NATIONALER WASSERSTOFFRAT

STATEMENT 2026-02-26

Hydrogen and carbon management: Integrated strategies to achieve the Climate neutrality

Germany's transformation to a climate-neutral economy by 2045 requires a consistent and systematic reduction in emissions in all sectors. The ambitious expansion of renewable energies, increases in energy efficiency and the ramp-up of the hydrogen economy are key pillars for this. At the same time, residual emissions that are difficult or unavoidable will remain in certain sectors,[1] particularly industrial ones, and net-negative emissions must be made possible in the future.[2] These need to be addressed through an integrated interplay of natural sinks and carbon management approaches.

Carbon management (CM) is therefore not a substitute for emissions avoidance, but a necessary addition on the path to climate neutrality, which enables both solutions for unavoidable residual emissions and the production of low-carbon hydrogen in the transformative transition. In addition, some industrial processes also require carbon as a raw material. In this way, carbon management contributes to strengthening Germany as an industrial location In addition to carbon management, natural sinks such as forests, soils and moors also make an important contribution and should therefore be consistently protected, restored and expanded.

There are close interactions between carbon management and the development of a hydrogen economy, which make the topic highly relevant for the National Hydrogen Council (NWR). With this statement, the NWR aims to contribute to a better understanding of the similarities and potential areas of tension in the ramp-up of hydrogen and carbon management and to outline resulting recommendations for action.

---

1 The cement and lime industries alone will have to capture over 20 million tonnes of CO_2 per year by 2045 in order to become climate-neutral (VDZ (2024) – Requirements of a CO_2 infrastructure in Germany). For the (fossil and biogenic) CO_2 emissions from thermal waste treatment plants, current analyses show levels of up to 30 million tonnes of CO_2 per year (Projection Report 2025). Even if biogenic and fossil waste volumes were significantly reduced through avoidance and recycling (well over 50% according to current EU plans), the cement and lime industries and waste treatment alone would still have to reduce emissions by at least 35 million tonnes of CO_2 through CCS/U.

2 These negative emissions serve to compensate for unavoidable residual emissions in order to achieve the net-zero emissions situation and the net-negative emissions balance targeted for the EU for the period after 2050 (Art. 2 (2) of the EU Climate Protection Act). The level of negative emissions from technical sinks required in the context of climate neutrality is currently estimated to be in the range of 20 to 60 million tonnes of CO_2 for Germany (UBA Climate Change 47/2025).

1. CARBON MANAGEMENT AND ITS ROLE IN CLIMATE NEUTRALITY

Carbon management encompasses the capture, utilisation and storage of carbon dioxide (Carbon Capture and Storage – CCS, Carbon Capture and Utilisation – CCU), as well as other methods for actively removing CO_2 from the atmosphere (Carbon Dioxide Removal – CDR), including natural sinks. This also includes processes in which the CO_2 from the material processing or energy utilisation of biomass is captured and safely stored (Biomass Carbon Capture and Storage – BioCCS or Bioenergy Capture and Storage – BECCS).

The time pressure for action to build up carbon management capacities is considerable. With the gradual phasing out of emission allowances in EU emissions trading for the energy sector and industry by the end of the 2030s, the economic challenges for affected industrial sectors will increase significantly and require an early decision on the adaptation of production processes and the associated business models. At the same time, the planning, authorisation and construction of transport and storage infrastructures require long lead times. Carbon management and the development of a hydrogen economy are interlinked in many ways. Both transformation paths are new, capital-intensive, require significant infrastructure investments, rely on economies of scale and public support and require a market ramp-up in a competitive environment. With the amendments made last year to the Carbon Dioxide Storage and Transport Act (KSpTG) and the Ocean Dumping Act (HSEG), as well as the ratification of the London Protocol this year, the federal legislator has already set the first important course for the permissibility of carbon management. As part of the announced carbon management strategy, the ramp-up must now take place quickly and together with hydrogen in order to create predictability for companies as well as opportunities for commercial application and to be able to take effect in good time.

2. HISTORICAL EXPERIENCE WITH CARBON MANAGEMENT CALLS FOR A NEW APPROACH IN GERMANY AND EUROPE

The debate on carbon management in Germany is strongly characterised by questions of social acceptance of CCS. Earlier debates on CCS, particularly in connection with coal-fired power generation, were accompanied by concerns that emission reductions would be delayed, fossil fuel business models prolonged and regional risks insufficiently taken into account. As a result, CO_2 storage in Germany was largely ruled out.

These experiences continue to shape the current debate. However, the context has changed in light of the new goal of climate neutrality. Carbon management is increasingly no longer seen as an alternative to reducing emissions, but rather as a necessary supplement for dealing with difficult and unavoidable residual emissions, namely in the production of low-carbon hydrogen, as well as for the long-term use of carbon as a raw material for production processes, chemical base materials or for e-fuels for aviation and shipping. It is crucial for further development that this understanding is clearly communicated and anchored in the regulatory framework. The clear prioritisation of areas of application plays an important role here.

A European comparison reveals a heterogeneous picture. Several member states have already been pursuing a more active carbon management policy for years and have established or are implementing corresponding infrastructures, storage options and regulatory frameworks. Examples from Northern Europe illustrate that the ramp-up of carbon management is possible, but at the same time remains associated with high investment costs, long lead times and complex governance issues. These experiences emphasise that the establishment of carbon management structures is not a short-term project, but requires a long-term, learning process that spans all stages of the value chain.

Technological experience from existing projects makes it clear that the geological storage of CO_2 has been tested and is therefore technically feasible under certain conditions, but is also associated with uncertainties. Building on this experience, continuous monitoring and, if necessary, adjustments to the processes used are therefore necessary due to the unique geology of each project.[3] This also applies to monitoring a storage facility after closure and determining the legal and financial obligations for any necessary subsequent interventions. The expected ramp-up will therefore not be linear. Rather – analogous to other transformation paths such as the ramp-up of hydrogen – a phase of disillusionment is to be expected in which costs, technical complexity, a more realistic assessment of actual storage potential and social requirements become more clearly visible. This phase is part of a realistic learning process and should be taken into account at an early stage in planning, regulation and communication. Ultimately, carbon management must be measured against its actual climate impact and evidence-based monitoring must be carried out independently.

This means that Germany needs to redefine its own path in the European context. Due to the limitations of storage options accessible to Germany (particularly with regard to the required injection infrastructure) and the continuing significant challenges in terms of social acceptance, prioritising CCS applications for hard-to-abate and unavoidable emissions in order to achieve net-negative emissions, or to make the necessary contributions to Germany's successful transition to climate neutrality, appears both appropriate and effective. Whether this must be legally binding or whether a corresponding concentration of financial support or infrastructure development would be more expedient is a controversial issue both in politics and in the National Hydrogen Council. Irrespective of this, carbon management in Germany will be highly dependent on European co-operation, cross-border infrastructures and common standards. What is needed is a clear and comprehensive political strategy for carbon management and transparent decision-making processes, as well as a consistent link with the hydrogen strategy and the European climate targets.

[3] Like almost all geological projects, CO_2 storage projects are associated with considerable uncertainties in the forecasts for capacities and underground processes due to the complexity of geological systems. Practical experience with existing projects in Norway, North Africa, North America and Australia, albeit limited to date due to the rather small number of projects, shows that the forecast capacities could not be achieved in some projects (e. g., Snovit/Norway, In Salah/Algeria, Gorgon/Australia) or the underground expansion was different than expected (e. g., Sleipner/Norway), while in other projects (e. g., Sleipner/Norway, Quest/Canada, ACTL/Canada, IBPD/USA, Greensand/Denmark) the planned capacities were fully achieved or even exceeded.

3. HYDROGEN AND CARBON MANAGEMENT: SIMILARITIES AND SYNERGIES

3.1 FIELDS OF APPLICATION AND INFRASTRUCTURE

The ramp-up of carbon management and the development of a hydrogen economy have many similarities. Both transformation paths address central components of industrial decarbonisation, are capital-intensive and rely on long-term planning certainty. They are aimed in particular at large industrial consumers and infrastructure applications where alternative decarbonisation options are not available or only available to a limited extent.

There are direct synergies between the two systems. Carbon management – especially in connection with the production of low-carbon hydrogen – can make an early contribution to the ramp-up of the hydrogen economy. Low-carbon hydrogen can create availability in the short term, stimulate demand and thus help to establish and utilise value chains, infrastructure and market structures. At the same time, it is clear that low-carbon hydrogen will have to be replaced by renewable hydrogen in the future. However, it should be borne in mind that this in turn can pose a challenge for the financing of the infrastructure for the production of low-carbon hydrogen, as this limits the amortisation period of the investments.

Conversely, the ramp-up of the hydrogen economy can also support the development of carbon management structures by utilising low-carbon hydrogen and carbon-based derivatives. In addition to industrial CCUS users, large hydrogen customers can act as anchor customers, bundling demand, enabling economies of scale and thus contributing to cost reductions along the entire value chain.

Both hydrogen and CCUS are highly dependent on efficient infrastructures. The development of pipeline transport networks, efficient transport options by rail and sea and corresponding hub infrastructures, storage and separation capacities requires high initial investments and long lead times. An isolated consideration of individual technologies therefore falls short of the mark. Existing expertise in pipeline construction, major infrastructure, operation and regulation can be utilised and further developed. Due to its geographical location, Germany also plays an important role as a transit country within Europe for both hydrogen and CO_2.

Carbon management in Germany will be particularly reliant on cross-border solutions due to the need to develop national storage facilities. The coordinated expansion of European transport and storage infrastructures is also necessary in view of limited injection capacities, e.g., in the North Sea. Close European coordination is therefore a prerequisite for an efficient ramp-up of both systems. The first cross-border projects are already being developed. These include: Connections from Germany to Belgium, the Netherlands and Norway to storage sites in the North Sea and to Denmark. At the same time, the National Hydrogen Council points out that a CO_2 pipeline network should run along the same routes as parts of the hydrogen network in order to maximise synergy potential, e.g., in the (time-consuming) regional planning procedures and, if necessary, cost reduction opportunities.

3.2 MARKET, FINANCING AND REGULATORY FRAMEWORK

The market ramp-up of hydrogen and carbon management is characterised by comparable economic challenges. Both markets are characterised by high initial costs, a lack of liquidity and considerable uncertainty with regard to price and sales trends and must be shaped in a competitive environment from the outset. Self-sustaining business models do not yet exist. In addition, the current price in EU emissions trading or other instruments such as the greenhouse gas quota model are not sufficient to cover the additional costs for CCS, CCU or hydrogen projects.

Supplementary state instruments are required to bridge these profitability gaps and cover risks. Differential cost instruments such as CCfDs for emitters, as well as market-based hedging mechanisms, have proven to be suitable approaches to de-risk investments and enable market ramp-up under conditions compatible with capital markets.

Regardless of the specific organisation, it is crucial for both areas that the regulatory framework creates long-term planning certainty. An early, coordinated approach reduces investment risks and helps to harmonise the timing of infrastructure and market development.

3.3 RESEARCH, TECHNOLOGY DEVELOPMENT AND DEMONSTRATION AS A CROSS-SECTIONAL TASK

The ramp-up of the hydrogen economy and carbon management is not just an infrastructure and investment task, but is also highly dependent on continuous research, technology development and demonstration. Some carbon management technologies such as CCS are largely mature, while others still require more research and development. Technological maturity, cost development, standardisation in operational safety and social acceptance can be achieved through the accompanying further development of technical solutions and regulatory standards.

There is a substantial need for research and development along the entire value chain, which must be considered systemically. These include, in particular, issues relating to the system integration of hydrogen, CO_2 and electricity infrastructures, the repurposing and new construction of transport and storage infrastructures, material and corrosion-related issues, the safe and efficient operation of capture, transport and storage facilities and the further development of monitoring, safety and control concepts over the entire life cycle.

Previous experience from demonstration and reference projects shows that technological learning processes are not linear and that realistic assumptions about costs, risks and scalability are required at an early stage. Research and innovation must therefore be closely interlinked with demonstration projects and early-stage projects. This enables the systematic evaluation of operating data, the reduction of technological and regulatory uncertainties and the gradual development of robust standards.

Research is also being carried out into alternatives and additions to CCS (in the area of cement and lime production), in which the carbon is pyrolytically separated and can be used as a raw material, e.g., for battery cell production or steel production in the cycle or stored permanently by means of CCU. This research and innovation must also be driven forward.

4. HYDROGEN AND CARBON MANAGEMENT: POTENTIAL AREAS OF TENSION AND PRIORITISATION ISSUES

4.1 FIELDS OF APPLICATION AND INFRASTRUCTURE

Carbon management and hydrogen ramp-up have a competing relationship in some areas. For example, industrial CCS applications, the production of low-carbon hydrogen and CDR projects can compete for limited storage capacities. This competition can lead to bottlenecks, especially if storage and transport infrastructures are not yet sufficiently developed. In any case, foresighted planning is crucial, especially in the ramp-up phase.

Since CO_2 transport, unlike hydrogen, can take place via multiple transport options with very different characteristics (in terms of capital intensity, flexibility, etc.), and hub infrastructures will play a much greater role than for hydrogen, there is a significantly greater need for coordination in the area of CO_2 transport and substantially greater planning requirements for both industry and policymakers, which must be taken into account when designing the regulatory framework.

Furthermore, gas-fired power plants are one of the central anchor customers for the hydrogen ramp-up. An ambitious hydrogen pillar in the power plant strategy is therefore of central importance for the ramp-up of hydrogen and the realisation of cost reduction potential. CCS at gas-fired power plants only makes sense in individual cases, such as industrial combined heat and power plants (CHP plants) with continuous heat and steam requirements.

4.2 MARKET, FINANCING AND REGULATORY FRAMEWORK

The current market prices in EU emissions trading for the energy sector and industry (ETS 1) do not cover the additional costs of carbon management and hydrogen projects. At the same time, these different technologies and fields of application are competing for limited funding. Differential cost instruments, CCfD or other market-based hedging mechanisms must be designed in such a way that they take into account both synergies and prioritisation conflicts and specifically address investment risks for all players along the value chain.

While the hydrogen infrastructure in Germany is planned as a regulated business, the construction of CO_2 infrastructures will initially be carried out by the private sector as things stand. Nevertheless, government risk hedging and subsidy instruments can help to avoid uncertainties in investment decisions, reduce risks for investments and thus ensure the ramp-up of carbon management technologies in line with demand.

5. CONCLUSIONS AND RECOMMENDATIONS FOR ACTION

The NWR recommends the swift development, adoption and consistent implementation of a carbon management strategy by the German government. The interactions with the hydrogen strategy should be carefully considered. The National Hydrogen Council emphasises the need to quickly remove regulatory, technological and financial hurdles.

Regulation and framework conditions

- Design funding conditions in such a way that hydrogen ramp-up and carbon management can run in parallel, not in competition
- avoid overregulation and ensure social acceptance and sustainable business models through transparent prioritisation

Funding and financing

- Create reliable funding and security instruments (e.g. CCfD, lead markets) to enable investment.
- only grant public support with secure financing and a clear source of funds
- Establish capital market-compatible framework conditions and state risk protection along the entire value chain
- Promotion and protection of natural sinks such as forests, soils and moors

Infrastructure and realisation

- Targeted promotion of regional CO_2 clusters and hubs as starting points for infrastructure development
- Integrate hydrogen and carbon management infrastructure to realise synergies and cost benefits
- Development of a clear roadmap for the decision in favour of purely private or regulated infrastructure

Research and innovation

- Establish an integrated, practical research and innovation agenda for hydrogen and carbon management
- Integrate research into planning and infrastructure projects at an early stage to reduce risks and accelerate market maturity
- Utilise synergies between hydrogen, CCU and CCS in a targeted manner and promote joint fields of development

H2 NATIONALER WASSERSTOFFRAT

THE GERMAN NATIONAL HYDROGEN COUNCIL

On 10 June 2020, the German Federal Government adopted the National Hydrogen Strategy and appointed the German National Hydrogen Council. The Council consists of 22 high-ranking experts in the fields of economy, science and civil society. These experts are not part of public administration. The members of the National Hydrogen Council are experts in the fields of production, research and innovation, industrial decarbonisation, transportation and buildings/heating, infrastructure, international partnerships as well as climate and sustainability. The National Hydrogen Council is chaired by former Parliamentary State Secretary Felix Chr. Matthes.

The task of the National Hydrogen Council is to advise and support the State Secretary's Committee for Hydrogen with proposals and recommendations for action in the implementation and further development of Germany's National Hydrogen Strategy.

Contact: info@leitstelle-nws.de, www.wasserstoffrat.de/en

APPENDIX

List of abbreviations and glossary

Abbreviation	Term	Description
BioCCS/U	Biomass Carbon Capture and Storage/Utilisation	Refers to the combination of material processing or energy utilisation of biomass and capture and storage (BioCCS) or utilisation (BioCCU) of the resulting CO_2.
BECCS/U	Bioenergy Carbon Capture and Storage/Utilisation	Refers to the combination of energetic utilisation of biomass and capture and storage (BECCS) or utilisation (BECCU) of the resulting CO_2.
–	Biochar	Biochar (also: Biochar) is a carbon-rich, porous material that is produced from organic biomass by pyrolysis (heating in the absence of oxygen).
CCfD	Carbon Contracts for Difference.	Carbon Contracts for Difference are (state) funding instruments that cover the additional costs of climate-friendly technologies compared to fossil-based methods by offsetting the difference between an agreed fixed CO_2 price and the actual market price (e.g., EU ETS).
CCS	Carbon Capture and Storage	Refers to the capture of CO_2 emissions from the exhaust gas stream of point sources (e.g. industrial plants, usually more than 90%), subsequent transport to the storage site and long-term injection into the deep geological subsurface. Carbon can be stored both in gaseous form (CO_2) and in solid form (C). The aim is to prevent CO_2 that has already been produced from being released into the atmosphere. The net CO_2 emissions balance of CCS is primarily dependent on the degree of capture.
CCU	Carbon Capture and Utilisation	Refers to the capture of CO_2 emissions from the exhaust gas stream of point sources (e.g. industrial plants, usually more than 90%) with subsequent utilisation as a raw material for industrial or chemical processes, materially in products (e.g. plastics or building materials) or as fuel for applications in transport (e-fuels) or in the energy industry (long-term storage). The net CO_2 emissions balance of CCU depends not only on the degree of capture, but above all on whether or to what extent the utilised carbon is prevented from being released back into the atmosphere as CO_2.
CDR	Carbon dioxide removal	Includes all human activities aimed at actively removing and extracting CO_2 already emitted from the atmosphere. A distinction is made between technical and natural sinks. See figure 1.
CM	Carbon management	Carbon management includes the capture, utilisation and storage of CO_2 (CCS and CCU) as well as processes for actively extracting CO_2 from the atmosphere (CDR). This also includes biomass-based processes with CO_2 capture and storage (BioCCS/BECCS), which enable negative emissions.
CO_2	Carbon dioxide	–
DACCS/U	Direct Air Carbon Capture and Storage/Utilisation	A technical process in which CO_2 is extracted directly from the ambient air. With DACCS, this CO_2 is then permanently stored geologically, resulting in negative emissions. In DACCU, atmospheric CO_2 is utilised as a raw material for industrial or chemical processes and as a material in products (e.g. plastics or building materials).
ETS	Emissions trading system	–

Abbreviation	Term	Description
EU ETS	European emissions trading system	–
ERW	Enhanced Rock Weathering (accelerated weathering)	Technical acceleration of natural weathering processes in order to remove and extract CO_2 already emitted from the atmosphere.
–	Humus build-up	Includes human activities to build up humus, i.e. the entirety of dead organic matter in the soil, in arable soils; in this context, to be understood as a natural CO_2 sink.
–	Natural sinks	For the purposes of CDR, the following processes are considered natural sinks: ◆ Forest management ◆ Humus build-up ◆ ocean-based processes
–	Ocean-based processes	Includes human activities that absorb CO_2 from the atmosphere into the oceans, bind it there and store it for the long term.
–	Technical sinks	For the purposes of CDR, the following processes are considered technical sinks: ◆ CCS/U ◆ BioCCS/U or BECCS/U ◆ DACCS/U ◆ direct material utilisation or fixation of biomass or the carbon contained in biomass ◆ EW
GHG	Greenhouse gas	–
–	Forest management	Includes human activities to conserve and enhance the economic, social and ecological values of all types of forests for the benefit of present and future generations; in this context, to be understood as a natural CO_2 sink.
–	Rewetting of moors	Includes human activities to raise the water level in wetlands such as peatlands, wet meadows or floodplains with the aim of restoring or renaturalising these ecosystems; in this context, it should be understood as emission reduction in the short term and restoration of a natural sink in the long term.

Figure 1: Technical and natural sink or CDR options

Fossil CO_2	CO_2 from the atmosphere						Biogenic CO_2	
Technical sinks					Natural sinks		Emissions reduction	
Exhaust gas	Plants	Plants	Atmosphere	Atmosphere	Plants	Atmosphere	Soil	Soil
Fossil CCS	BioCCS/ BECCS	Biochar	DACCS	Weathering (ERW)	Reforestation/ Forest conversion	Ocean-based processes	Humus build-up	Rewetting of bogs
Carbon storage								
Rock*	Rock*	???*	Rock*	Rock*	Plants*	Oceans*	Soil*	Soil*
Reversibility								
barely	barely	???	barely	barely	yes	???	yes	yes
Option carbon usage (with different involvement durations and permanence risks)								
yes*	yes*	yes*	yes*	yes*	yes*			
Usage								
DE	DE	DE	DE/ global	DE/ global	DE/ global	global	DE/ global	DE

***Net GHG emissions balance**			
	>0	≤0	<0