Industrial Energy-Related Technologies and Systems iets
An IEA Technology Collaboration Programme

Decarbonizing Industrial Systems in a Circular Economy

Comparison of national perspectives on CCUS

IEA IETS XXI Phase #3 / Activity 4A

08.06.2026 – Public final workshop (online)

Dr. techn.Valerie Pfeffer-Rodin – Energieinstitut an der JKU Linz, Austria

Project framing

- International Energy Agency (IEA)
- Technology Collaboration Programmes (TCPs)
  - several topics represented by one or more TCPs
    - Buildings
    - Electricity
    - Industry
    - Transport
    - Renewable energy
    - Fossil energy
    - Fusion power
    - Cross-cutting

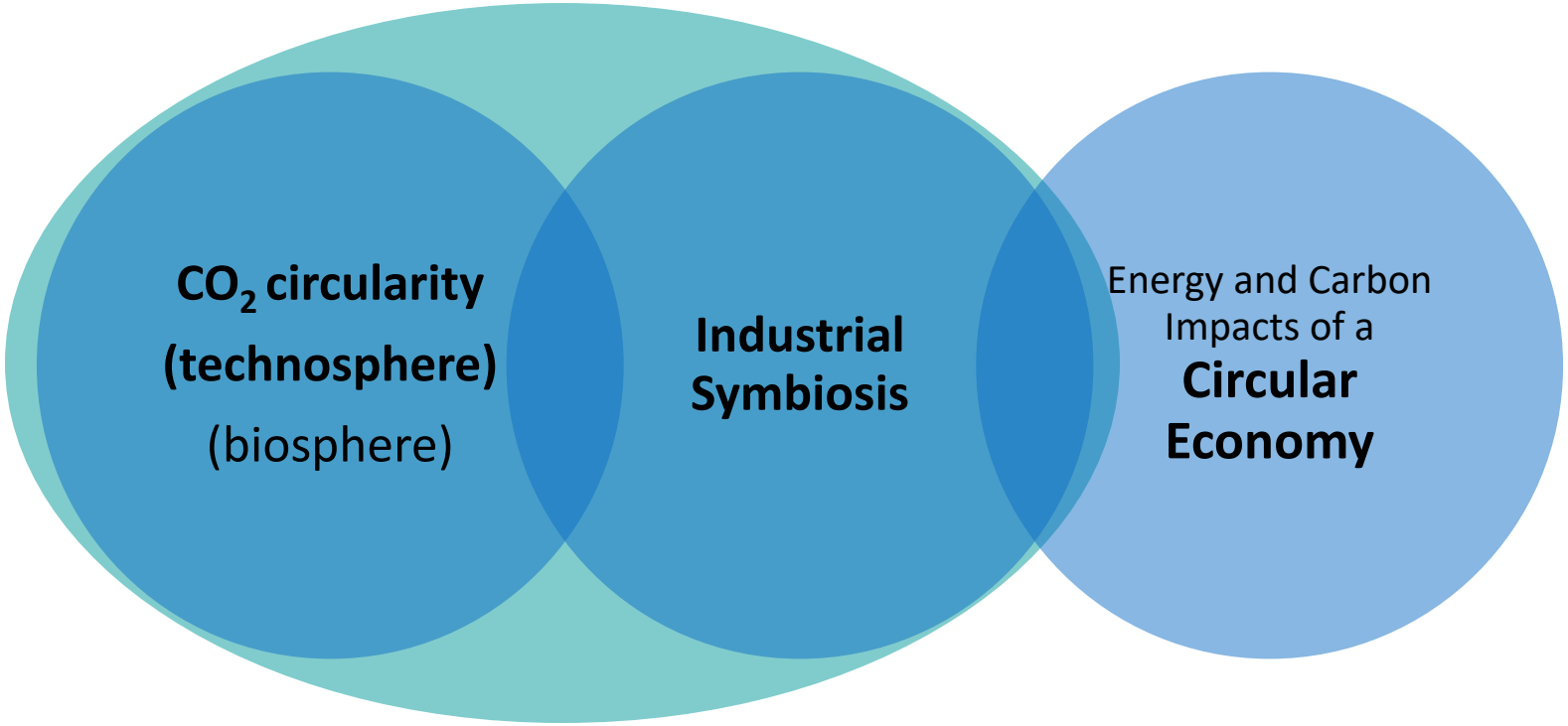
Technology Collaboration Programme by IEA

- Global network driving energy innovation through international cooperation
- Connects governments, industry, and experts to develop energy solutions
- Supports expert groups advancing research and commercialization

- Each of the TCPs has 1+ Tasks on specific sub-topics
  - Example: Industry TCP "Industrial Energy-Related Technologies and Systems"
    - **Task XXI on "Net-zero Industrial Processes in a Circular Economy Framework"**

Net-zero Industrial Processes in a Circular Economy Framework

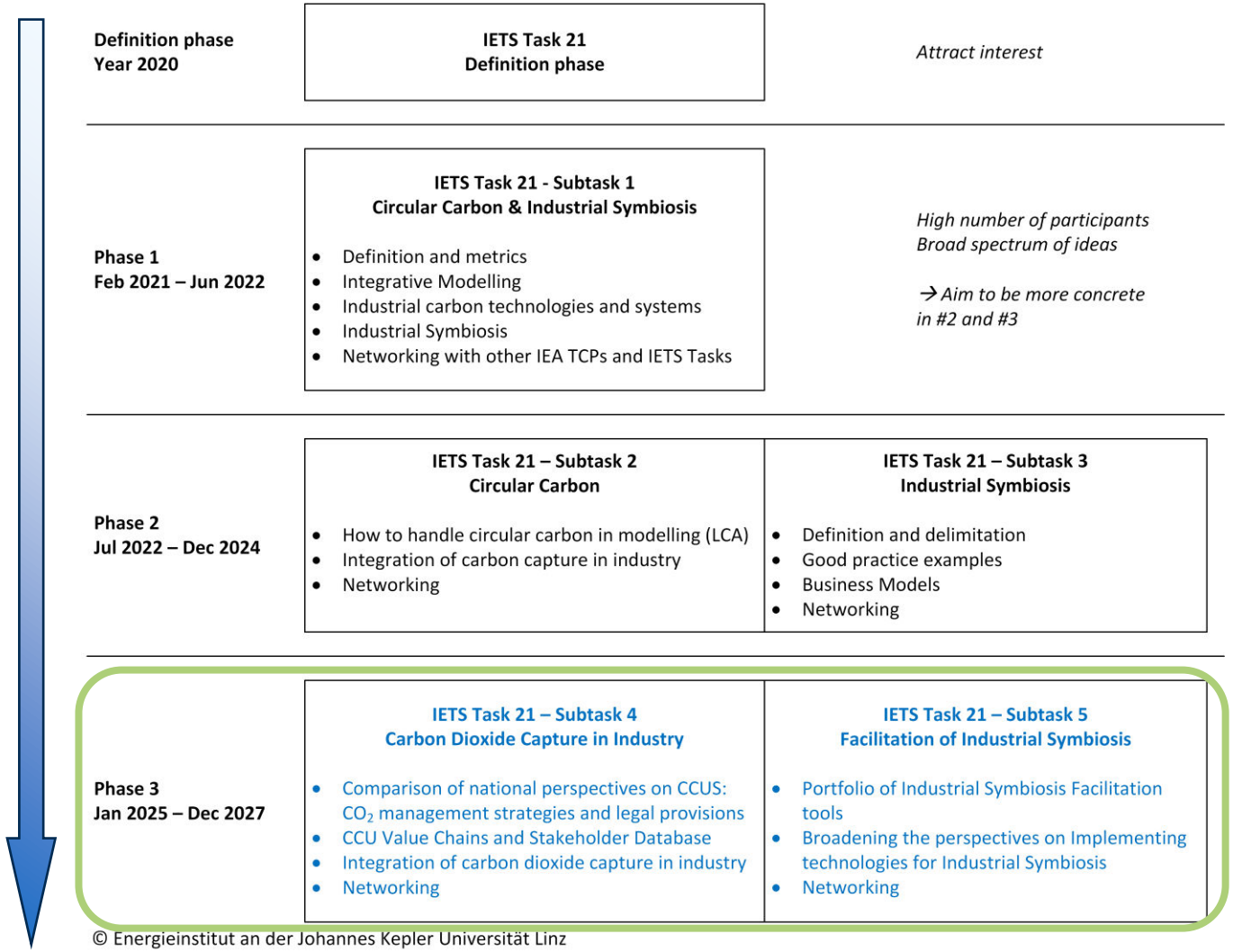
IEA IETS Task XXI



Net-zero Industrial Processes in a Circular Economy Framework

IEA IETS Task XXI

- **Task Manager:**
  - Simon Moser – Energieinstitut an der JKU Linz
- **Participating countries:**
  - Austria
  - Denmark
  - Germany
  - Italy
  - the Netherlands
  - Norway
  - Portugal
  - Sweden



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IEA IETS XXI Phase #3 Structure

Subtask 4: Carbon Dioxide Capture in Industry

Activity A. Comparison of national perspectives on CCUS*
- CO_2** management strategies
- National legal provisions

today's focus

Activity B. CCU*** Value Chains and Stakeholder Database

Activity C. Integration of carbon dioxide capture in industry
- CC**** trade-offs (purity, quality, energy)
- Real-life challenges of CC in industry

Activity D. Networking

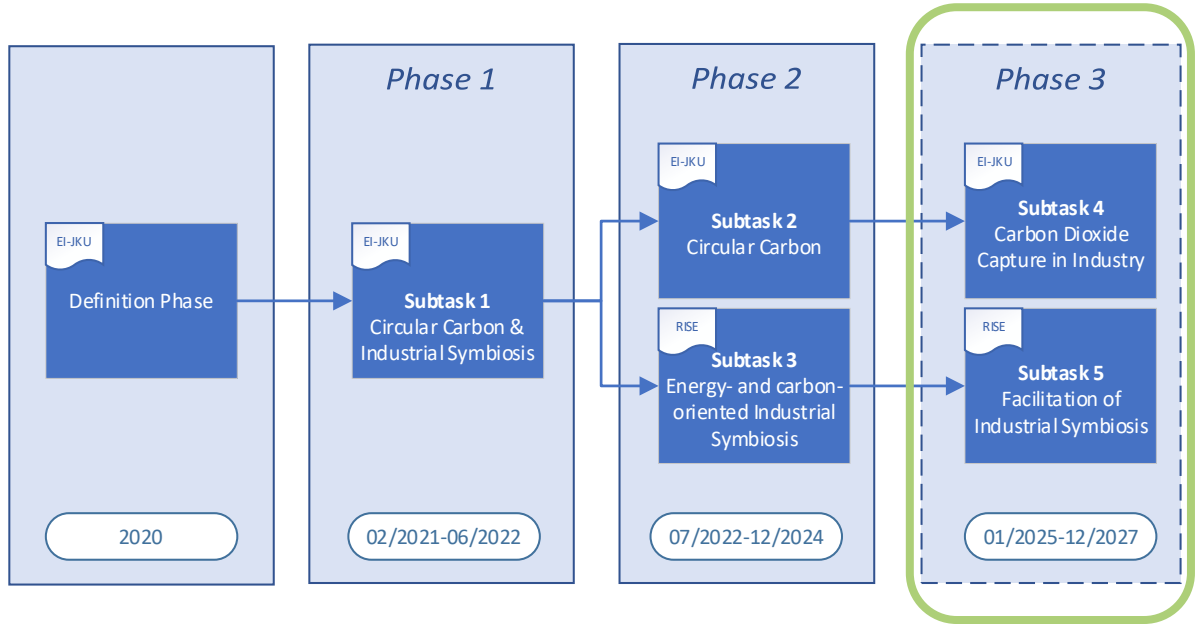
Subtask 5: Facilitation of Industrial Symbiosis

Activity A. Portfolio of Industrial Symbiosis Facilitation tools

Activity B. Broadening the perspectives on Implementing technologies for IS

Activity C. Networking

IETS Task XXI: Net-zero industrial processes in a circular economy framework



*CCUS = Carbon Capture, Utilization and/or Storage
**CO_2 = Carbon Dioxide
***CCU = carbon capture and Utilization
****CC = Carbon Capture

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Objectives of IEA IETS XXI Phase 3 Subtask #4 Activity A

Comparison of national perspectives on CCUS

Background and Policy Context

- **Challenges in Industrial Decarbonization**
  - Energy-intensive industries emit significant greenhouse gases that are difficult to reduce using conventional methods alone.
- **Role of CCUS Technologies**
  - CCUS technologies enable capture and storage or reuse of carbon emissions in industries lacking alternatives.
- **Circular Carbon Economy**
  - Circular carbon concepts focus on recycling and substituting fossil carbon with renewable and recycled sources.
- **Policy and Strategic Context**
  - Policies prioritize mitigation first, integrating CCUS as a complementary solution within broader climate strategies.

Analytical Aims and Research Questions

- **Identification of CO_2 Management Strategies**
  - The activity aimed to compile national CO_2 management strategies and examine how CCUS is framed within climate and energy policies.
- **Mapping Legal Frameworks**
  - Comparative analysis of national and EU legal provisions related to CCUS focused on regulatory scope and maturity.
- **Comparative Perspective and Systemic Challenges**
  - Identification of similarities, differences, and barriers like infrastructure and regulatory fragmentation across countries.

Integrated Research Design and Sources

- **Collaborative Workshops**
  - Two workshops enabled expert interaction, alignment on activity tasks, deep dives to specific national CCUS frameworks and validation of project insights.
- **Standardized Template**
  - A template guided structured input from countries, ensuring information comparability across diverse contexts.
- **Structured Web Research**
  - Web research complemented and verified template inputs using policy documents and scientific literature.

➔ The results will be published in a separate report within the next weeks, including detailed literature for each included country

Geographical Scope of the Comparative Analysis

- **Focus on IETS Task XXI Members**
  - The analysis centered on (European) IEA IETS Task XXI countries with common regulatory frameworks and diverse industrial contexts.

- **Inclusion of further IEA IETS Countries (+ Australia)**
  - Countries like the UK, Switzerland, and Canada were included to broaden perspectives beyond the EU regulations.
  - Australia was analyzed due to its interest in the IETS and remarkable geographical/geological background - adding valuable insights.

- **Diverse Geological and Policy Contexts**
  - Selection includes countries with varied geological storage capacities and policy ambitions supporting cross-border cooperation.

Role of Workshops and Standardized Template

Two invited workshops with 34 participants from 7 countries

- Austria, Germany, Sweden, Denmark, Norway, United Kingdom, Portugal

Template filled in for 11 countries

- Basis for further analysis
- Available in the report's Annex including references to national law and strategies

Nr	Country	Member status	Template filled in by
1	Austria	IEA IETS Task 21	Energieinstitut an der JKU Linz
2	Denmark	IEA IETS Task 21	SDU Center for Energy Informatics
3	Norway	IEA IETS Task 21	(Norwegian Ministry of Energy)
4	Germany	IEA IETS Task 21	FfE
5	Italy	IEA IETS Task 21	ENEA, POLITO
6	Sweden	IEA IETS Task 21	RISE
7	Netherlands	IEA IETS Task 21	-
8	Portugal	IEA IETS Task 21	-
9	France	IEA IETS	Energieinstitut an der JKU Linz
10	Canada	IEA IETS	Energieinstitut an der JKU Linz
11	United Kingdom	IEA IETS	Energieinstitut an der JKU Linz
12	Switzerland	IEA IETS	Energieinstitut an der JKU Linz
13	Australia	Interested in IEA IETS	Energieinstitut an der JKU Linz

Template on CCUS Management Strategies and Legal Provisions

1

Template for Task XXI, Subtask 4 Carbon Capture, Activity A

Comparison of national perspectives on CCUS

Version 2025-06-12

Country:	
Person/Institution filling out:	
Date of filling out	

Laws on CCU and/or CCS in your country

Is your country subject to the EU's CCS directive?
What laws/regulation is additional to the EU's CCS directive and in force?
CO_2 capturing:
CO_2 transport:
CO_2 utilization
CO_2 storage

2

Strategies on CCU and/or CCS in your country (at the national level)

General content and intention (CCUS topics addressed):
Proposed legal framework adoptions:
Proposed measures on CO_2 capturing: Specific subquestion: is there a definition on hard-to-abate sectors and their eligibility
Proposed measures on CO_2 transport:
Proposed measures on CO_2 utilization:
Proposed measures on CO_2 storage: Specific subquestion: are there limitations regarding emissions allowed for CCS Specific subquestion: social acceptance

3

If applicable

Strategies on CCU and/or CCS in your country (at the regional level)

(same headlines as above)

Strategies on CCU and/or CCS of relevant industrial companies located in your country (at the regional level)

(same headlines as above)

Please include sources/links.

*CCS = Carbon Capture and Storage

High-Level Findings Across Countries

- **CCUS as Complementary Tool**
  - CCUS is framed as a complementary element in decarbonization, following energy efficiency and renewables.
- **Focus on Hard-to-Abate Sectors**
  - Emphasis on industrial sectors like cement, steel, chemicals where emissions are difficult to eliminate.
- **Policy Maturity Variations**
  - Countries vary significantly in policy development and implementation of CCUS strategies and infrastructure.
- **Infrastructure Bottlenecks**
  - CO_2 transport and (intermediate) storage capacity remain critical bottlenecks limiting CCUS deployment across countries.

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Carbon Management Strategies (CMS)

CMS - Overview

- In the EU, binding **legislation at the EU level** must be implemented by member states, **driving some national actions**
  - In 2024, the **European Commission published a strategy linking CCS, CCU, and *CDR** to achieve climate goals and support industrial transformation
- All analyzed countries have CCUS-related legislation and regulatory frameworks, but the **level of activity varies** significantly
- Many countries show **active carbon management efforts**, though **approaches differ widely**
- Only a **few countries have formal national carbon management strategies** published as standalone documents
  - However, several countries effectively **implement carbon management** through laws, regulations, and support schemes
  - **In some cases, regions or federal states develop their own strategies**, influenced by factors like industrial presence or CCS suitability

*CDR = Carbon Direct Removal

Overview of National Carbon Management Strategy Documents

Country	National CMS or similar documents
Australia	Regulatory framework on national and regional levels, mainly regarding CCS
Austria	Carbon Management Strategie (CMS)
Canada	Capturing the opportunity: A Carbon Management Strategy for Canada (2023)
Denmark	NECP 2024 and DK2020 initiative
France	État des lieux et perspectives de déploiement du CCUS en France
Germany	Germany's Carbon Management Strategy (CMS)
Italy	Italian Long-Term Strategy on greenhouse gas emissions reduction
Netherlands	Netherlands Carbon Dioxide Removal Roadmap (2025)
Norway	Meld. St. 33 (2019–2020) Report to the Storting (white paper) Longship – Carbon capture and storage & regulatory framework
Portugal	Roadmap for Carbon Neutrality 2050 & NECP
Sweden	Sweden's Climate Act and Climate Policy Framework
Switzerland	Climate and Innovation Act (Klima- und Innovationsgesetz (KIG)) (2022) Bundesgesetz über die Reduktion der CO_2-Emissionen 'CO_2-law' (2025)
United Kingdom	Carbon Capture, Usage and Storage - A Vision to Establish a Competitive Market, Department for Security & Net Zero (2023)

➔ Source links available in the report!

Definition of „Hard-to-Abate“ Sectors

- The definition of “hard-to-abate” (HtA) emissions is a key consideration in terms of policy strategies, legal frameworks, and regulations.
- In general, **most countries’ CMS focus on fossil CO_2 emissions**, while others place (additional) emphasis on biogenic CO_2 emissions (BECCS*, DACCS** as CDR*** measures)
- Typical sectors mentioned
  - Cement / Lime
  - Steel / Metallurgy
  - Chemicals
  - Waste

→ Only a few countries have an explicit HtA definition (e.g., Austria and Germany)
→ Most countries have implicit definitions, e.g., through sector-specific funding programs

*BECCS = bioenergy CCS
**DACCS = Diret Air CCS
***CDR = Carbon Direct Removal

Overview of definitions of „Hard-to-Abate“ Sectors

Country	Type of Definition	Content / Core Criterion	Identified HtA Sectors
Austria	Explicit, conditional (CMS)	Process-related emissions are “unavoidable” if no alternatives exist despite optimisation; dynamic concept	industry examples: waste, refinery (partially), iron/steel (partially), glass/stone (cement, lime, refractory)
Denmark	Functional / policy-based	No fixed definition; focus on sectors lacking alternatives; emphasis on CO_2 type rather than sector	No fixed sector list; focus on biogenic emissions (BECCS)
France	Implicit / strategic	HtA refers to industrial sectors with emissions difficult to avoid; prioritised in CCUS strategy	Cement, lime, chemicals, metallurgy
Germany	Explicit (CMS)	No technically or economically viable alternatives; focus on unavoidable process emissions	Cement, lime, chemicals, waste incineration, steam crackers
Italy	Implicit, sector-based	Defined through strategic documents; CCS mainly for sectors without alternative decarbonisation pathways	Cement/lime, iron & steel, chemicals/petrochemicals, refineries, hydrogen (SMR), waste-to-energy
Norway	n/a (Note: According to a web search, Norway does not have an officially recognized definition.		
Sweden	Implicit (programme-based)	Defined indirectly via funding programmes and residual emissions	Cement, iron & steel, chemicals, refineries, pulp & paper; plus agriculture (residual emissions)
United Kingdom	Policy / strategic	No formal definition; consistently used for emission-intensive sectors	Steel, cement, chemicals, refineries, waste, heavy transport, aviation, shipping
Switzerland	Implicit (research / policy)	Used in funding calls and strategies; includes remaining emissions towards net zero	Cement, waste incineration, agriculture, aviation
Canada	Functional / policy-based	Sectors difficult to electrify or decarbonise through other means	Cement, chemicals (fertilisers), iron & steel; plus agriculture and waste (residual emissions)
Australia	Functional / typological	Emissions difficult to reduce due to processes or high costs	High-temperature industries (e.g. chemicals), cement (process emissions), agriculture, aviation/shipping, heavy transport

CMS Comparison (examples)

Dimension	Common Pattern	Austria	Norway	Sweden	Australia
Role of CCUS	Complementary to decarbonization (mitigation first)	Strongly complementary	Complementary; strong focus on CCS	Complementary with emphasis on negative emissions	Central role
Target: HtA sectors	Focus on HtA	Dynamic definition	Implicit	Implicit	Implicit
Emission types	Process & residual emissions	Process emissions	Industrial + residual emissions	Residual + negative emissions	Broad sector spectrum + residual
Storage strategy	Storage essential	No domestic storage permitted – permission in discussion	Offshore-focused, large-scale storage; core element with commercial deployment	Export-dependent	Domestic storage
International cooperation	Important for scaling	●●●	●●●●	●●●●	●
Infrastructure approach	Full value chain development	Early stage	Full value chain; project-based with integrated capture, transport, storage	Transport solutions	Project-based
Policy ambition	CCUS part of net zero	●	●●●●	●●	●●●
Regulatory approach	Strong state involvement	Highly regulated	Strong state involvement; licensing regime (state owned)	Programmatic	Market + policy driven
Lock-in avoidance	Important objective	●●●●	●	●	●●●
Funding instruments	Public support necessary	Limited support	Public support via flagship projects + state-backed schemes	Reverse auctions	Australian Carbon Credit Units (ACCU)
Industrial focus	Industry central	●●●	●●●●	●●●	●●●
Negative emissions	Increasing relevance	Secondary role	Increasing relevance	Central (BECCS)	Relevant
Public acceptance	Key for implementation	Critical issue	Not explicitly addressed	Important	Less focus

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Legal Frameworks for CCUS

CCS Directive & London Protocol (Art. 6)

Country	Subject to EU CCS Directive	Adaption Art 6. London Protocol
Australia	no	ratified + provisional application
Austria	yes	No (not a signatory to the Convention/ Protocol)*
Canada	no	No (but signatory to the Convention/Protocol)*
Denmark	yes	ratified + provisional application
France	yes	ratified + provisional application
Germany	yes	ratified + provisional application (2026)
Italy	yes	No (but signatory to the Convention/Protocol)*
Netherlands	yes	ratified + provisional application
Norway	yes	ratified + provisional application
Portugal	yes	No (signatory to the Convention, but not the Protocol)*
Sweden	yes	ratified + provisional application
Switzerland	No but links to EU framework	ratified + provisional application
United Kingdom	No but links to EU framework	ratified + provisional application

Excursus on London Protocol Art. 6

- **Original rule (Article 6, London Protocol)**
  - Strict ban on exporting waste or other materials for disposal at sea
- **Purpose**
  - Prevent states from avoiding environmental regulations by exporting harmful substances
- **2009 amendment** introduced an **exception for CO_2**
- **Effect**
  - Enables **carbon capture and storage (CCS)** projects
  - CO_2 can be transported across borders and stored in subsea geological formations
- **Conditions**
  - Agreement between exporting and importing states
  - Compliance with international environmental standards
- **Legal status**
  - Amendment not yet fully in force (insufficient ratifications)
  - Currently applied **provisionally** between some states

*IMO (2022) Map of Parties 2022.pdf

Regulatory Landscapes (examples)

Dimension	Germany	France	Sweden	United Kingdom	Switzerland	Canada
Reference to EU CCS Directive	Yes	Yes	Yes	Formally transposed; retained in national law post-Brexit	No	No
Basic structure of the legal framework	Transition from restrictive to enabling	Fully implemented legal framework	Supplemented environmental law framework	Comprehensive national framework; strong state steering via regulator	Independent framework under development	Multi-level (federal + provinces)
CO_2 storage	Formerly only research; expansion in 11/25 (off-shore + optional onshore)	Regulated (permitting, monitoring, closure)	Regulated - Permitted	Permitted and regulated; strong offshore	No complete framework yet; focus on export sue to limited storage options	Permitted, highly regulated (incl. provincial law), regional frameworks
CO_2 transport	Regulated since 2025; being opened (London Protocol)	Regulated in environmental law; international agreements	Part of environmental and support schemes	Licensing system; regulation for non-pipeline transport in development	No transport law so far; future regulation and export options planned	Infrastructure exists + eligible for support
CO_2 capture	Permitted under strict conditions	Regulated in environmental law	Part of state support programs	Regulated; CfD-like contracts + tax incentives	Part of climate legislation	Broad recognition (incl. DAC, BECCS)
CO_2 utilisation	Politically promoted, legally under development	Indirectly regulated (industrial & environmental law)	Part of support architecture	Integrated in Energy Act 2023; cluster-based industrial applications	Regulated (only eligible if permanently bound)	Strictly linked to "permanent storage"
Key laws/ instruments	Kohlendioxid-Speichergesetz (KSpG) (2012) → Kohlendioxid-Speicherung-und-Transport-Gesetz (KSpTG) (2025)	Environmental Code + decrees (2010–2011)	Environmental Code + CCS regulation	Energy Act 2023; Storage of CO_2 Regulations 2010; EU Exit Regulations 2019; cluster funding programmes; EU ETS linkage	Climate and Innovation Act + CO_2 Act (revised); CCS Act in preparation	Environmental Protection law + provincial laws + Investment tax credit rules
Regulatory level	National + federal states	National	National + agency	National + regulator	Federal + cantons	Federal + provinces

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Conclusions

EU Level

- Significant carbon management activities exist across Europe and beyond, **but readiness for CCU and CCS varies widely**
  - This **variation limits the development of international CO_2 markets, value chains, and climate progress**
  - Policy focus at EU and national levels is **mainly on CCS and CDR**

Focus CCU

- **CCU** is included in policies and research, but **receives less practical attention**
  - Strong policy frameworks exist for CCS/CDR,
  - while CCU requires complex industrial and chemical integration
  - CCU is barely recognized in emissions trading systems (ETS), making it less economically attractive
- However, replacing fossil carbon with **recycled or renewable carbon is widely recognized as essential**
  - Focus areas include CO_2-based chemicals (e.g. methanol), as well as biomass and direct air capture pathways
  - Key challenges: high energy demand, CO_2 purity requirements, and infrastructure limitations
  - Transport and (intermediate) storage of CO_2 are also bottlenecks
- The **EU promotes CCUS hubs** (regional CO_2 clusters) as a solution to improve infrastructure and coordination

Carbon Management Strategies

- **Carbon management strategies consistently position CCUS as a complementary tool**
  - Strong “mitigation-first” approach: focus on energy efficiency, renewables, and electrification before CCUS
- **CCUS is considered essential for unavoidable emissions and achieving net-zero targets**
  - Main focus on hard-to-abate sectors: such as cement, steel, chemicals, and waste
  - Regulatory approaches differ, but mostly converge on similar industrial use cases
- **Carbon removal gaining importance as part of national climate strategies**
  - Increasing role of CCUS in CDR, including BECCS and direct air capture
  - CCUS increasingly seen as a tool for balancing residual emissions long-term
- **Countries differ in policy maturity and implementation speed**
  - Some: advanced deployment (investments, clusters, infrastructure)
  - Others: early stages (legal frameworks, pilot projects)
- **Infrastructure is the key enabler for scaling CCUS**
  - Structural challenges include limited storage capacity and regulatory barriers
  - CO_2 transport, storage, and industrial hubs are critical bottlenecks
  - Shared infrastructure (pipelines, shipping, hubs) supports large-scale deployment
- **Growing importance of international cooperation for CO_2 transport and storage**
  - Emergence of cross-border infrastructure and aligned regulations, especially in Europe
- **Public acceptance remains a challenge due to limited awareness and varying regional perceptions**
  - Stakeholder engagement and transparency are critical
- **Overall trend: carbon management becoming a core pillar of climate strategies**

Legal frameworks

- **Legal frameworks for CCUS vary widely in development and maturity** across countries
  - Advanced systems exist in countries like Australia, Canada, Denmark, and Norway
  - Many European countries are still in a transitional phase
  - Denmark and Norway strongly focus on CO_2 import and storage
- **Different legislative approaches:**
  - Dedicated CCUS regulations vs.
  - Integration into existing environmental and climate laws (common in Europe)
- **Outside the EU, multi-level governance systems (e.g. Canada, Australia) give regions/provinces key roles**
- **Within the EU, a shared legal basis is provided by the EU CCS Directive and other laws/policies/strategic documents**
- **Cross-border cooperation is crucial for CO_2 transport and storage**
- **Regulation is most developed for CO_2 storage (Permitting, Monitoring, Liability, Operational limits)**
  - (Domestic) CO_2 storage policies vary significantly – from prohibited to actively supported
- **CCU regulations including transport; intermediate storage and CO_2 quality regulations are less developed and fragmented**
  - CCU receives less regulatory and policy attention, despite industrial relevance

→ **Strong regulation for CO_2 storage**

→ **Transport and utilization frameworks still evolving**

EU Level – CCU constraints

"Towards an ambitious Industrial Carbon Management for the EU"

- **High energy demand** of CCU processes reduces overall climate benefits
- **High costs** and uncertain economic viability at scale
- **Incomplete recognition of CCU benefits** in current policy frameworks
- **Need for robust carbon accounting systems** (avoiding double counting, tracking CO_2 flows)
- **Lack of clear regulatory framework** for large-scale CCU deployment
- **Infrastructure gaps**, especially for linking CO_2 sources, users, and hydrogen supply
- **Dependence on hydrogen availability** for many CCU applications
- **Uncertainty in emissions accounting** (upstream vs downstream)
- Limited inclusion of non-permanent CCU products in **EU ETS rules**
- Strong reliance on fossil carbon still persists (e.g. >90% in chemical industry)
- Need to ensure **environmental integrity** and liability management (e.g. leakage risks)
- Remaining structural and market barriers slowing deployment

➔ **High-level constraints at the EU/international level hinder ambitions at the national level!**

EU Level – CCU strategy

"Towards an ambitious Industrial Carbon Management for the EU"

- Assess **"demand-pull" policy options** to increase uptake of sustainable carbon in industry
- Develop **sector-specific CCU roadmaps** together with industry stakeholders
- Use the **knowledge-sharing** platform for CCUS projects to coordinate and accelerate deployment
- Establish a **coherent EU-wide carbon accounting framework** covering the full value chain
- Ensure the framework **reflects actual climate benefits** and creates effective incentives
- Introduce measures to **incentivise** both permanent and non-permanent CCU applications
- Identify and **remove regulatory and structural barriers** to CCU deployment
- **Promote market uptake** of sustainable carbon as an alternative to fossil carbon
- Support **development of production pathways in industry** (especially chemicals) using sustainable carbon (e.g. sustainable aviation)
- Strengthen **policy alignment with initiatives** such as biotech and biomanufacturing
- **Support innovation and scaling** of CCU technologies across all maturity levels (R&D to deployment)

➔ **Combination of strategic, regulatory/legislative and funding mechanisms**

➔ **Delayed effects at the level of individual states.**

Synthesis of Strategic and Regulatory Insights

- **Central Role of CCUS**
  - CCUS is becoming a key part of industrial climate strategies, complementing primary mitigation efforts.
- **Policy Maturity and Alignment**
  - National strategies are converging despite differences in policy maturity and implementation progress.
- **Infrastructure and Cooperation**
  - Infrastructure development and international cooperation are critical enablers for scaling CCUS deployment.

Barriers to Scaling CCUS

- **Infrastructure Limitations**
  - Lack of transport networks and storage sites limits CCUS scalability and increases project costs.
- **Regulatory Fragmentation**
  - Unclear regulations and accounting methods reduce investment incentives for CCUS deployment.
- **Economic Barriers**
  - High capital and operational costs with dependence on subsidies and carbon pricing slow down CCUS growth.
- **Social Acceptance and Policy Risks**
  - Public concerns and uncertain long-term policies create risks for investors.

Future Research and Policy Development

- **Expanding Research Scope**
  - Future research should include more countries, focusing on high emissions and industrial activities for broader insights.
- **Strengthening Regulatory Frameworks**
  - Policymakers need to harmonize CO_2 transport and utilization regulations and improve carbon accounting methods to support CCUS.
- **Promoting International Cooperation**
  - Cross-border collaboration is essential for effective CO_2 transport, storage, and CCUS deployment success.
- **Focus on Circular Carbon and Symbiosis**
  - Emphasizing circular carbon and industrial symbiosis can fill deployment gaps and enhance climate benefits.

Thank you!

➔ It is time for discussion!

Contact

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