

CCS –

A useful climate protection measure?

Onshore storage Interview with Dr Michael Münter

Capture, store, utilise



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It won't work without CCS. That is the view of the International Energy Agency (IEA), for example. It regards carbon capture and storage (CCS) and carbon capture utilisation and storage (CCUS) as essential on the path to climate neutrality. In most of the scenarios put forward by the Intergovernmental Panel on Climate Change (IPCC), CCS is also a necessary component for offsetting residual emissions from industry or agriculture and achieving international climate targets. Examining global CCS projects also emphasises the technology's high and ever-increasing relevance. In 2025, 77 projects were in operation worldwide, with a storage capacity of 64 million tonnes of CO₂ per year. The Global CCS Institute expects this figure to rise to 337 million tonnes by 2030 alone. In 2025, 47 plants were in the planning stage, 297 were at an advanced stage of development and 313 were in the early stages of development.

China is one of the key pioneers in this field. There, CCS is primarily driven by the coal industry in an effort to decarbonise the country's power plants. The aim is to reduce China's emissions by 15 per cent through this method. According to a recent Australian study, there are currently approx. 40 plants in operation in China, six are being built and nine are in the planning stage. China has also invested heavily in carbon capture research and has developed technologies that can, for example, achieve CO₂ concentrations in flue gas of less than five per cent while significantly reducing the cost of CO₂ capture. In the Ningxia project, for example, these costs are just 30 dollars per tonne of CO₂. China is also a pioneer in the use of captured CO₂, e.g. in the production of methanol or synthesis gas for the manufacture of chemical products and fuels.

Our researchers, too, see CCS as a key component of climate protection, particularly in industries and sectors where decarbonisation is challenging and emissions cannot be prevented. However, by global standards, both Europe and Germany are still in the early stages of development in this regard. If we exclude Norway and Iceland, only three of the 77 CCS plants in operation worldwide are located in the EU. It is time we started implementing this technology in the EU, including Germany. After all, time is of the essence when it comes to climate protection – a fact made all the more apparent by the recent heatwave. This issue shows what is currently happening in Germany with a view to CCS.

Yours,
Anke Herold

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eco@work – October 2026 (date of publication of German edition: September 2026) – ISSN 1863-2025
Published by: Oeko-Institut e.V.
Edited by: Mandy Schossig, Christiane Weihe
Responsible editor: Anke Herold
Translated by: Dr Vanessa Cook
Design/Layout: Hans Loebermann – Technical implementation: Markus Werz
Address of editorial office: Borkumstrasse 2, 13189 Berlin, Germany
Phone: +49 (0) 30/4050 850, redaktion@oeko.de, www.oeko.de

Account Details for Donations:

GLS Bank, Bank Code No.: 430 609 67, Account No.: 792 200 990 0,
IBAN: DE50 4306 0967 7922 0099 00, BIC: GENODEM1GLS
Donations are tax deductible for German income tax purposes.

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"CCS requires a joint effort by all stakeholders."

Everyone is talking about the North Sea. But what about onshore carbon storage? Much further south, the government of the German state of Baden-Württemberg has recognised the important role of CCS in climate protection since the last legislative term, and is currently laying the groundwork for its implementation on land. What is the current status of implementation, where could CO₂ be stored, and what are the next steps? To find out, we spoke to Dr Michael Münter, Director-General of the Baden-Württemberg Ministry for the Environment, Climate and the Energy Sector.

Dr Münter, why is Baden-Württemberg driving the CCS agenda forward?

We want to provide industries that are more difficult to decarbonise with a way forward in our state. This applies not only to the six cement works in Baden-Württemberg, but also to the lime industry and the waste management sector. At the start of 2024, we began working closely with these sectors, as well as other stakeholders such as trade associations and pipeline operators, in collaboration with the Ministry of Economic Affairs. Following the Bundestag and Bundesrat's passing of the Carbon Dioxide Storage Act – which gives individual states the opportunity to examine and implement onshore storage where appropriate – we decided to do just that.

As early as October 2024, the government of Baden-Württemberg adopted a position paper on carbon management. What do you consider to be the most important guidelines in it?

It is crucial that CCS is only used for emissions that cannot be prevented or can only be prevented with great difficulty. This includes emissions from waste incineration, the lime and cement industries, and potentially parts of the chemical industry. Wherever possible,

de-carbonisation should be achieved through means such as electrification. At the same time, the capture and storage processes must be safe.

What is the current status of implementation?

Firstly, we are continuing the work that we have already started. For instance, we are exchanging ideas and experiences with other federal states and countries, including Denmark, Austria and Switzerland. Secondly, we are making concrete preparations for the entire legislative process. This includes matters such as responsibilities, as well as the question of whether potential sites for future storage should be identified at this stage. Additionally, we are laying the groundwork for a feasibility study focusing on potential routes.

Does that mean there will be no transport by ship or train?

In the medium and long term, the volumes involved are simply too large for this. This may be a factor during the ramp-up phase and for individual sites, but we should not create path dependencies that hinder the roll-out of the pipeline network. We are also unlikely to be able to store everything in Baden-Württemberg and must therefore also discuss pipelines to offshore storage sites or a connection to a Europe-wide CO₂ pipeline network. And, of course, CCU – that is, the utilisation of captured CO₂ – also plays a role.

Which areas are suitable for onshore storage?

Geologically speaking, these are primarily the Upper Rhine Graben and the Molasse Basin in the Alpine foreland – which we share, however, with the state of Bavaria. We already know that there is a cap rock in both areas that could effectively and tightly contain gaseous substances. However, more detailed investigations will be needed.

Do you anticipate any conflicts of use, such as with geothermal energy in the Molasse Basin?

We expect very few conflicts of use; rather, we hope to see synergies. The subsurface is being investigated at various locations and for different purposes, such as geothermal energy, storing high-level radioactive waste, extracting raw materials, and CCS. All of these applications could benefit from sharing results, making their processes more efficient.

What do you see as the greatest challenges in this process?

Firstly, we need to investigate the most suitable rock formations in greater detail, and we need to do this quickly because the industry has just over a decade left to become climate-neutral. Secondly, there is the issue of funding. We cannot expect companies to bear this cost alone. A third factor is public acceptance. We are currently discussing various ways of involving the public. A joint effort by all stakeholders is required when it comes to CCS.

Thank you for speaking to eco@work.

The interviewer was Christiane Weihe.



Speaking to eco@work: Dr Michael Münter, Director-General of the Baden-Württemberg Ministry for the Environment, Climate and Energy
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CCS – why, what for

Carbon capture and storage in Germany

CO₂ is captured from the air or during industrial processes. It is then transported in compressed form by ship, train or pipeline to suitable storage sites. Ultimately, this greenhouse gas is stored long-term in geological formations, either beneath the sea or on land – for example, in saline aquifers or depleted gas fields. Additionally, CO₂ can be used as a raw material in processes such as the production of synthetic fuels. The capture, transport and safe storage of carbon dioxide, as well as its utilisation – also known as carbon capture and storage (CCS) and carbon capture and utilisation (CCU) – are intended to support the transition to climate neutrality. Oeko-Institut is working to determine what role these technologies could play in achieving effective and affordable climate protection in Germany.

★ ★ ★
★ **The EU aims** ★
★ **to store a total of** ★
★ **50 Mt CO₂** ★
★ **by 2030.** ★
★ ★ ★

Should we even be doing this? Doesn't it make more sense to prevent emissions rather than making them disappear somewhere underground? CCS is the subject of heated debate – because of the costs and the risk that the technology might hinder necessary climate protection efforts, but also because of potential environmental impacts (for more on this, see 'Under the North Sea?' on page 6). "In Germany, we will have no choice but to use CCS on the path to climate neutrality. After all, it is not possible to prevent all emissions. Oeko-Institut's climate scenarios therefore also incorporate CCS," says Christoph Heinemann, Senior Researcher in the Energy & Climate Division. "Using it for certain applications makes perfect sense, such

as in the cement and lime industries and in waste management. However, this should be done without jeopardising emission reductions and should certainly not be used for applications where renewable energies or green hydrogen can be used."

CAPACITIES AND MARKET RAMP-UP

However, before CCS becomes commercially viable in Europe, not only are carbon storage capacities and a transport infrastructure required, but also appropriate financial and regulatory frameworks. In the study titled 'Deploying carbon capture and storage (CCS) for climate neutrality' by Oeko-Institut and Agora Industry, the experts examine the capacities of existing and planned European offshore carbon storage projects and the associated costs. "In addition, we have analysed the various transport options and developed recommendations for policymakers on how they can establish the appropriate framework conditions

for a rapid and efficient market ramp-up," adds Roman Mendelevitch, a Senior Researcher in the Energy & Climate Division.

CO₂ IN THE NORTH SEA

Taken together, the planned CCS projects show that the North Sea region is set to become the centre of carbon storage in Europe – with Denmark, Norway and the Netherlands being particularly active in this area. "The geology beneath the North Sea has been well explored due to decades of oil and gas extraction; also, the Mediterranean region offers poorer geological conditions and there are potential risks of underground faults," said Heinemann. The UK is a clear frontrunner: 40 percent of the storage capacity planned in Europe by 2030 stems from projects in that country. Overall, scientists currently expect existing CCS projects in the EU and Norway to achieve an annual storage capacity of just ten million tonnes of CO₂ by the early 2030s, however. "If the storage requirements of the entire EU are to be

and how much?

met by 2050, we would need to add two large-scale storage hubs each year, each with an injection capacity of five million tonnes per year," says Heinemann. In addition, the experts have examined the necessary transport infrastructure – CO₂ can be transported by pipeline, train or ship. "Particularly when it comes to establishing a pipeline infrastructure, but also when selecting a suitable transport option for a specific site, very forward-looking planning is required, as there are significant differences in terms of flexibility and costs. It is therefore important to have clarity as early as possible regarding sites, the volumes to be transported and the timing of their production."

A RELIABLE FRAMEWORK

To accelerate the ramp-up, the German government must create a reliable regulatory framework. While it has established the legal basis for the commercial use of CCS across the country through the amended Carbon Dioxide Storage and Transport Act, which came into force at the end of 2025, there is still a lack of an industrial policy strategy for its targeted implementation. "An integrated approach is needed which ensures legal compliance as well as establishing market foundations and initiating market ramp-up." The necessary legal regulations are either already in place or can be implemented very quickly; however, there is still a great

deal to be done with a view to market foundations and ramp-up. "What is needed is a robust carbon price, as well as planning and financial measures to ramp up capture, transport and storage. In the medium term, for emission-intensive companies that are already covered by the European Union Emissions Trading System (EU ETS) and wish to use CCS as an emission-abatement technology, the carbon price alone is not sufficient to make the technology attractive. Subsidies make sense here." Government guarantees for pipeline infrastructure could become necessary to cushion the risk of default by anchor customers in the transport network.

MORE EXPENSIVE THAN EXPECTED

But just how big is the cost gap? "CCS is more expensive than many people think," states Heinemann. "We expect costs of between 150 and 300 Euro per tonne – whereas the carbon price in the EU ETS currently stands at only around 85 Euro. For the market to take off, this cost gap must be closed." Investments in CCS are thus not yet economically viable. "The construction of carbon storage sites beneath the seabed takes between six and 13 years, and the capacity can only be increased slowly." Experience gathered in the hydrogen sector has also highlighted the challenges posed by entirely new value chains – their complexity, their uncertainties and their costs.

Should we even be doing this? Yes, says the expert from Oeko-Institut. And Europe is also taking further steps on the issue of CCS. The European Commission has announced a far-reaching CO₂ infrastructure package for autumn 2026. "This is intended to establish the legal framework for, among other things, cross-border networks," says Heinemann. "With this in mind, it is time for the German government to present a long-term strategy here at home as well, and to back it up with appropriate measures."

Christiane Weihe



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Under the

Site selection for CO₂ storage

As environmentally friendly as possible. As risk-free as possible. In short: as safe as possible. This is how carbon storage should be implemented – in Germany and, of course, in other countries too. But what risks are actually involved in carbon storage, and how can they be minimised? Oeko-Institut is tackling these issues in various projects. The North Sea is one area of focus, as it is home to a number of European carbon storage projects.

There are numerous suitable geological formations in Europe for storing carbon dioxide. According to forecasts, the EU plans to store a total of 50 million tonnes of CO₂ by 2030. This figure is certain to rise considerably on the path to climate neutrality by 2040. "There are already many carbon storage projects in Europe. It is currently being driven forward primarily by Norway, Denmark, the UK and the Netherlands," says Dr Florian Krob, Senior Researcher at Oeko-Institut. "Norway, for example, has been storing carbon dioxide since mid-2025 as part of the Northern Lights project near Bergen."

In Germany, there are several areas that are suitable for CCS in principle. These are primarily saline aquifers, which are deep rock layers containing salt water,

and – in theory – depleted natural gas fields. Saline aquifers are mainly found in northern Germany, but also in the Upper Rhine Graben and the Alpine foothills. "However, not all sites are actually suitable, for example where there are other uses for the land. Currently, Germany's plans are focused on the North Sea. The assumption here is a total storage capacity of between one and one-and-a-half gigatonnes of CO₂. However, I estimate that the actual figure is more likely to be below one gigatonne."

RISKS. WHAT RISKS?

In the study titled 'Securing the Underground – Managing the Risks of Carbon Storage through Effective Policy Design,' which was initiated by the Nature and Biodiversity Conservation Union (NABU)

and funded by the European Climate Foundation (ECF), Oeko-Institut examines the potential risks associated with carbon storage – focusing on storage beneath the seabed – and how these risks can be managed. "We are looking not only at the technologies themselves, but also at the regulation needed to minimise risks and improve the safety and sustainability of carbon storage." But what risks are we actually talking about? "Experience gathered with previous projects shows that a wide variety of enormous operational difficulties can arise during injection. At the same time, there are many other challenges that interact with this. These include public perception, financial incentives, environmental impacts on marine ecosystems and a delay in the actual effectiveness of emission reductions."

North Sea?

By 2040, the
potential offshore
storage capacity
in Europe is
estimated at
around

**100–300
Mt
CO₂**

With a view to the legal and technical framework, the project team emphasises that the EU Directive on the geological storage of carbon dioxide provides a basis for managing the storage of CO₂. But it is also in need of improvement – for example, in terms of transparency and public trust. “We need independent third-party oversight, confidential reporting of irregularities and harmonised CO₂ purity standards,” states Krob. “Furthermore, if there is insufficient regulatory standardisation within the EU, this leads to inefficiency and higher operating costs for project operators.” Speaking of operators: the Sleipner and Snøhvit Norwegian storage projects saw costs significantly exceed expectations due to operational difficulties during CO₂ injection. “There is, for example, a risk that the rock layers will not show the injection and storage behaviour that was predicted. The correct selection of the site and the injection protocols – that is, the precise procedure for storage – is therefore crucial. Additional risks arise when existing infrastructure, such as pipelines from the fossil fuel industry, is to be reused. Technically, they are not compatible with the requirements of storing CO₂.”

LOW ENVIRONMENTAL RISKS

According to the study, offshore storage is associated with relatively low

environmental risks. However, these cannot, of course, be ignored. “These include direct effects such as the impact on marine ecosystems caused by CO₂ leaks, but also indirect consequences such as noise pollution resulting from increased shipping traffic.” The project team therefore recommends extending environmental impact assessments for carbon storage projects to include such indirect effects. Furthermore, the team calls for comprehensive and multidimensional spatial planning to avoid conflicts with other surface and subsurface uses, particularly in ecologically sensitive areas. “Efforts should also be made to find ways to reconcile these projects with other land uses.”

LOW EXPOSURE RISK

The risk of exposure to humans is low; nevertheless, comprehensive and continuous monitoring is required so that any irregularities in storage can be detected and mitigated. This monitoring is necessary both during the injection phase and after the storage site has been closed. “Furthermore, independent verifiers should be involved, and a clear framework for long-term liability is needed,” said Krob. “This must ensure that financial provisions are in place to cover remediation and maintenance costs following the closure of the storage site.” To date, EU guidelines stipu-

late a 20-year post-closure phase, while in Germany a 40-year period is envisaged. After this, the individual state authorities assume responsibility. “It is also important that policymakers regularly review and update the framework – for example, with a view to technological developments or cross-border carbon transport.”

THE NORTH SEA – OUR STORAGE SITE

In the study titled ‘Requirements in site selection to identify environmentally compatible storage sites’ commissioned by the German Environment Agency, researchers at Oeko-Institut examine in greater detail the suitability of the North Sea for German carbon storage projects. “From a purely geological perspective, it appears promising, but there are serious conflicts of use here – with nature conservation and marine protection, wind energy, fisheries and even military purposes. Unless compromises or opportunities for multiple use can be found, CCS will be very difficult to implement in the German sector of the North Sea.” CCS, for example, requires accompanying monitoring to oversee the storage process, says the researcher. “To this end, seismic measurements are carried out at regular intervals from ships – these must systematically survey quite large areas. This is not possible if there is a wind farm



there, because ships cannot simply pass through it, and the vibrations from the wind farms can interfere with seismic measurements. Multiple use could also be difficult on areas managed by the German Armed Forces." Furthermore, there are technical uncertainties that could significantly affect the potential for storage.

In this project, too, the researchers have considered environmental risks. There are direct risks – such as problems with storage or leaks. "Should large quantities of CO₂ be released uncontrollably, this would affect soil and water chemistry, resulting in acidification and risks to crustaceans and plankton, for example." However, CCS could also have an indirect impact on the environment. "The technology can affect sensitive species such as porpoises – for example, during exploration, pipeline construction or seismic monitoring activities." In principle, Krob sees only minor and acceptable risks from leaks, partly because these are highly unlikely. Impacts on marine ecosystems, such as those caused by noise, are, in his view, very likely and should be avoided at all costs. "Our study also aims to answer the question of how we can ensure long-term safety and environmental sustainability. Key aspects also include monitoring and an examination of processes and methods to prevent environmental impacts."

In the North Sea, therefore, the storage of CO₂ should be carried out according to the principle 'the less, the better'. "For it to be environmentally sustainable, a moderate and responsibly planned ramp-up is required, one that prevents undesirable developments and provides sufficient safety margins." For example, clear exclusion criteria and binding minimum requirements are necessary when selecting sites. In addition to sufficient storage capacity and a favourable geological depth of at least 800 metres, these include a minimum thickness of the primary, sealing cap rock, as well as the long-term stability and integrity of this barrier. "Furthermore, safe and environmentally sound storage of CO₂ also requires what is known as favourable injectivity. This prevents technical difficulties during injection." The exclusion criteria include, among other things, active faults in the subsurface, large-scale vertical movements, seismic or volcanic activity, and any adverse impact on usable groundwater caused by the storage projects.

From Dr Florian Krob's perspective, it is crucial to establish the relevant processes at an early stage and in a standardised manner. "At present, for example, the legal framework only provides for an in-depth assessment once site investigations have been carried out by the operators – this is too late; we need a procedure that makes it clear at an early

stage which areas are unsuitable due to environmental and safety concerns or conflicts of use." Experience gathered in Denmark has also shown that an early, systematic and transparent process can significantly increase public acceptance of CCS. "It is important to involve the public at an early stage and on an ongoing basis to build trust," emphasises the researcher from Oeko-Institut.

Christiane Weihe



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