BioNET's enhanced carbon sequestration methods.²²³

In **Scenario B: High ambition, energy efficiency focused**, a larger portion of the theoretical maximum biomass availability is assumed for CDR since there is higher political and financial will to divert a larger portion of biomass to CDR and invest in CDR technologies. **For the non-forest biomass, 50% of the theoretical maximum availability is assumed available.** For wood biomass, the WEHAM NPS scenario projections are used (see Box 2 for details). BECCS was assumed to be installed in 40% of the locations where wood is combusted for energy. For wood used for pulp, about half of the exported quantity was assumed to be diverted to CDR. For sawmilling and plywood wood types, 40% was assumed to be available for CDR, most of which for durable products, with a small portion diverted to biochar. The availability of wood was estimated low enough to allow also for possible reductions in harvest levels in line with BioNET's enhanced carbon sequestration methods.

In **Scenario C: High ambition, reduced BECCS**, biomass availability is the same as in Scenario B except for energy wood. In Scenario C, only 30% of geologic CO₂ storage is allocated to BECCS compared to 100% in Scenarios A and B. Correspondingly, the amount of wood biomass needed decreases. Only 0.2-2.7 Mt dry of energy wood is required to produce the CO₂ to fill the reduced storage capacity compared to the ~10 Mt used in Scenario B. Half of the reduced need for energy wood is assumed to be diverted from energy to material use, and the other half is assumed to result in reduced harvests and preserved forest sink. With this assumption, harvest levels in Scenario C are 18% (5.5 MtDt) and 14% (4 MtDt) lower than in the WEHAM NPS scenario in 2035 and 2045, respectively. Therefore, wood biomass availability in Scenario C is about 20 Mt in 2035 and 26 Mt in 2045. The **forest sink** is estimated to be **~16 MtCO₂** in 2035 and **~36 MtCO₂** in 2045.

In all scenarios, only a portion of the biomass available for carbon removal is used, as CO₂ storage capacity limits BECCS deployment before biomass resources are fully utilised. Overall, 17–50% of the identified biomass is consumed by CDR methods.

7.4.4 Allocation of mineral feedstock

In all realistic scenarios, the available mineral feedstock was allocated to enhanced rock weathering and ocean alkalinity enhancement, using basalt and carbonate minerals (limestone and dolomite) respectively, as other minerals are largely imported. The quantities of basalt and carbonate minerals were assumed to be lower than in the theoretical potential and follow the production scenarios in RWI's "*Rohstoffnachfrage 2045*".²⁰⁶ In the future, while production of basalt and carbonate minerals is expected to decline, the realistic CDR potential assumes that production would remain at current levels, with the projected decline in demand being redirected to CDR methods.

Two scenarios for the decline of mineral production were considered: the lower scenario was the basis for Scenario A's CDR potential, while the upper scenario informed Scenarios B and C. As a result, **basalt availability for CDR** was assumed to be ~0.3 Mt in 2035 and **~2 Mt** in 2045 in Scenario A, while in Scenarios B and C it was ~3 Mt in 2035, rising to **~6 Mt in 2045**. **Carbonate minerals (limestone and dolomite)** were projected at ~5 Mt in 2035 for Scenario A rising to ~9 Mt in 2045, while in Scenario B and C they were ~7 Mt in 2035 rising to **11 Mt in 2045**. Basalt was allocated to ERW, while limestone and dolomite were allocated to OAE.

Germany also generates about 220 Mt of **mineral construction waste** annually, over 90% of which is reused, often in low-value applications such as landfill construction. This volume is expected to remain relatively stable in the coming years,²⁰⁷ offering notable potential for ex-situ mineralisation. Due to limited data on suitability for CO₂ mineralisation, a cautious theoretical availability of **5%** of the annual waste volume is assumed for CDR. In practice, around 1% (**~2.2 Mt**) of the annual waste could be available for CDR by 2035, rising to 3% (**~6.6 Mt**), **by 2045**. By 2045, advances in technology, safety assessments, infrastructure, and data are expected to enable more efficient use of mineral construction waste for mineralisation and/or CDR. Stronger market dynamics and incentives will further drive adoption, raising utilisation from 1% in 2035 to 3% in 2045.

7.4.5 Allocation of CO₂ storage resources

The most significant limiting factor in realistic scenarios is CO₂ storage capacity, allocated to BECCS and DACCS. While Germany's geological formations, particularly saline aquifers and depleted gas fields, offer significant storage potential, none of it has been realised to date. First geological storage is to be deployed 7-10 years after the research phase. To start with, it was assumed that the first projects have somewhat modest CO₂ capacity per year, and that the annual storage need will be higher, with priority for hard-to-abate until 2045.

In **Scenario A**, domestic geological CO₂ storage capacity is assumed to be 2 Mt in 2035, of which 5% (**0.1 Mt**) would be available for CDR. In 2045, the capacity is assumed to be 20 Mt, of which 25% (**5 Mt**) is available for CDR. Additionally, the potential for ex-situ mineralisation is assumed to grow from 0 in 2035 to **0.8 MtCO₂** in 2045, leveraging a small share of the existing feedstocks of demolition concrete.

In **Scenarios B and C**, the domestic CO₂ storage capacity is assumed to be 3 Mt in 2035, of which 15% (**0.45 Mt**) would be available for CDR. In 2045, the capacity is assumed to be 20 Mt, of which 50% (**10 Mt**) is available for CDR. We assume that large geological storage potential exists in and around Germany, but that real-world deployment is constrained by the pace of pipeline, port, and injection-scale-up, rather than by static capacity. Annual storage is therefore capped by the minimum of (i) domestic injectivity in the German EEZ, (ii) export and transport capacity via pipelines and ports, and (iii) cross-border acceptance in North Sea hubs (NL, NO, DK), consistent with the Carbon Management Strategy (key points version) and EU targets anchor figures and known projects (Porthos, Northern Lights, Greensand, Aramis). Because transport and storage are shared with fossil CCS, a time-dependent allocation factor, starting low in the 2030s and rising toward mid-century as industrial and power CCS decline and policy support ring-fences capacity for CDR.²⁰⁸ Finally, in these two scenarios, ex-situ mineralisation is assumed to deploy more quickly and to allow for an additional storage capacity of 0.8 MtCO₂ in 2035 and **2.6 MtCO₂** in 2045, leveraging 1% and 3% of the theoretical potential, respectively.

Assumptions about Germany's ability to export CO₂ for geological storage considered several factors: the development of storage capacity abroad, CO₂ transport infrastructure, Germany's potential share of foreign storage, and prioritisation of hard-to-abate fossil emissions. For 2035, estimates relied

largely on existing projects such as Northern Lights (Norway) and Porthos (Netherlands),²⁰⁹ whereas projections for 2045 were based on broader capacity-development estimates from the project team. The export capacities were assumed to be the following:

- Scenario A (2035): **0.05 Mt** CO₂ (total capacity 5 Mt, share for Germany 20%, allocation to CDR 5%).
- Scenario A (2045): **0.75 Mt** CO₂ (total capacity 15 Mt, share for Germany 20%, allocation to CDR 25%).
- Scenario B & C (2035): **0.72 Mt** CO₂ (total capacity 12 Mt, share for Germany 40%, allocation to CDR 15%).
- Scenario B & C (2045): **6 Mt** CO₂ (total capacity 30 Mt, share for Germany 20%, allocation to CDR 50%).

In all scenarios, the entire geological CO₂ storage assumed for carbon removal is fully utilised, and the availability of geological storage limits the potential of BECCS and DACCS, even though other resources required for these methods would still be sufficient.

7.5 Estimated cost of implementing the scenarios

While this background report does not provide a full techno-economic assessment of the various CDR methods, costs were considered in the "merit order" when shaping the CDR portfolio. For example, BECCS was favoured over the generally more expensive DACCS. However, investment costs for capture, storage, and infrastructure were not estimated, as they vary widely by project, company circumstances, and other factors.

Ecosystem management CDR methods are generally cheaper than synthetic methods. Forest carbon measures - such as altering tree species or using timber in long-lived products - often cost under €50/tCO₂e.²¹⁰ According to the European Scientific Advisory Board (ESAB) on Climate Change,²¹¹ cost ranges are:

- Afforestation: €0-216/tCO₂e. Estimates vary widely due to variations in land opportunity costs, included expenses, time horizon considered, and regional context - ranging from low-cost global cases to high-cost EU deployments on valuable agricultural land;

- Improved forest management: typically, less than €50/tCO₂, one study suggesting up to €113/tCO₂;
- Soil carbon sequestration: €-45 to 123/tCO₂ (highly context dependent, sometimes yielding cost savings);
- Agroforestry: €20-90/tCO₂
- Peatland restoration: €8-110/tCO₂

Cost estimates for coastal revegetation are scarce and highly variable, with median values of USD 240/tCO₂ for mangroves, USD 30,000/tCO₂ for salt marshes, and USD 7,800/tCO₂ for seagrass. The German Environment Agency (*Umweltbundesamt*) has published an extensive study on carbon mitigation opportunities in the agricultural sector, discussing also the economic mitigation potential. Data limitations make it difficult to estimate precise costs, which depend on soil type, climate, and existing farming practices. Overall, cropland management offers affordable and scalable CDR potential, especially when co-benefits such as improved biodiversity and soil health are considered. However, policy support, financial incentives and farmer education are essential to unlock this potential.²¹²

Among **biomass conversion methods**, BECCS is estimated at USD 100–200/tCO₂ removed, reflecting sustainability and infrastructure challenges. Biochar costs are projected at USD 90–120/tCO₂, though uncertainties remain due to limited large-scale deployment. The estimates are based on the European Parliament briefing on carbon dioxide removals.²¹³ The study by ESAB (2025) summarises that the cost of BECCS ranges from €27–360/tCO₂ and biochar from €10–200+/tCO₂.

For **geochemical methods**, the European Parliament has indicated that the cost of deploying enhanced rock weathering is estimated to cost USD 50–200/tCO₂, with ESAB reporting a wider range of ~€50–400/tCO₂ depending on rock type and source, grinding and transport

costs, application method, and monitoring and verification requirements. Mineral-ocean alkalinity enhancement with carbonates is projected at USD 70–120/tCO₂.²¹⁴

Lastly, **DACCS** costs are estimated at USD 100-300/tCO₂ by the European Parliament briefing, while ESAB reports a wider range of €450–900/tCO₂. ESAB cautions that these figures carry significant uncertainty, with future learning rates, energy availability and costs, and infrastructure development expected to drive reductions over time.

A rough cost estimate (based largely on ESAB method-cost ranges combined with the scenario potentials) suggests ~€3–19 billion per year by 2045 for Scenarios B and C - underscoring the need for durable market design, public procurement/finance mechanisms, and infrastructure investment to mobilise private capital.

Table 10 summarises cost estimates for different scenarios based on calculated CDR potential. Minimum values reflect either the lowest or average estimates (where variation is high), while maximum values use the highest estimate per method. Given the uncertainty and variance, these figures should be seen as indicative only. Detailed assumptions and data are provided in Annex B.

Based on these estimates, ecosystem-based methods offer the most cost-effective options for deploying CDR potential in Germany. Comparing Scenarios B and C, Scenario B is more affordable because it leans more towards BECCS than DACCS. However, especially for these technical CDR methods, there is high uncertainty about how the costs will evolve in the future.

The annual costs of the three scenarios not only quantify the financial requirements but also define the potential size of the addressable market for CDR providers. At the same time, they indicate the scale of demand that policy makers must anticipate and plan for, ensuring that both industry and governance are aligned in meeting future carbon removal targets.

Scenario A 2035	Scenario A 2045	Scenario B 2035	Scenario B 2045	Scenario C 2035	Scenario C 2045
~0.58-1.7	~0.9-5.1	~1.7-5.1	~3.3-13.8	~2.1-5.1	~8-19.9

Table 10. Indicative costs of deploying the scenarios, in € billion. See Table B.1 for the cost breakdown.

8. Conclusions

This report emphasises three key dimensions to analyse the carbon removal readiness of Germany: 1) a comprehensive assessment of domestic CDR methods and their interconnections, 2) a bottom-up analysis of potential, grounded in actual resource availability, and 3) consideration of Germany's unique 'social geography'—the societal, cultural, and regional factors that shape the feasibility and public license of CDR.

A variety of methods

Of the many existing and proposed CDR methods, this study focused on those with potential for large-scale deployment in Germany by 2045 and showcased enough technical maturity to assess their potential. A few methods were excluded due to low level of maturity or constraints set by especially regulatory limitation specific to the German context or lack of research. The excluded methods were bio-oil storage, marine biomass sinking, terrestrial biomass burial, ocean fertilisation and direct ocean capture and storage (DOCCS).

Despite these exclusions, the final portfolio of CDR methods used in the deployment scenarios encompasses all four major categories: (i) Enhanced ecosystem management, (ii) Biomass conversion/preservation, (iii) Geochemical carbon removal, and (iv) Synthetic carbon removal.

Bottom-up analysis

The theoretical and realistic CDR potentials were estimated using a bottom-up analysis. First assessing the quantity of resources available in Germany for various CDR methods, and then determining each method's primary limiting resource - such as land, biomass, or energy. Finally, the resources were allocated to the most efficient methods in terms of CO₂ removal per unit of resource. This optimisation ensured the highest possible overall removal potential.

For the theoretical potential, all available resources were considered without constraints. In contrast, the realistic potential was adjusted to reflect real-world constraints, including competing demands for energy production, biomass utilisation, and land availability.

The bottom-up assessment provided a detailed estimate of the amount of CDR Germany could realistically achieve by deploying its resources across a diverse portfolio of CDR pathways.

Germany's social geography provides a good launchpad for CDR

Germany has the potential to become a major pioneer of CDR in Europe, and with both Länder and the federal government, alongside industry, academia, and civil society taking active steps towards the goal of deploying CDR. The stakeholder interviews emphasised the need for regulatory coherence, transparent and ambitious CDR strategies, and robust policy support for the emerging CDR industry. The citizen panel indicated that while the public generally understands and supports the need of deploying CDR, questions remain on the method-level around costs and benefits.

Key messages

- 1. The realistic CDR potential in Germany shows that CDR could make a meaningful contribution to Germany's climate targets.** By 2045, *Scenarios B: High ambition, energy-efficiency focused* and *Scenario C: High ambition, reduced-BECCS* reveal CDR volumes that could enable net-zero within range of expected residual emissions and may allow Germany to go net negative slightly earlier than planned.
- 2. Most CDR methods are possible in Germany.** Mobilising a diversified portfolio of CDR methods distributes risk and resource pressure. It also provides flexibility to offtake markets and governance structures. However, a diversified CDR portfolio requires significant coordination between public and private actors to ensure that all potential methods are developed to their full potential.
- 3. The limited geological storage capacity constraints DACCS and BECCS.** In all scenarios, geological storage capacity emerges as the limiting factor for BECCS and DACCS. Accelerated, large-scale industrial policy interventions and market investment are needed to ensure that CO₂ transport and storage capacity align with Germany's capture potential.
- 4. Interviews with experts and a citizen panel demonstrated support for CDR, but scepticism and uncertainty persist regarding scaling novel CDR methods.** Stakeholders across academia, industry, government, and civil society agree on scaling a CDR portfolio, though insufficient policies and infrastructure investments were noted. The citizen panel was more aware - and favoured - conventional nature-based CDR methods, though positive attitudes towards all

methods increased after a detailed discussion on CDR. Citizens were less aware and more critical of novel, technical solutions. Expert stakeholders and citizen panels agreed on the need for regulation and oversight to prevent greenwashing and ensure transparent, sustainable practices.

5. Germany cannot risk “low ambition”, as it lands at ~47 MtCO₂ by 2045 – likely not enough margin for resilience. In Scenario A, the pathway offers limited room against real-world uncertainties – especially given the recent volatility of land sinks – and increases the risk of missing the net-zero and net-negative targets.

6. Portfolio choices have real consequences: less BECCS can mean more DACCS. Scenario C reflects a potential political preference to constrain BECCS biomass use; as a result, a larger share of geological storage capacity is available for DACCS, and the pathway also delivers higher natural-sink outcomes than Scenario B. This illustrates that Germany can shape its CDR mix through explicit choices, such as biomass allocation and the prioritisation of transport and storage infrastructure, but must acknowledge and manage the associated trade-offs.

7. There is no viable business case yet – CDR deployment still depends on public support and market design. Stakeholders emphasise that early CDR deployment still hinges on public support programs, such as financial incentives, establishing standards, and public procurement, alongside nascent voluntary demand. Stakeholders point to the need for investment in CO₂ transport and storage infrastructure, as well as clearer market incentives to unlock private capital and create a durable business case.

8. Net-zero is not the finish line, and substantial theoretical potential remains to be unlocked in the second half of this century, beyond 2050. Germany's stated objective of becoming net-negative after 2050 means continued scaling beyond the ~100 MtCO₂/year level in 2045 pathways, potentially toward the domestic upper threshold (~258 MtCO₂/year under maximalist assumptions). This is essential for addressing historical emissions and reversing a likely temperature overshoot.



Annex A. Biomass availability in the theoretical CDR scenario

Table A.1 lists the total availability of biomass resources and the maximum theoretical availability for CDR. Biomass types were allocated to CDR

methods based on current uses and potential for other uses. The availability of non-forest biomass was estimated based on the DBFZ Biomass Monitor.⁹⁹ Forest biomass amounts are based on the WEHAM NPS scenario and availability was estimated based on current uses of wood.⁸¹

Type of biomass	Total projected amount (2035)	Amount available for CDR (2035)	Total projected amount (2045)	Amount available for CDR (2045)	Allocation to CDR methods	Key assumptions
Cereal straw	11.9	5.6	11.9	5.6	BECCS with anaerobic digestion (AD)	47% available for CDR.
Green waste	8.2	5.4	8.2	5.3		Energy use assumed to be compatible with BECCS. Unused potential available for CDR. In total 65% available.
Cattle slurry	8.3	8.3	8.2	8.2		Energy use assumed to be compatible with BECCS. Unused potential available for CDR. In total all technical potential available.
Cattle solid manure	5.9	5.9	5.9	5.9		
Biogenic share of wastewater	3.8	3.8	3.7	3.7		Energy use assumed to be compatible with BECCS. Unused potential (56%) available for CDR.
Municipal organic waste	2.7	1.5	2.7	1.5		
Wood from landscaping	2.1	2.1	2.1	2.1	BECCS (combustion), biochar	Energy use assumed to be compatible with BECCS. Unused potential available for either biochar or BECCS. In total all technical potential available.
Pig slurry	1	1	1.1	1.1	BECCS (AD)	Energy use assumed to be compatible with BECCS. Unused potential available for CDR. In total all technical potential available.
Chicken solid manure	0.6	0.6	0.7	0.7		Energy use assumed to be compatible with BECCS, so all assumed available for CDR.
Pig manure	0.2	0.2	0.2	0.2		Energy use assumed to be compatible with BECCS. Unused potential available for CDR. In total all technical potential available.
Cattle liquid manure	0.2	0.1	0.2	0.1		Assumed 50% of technical potential available for CDR.
Chicken liquid manure	0.08	0.04	0.08	0.04		
Pig liquid manure	0.01	0.01	0.01	0.01		
Energy wood	12.1	7.3	12.1	7.2	BECCS (combustion)	About 40% used in households and excluded from CDR.
Residual wood	1.8	1.1	2.9	1.7		
Pulp wood	2.9	0	2.7	0	80% products, 20% biochar	Estimated 60% of pulp production ends in end products and the rest as black liquor. Due to lower wood availability in NPS scenario, estimated all needed for households and unavailable for CDR.

continued>

Type of biomass	Total projected amount (2035)	Amount available for CDR (2035)	Total projected amount (2045)	Amount available for CDR (2045)	Allocation to CDR methods	Key assumptions
Sawmilling and plywood	5.7	3.4	5.2	3.1	80% products, 20% biochar	Assumed half of raw wood mass end up in end-products and the rest as side products. Some already used for long-term products so this amount assumed to be possible to increase. A small amount assumed to be possible to direct to biochar. Assumed 60% in total could be used for CDR.
Side products from wood industry	5.7	5.7	5.2	5.2	80% BECCS (combustion), 20% biochar	Assumed half of raw wood mass end up in end-products and the rest as side products. Assumed all available for CDR because used in industry.
Black liquor	2	2	1.8	1.8	BECCS (combustion)	Estimated 60% of pulp production ends in end products and the rest as black liquor. Assumed all available for CDR because used in industry.

Table A.1. Biomass availability for CDR in Scenario A (Mt, dry). Non-forest biomass availability based DBFZ Biomass Monitor.⁹⁹ Non-wood biomass total figures from BIOSTRAT⁹⁹ and wood biomass total figures based on WEHAM.

Annex B. Break-down of cost estimates for deploying the scenarios

Table B.1 presents the detailed breakdown of cost estimates for deploying the scenarios. The first two columns show the minimum and maximum cost of each method (€ per tCO₂ removed), followed by scenario-year CDR potentials (in MtCO₂) and the resulting cost ranges.

Most of the method-specific cost estimates are based on the study by ESAB²¹⁵

except for ocean alkalinity enhancement.²¹⁶ The cost estimate was converted from USD to EUR with InforEuro exchange rate on 7th November 2025. For DACCS, the cost ranges were drawn from the summary table of DACCS costs (p. 333). For BECCS, the study doesn't define if the cost ranges are for combustion-based or anaerobic digestion, thus those are combined in the cost estimation for scenario deployment. Afforestation and reforestation use cost estimated from ESAB's study table 43, with minimum costs defined as the average where ranges start at zero. Durable bio-based products and coastal revegetation were excluded due to lack of robust estimates, though their small potential means this does not affect overall scenario costs.

Type of biomass	Unit cost (€/tCO ₂ removed)	Scenario A				Scenario B				Scenario C			
		Amount (2035)	Cost m€ (2035)	Amount (2045)	Cost m€ (2045)	Amount (2035)	Cost m€ (2035)	Amount (2045)	Cost m€ (2045)	Amount (2035)	Cost m€ (2035)	Amount (2045)	Cost m€ (2045)
E-DACCS	450-900					0.8	360-720	2.4	1080-2160	1.61	724-1449	13.6	6120-12240
BECCS	27-360	0.02	0.54-7.2	0.65	17.55-234	1.17	31.6-421.2	16	432-5760	0.36	9.72-129.6	4.8	129.6-1728
Biochar	100-223	2.4	240-535.2	3.13	313-698	5.68	568-1266.6	5.34	534-1190.8	5.7	568-1266.6	5.3	534-1190.8
Mineral OAE	60.6-103.9					0.43	26-44.7	1.85	112-192	0.43	26-44.7	1.85	112-192
ERW	54-400	0.07	3.8-28	0.4	21.6-160	0.65	35.1-260	1.44	77.8-576	0.65	35.1-260	1.44	77.8-576
Peatland restoration	8-110	0.15	1.2-16.5	0.3	2.4-33	1.88	15.04-206.8	3.75	30-412.5	1.9	15-206.8	3.75	30-412.5
Cropland management	36-123	2.68	96.5-329.64	5.23	188.3-643.3	5.36	193-659.3	11.2	404.6-1382.5	5.4	195.8	11.24	404.6-1382.5
Pasture management	36-123	1.89	68-232.47	3.24	116.6-398.5	3.79	136.4-466.2	4.8	171.3-585.5	3.8	136.4-466.2	4.76	171.4-585.5
Agroforestry	20-90	0.31	6.2-27.9	3.12	62.4-280.8	1.56	31.2-140.4	7.5	149.8-674.1	1.6	31.2-140.4	7.49	149.8-674.1
Afforestation	73-216	0.11	8-23.76	1.79	130.7-386.6	1.05	76.7-226.8	3.6	262.07-775.4	1	76.7-226.8	3.59	262.1-775.4
Reforestation	73-216	2.11	154-455.76	1.05	76.7-226.8	3.16	230.7-682.6	0.5	38.7-114.5	3.2	230.7-682.6	0.53	38.7-114.5
Total costs		582.7-1656.4 M€		929.2-3061 M€		1703.7-5094.6 M€		3292.3-13,823 M€		2048.6-5068.5 M€		8030-19,871 M€	

Table B.1. Breakdown of cost estimates for deploying the realistic scenarios. Scenario-year CDR potential amounts are in MtCO₂.

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ABOUT

Carbon Gap

Carbon Gap was established to be Europe's first philanthropically funded environmental advocacy organisation, focusing exclusively on CDR. The mission is to ensure that Europe becomes a leader in developing and deploying CDR solutions at scale in a safe and equitable manner to preserve a stable climate. Carbon Gap is coordinating the delivery of the project that has produced this report.

www.carbongap.org

Sweco

Sweco is Europe's leading engineering and architecture consultancy. Sweco Finland's Strategic Sustainability Consultancy was responsible for this report.

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