RAMBØLL

Bright ideas.
Sustainable change.

CCUS market opportunities in Germany

Report for Scottish Enterprise

Published: May 2026

Contents

This report assesses opportunities for Scottish companies within the German Carbon Capture, Utilisation & Storage (CCUS) value chain

The objectives are:

- **Identify and assess short-, medium-, and long-term opportunities** for Scottish companies in the German CCUS market and value chain.
- **Develop strategic recommendations** for Scottish companies, including actions for Scottish Enterprise/Scottish Development International, and partners to support market engagement.

Approach and results

Based on Ramboll's existing CCUS expertise, structured research, German CCUS stakeholder interviews, and a gap-fit workshop with Scottish CCUS stakeholders, a consolidated project report was created covering:

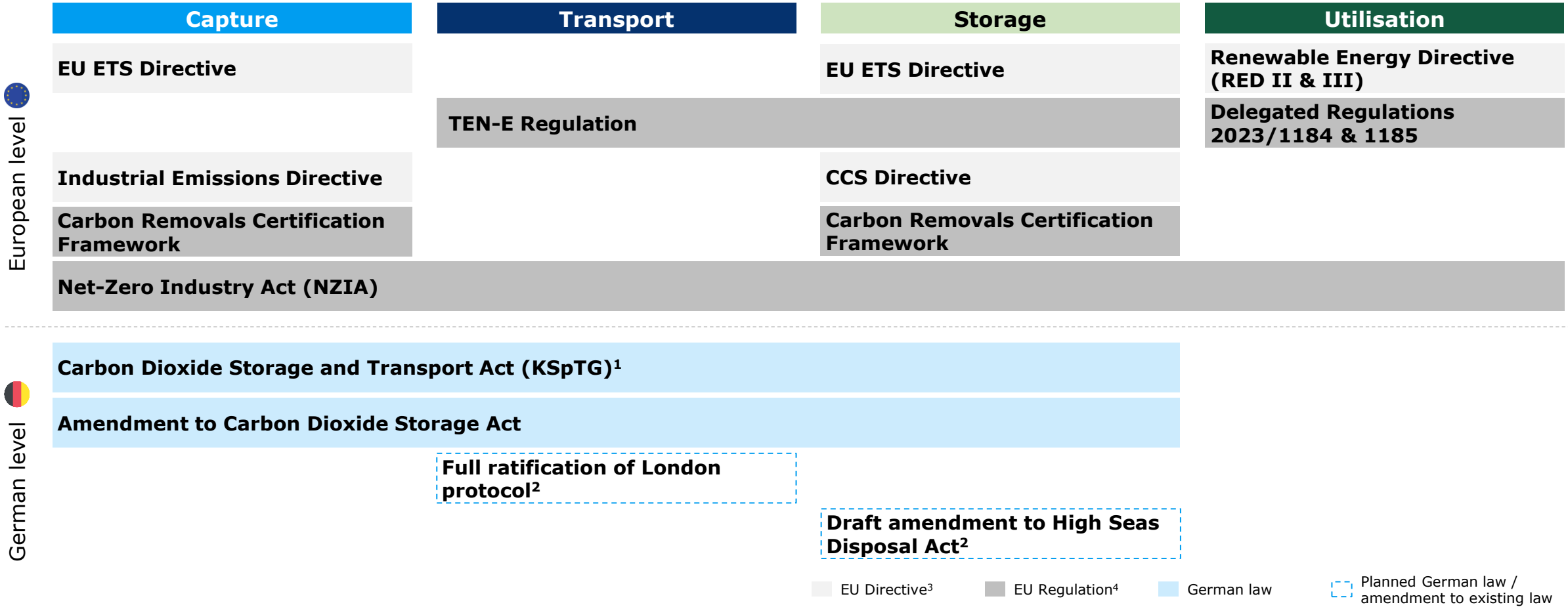
- The regulatory framework for CCUS in Germany and the EU, including funding instruments for CCUS projects as well as barriers and enabling factors for CCUS deployment in Germany;
- An overview of the German CCUS value chain;
- Opportunities in the German CCUS market for Scottish CCUS capabilities; and
- Strategic recommendations for Scottish companies and suggested actions for Scottish Enterprise, and partners, to support market engagement.

Enabling environment

While the legislative framework is supportive and some funding instruments are in place, there remain significant challenges to the development and deployment of CCUS in Germany

Regulation

CCUS deployment in Germany is being shaped by regulations on a European and a national level, which occur across different stages of the value chain



1) Approved by Bundesrat on 21st of November 2025; 2) Parliamentary process ongoing; 3) EU Directive sets out goal that EU country must achieve; up to individual countries to devise laws on how to reach these goals; 4) EU Regulation is binding legislative act that must be applied in its entirety across the EU

On a European level, wide range of regulation exists to establish regulatory certainty and support growth of European CCUS market

European regulation	Description
CCS Directive – Directive 2009/31/EC	• Establishes EU legal framework for CO_2 storage, incl. technical, environmental and safety standards • Ensures monitoring, liability transfer and legal certainty for investors and regulators to authorise storage sites
TEN-E Regulation – Regulation (EU) 2022/869	• Includes CO_2 transport networks and storage infrastructure as eligible PCIs[1] (PCIs enjoy several advantages including faster planning and permit approvals and increased visibility to investors) • Enables EU funding support (e.g., CEF grants) for CCUS infrastructure
EU ETS Directive – Directive 2003/87/EC	• Emission trading system that puts limits on GHG emissions from high-emitting sectors and allows companies to trade emission allowances • Capturing and storing CO_2 eliminates need for buying allowances, making CCUS financially attractive for emitters
Net-Zero Industry Act (NZIA) – Regulation (EU) 2024/1735	• Designates CCS/CCUS as strategic net-zero technologies and sets binding target of 50 million tonnes of CO_2 storage by 2030 • Streamlined permitting and priority treatment aim to accelerate CCUS infrastructure development and industrial investment
Carbon Removal Certification Framework – Regulation (EU) 2024/3012	• EU-wide voluntary framework for certifying carbon removals, carbon farming and carbon storage in products across Europe • Lays foundation for carbon removal credits and markets, creating new revenue streams for CCUS
Renewable Energy Directive II & III – Directive (EU) 2018/2001	• Defines rules for Renewable Fuels of Non-Biological Origin using captured CO_2 as feedstock • Enables CCU-based fuels (e-fuels, methanol, etc.) to count toward renewable targets • Sets GHG accounting & sustainability criteria for CCU pathways
Industrial Emissions Directive – Directive 2010/75/EU	• Regulates emissions from large industrial installations, such as power plants, refineries, waste treatment • Simplifies permitting for "breakthrough technologies" such as CCUS technologies
Delegated Regulations (EU) 2023/1184 & 1185	• Defines life-cycle GHG calculation methods and ensures CO_2 source tracing with consistent emission accounting • Establishes regulatory pathway for commercial fuel projects with captured carbon

Key insights EU regulations

- A wide range of **regulation exists intending to accelerate market ramp up of CCUS within the EU** by addressing entire CCUS value chain
- **Regulatory uncertainty regarding CCUS is fading on European level**, making CCUS investments more attractive for companies across the entire value chain

! **Transcription of EU directives into national law** in member states **is crucial** for successful CCUS market ramp up

1) Project of common interest (PCI)

Approval of the 'Carbon Dioxide Storage and Transport Act' in late 2025 created a legal framework for commercial CCUS projects in Germany

European regulation	Description
Carbon Dioxide Storage and Transport Act (Gesetz zur dauerhaften Speicherung und zum Transport von Kohlendioxid; KSpTG)	• Allows large-scale, commercial CO_2 capture and storage • Enables offshore CO_2 storage in German EEZ[1] and continental shelf as well as opt-in clause for federal states to allow onshore storage on their territory • Declares CO_2 infrastructure as being of overriding public interest • Introduces faster permitting, simplifies muti-agency coordination and clearer liability rules • Establishes dedicated approval routes for CO_2 pipelines • Reinforces CO_2 networks as part of national energy transition infrastructure
Federal Immission Control Act (Bundes-Immissionsschutzgesetz)	• Governs emission permits for industrial plants that could integrate CO_2 capture • Capture units must comply with air-quality and environmental protection rules • Provides legal pathway to authorise CO_2 capture facilities as part of plant permits
Full ratification of London protocol[2]	• London protocol is an international agreement that restricts dumping of waste at sea and governs cross-border transport and sub-seabed storage of CO_2 (includes borders with EU/EEA other countries) • Full ratification of London Protocol establishes legal basis for cross-border export of CO_2
Draft amendment to High Seas Disposal Act (Hohe-See Einbringungsgesetz)[2]	• High Seas Disposal Act prohibits disposal of waste and other substances on high seas • Amendment intends to establish domestic legal basis for permanent storage of CO_2 in German EEZ and on continental shelf

Key insights German regulations

- **Approval of Carbon Dioxide Storage and Transport Act** (KSpTG; approval in late November 2025) **enabled CCUS deployment in Germany on commercial scale** (incl. transport)
- **However, some legal barriers still exist:**
  - Opt-in clause in KSpTG for federal states to permit onshore storage on their territory might result in limited **onshore CO_2 storage capacity**
  - Full ratification of London protocol and amendment to High Seas Disposal Act would enable **cross-border export of CO_2**

Ramboll

Active | Planned

1) EEZ = Exclusive economic zone (area where a coastal state assumes jurisdiction over exploration and exploitation of marine resources in its adjacent section of continental shelf); 2) German Federal Parliament has adopted bill to remove obstacles to export of carbon dioxide – required approval by Bundestag still pending

Funding instruments

Different funding instruments exist at the European level for CCUS projects across the entire value chain

Funding instrument	Description	Subsidy type	Available funding	Eligibility / Access[1]	CC	U	S	T
Innovation Fund	• Funds the demonstration of innovative low-carbon technologies, incl. CCUS technologies • Flagship instrument for scaling industrial CCUS	Non-repayable grants (up to 60% of additional costs)	40 billion EUR (2020-2030)	Beneficiaries must be legal entities established in the EU/EEA. Non-EEA firms can participate in consortia as suppliers or via an EU/EEA-established entity (e.g., subsidiary/SPV) if they wish to be a funded beneficiary.	✓	✓	✓	✓
Connecting Europe Facility – Energy (CEF-Energy)	• Enables CO_2 transport & storage infrastructure • Ideal for companies participating in hub or cluster projects	Co-funding grants (typically up to 50% of eligible costs)	5.84 billion EUR Energy, 25.81 billion EUR Transport	Open to projects designated as Projects of Common Interest (PCI) or Projects of Mutual Interest (PMI) under Regulation (EU) 2022/869. Non-EU firms may join EU consortia where the project is in the EU.			✓	✓
Horizon Europe	• EU's key funding programme for research & innovation • Supports innovation & technology maturation • Useful for process developers & technology providers entering CCUS	R&D grants (typically 70–100% of eligible costs)	93.5 billion EUR (2021-2027)	The UK is fully associated from the 2024 Work Programme; Scottish entities are full beneficiaries (can coordinate), except for EIC Fund equity under the Accelerator.	✓	✓	✓	✓
Just Transition Fund (JTF)	• Supports regional CCUS readiness, workforce & site re-use • Suitable entry for brownfield industry in transition areas	Grants via regional Ops (up to 85 % co-funding)	19.32 billion EUR (2021-2017)	Shared-management via Member State/region programmes. Projects must be located in designated territories in Germany; a local project owner is typically required.	✓	✓	✓	

1) A high-level screening of eligibility for Scottish companies has been carried out and information displayed is accurate as of January 2026

CC – Carbon Capture U – Utilisation S – Storage T – Transport

Different funding instruments exist at the European level for CCUS projects across the entire value chain

Funding instrument	Description	Subsidy type	Available funding	Eligibility / Access	CC	U	S	T
InvestEU Programme	• Helps de-risk private investment & access long-term finance • Useful for scaling & replication of CCUS business models	Loans, guarantees, equity backed by EU budget	372 billion EUR (2021-2027)	EU-located projects; non-EU ownership is acceptable. Financing via debt/guarantees/equity; can blend with grants (e.g., IF/CEF).	✓	✓	✓	✓
European Regional Development Fund (ERDF)	• Supports regional industrial decarbonisation and ecosystem building • Best for mid-scale or regional demonstration	Co-funded grants (typically 50–85% of project costs)	226.05 billion EUR	Place-based programmes at national/regional level; to receive ERDF in Germany, companies usually need a German project entity; alternative: act as supplier to ERDF-funded projects.	✓			✓
LIFE Programme	• Supports innovative CCUS projects • Ideal for technology validation and niche applications	Grants up to 60% of project cost	5.45 billion EUR (2021-2027)	EU-registered entities or associated countries. The UK is not associated; UK entities may participate only exceptionally and generally at their own cost unless essential to the action.	✓	✓	✓	

At the German level, the number of existing funding instruments for CCUS projects is significantly smaller than at the EU level

Funding instrument	Description	Subsidy type	Available funding	Eligibility / Access	CC	U	S	T
Carbon Contracts for Difference (CCfDs)	• Intend to initiate climate-friendly production processes in energy-intensive industries • CCfDs compensate for additional costs of climate-friendly production processes compared to conventional processes • Carbon capture projects are eligible to participate in 2026 auction (auction expected to be held in mid 2026)	Non-repayable grants compensating additional costs of climate-friendly production processes compared to conventional processes	6 billion EUR (2026 round; not exclusively for CCUS projects)	Eligible applicants are energy-intensive industrial installations operating in Germany. Scottish companies are not direct beneficiaries but may participate as technology, EPC, or CCUS service providers.	✓			
Federal Fund for Industry and Climate Action (Module 2)	• German federal funding program to support industrial decarbonisation and carbon management • Includes two main modules — one for industrial decarbonisation and one focused on Carbon Capture & Utilisation (CCU) and Carbon Capture & Storage (CCS) • Deadline for project draft submission: 28th of February 2026	Non-repayable grants provided as direct funding covering share of eligible investment and research costs	476 million EUR (for both modules – split between modules unknown)	Eligible applicants are industrial companies with sites in Germany. Projects must be implemented in Germany. Scottish companies are not direct beneficiaries but can participate as technology, EPC, or CCUS service providers.	✓	✓	✓	
Climate offensive for companies (KfW programme 293)	• Supports investments into production of equipment for capture, utilisation, and storage of CO_2	Low-interest loans and partial grants	25 million EUR	Projects must be located in Germany. Foreign-owned companies, including Scottish firms, are eligible if the project is implemented in Germany or via a German entity/JV.	✓			

At the German level, the number of existing funding instruments for CCUS projects is significantly smaller than at the EU level

Funding instrument	Description	Subsidy type	Available funding	Eligibility / Access	CC	U	S	T
8th Energy Research Programme	• Federal research funding programme that aims to accelerate applied energy research in support of Germany's climate neutrality goals • Targets project-based research, development and demonstration of novel technical solutions across key energy sectors, incl. carbon capture and utilisation	Funding is provided primarily as non-repayable grants	1.46 billion EUR (2023)	Applications must be submitted by German entities. International partners may participate, but funding is restricted to R&D performed and exploited in Germany.	✓	✓		
NRW.BANK.Invest Zukunft	• Provides low-interest loans and partial grants that can be used for CCUS projects or infrastructure	Low-interest loans and partial grants	10 million EUR	Projects must be located in North Rhine-Westphalia (NRW). Non-resident and foreign ownership is permitted where the investment is in NRW	✓	✓	✓	✓

Barriers and enabling factors for CCUS deployment in DE

With the approval of the 'Carbon Dioxide Storage and Transport Act', regulatory and political barriers to CCUS deployment were largely eliminated

Area	Barriers and enabling factors for CCUS deployment in Germany	CC	U	S	T
Regulatory	**Recent approval of Carbon Dioxide Storage and Transport Act** allows commercially operated CO_2 capture and storage facilities and deems construction of pipelines for CO_2 of overriding public interest.			✓	✓
	Cross-border CO_2 transport is currently still prohibited as London Protocol is not fully ratified. This includes borders within the EU/EEA.[1]				✓
	No international standard regulating specifications of CO_2 exists (e.g., in terms of purity), which can lead to liability risks between emitter and transport companies in case problems arise during transport of captured carbon.[2]				✓
Political	**New political importance of CCUS**: In coalition contract of German government, CCUS is described as indispensable instrument for reaching climate neutrality and plans are outlined to pass legislative package to commercially allow CCUS.	✓	✓	✓	✓
	Amendment to Carbon Dioxide Storage Act intends to simplify muti-agency coordination.	✓	✓	✓	✓
	Changes in political importance of climate protection in many geographies (e.g., United States, but also in Germany) results in companies being hesitant when investing in climate protection measures (incl. CCUS projects).[2]	✓	✓	✓	✓
	Divergent **positions among federal states when it comes to on-shore storage** with majority currently against on-shore storage.			✓	
	Governance across multiple ministries and states as well as unclear coordination can slow down project progress.	✓	✓	✓	✓

1) German Federal Parliament has adopted a bill to remove obstacles to export of carbon dioxide but approval by Bundestag is still pending
2) Insight from interview

CC – Carbon Capture U – Utilisation S – Storage T – Transport

However, the lack of a robust business case for CCUS projects is currently the largest barrier for CCUS deployment in Germany

Area	Barriers and enabling factors for CCUS deployment in Germany	CC	U	S	T
Financial & market	**European and German funding instruments** are in place that can cover significant share of research or capital expenditures for CCUS projects across entire value chain.	✓	✓	✓	✓
	Planned auction of **Carbon Contracts for Difference** for CCUS projects in Germany in 2026 creates financial planning security for companies investing into CCUS projects.	✓			
	Difficulty demonstrating **business cases for CCUS projects** due to low carbon price and unknown carbon price development under EU ETS, resulting in high planning uncertainty and reduced bankability of CCUS projects.[1]			✓	✓
	Implementation of carbon capture technologies requires **significant upfront capital expenditures as well as high operational expenses**.[1]	✓			
	Fully developed CO_2 transport and storage infrastructure currently very limited, resulting in additional expense for companies intending to install carbon capture plants on their sites.[1]	✓		✓	✓
	Although rail transport of CO_2 is technically feasible, rail companies in Germany currently have **limited practical experience and operational know-how in handling and transporting CO_2**.[1]				✓
	Currently **Low demand for green products** which could be produced using carbon capture technology (e.g., low-carbon cement) due to price premium for green products.[1]	✓			
Social	Some environmental **NGOs** (e.g. NABU, WWF Germany) now **cautiously support CCUS** for unavoidable emissions.	✓	✓	✓	✓
	Negative public perception of CCUS: CCUS has long been controversial in Germany due to environmental and safety concerns, particularly regarding onshore storage, resulting in public opposition and protests against CCUS projects.	✓	✓	✓	✓
	Not in my backyard **(NIMBYI) attitudes** towards onshore storage and CO2 pipeline infrastructure.[1]			✓	✓

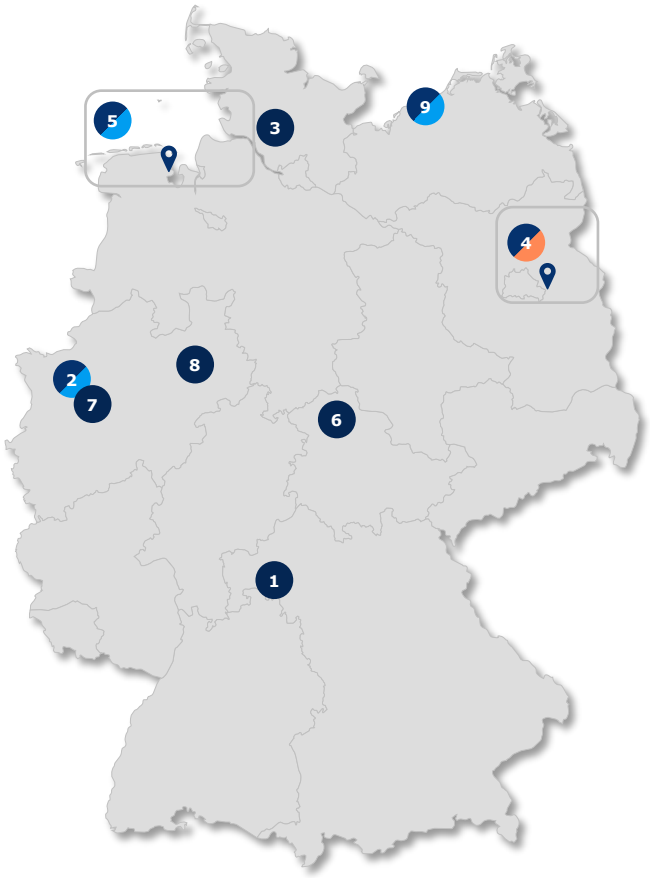
1) Insight from interview

CC – Carbon Capture U – Utilisation S – Storage T – Transport

Overview of CCUS projects in Germany

18 projects have been identified across varying stages of the value chain, illustrating the current extent of CCUS in Germany

Despite barriers, several CCUS projects in Germany are approaching their Commercial Operation Dates (COD) – most are carbon capture projects

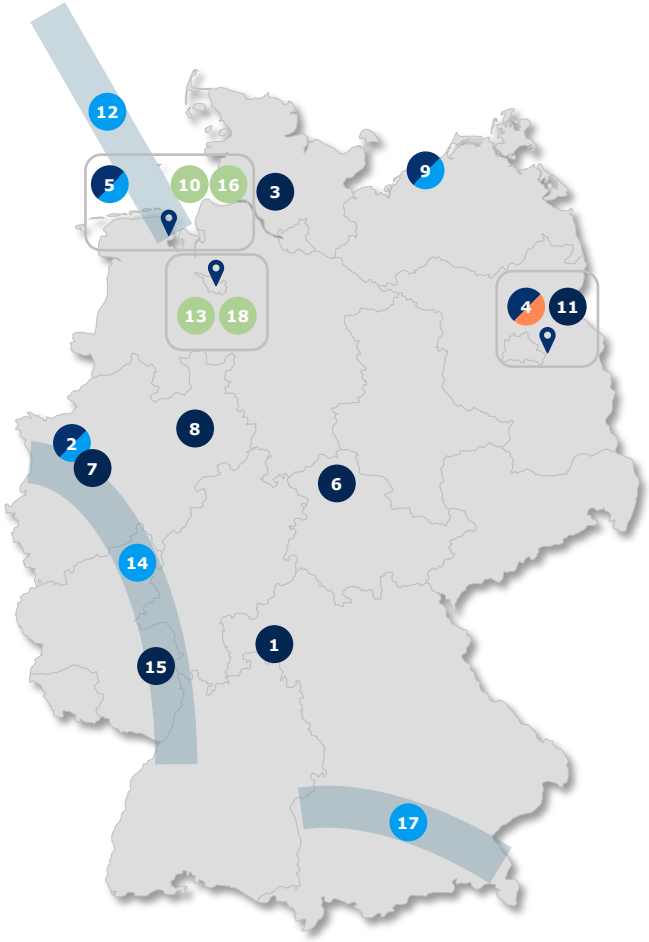


	Project name	Key developers	COD	Status	Capital expenditures	CO_2 capacity[1]
1	Cap2U Lengfurt	HeidelbergMaterials, Linde	Expected 2026[2]	In Construction	N/A	0.07
2	H2morrow	Equinor, OGE, thyssenkrupp Steel	2027	Early development	N/A	1.9
3	Carbon2Business	Holcim, thyssenkrupp Polysius, Linde	2028	In Construction	410mn€	1.2
4	Concrete Chemicals	CEMEX, Enertrag, Zaffra	2028	Early development	N/A	N/A
5	BlueHyNow	Wintershall Dea, NWO	2028	Announced	N/A	N/A
6	Dyckerhoff Deuna	Dyckerhoff	2029	Advanced Development	350mn€	0.62
7	EVEREST	Lhoist; AirLiquide	2029	Advanced Development	N/A	1.4
8	GeZero	HeidelbergMaterials, thyssenkrupp Polysius	2029	Advanced Development	~>500mn€	0.7
9	H2GE Rostock	Equinor, VNG AG	2029	Early development	N/A	~2.0

Carbon capture · Utilisation · Interim storage · Transport · Pipeline project

1) CO_2 capacity in million tonnes / year; 2) Announced COD late 2025, however not operational yet

CCUS projects with a later COD are more varied in terms of value chain segments



	Project name	Key developers	COD	Status	Capital expenditures	CO_2 capacity[1]
10	CO2nnectNow	Wintershall Dea; HES Wilhelmshaven Tank Terminal GmbH	2029	Early development	N/A	10
11	CO2llect	CEMEX, Linde	2030	Advanced Development	N/A	1,3
12	NOR-GE Pipeline (part of EU2NSEA)	Equinor, Wintershall Dea	2030	Advanced Development	N/A	20-40
13	CarbonBridge	Ambrian Energy	2030	Early development	N/A	N/A
14	Delta Rhine Corridor	BASF, Gasunie, OGE, Shell	N/A	Early development	N/A	N/A
15	Röhm chemical plant	Röhm	N/A	In planning	N/A	0,5
16	CO_2 export terminal Wilhelmshaven	Tree Energy Solutions	N/A	Announced	N/A	3-5
17	CO2peline	bayernets	Under Evaluation	Early development	N/A	N/A
18	Bremen Carbon Dioxide Transshipment Hub	CO2 Management AS; bremenports GmbH & Co. KG	Under Evaluation	Announced	N/A	N/A

Carbon capture · Utilisation · Interim storage · Transport · Pipeline project

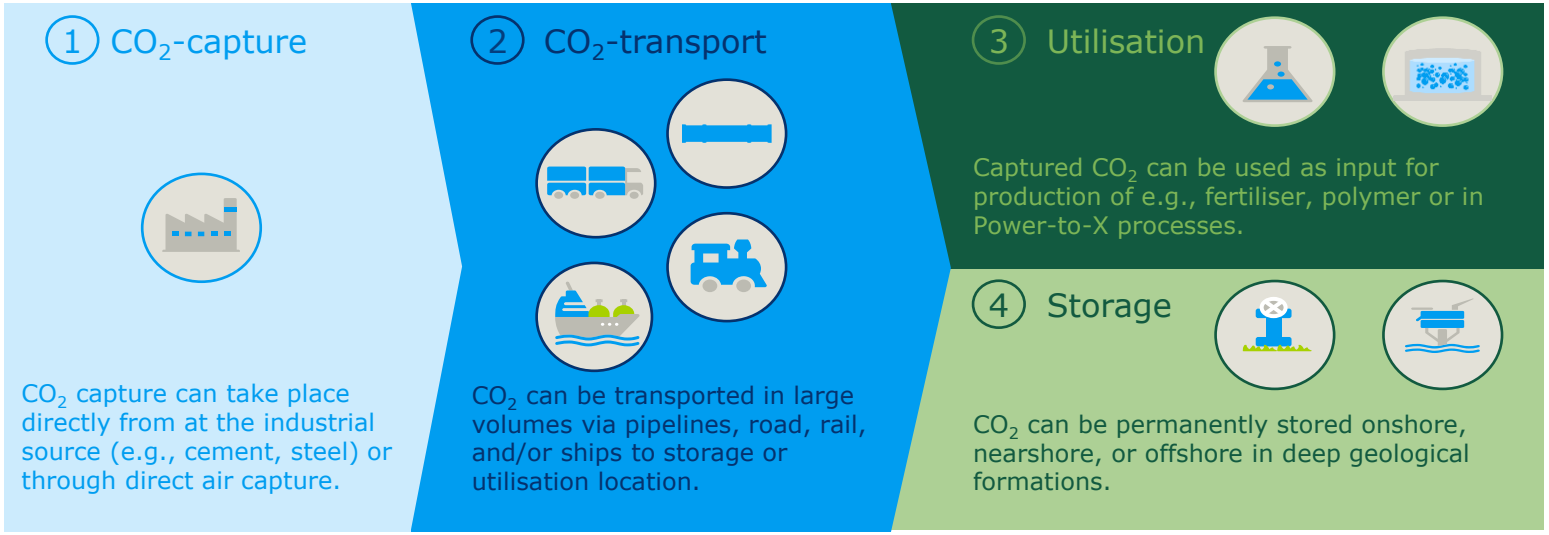
1) CO_2 capacity in million tonnes / year

German CCUS value chain opportunities

Carbon capture and transport are the most relevant and mature segments of German CCUS value chain – opportunities mainly exist in capture, transport and storage

The value chain segments were evaluated based on development status and relevance for Germany, while opportunities were mainly derived from interviews with key stakeholders

Overview of value chain



Approach to identification of opportunities / expected bottlenecks

Potential bottlenecks

Bottlenecks across each segment of the German CCUS value chain were identified through structured interviews with key market stakeholders, including representatives from industry associations, project developers, infrastructure operators, and consultancies. The interviews focused on current and anticipated constraints across the German CCUS value chain and cross-cutting enablers such as permitting, financing, and supply-chain capacity. Insights from individual interviews were consolidated and cross-validated to distinguish structural market bottlenecks from project-specific issues.

Approach to evaluation of German CCUS value chain

Development status

Evaluation of development status of value chain segment , i.e., an indicator of maturity. It is a qualitative evaluation of the activities in each segment, e.g., types of projects, timelines, and progression.

High maturity
Medium maturity
Low maturity

Relevance for Germany

Evaluation of relevance status of value chain segment for Germany. It is a qualitative evaluation of existing conditions (e.g., priorities, projects, infrastructure, etc.) in Germany that may support the deployment of a value chain segment.

High relevance
Medium relevance
Low relevance

Capture

This section contains a value chain segment overview, alongside information on potential CCUS clusters and capture technologies used in different projects

Capture projects are in development with 11 announced projects, and first COD expected in 2026[1]

Development status

Value chain maturity

- Capture represents the most mature part of the German CCUS value chain with approx. 11 commercial projects having been announced
- The technologies used for carbon capture are largely already proven with a TRL[2] from 6-9
- However, there are only research and testing projects operational in Germany so far, and commercial operation is still outstanding

Relevance for Germany

Relevance of value chain segment

- Germany is the largest CO_2 emitter in the EU with approx. 649 m tons of CO_2 emitted in 2024[3]
- Hard-to-abate sectors (e.g., chemical, steel, cement) play an important role in Germany and decarbonisation via CCUS may be the only viable option for emission reductions in these sectors
- Germany intends to become carbon neutral by 2045 – to achieve this, carbon capture is viewed as indispensable instrument[5]

Key actors

Emitters

Heidelberg Materials, Lhoist, HOLCIM, RÖHM TRADITIONALLY INNOVATIVE, CEMEX, Dyckerhoff, thyssenkrupp

Technology providers

thyssenkrupp Polysius, Air Liquide, Linde, GEA, GCT

Current technologies in use

Technology	TRL	Sectors
Chemical absorption	9	Power, WtE[4], cement, steel, refinery
Physical absorption	9	Power (biomass), WtE
Cryogenic	6-7	Cement
Adsorption	6-7	Cement, refinery
Oxy-fuel	6	Cement

Expected bottlenecks

Long lead times for columns (pillar-shaped vessels) for carbon capture:
Most carbon capture technologies require large pillar-shaped steel vessels, so-called columns (e.g., physical and chemical absorption, cryogenic, oxyfuel). There are only a few suppliers for these vessels, resulting in long lead times of ~15 months.

Shortage of expertise for on-site column assembly:
Large columns that are required for most carbon capture technologies are usually set up on site, which requires particular mechanical engineering expertise.

Implications for 2026-2030

Carbon capture is the most mature and the most relevant CCUS value chain segment in Germany. From now to 2030, several carbon capture projects are expected to reach COD - most of them in the cement and lime industry.

1) Cap2U Lengfurt; 2) TRL = Technology Readiness Level (ranging from 1: basic principles observed to 9: actual system proven in operational environment); 3) Umweltbundesamt (2025); 4) WtE = Waste-to-Energy; 5) Coalition contract of CDU/SPD government coalition (2025)

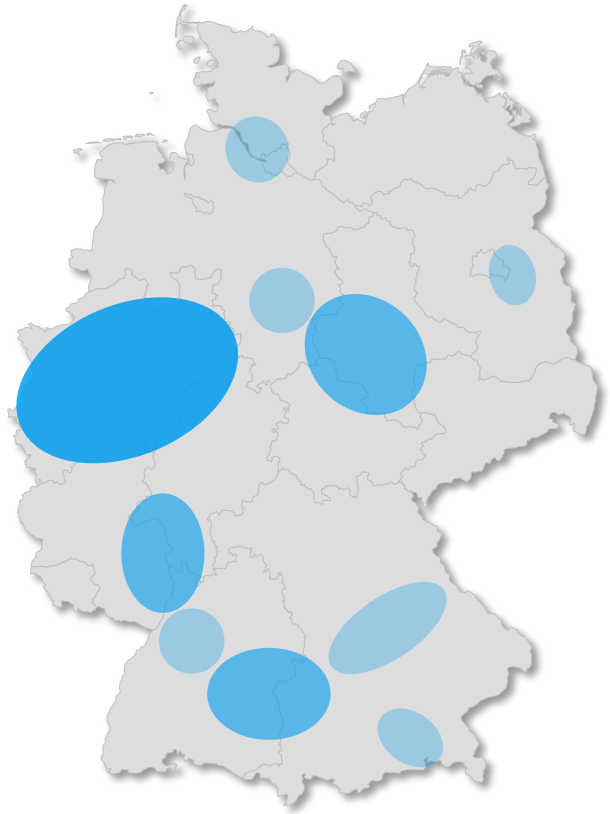
The cement and lime industries are the most advanced for carbon capture deployment in Germany and NRW[1] is expected to become capture hotspot

Emissions in different German industries

Industry	Emissions (mtons of CO_2 equivalents)[2,3]
Power (incl. waste incineration)	171
Waste incineration	**22**
Iron and steel	33.1
Refineries	21.8
Cement	**14.5**
Chemical industry	13.3
Lime	**5.9**

- The **cement and lime sectors are the most advanced in terms of CCUS deployment in Germany**, with waste incineration showing significant potential as well
- Early adoption of CCUS in the iron and steel industry is improbable due to alternative decarbonisation routes like hydrogen as well as the industry's current ETS exemption, which reduces the urgency for emission reductions

Potential carbon capture hotspot within Germany[4]



Carbon capture hotspots in Germany are expected in areas with large emitters from hard-to-abate sectors, which are geographically dispersed. However, state of **North Rhine-Westphalia (NRW) is expected to become largest carbon capture hotspot** due to multiple factors:

- High concentration of companies from hard-to-abate sectors
- Strong support for CCUS and carbon management signalled from state government, incl. publication of Carbon Management Strategy in 2021
- Good railway and road infrastructure for CO_2 transport as well as pipeline plans (e.g., the Delta-Rhine-Corridor)
- Proximity to the Netherlands as well as North Sea, allowing for export of CO_2 and hub development

1) NRW = North Rhine-Westphalia; 2) Umweltbundesamt (2024); 3) Wuppertal Institute for Climate, Environment and Energy (2022); 4) VDZ (2024)

While capture technologies applied are commonly mature, technical and practical challenges remain

Technology	TRL	Process description	Industries	Projects in Germany	Advantages of technology	Challenges of technology
Chemical absorption	9	• Uses solvents (e.g., amine, HPC[1]) to absorb CO_2 through chemical reactions • Loaded solvents are thermally regenerated and circulated in wash loop	• Power (gas, biomass) • Waste-to-Energy • Cement & lime • Steel • Refinery	• CAP2U Lengfurt (cement)	• Established technology • Easy retrofit for existing plants	• Requires significant amounts of heat for solvent regeneration (often provided in form of steam)
Physical absorption	8	• Uses solvents in which CO_2 dissolves under high pressure without any chemical reactions taking place	• Power (biomass) • Waste-to-Energy	• -	• Lower energy demand for regeneration of solvent • Cheaper than chemical absorption if CO_2 concentration is high	• Requires high pressure • Requires high CO_2 concentration (>30%)
Cryogenic	6-7	• Cools flue gas to desublimation point of CO_2 (-100 to -135 °C) and separates CO_2 as a solid	• Cement & lime	• EVEREST (lime) • CO2llect (cement; adsorptive-cryogenic)	• Only requires power to lower temperature • No additional chemicals required • No heat required	• Treating large amounts of CO_2 (in solid state) represents major challenge • Requires special equipment and materials as well as insulation
Adsorption	6-7	• Uses adsorbent for selective adsorption of CO_2 from gas mixture, which can be controlled by pressure or temperature	• Cement & lime • Refinery	• CO2llect (cement; adsorptive-cryogenic)	• Easy retrofit for existing plants • No additional chemicals required • No heat required	• Requires multiple columns, which may demand more footprint for large-scale applications • High pressure drop compared to absorption • Low efficiency at low CO_2 concentrations (e.g., flue gas)
Oxy-fuel	6	• Fuel is burned in pure O_2 rather than in ambient air • Requires energy-intensive air separation unit or alternative sources of pure O_2	• Cement & lime	• GeZero (cement) • Carbon2Business (cement)	• Highly concentrated CO_2 that can be liquefied	• Retrofitting of existing plants not possible • High energy demand due to air separation unit • Potential corrosion problems for systems with high O_2 content

1) HPC = Hot potassium carbonate

Transport

This section contains a value chain segment overview as well as a deep-dive on different transport modes

Similarly to carbon capture, transport is highly relevant in Germany, though maturity levels differs across transport mode

Development status

Value chain maturity

- There are 4 transport modes for CO_2 with varied levels of maturity: truck, train, ship and pipeline
- Truck, train and ship are significantly more developed than pipeline due to existing infrastructure
- While there are plans for three CO_2 pipelines in Germany, no CO_2 pipeline is currently under construction or operational

Relevance for Germany

Relevance of value chain segment

- CO_2 transportation is a crucial element of CCUS as an instrument for reaching climate neutrality in Germany by 2045
- Emitters and potential off-takers of captured carbon are geographically dispersed in Germany and current CO_2 storage sites are located in other countries, making transport a highly relevant part of the CCUS value chain

Key actors

Truck

EUROTANK, Air Liquide, TOMCO2 SYSTEMS, AIR PRODUCTS

Train

DB, VTG, CAPTIMISE

Ship

DAN-UNITY CO2, EVERGAS, CO2LOS – CO2 Logistics by Ship Phase II

Pipeline

wintershall dea, equinor, TES, OGE

Current transport modes

Transport mode	TRL	Comment
Truck	9	Typical for pilot and demonstration projects
Train	8	Typical for pilot and demonstration projects
Ship	8	Mainly for cross-border transport to storage sites
Pipeline	9	Ideal for large quantities; no CO_2 pipelines in DE

Expected bottlenecks

Shortage of ships for CO_2 transport:
CO_2 is expected to be transported via ships to storage sites in North Sea until pipelines from the mainland to storage sites are built. There are currently not enough ships available to enable this.

Shortage of barges for CO_2 river transport:
There is an expected shortage of barges for CO_2 river transport.

Shortage of tank wagons for CO_2 transport on rail:
There is an expected shortage of tank wagons for transporting CO_2 on rail.

Implications for 2026-2030

Transport is highly relevant for the development of the German CCUS market. Pipelines are not expected to be operational before 2030. Due to the existing rail connection of many cement and lime plants, trains are expected to play a major role in the transport of captured CO_2 until 2030.

The ideal use case differs across the four transport modes, while technology readiness level are consistently high

	Truck	Ship	Pipeline	Rail
				
	TRL 9	**TRL 8**	**TRL 9**	**TRL 8**
	Already widely used with high technological maturity	Commercial technology, currently only for smaller quantities	Commercial CO_2 pipelines already in operation (not in DE)	Technically possible but little used
	In liquid form from 15 to 18 bar & -25 to -30°C	In liquid form 5 to 50 bar & -56 to 15°C	In liquid form 7 bar & -50°C Gaseous 30 bar & 5°C	In liquid form approx. 20 bar & -20°C
	Smaller quantities	Medium quantities (large quantities planned)	Large quantities	Medium quantities
	Short distances and with higher uncertainty	CO_2 tankers for transport over longer distances	For transport over short to long distances (e.g., in clusters)	Limitation depends on station and rail network
	Air Liquide supplies CO_2 for further use in various industries	Northern Lights will direct CO_2 from ships (up to 12.000m³) to the terminal in Øygarden	In Europe, Norway (153km) and the Netherlands (97km), further projects planned (3 in Germany)	Air Liquide announced plans in 2022 for a CO_2 transshipment hub in Duisburg
[1]	EUROTANK, Air Liquide, TOMCO2 SYSTEMS, AIR PRODUCTS	DSIC, DAN-UNITY CO2, PRIME, EVERGAS, CO2LOS CO2 Logistics by Ship Phase II	wintershall dea, eni, Air Liquide, TES, OGE, equinor	DB, VTG, CAPTIMISE

1) Key players; Sources: Interview insights, Global CCS Institute, Air Liquide; Energienet; Umweltbundesamt, Greenfacts, Energy Research, OGE

Utilisation

This section contains a value chain segment overview

While there are many potential use cases, utilisation of captured carbon has a low development status and relevance in Germany

Development status

Value chain maturity

- CCU technologies (e.g., conversion of CO_2 into chemicals, fuels, or building materials) are mostly in research, pilot, or demonstration phase in Germany
- Only 1 commercial-scale utilisation projects has been announced so far with Commercial Operation Date (COD) in 2028 (joint project of CEMEX, Enertrag, Zaffra)

Relevance for Germany

Relevance of value chain segment

- CCU is less critical for meeting carbon neutrality goals when compared to other CCUS value chain segments (e.g., capture, transport)
- Nevertheless, utilisation of captured carbon provides opportunities for circular economy solutions, especially for Germany's strong chemical industry, which might become major off-taker of captured carbon

Key actors

Heidelberg Materials, ZAFFRA, VICAT, SCHWENK, ENERTRAG One energy ahead, Linde, Dyckerhoff, CEMEX

Use cases with high potential

Use case	Assessment
Methanol production	High potential due to wide range of potential applications and deployment of innovative technologies
Methane production	High potential due to wide range of potential applications and greater desired independence in natural gas supply
Kerosine production	High potential due to potential utilisation in sectors with legally mandated blending quotas

Expected bottlenecks

No bottlenecks identified

Implications for 2026-2030

The low maturity of this value chain segment, and the likelihood of captured carbon being stored permanently elsewhere, suggests that utilisation is unlikely to be a significant area of development over this time period. Given the range of use cases and potential offtakers in Germany (chemicals industry), demand for utilisation projects may increase from 2030, when earlier value chain stages are better established. A higher ETS price would potentially provide a financial incentive to utilisation and therefore increase its relevance.

Storage

This section contains a value chain segment overview

Permanent storage is immature and likely to be less relevant, due to expected utilisation of more developed storage sites in other countries

Development status

Value chain maturity perm.[1] storage ●○○○○

Value chain maturity interim storage ●●○○○

- Offshore storage is permitted since Nov. 2025 – however, no announced offshore storage projects
- Federal states can permit onshore storage in their territory – so far, no federal state has permitted onshore storage
- For interim storage, existing infrastructure can be utilised, hence higher maturity

Relevance for Germany

Relevance of permanent storage ●○○○○

Relevance of interim storage ●●●●●

- CO_2 captured in Germany expected to be permanently stored in storage sites abroad (e.g., Denmark, Norway, UK) which are further developed than potential German storage sites
- Interim storage between capture and permanent storage sites has a high relevance, esp. in potential transport hubs in North Sea region

Key actors

TES Hydrogen for life

HES International

Ambrian Energy

Expected CO_2 transport (interim storage) hubs

Wilhelmshaven
Expected to become main transport hub with 4 interim storage and pipeline projects announced

Bremen
2 interim storage projects announced in Bremen

Hamburg
Hamburg Port Authority major player pushing CCUS

Expected bottlenecks

Onshore and offshore storage capacity:
Onshore and offshore storage was only allowed for research purposes until Nov. 2025. Hence, potential onshore and offshore storage sites are currently unexplored and undeveloped

Lack of storage development expertise:
Germany lacks expertise when it comes to the development of potential storage sites

Implications for 2026-2030

Permanent storage projects / opportunities are unlikely in Germany until 2030. However, interim storage, especially in export hubs, are highly relevant to facilitate export to storage sites in other countries (expected to be permitted in 2026)

1) Permanent storage

CCUS value chain opportunities over time

Within the German CCUS market, there are various opportunities from now to 2035 and beyond

Short-term
2026 – 2030

1. **Steel columns for carbon capture technologies**: For most carbon capture technologies, large steel columns are required. Carbon capture is the most mature CCUS value chain segment in Germany with 11 capture projects already announced. As of now, there are only a few suppliers for these vessels, resulting in long lead times of ~15 months. This creates opportunities for companies that have the capabilities to manufacture these steel columns.
2. **Engineering expertise for on-site column assembly**: Steel columns for carbon capture technology are usually assembled on site. There are opportunities in the provision of the engineering expertise required for the on-site assembly of these steel columns.
3. **Tank wagons for CO_2 transport on rail**: Until pipeline network connection exists, large quantities of captured CO_2 are expected to be transported via rail. Not enough tank wagons are available to enable this resulting in opportunities for companies that manufacture tank wagons or parts of them.

Medium-term
2030 – 2035

4. **Ships for CO_2 transport**:CO_2 is expected to be transported via ship to storage sites in North Sea until pipelines from the mainland to storage sites are built. Current ship availability is insufficient to transport the expected amount of CO_2. Additional ships are required, resulting in opportunities for companies that manufacture these ships or parts of them.
5. **Barges for CO_2 river transport**: Until pipeline network exists, river transport of CO_2 is expected to be widely used. There is an expected shortage of barges for CO_2 river transport, resulting in opportunities for companies that manufacture these barges or parts of them.
6. **Storage capacity**: There is currently no on- or offshore storage capacity in Germany. Even after the development of storage sites in Germany, local emitters are expected to export notable quantities of CO_2 to other countries, creating opportunities for countries with storage capacity.

Long-term
2035+

7. **Engineering expertise for (offshore) storage development**: While onshore storage in Germany is currently expected to be unlikely, offshore storage in the German EEZ is geologically feasible and is currently being explored. Germany has limited expertise for the development of these potential offshore storage facilities. This creates opportunities for companies with offshore storage capabilities (e.g., from the oil and gas industry)

Capability and opportunity matching

Scottish companies are well positioned to capitalise on opportunities within the German CCUS market, given their known existing capabilities

Scottish companies are well positioned to export CCUS-related goods and services to Germany, across the entire value chain

Overall CCUS-related strengths of Scotland:

~1,000
companies with potential CCUS supply-chain capabilities

Skilled workforce
in key areas including engineering, construction and professional services

Existing skills and knowhow
from oil and gas sector and process industries that are adaptable for CCUS

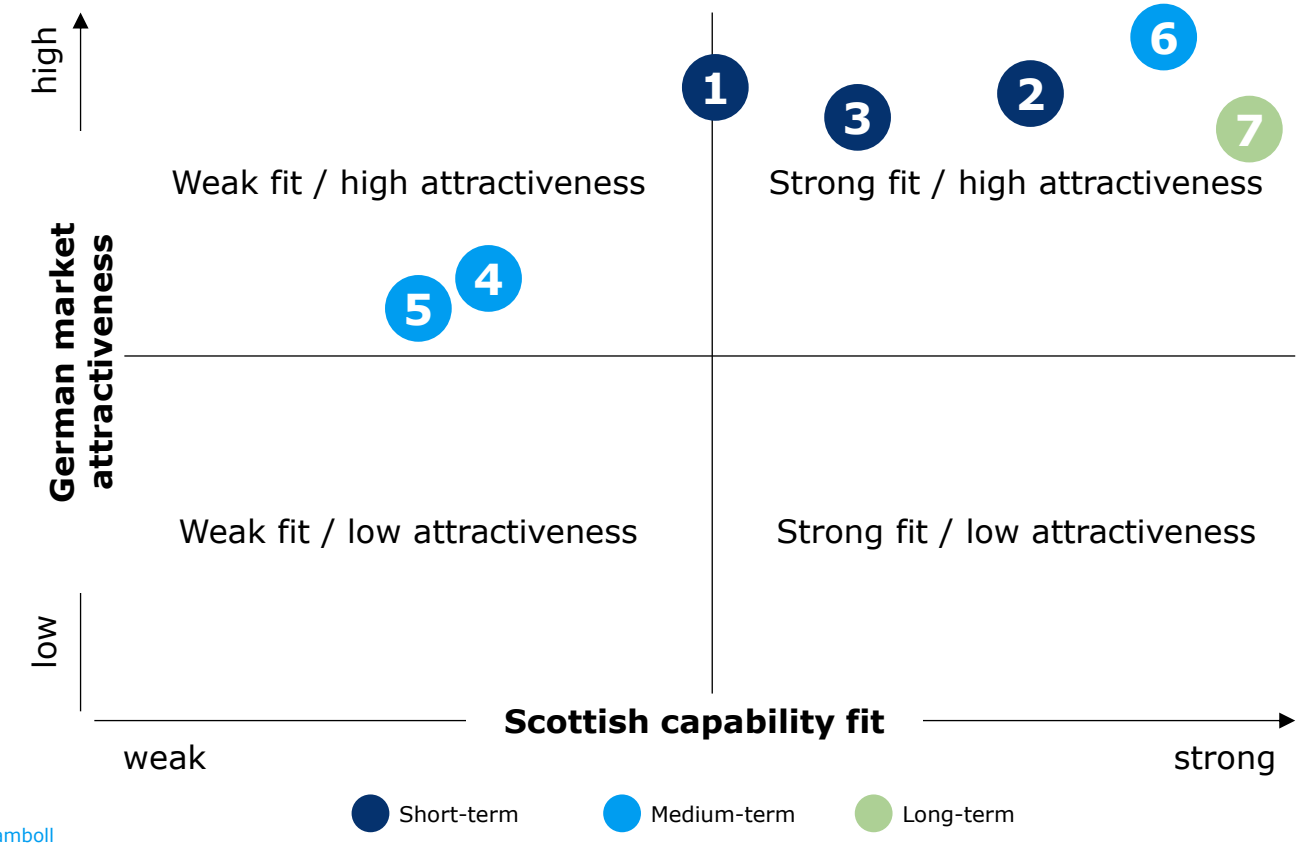
Specific Scottish CCUS capabilities

Area of capabilities	Details (non-exhaustive)	CC	U	S	T
Engineering and construction	Modular construction techniques, project management expertise, and specialised engineering services for designing complex installations (e.g., skills and technologies in constructing offshore oil platforms can be adapted for building offshore CO_2 storage facilities, incl. subsea injection systems and pipeline networks)	✓	✓	✓	✓
Monitoring and control equipment	Sensors and software for real-time monitoring of emissions, process control technology for managing capture and storage operations, and safety systems designed to prevent leaks and ensure integrity of storage sites	✓		✓	✓
Pipelines	Pipeline design, construction, and operation including use of advanced materials for high-pressure environments, corrosion protection systems, and leak detection technologies which are required for CO_2 transportation networks on land and underwater				✓
Storage	Scotland possesses significant storage potential in the North Sea			✓	

Considering the opportunities within the German CCUS market, many are aligned and highly attractive to the Scottish supply chain

Approach to identification of key opportunities

Once opportunities had been identified in Germany, a gap-fit workshop was conducted with a range of stakeholders representing Scottish supply chain companies. As part of the workshop, these opportunities were considered from a Scottish perspective. The output included the prioritisation matrix presented below, where opportunities 1-7 were mapped. In some cases new ideas were generated considering Scotland's strengths and potential competitive advantages, as these were not raised in interviews with German stakeholders, these are narrated in the strategic recommendations section to be explored at a later date.



Opportunity

1. **Steel columns for carbon capture technologies**
2. **Engineering expertise for on-site column assembly**
3. **Tank wagons for CO_2 transport**
4. **Ships for CO_2 transport from mainland to storage sites**
5. **Barges for CO_2 transport on inland waterways**
6. **Storage capacity**
7. **Engineering expertise for (offshore) storage development**

These opportunities are explored in more detail in the following pages

Amongst the most promising opportunities are the engineering expertise for storage development, alongside the provision of storage capacity

Ranking	Opportunity
Strong fit / high attractiveness	**Engineering expertise for (offshore) storage development:** Germany is currently exploring potential offshore storage sites in the German EEZ. Scottish companies from the oil and gas industry could play a crucial role in the development of these storage sites given their capabilities (e.g., constructing offshore oil platforms can be adapted for building offshore CO_2 storage facilities).
	Storage capacity: There is a high short- to medium-term demand for storage capacity of German emitters to permanently store their capture CO_2. Scotland's offshore geological formations offer significant long-term CO_2 storage potential where CO_2 from German emitters could be stored.
	Tank wagons for CO_2 transport: Until 2035, additional tank wagons will be required to facilitate CO_2 transport. Scottish companies are well positioned to contribute to this segment through the fabrication of high-specification CO_2 tanks, specialised components, and engineering services.
	Engineering expertise for on-site column assembly: High short-term need for steel columns in Germany. Scottish companies possess strong engineering and project execution capabilities that are directly transferable to the on-site assembly and installation of large carbon capture columns, particularly for brownfield and retrofit projects.
	Steel columns for carbon capture technologies: High short-term need for steel columns in Germany. Scottish companies possess strong engineering and manufacturing capabilities. However, for standardised onshore capture plants, column fabrication is often procured on a cost-optimised basis, with strong competition from lower-cost international suppliers. Opportunities exist when it comes to complex installations.
Weak fit / high attractiveness	**Ships for CO_2 transport from mainland to storage sites:** Until 2035, additional ships are required to facilitate CO_2 transport from mainland Germany to storage sites. Scottland has a strong shipbuilding capabilities. However, for standardised large-scale CO_2 carriers, international competitiveness is likely constrained by cost structures.
	Barges for CO_2 transport on inland waterways: Until 2035, additional barges are required to facilitate CO_2 transport on inland waterways. Scotland has strong shipbuilding capabilities. However, CO_2 transport barges are characterised by highly standardised designs and strong cost sensitivity, which poses a constraint for Scottish shipbuilders.

Engineering expertise for storage development and permanent storage capacity are among the highest ranked opportunities in terms of fit and attractiveness, but these are longer-term

Engineering expertise for offshore CO_2 storage development

Medium term

Rationale

- German offshore engineering expertise is limited
- High reliance on proven North Sea experience
- Not price-driven; trust and track record matter

Recommended entry modes

- Engineering, advisory, and project development services
- Position as:
  - Technical advisor
  - Subsurface and injection system designer
  - Offshore CCS project developer

Recommended engagement approach

- Support:
  - German storage site appraisal
  - Offshore storage projects outside Germany serving German emitters
- Engage early in project development phase

Example pathways

- Advisory roles in FEED studies or permitting and MMV design
- Long-term involvement in German offshore CCS hub development

Provision of CO_2 storage capacity

Long term

Rationale

- Germany lacks sufficient domestic permanent storage
- Storage is a system-level bottleneck
- Access is controlled by a small number of operators

Recommended entry modes

Long-term commercial agreements and cross-border CCS chains

- Enter via:
  - Storage service agreements
  - Capacity reservation contracts
  - Joint ventures with German infrastructure players

Recommended engagement approach

- Engage at:
  - Government-to-government level
  - Large industrial consortia level
  - Focus on anchor emitters with large, long-term CO_2 volumes

Example pathways

- Cross-border CCS hubs linking: German industrial clusters with Scottish offshore storage
- Participation in EU-funded cross-border CCS projects

Components for tank wagons and engineering expertise for on-site steel column assembly are attractive opportunities in the short term

Manufacturing of components for tank wagons for CO_2 transport

Short term

Rationale

- Full wagon manufacturing is dominated by incumbents
- Severe wagon shortage creates openness to new component suppliers
- Certification barriers favour partnerships

Recommended entry modes

- Component supply and engineering partnerships
- Focus on:
  - CO_2 pressure tanks
  - Specialised valves and safety systems
  - Engineering for wagon conversion or adaptation

Recommended engagement approach

- Partner with:
  - German wagon manufacturers
  - Rail leasing companies
- Engage via pilot corridors linking emitters to ports or storage hubs

Example pathways

- Supply tanks for small series of CO_2 wagons
- Support conversion of existing LPG wagons where feasible

Engineering expertise for on-site column assembly

Short term

Rationale

- German industrial sites are often brownfield
- Installation risk is a key concern for project owners
- Less price-driven than column manufacturing

Recommended entry modes

Engineering services, installation packages, and execution support

- Enter as:
  - Installation engineering contractor
  - Modular assembly specialist
  - Construction management partner

Recommended engagement approach

- Target early CCS projects under strong schedule pressure
- Engage with
  - Industrial operators directly
  - EPCs[1] responsible for capture plant delivery

Example pathways

- Framework agreements with EPCs for installation support
- Participation in FOAK capture projects supported by German or EU funding

1) EPC = Engineering, Procurement, and Construction (project delivery model that gives contractor (EPC) responsibility of handling project from start to finish)

Manufacturing of steel columns required for carbon capture technologies is also identified as a short term opportunity

Manufacturing of steel columns for carbon capture technologies

Short term

Rationale

- German EPCs control capture equipment procurement
- Price competition is intense for standard columns
- Scottish value lies in complexity, logistics, and execution reliability

Recommended entry modes

- Selective manufacturing via EPC integration and modularisation
- Position as specialist supplier for:
  - Large-diameter or oversized columns
  - Modularised columns assembled on site
  - First-of-a-kind or retrofit-heavy projects
- Avoid open tendering for standardised columns

Recommended engagement approach

- Early-stage collaboration with EPCs active in German CCS (pre-FEED/FEED)
- Consortia with German installation contractors
- Pilot-scale capture projects in industrial clusters (cement, lime, waste-to-energy)

Example pathways

- Partner with a German EPC to deliver column fabrication + on-site assembly
- Offer design-for-modularisation services tied to fabrication

Strategic recommendations for SE

There are a number of ways Scottish Enterprise and its partners can support Scottish companies to capitalise on the opportunities that the German CCUS market offers

There are a range of ways in which Scottish Enterprise and its partners can support Scottish companies engaging with opportunities in the German CCUS market

An overview of key recommendations is shown below, with more detail on the following pages including actions and examples.

Facilitate dialogue between Scottish and German companies

Lower market-entry barriers by creating structured, repeated interactions between Scottish capability providers and German CCUS project developers, EPCs, operators, and OEMs.

Promote Scottish CCUS capabilities to the German CCUS market

Position Scotland as a credible, differentiated CCUS partner in areas where it has genuine competitive advantages, rather than as a generic supplier base.

Help Scottish companies to better understand the German CCUS market

Help Scottish companies to obtain a thorough understanding of the German CCUS market including its needs and opportunities.

Policy engagment to resolve remaining barriers (regulatory and structural)

Address system-level barriers that individual companies cannot influence but that affect cross-border CCUS value chains.

Regular dialogue and improved understanding of the German CCUS market are priority recommendations to begin to realise opportunities

1. Facilitate dialogue between Scottish and German companies

Objective

Lower market-entry barriers by creating structured, repeated interactions between Scottish capability providers and German CCUS project developers, EPCs, operators, and OEMs.

Why this matters

- The German CCUS market is EPC- and project-developer led
- Supplier access is relationship-driven, especially in early project phases
- Many German projects are still at pre-FEED / FEED, where informal dialogue strongly shapes procurement

Recommended actions for SE & partners

- Organise targeted B2B matchmaking formats, not generic networking:
  - Thematic roundtables (e.g. capture installation, CO_2 transport, offshore storage)
  - Closed-door workshops aligned to specific project types
- Facilitate EPC–supplier engagement, not just operator–supplier dialogue
- Enable consortium building among Scottish firms for integrated offerings

Practical examples

- Annual Scotland–Germany CCUS Industry Roundtable
- Delegation visits to German CCS clusters and EPC offices
- Invitation-only workshops linked to specific CCS project archetypes

2. Help Scottish companies to better understand the German CCUS market

Objective

Help Scottish companies to obtain a thorough understanding of the German CCUS market including its needs, opportunities and how to engage.

Why this matters

- To benefit from the expected CCUS market ramp up in Germany, Scottish companies need to understand the German CCUS market (incl. its needs and resulting opportunities)
- Misunderstanding the market structure leads to misaligned entry strategies

Recommended actions for SE & partners

- Provide regular market intelligence updates, including:
  - Project pipeline tracking
  - Policy and regulatory developments
  - More detail on potential funding instruments such as the Innovation Fund and how to access these, including timelines
- Provide targeted support to Scottish companies to tap into opportunities
- Focus on how to engage, not just what is happening

Practical examples

- Webinar in which results of this study are presented to Scottish companies
- Periodic German CCUS Market Briefings
- Organisation of peer learning and knowledge sharing sessions on opportunities in the German market

Promotion of Scottish CCUS capabilities and lobbying to resolve remaining barriers are also important to maximise potential

3. Promote Scottish CCUS capabilities to the German CCUS market

Objective

Position Scotland as a credible, differentiated CCUS partner in areas where it has genuine competitive advantages, rather than as a generic supplier base.

Why this matters

- German stakeholders are risk-averse and value:
  - Proven execution capability
  - Reference projects
  - System-level thinking
- Scottish strengths are often under-recognised or poorly understood

Recommended actions for SE & partners

- Develop a clear value proposition narrative by CCUS segment for Scotland
- Move from general promotion to opportunity-specific messaging
- Further explore ideas generated in the workshop such as digital solutions and provision of measuring, monitoring and verification equipment.
- Act as a trusted interface between Scottish industry and German stakeholders

Practical examples

- CCUS-focused capability catalogues aligned to German needs
- Themed showcase events (e.g. offshore storage expertise, installation engineering)
- Joint appearances at German and European CCUS conferences
- Case studies highlighting transferable North Sea experience

4. Policy engagement to resolve remaining barriers (regulatory and structural)

Objective

Work to address system-level barriers that individual companies cannot influence but that affect cross-border CCUS value chains.

Why this matters

- Cross-border CCS requires:
  - Regulatory alignment
  - Technical standardisation
  - Political coordination
- Remaining uncertainties slow down investment decisions

Recommended actions for SE & partners

- Act as a collective voice for Scottish industry
- Engage in bilateral policy dialogue with German counterparts

Practical examples

- Position papers on CO_2 specifications and cross-border CCS governance
- Participation in German–UK CCUS working groups and EU-level CCS policy forums
- Coordination with other industry associations and public authorities on both sides

Bright ideas. Sustainable change.

RAMBØLL