RESEARCH DIVISION EU / EUROPE | WP NR. 02, APRIL 2023

# mCDR Foresight Scenarios: Policy Frameworks for Marine Carbon-Dioxide Removal in 2040

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[1] This report outlines processes and insights from a participatory foresight workshop held in December 2022 the SWP in Berlin, supported by the German Federal Ministry of Education and Research grant number 03F0898E. The workshop was conceptualised and facilitated by Dr. Johannes Gabriel and Marcel Hadeed, two members of Foresight Intelligence, an organisational consultancy specialised in foresight. However, this report represents the **author's** summary of and reflection on the workshop and does not necessarily represent the views of the participants or organisations involved.

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# 1. Introduction

## 1.1 Background on mCDR

Since net zero greenhouse gas emissions targets have become a keystone of climate policy, there has been increasing debate about the need to actively remove carbon dioxide from the atmosphere in addition to reducing emissions (Schenuit et al. 2022; IPCC 2022).

The ocean already plays a key role in regulating the global climate by absorbing a large proportion of anthropogenic carbon dioxide emissions (Watson et al. 2020: Friedlingstrein et al. 2022) and the majority of additional heat kept in the Earth system (von Schuckmann et al., 2020). As the technical and political challenges of the land-based carbon dioxide removal (CDR) approaches are becoming more apparent, the oceans seem to be becoming the new »blue« frontier for enhanced carbon drawdown strategies (Boettcher et al. 2021).

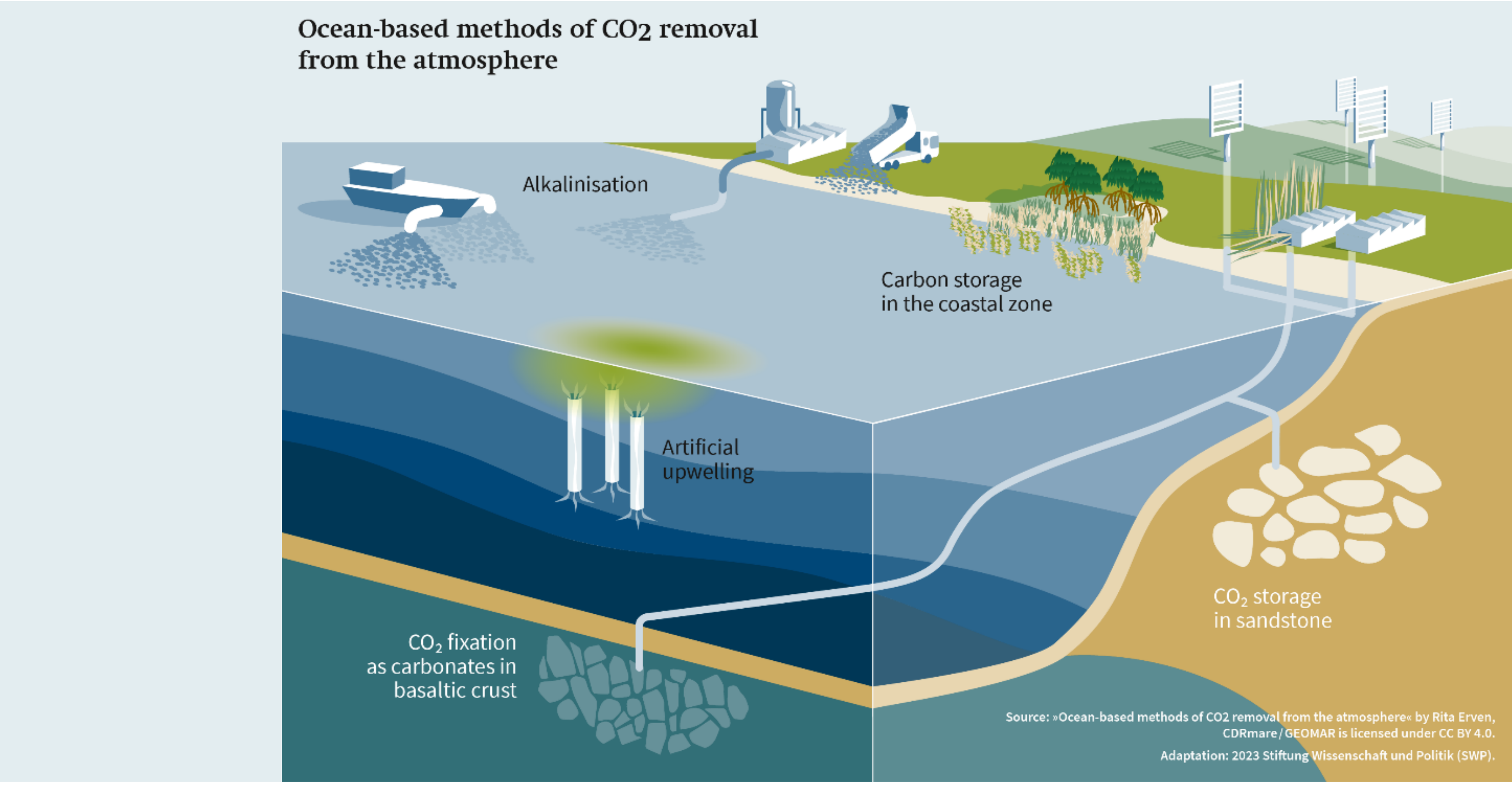
Some of the proposals being investigated in Germany and elsewhere for enhancing the carbon drawdown and storage potential of the ocean include:

- Ocean alkalinisation – adding materials like lime or olivine to the ocean, which then react with $CO_2$ and water to form bicarbonate and carbonate ions, thus enhancing the carbon storage capacity of seawater

- Artificial upwelling - enhancing the upward transport of nutrient-rich deep waters using pipes or wave pumps, which has a fertilizing effect. There is an increased growth of phytoplankton, and more $CO_2$ can be fixed in their biomass, which increases the carbon uptake of the upper ocean.

- »Blue carbon enhancement« – expanding coastal zone biomass such as seagrasses, seaweeds and mangroves to enhance biological $CO_2$ drawdown. The expanded cultivation of marine biomass can also be used in bioenergy generation, coupled with carbon capture and subsequent storage in subsea sandstone or basalt formations.

- Direct Air Capture using chemical reactions to pull carbon dioxide out of the air, coupled with storage in subsea sandstone or basalt formations.




## 1.2 Workshop aims: Developing qualitative scenarios to explore mCDR policy futures

This workshop was carried as part of work on a BMBF-funded research mission on marine $CO_2$ removal called: »CDRmare: Marine carbon sinks in decarbonisation pathways«. The research mission investigates how the carbon drawdown and storage effect of the ocean may be enhanced in the future. The objectives of the mission are: to explore and assess marine approaches to atmospheric $CO_2$ removal (mCDR) in terms of their potential and environmental, economic, social and political impacts and risks in the context of responsible and sustainable use of the ocean and; to provide information to policy makers and society on future opportunities and risks of marine $CO_2$ removal approaches and their governance.

One of the proven methods for exploring plausible futures is the development of qualitative foresight scenarios. The development of such scenarios on the topic of mCDR policy frameworks cannot be a purely academic endeavour, but should involve decision-makers from the administration as well as other relevant actors from science and civil society. This 1.5-day foresight workshop was therefore held on December 8 & 9, 2022, to enable relevant actors from Germany and the EU to engage in an exploratory process to identify policy-relevant factors that could impact decision-making on mCDR in plausible future scenarios.

This workshop aimed to switch the mode of thinking about the future of mCDR policy from predictive to anticipatory: a reorientation from »navigating 'what will be'« to »thinking through alternative 'what ifs?'« (Boettcher et al. 2016). The workshop organisers aimed to encourage the participants to engage experimentally with conceptions of the future derived from a broad field of perspectives. Additionally, the workshop was designed to help the participants explore the capacities of various policy frameworks and instruments to deal with threats and opportunities across a range of plausible futures.

The event was designed to apply a **participatory foresight method** – namely, the construction of qualitative scenarios – to enable structured thinking about complex systems and possible futures containing many unknown unknowns, and to provide an initial framework for a future-oriented discussion of mCDR policy proposals. The workshop furthermore made use of **explorative** scenarios, which focus on the broader context of a topic in order to explore alternative future environments. These lie in contrast to strategic policy planning scenarios, which are designed to plot alternative courses of action and their consequences. Explorative scenarios trace the complex interactions of a broad range of political, economic, technological, and social factors in a variety of hypothetical futures. They act as hypothetical thought experiments that deal with alternative assumptions about a wide range of developments in the future. Thus, they are context-dependent, subjective and **no not predict probable or desirable futures** (Gabriel 2014).

Qualitative scenario development processes are designed to draw upon inputs from multiple disciplinary perspectives, as well as alternative assumptions, expectations, and worldviews from policymakers and stakeholders. As individual biases can lead to one-sided or linear-extrapolative thinking, such scenarios are best constructed in a participatory process of group communication. A methodologically sound process for participatory scenario construction promotes critical reflection of the scenario development process, and allows for intersubjectivity, contributing to shared meanings and understandings and thus widening the range of plausibly imaginable futures. Participatory scenario construction thus provides a platform for structured communication that facilitates inter- or transdisciplinary thinking about possible futures. (Gabriel 2014: 5 – 7).

The qualitative foresight process implemented at this workshop applied in this workshop was conceptualised and facilitated by Dr. Johannes Gabriel and Marcel Hadeed from the organisational consultancy Foresight Intelligence (FI) to provide a platform for structured communication about a range of **logistically consistent** and **plausible** futures. A consistent scenario is composed of logically coherent **factor projections** that, taken together, describe a future situation. A plausible scenario also provides a credible and comprehensive illustrative trajectory that leads to a consistent future situation, exemplifying the changes necessary to end up in a certain future situation. So a qualitative scenario is not only a **picture of the future**, but it also includes also includes a rich **»history« of the future** – a pathway which describes how to get to that imagined future (Gabriel 2014: 3).

The workshop planning team set **two broad guiding conditions** for the participants. The first was the **scope** of the mCDR policy futures being discussed, which was set to focus on **the German context**, but taking wider the EU climate policy landscape into account. This choice was made as German climate policymaking is highly embedded in and dependent on EU climate policymaking (Knodt et al. 2020)[2]. Secondly, the **timeframe** for the scenarios was set to the

[2] Despite this focus on the German/EU context, linking to the wider context of global emissions scenarios and international climate targets was unavoidable. The group was encouraged to also consider future external influences on EU and German climate policy ambitions.

year **2040**. This choice was made based on the current expected timelines for German and wider EU climate policy, which stipulate that Germany should reach net-zero greenhouse gas emissions by 2045 and net negative emissions in 2050 (Presse- und Informationsamt der Bundesregierung 2023). Therefore, the assumption put forward by the organisers was that key decision-making processes on the role of CDR in climate policy would be initiated before 2040.

The workshop planning team also made choices about the types of participants to invite to the workshop. Such choices have a significant effect on the workshop outputs, given that – as described above – participatory scenario development processes are designed to draw upon the various knowledge types, perspectives, assumptions, expectations, and worldviews of those involved. The outputs of such processes can thus only be as diverse as the range of voices in the room. The workshop organisers aimed to invite a range of participants from relevant administrative bodies, as well as actors from science and civil society. The organisers additionally aimed for gender balance when inviting participants. To maintain the anonymity of the workshop participants, full details cannot be included in this report. However, the final group of 14 active participants included seven representatives from relevant administrative bodies, two from civil society, and five academics (two natural scientists and three social scientists). Only five of the participants did not identify as male. Reflections on the effects the group composition may have had on the participatory process and the resulting scenarios can be seen in section 3.3.

The following sections outline the participatory scenario development process (section 2), provide detailed descriptions of the resulting scenarios (section 3), and detail comparative reflections on all scenarios developed (section 4) before drawing preliminary conclusions about the workshop process and insights developed during it (section 5).

# 2. Participatory scenario development process

## 2.1 Exploring the broader context

The first step of the scenario development process was initiated before the workshop began. The participants were first sent an »environment scanning« survey. This asked them identify a broad range of political, economic, social, technological, environmental, and other factors (they could name up to twelve) that could shape mCDR policy development in the next 20-odd years. The resulting collection of factors where then clustered by Johannes Gabriel (FI) into **30 sets of factors** for the next step of the process.

## 2.2 Narrowing down to key uncertainties

Following an expansive first compilation of factors, a second survey was circulated in which the participants conducted an uncertainty-impact analysis to reduce complexity and select »key uncertainties«. This process is designed to identify factors that (in the participants' collective estimation) have a **very high potential impact** on the future of mCDR, and whose plausible future outcomes have a significant range or spread, meaning their outcomes are **very uncertain**. Using an online assessment tool designed by FI, the participants were asked **rate the uncertainty and impact** of each of the clustered 30 sets of factors gathered during the environment scanning survey. When they met in person on the first day of the workshop, the group was then presented the consolidated results of their joint ranking, and following several rounds of discussions, **agreed upon five highly ranked »key uncertainties«** to continue to work with (see Table 1 below).

| | |
|---|---|
| KU1 | **First experiences** with (in situ, small-scale) mCDR deployment (positive or not?) |
| KU2 | Level of **polarization of the political debate** around mCDR use to achieve NetZero or net negative emissions targets (high or low?) |
| KU3 | **Social preferences** towards tCDR and mCDR (perceived as a legitimate tool to combat climate change or not?) |
| KU4 | **Availability, feasibility and knowledge about riskiness** of various mCDR technologies (which ones are known to be sustainably useable/scientifically low risk to ecosystems?) |
| KU5 | **Existence of monitoring, reporting and verification (MRV)** technologies, infrastructures and regulatory accounting systems for (marine) carbon (fluxes) |

**Table 1**: Key uncertainties

## 2.3 Creating projections for key uncertainties

In small breakout groups, participants then developed at least **four distinct outcomes** for each key uncertainty in 2040 – a set of »projections« intended to cover the full spectrum of alternative plausible future states of a given key uncertainty. For this activity, the participants were asked to focus on each key uncertainty in isolation from all other factors, and try to imagine (at least) four possible outcomes of that factor in 2040 that were mutually exclusive, comprehensively exhaustive (MECE). Rather than thinking about likely future states of their factor, the groups were asked were to come up with a wide range of plausible future states of their respective factor, and reminded that a **plausible** future state is not to be confused with **probable** future state. Each group was asked to present their factor projections to the plenary, where they were then discussed, and in some cases adjusted within the larger group. The plenary discussion also led to the addition of another key uncertainty (KU 6), which the participants felt was necessary to address the political level on which future mCDR governance may be located. The resulting sets of factor projections are outlined in Table 2 below.

| | Description | Projection A | Projection B | Projection C | Projection D | Projection E |
|---|---|---|---|---|---|---|
| **KU1** | Positive or negative scientific and public experience with pilot deployments of mCDR | Successful first deployments and high level of public support (of some mCDR methods available) | science supportive, public opposed | Science: »naja...« Public supportive | Scientific failure, public backlash. Side effects of secret pilot study endanger precious ecosystems & release carbon | Scientifically successful first deployments and high level of public support (of almost all mCDR methods available) |
| **KU2** | Political Polarisation (GER/EU) | Low polarization, no debate. Matter of no-concern. | Differentiated polarization (different for individual methods) | High polarization (either/or, identities) | Low polarization in open debate. High plasticity of arguments, allows positions to change. | Volatility (waves of opening and closing of the debate and shifting position building) |
| **KU3** | Social preferences towards tCDR and mCDR methods | tCDR and mCDR methods are perceived as a legitimate tools to combat climate change | Only mCDR, not tCDR methods are perceived to be legitimate tools to combat climate change | No tCDR and mCDR methods are perceived to be legitimate tools to combat climate change | Only tCDR, not mCDR methods are perceived as legitimate tools to combat climate change | N/A |
| **KU4** | Sustainably useable/used mCDR methods | No mCDR methods are suitabibly usable/used | Some mCDR methods are suitably usable/useable | Not enough is known about risks to sustainability etc., and no mCDR is used | Despite (lack of) knowledge they are (un)sustainable, mCDR methods used anyway | N/A |
| **KU5** | Existence of MRV technologies, infrastructures, and regulatory accounting systems for (marine) carbon (fluxes) | Comprehensive MRV & accounting systems in place | Accounting system available, but very weak measuring/monitoring | No accounting in place but measuring/ monitoring is possible | no mCDR MRV or accounting at any scale | N/A |
| **KU6** | Level of CDR governance | Global | EU | Individual nations (Fragmented) | None | Germany only |

**Table 2:** Factor projections

## 2.4 Creating raw scenario frameworks

Participants then created a set of three raw scenario frameworks. Each scenario framework included one projection from each of the key uncertainties. Even with only four to five projections for each key uncertainty, there were a huge range of possible scenario frameworks. However, not all of them are conceptually consistent; certain projections could be mutually antagonistic. Consequently, the aim was to identify **logically consistent scenario frameworks**. Given the relatively small size of the group and the number of projections involved, this was done via group discussion in plenary. To begin constructing each scenario framework, one participant was selected to pick a projection to start from in the above factor projection table. The moderator then went around the room allowing others to volunteer to pick the subsequent projections from different factors in turn, always having to explain why and how their choice was consistent with the previously selected factor projections. If others in group disagreed with the consistency of the selected factor projection with those previously included in the framework, they were given the chance to suggest an alternative. However, if the participant who had originally selected the factor was not convinced by these arguments, s*he was free to stick with the original choice – provided s*he could justify the decision. Only one projection per factor was allowed to be used in each scenario framework. Once a factor projection had been used in one scenario framework, it could not be reused in another framework. Each participant was only allowed to pick one projection per scenario framework. Thus, each raw scenario framework was developed in as part of a participatory and communitive process. The factor projections that were grouped together to form the resulting three raw scenario frameworks (blue, green and orange) are colour coded in Table 3 below.

| | Description | Projection A | Projection B | Projection C | Projection D | Projection E |
|---|---|---|---|---|---|---|
| **KU1** | Positive or negative scientific and public experience with pilot deployments of mCDR | Successful first deployments and high level of public support (of some mCDR methods available) | science supportive, public opposed | Science: »naja...« Public supportive | Scientific failure, public backlash. Side effects of secret pilot study endanger precious ecosystems & release carbon | Scientifically successful first deployments and high level of public support (of almost all mCDR methods available) |
| **KU2** | Political Polarisation (GER/EU) | Low polarization, no debate. Matter of no-concern. | Differentiated polarization (different for individual methods) | High polarization (either/or, identities) | Low polarization in open debate. High plasticity of arguments, allows positions to change. | Volatility (waves of opening and closing of the debate and shifting position building) |
| **KU3** | Social preferences towards tCDR and mCDR methods | tCDR and mCDR methods are perceived as a legitimate tools to combat climate change | Only mCDR, not tCDR methods are perceived to be legitimate tools to combat climate change | No tCDR and mCDR methods are perceived to be legitimate tools to combat climate change | Only tCDR, not mCDR methods are perceived as legitimate tools to combat climate change | N/A |
| **KU4** | Sustainably useable/used mCDR methods | No mCDR methods are suitabibly usable/used | Some mCDR methods are suitably usable/useable | Not enough is known about risks to sustainability etc., and no mCDR is used | Despite (lack of) knowledge they are (un)sustainable, mCDR methods used anyway | N/A |
| **KU5** | Existence of MRV technologies, infrastructures, and regulatory accounting systems for (marine) carbon (fluxes) | Comprehensive MRV & accounting systems in place | Accounting system available, but very weak measuring/monitoring | No accounting in place but measuring/ monitoring is possible | no mCDR MRV or accounting at any scale | N/A |
| **KU6** | Level of CDR governance | Global | EU | Individual nations (Fragmented) | None | Germany only |

**Table 3:** Three raw scenario frameworks (Blue, Green & Orange)

## 2.5 Creating pictures and histories of the future

In breakout groups, the participants then fleshed out these scenario frameworks. They first described a coherent descriptive »picture« of the future, based on the projections in their respective scenario frameworks. They then created a corresponding narrative »history«, or trajectory that could plausibly lead to the situations they described. They did this by conducting a backcasting exercise and creating timelines of key events that lead to their described pictures of the future. The result of such a process was thus set of qualitative scenarios that not only provided a range of detailed pictures of the future, but also included a rich »history« of each future – a pathway which describes the key technological, economic, political and social changes that would have to happen between today and that imagined future.

## 2.6 Reporting back and group feedback

In plenary, each group was then asked to present their coherent descriptive »picture« of the future and the corresponding narrative »history«, or timeline of events that could plausibly lead to the situations they described. In addition to asking questions to better understand the future worlds presented, the audience was invited to provide feedback on two sets of questions; (1) *What would you like to hear more about? How could this scenario be made more plausible?* and; (2) *Where were there strategic decision points in the scenario pathway? What types of decisions were made to address the opportunities and risks presented in the scenario?*

# 3. Scenario descriptions

The following section contains details of the three scenarios developed at the workshop. The material presented for each scenario includes: (1) the raw scenario frameworks each breakout group used, (2) a set of »headlines« they developed to help describe their respective »picture of the future«, (3) the timelines they used to explain their imagined pathway from today to that plausible future, (4) narrative scenario descriptions,[3] and (5) a brief summary of the plenary feedback provided to each group when they presented their scenario.

## 3.1 Blue scenario: Mixed Blue Blessings

### Blue scenario description:

Today, in 2040, as Germany celebrates the 15th anniversary of its successful carbon removal strategy, we look back to reflect on how we got here. While many are still wondering if we could be doing better, those who prefer to focus on the positives highlight that we have now revived coastal wetlands across Europe and brought back biodiverse ecosystems. Largely thanks to these developments, Germany's annual marine carbon dioxide removal efforts now equal total national traffic emissions and – in combination with dramatic emissions reduction measures and increased DACCC in cooperation with Norway and Iceland – mean that Germany is on track to reach its Net-Zero target by 2045.

Things have certainly improved considerably since the 2020s, when droughts were prevalent, massive areas of forest were being destroyed every summer all over the continent, EU coastal wetland areas were seriously degraded due to increased storm surges, and marine ecosystems were struggling to recover from several major oil spills. Today, although forest fires are still a problem in some regions and the LULUCF sector remains a net emitter rather than remover of carbon, marine-based carbon removal, marine ecotourism, fisheries and aquaculture businesses are booming thanks to the successful restoration of coastal ecosystems throughout Europe. Recent news from the Netherlands has also provided much hope for the transition away from high-emissions food sources – thanks to the much improved conditions for marine farming, revenue from Dutch clam farms has overtaken that from pork sales, and land-grown-meat consumption has hit a new low.

In light of the broadly accepted need to compensate for overshoot by going »net negative«, a recent International Energy Agency (IEA) report showed that global momentum on CDR efforts is growing.

[3] The narrative scenario description texts included here are based on the material developed during the workshop, incorporate suggestions raised during the plenary feedback round, and were shared with the original group members for feedback prior to publication in this report, but were compiled by the report author. The scenario descriptions presented here thus represent the **author's** summary of and reflection on the workshop discussions and does not necessarily reflect the views of all participants.

| | Description | Projection |
|---|---|---|
| **KU1** | Positive or negative scientific and public experience with pilot deployments of mCDR | Successful first deployment and high level of support (of some methods mCDR available) |
| **KU2** | Political polarisation (GER/EU) | Differentiated polarization (different for individual methods) |
| **KU3** | Social preferences towards tCDR and mCDR methods | tCDR and mCDR methods are perceived as a legitimate tools to combat climate change |
| **KU4** | Sustainably used/useable mCDR methods | Some mCDR methods are sustainably usable/used |
| **KU5** | Existence of MRV technologies, infrastructures and regulatory accounting systems for (marine) carbon (fluxes) | Accounting System but very weak measuring/monitoring |
| **KU6** | Level of CDR governance | EU |

**Table 4:** Blue raw scenario framework

| |
|---|
| **Revived coastal wetlands across Europe bring back biodiverse eco-systems** |
| **Germany celebrates 15th anniversary of its CDR-strategy and reaches milestones ahead of time** |
| **Marine Carbon Removal now equals traffic emissions – Germany on track to reach net zero** |
| **IEA report shows global momentum for marine CDR after EU blue carbon sequestration exceeds expectations** |
| **Dutch clam farming overtakes revenue from pork as meat consumption hits a new low** |
| **As artificial upwelling remains a dead end, Iceland expands marine DACCS operation in the Arctic Ocean, helping to reach EU removal target** |
| **EU invests massively in upscaling of ocean carbon monitoring** |
| **IPCC AR9 confirms high potential of mCDR – German Scientist in lead** |
| **North Atlantic long-term alkalinisation project shows mixed results** |

**Table 5:** Blue scenario headlines

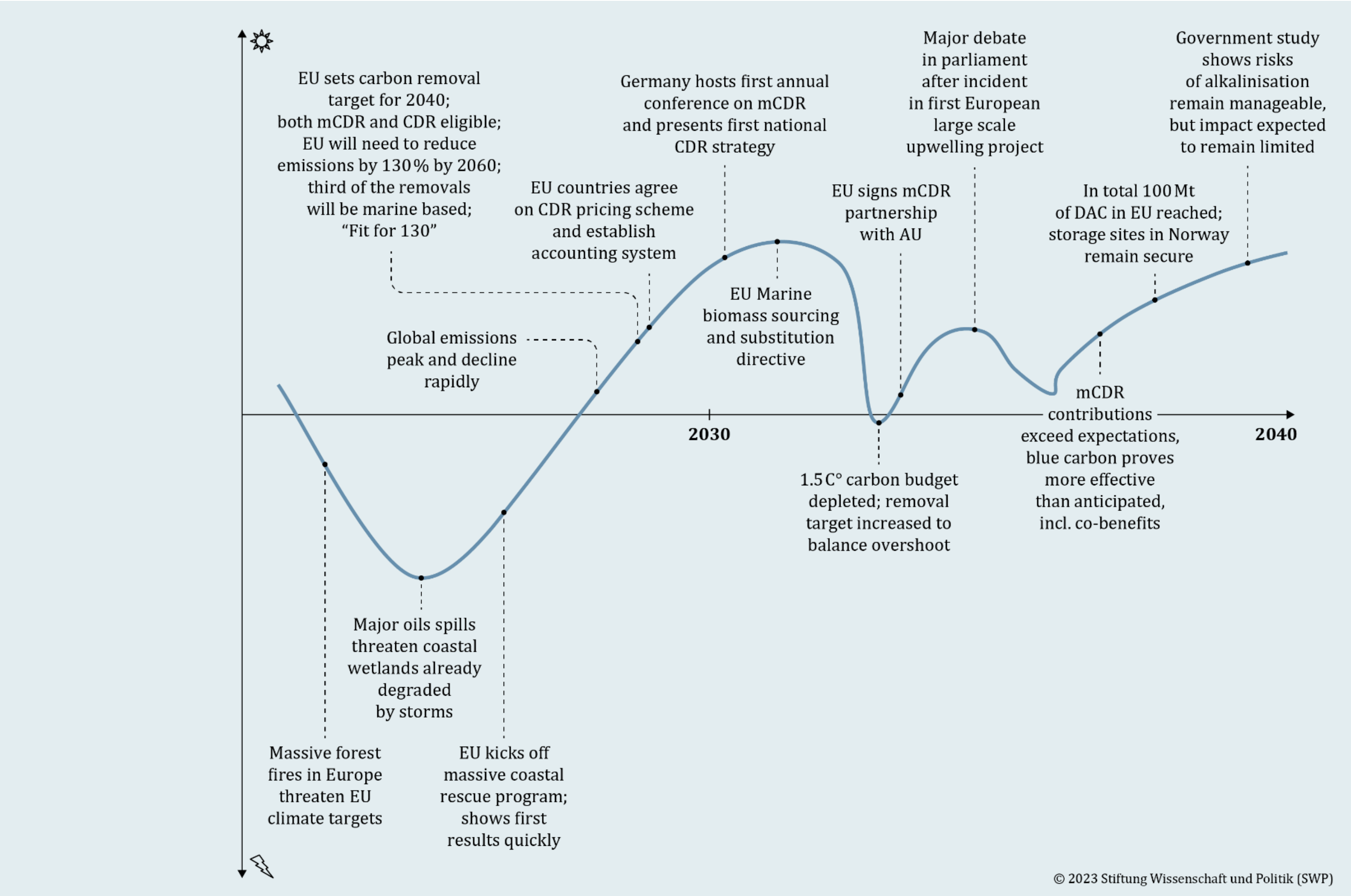



**Figure 1:** Blue scenario timeline

Backed by this knowledge, the EU has now invested massively in the upscaling of ocean and coastal carbon monitoring, which many hope will be the first step towards more robust mCDR MRV to complement the existing EU CDR accounting and pricing schemes, and serve as an example for how this could be done globally. Although the IPCC published guidelines for reporting for mCDR, the UNFCCC COP35 failed to find agreement on treatment of marine CDR under Article 6, and so global reporting processes remain to be developed. The EU is therefore well positioned to provide a positive example in this area. There is hope that the EU model will help to prevent »greenwashing« of the mCDR sector by establishing clear and transparent regulatory standards.

But not everyone is so positive about all types of mCDR. Those political pundits who like to remind us that not everything is as rosy as it may seem have pointed out that, despite first hopes – after multiple whales stranded due to sonic interference from deep-sea pumps and there were mounting public concerns about seemingly altered weather patterns – artificial upwelling remains an expensive dead end. In addition, the ongoing North Atlantic long-term alkalinisation project has shown mixed results –

while environmental risks seem to be relatively low, the carbon drawdown potential is reportedly also lower than proponents had hoped. Some political parties are now calling for public funding for the project be withdrawn.

Sceptics have also raised the legitimate question as to whether ecosystem-based approaches to mCDR that have worked well in European coastal zones are going to be as viable in other areas of the world. There has recently been increasing interest from many small island states and African Union (AU) members to deploy coastal ecosystem-based mCDR, and the EU has established partnerships to facilitate knowledge sharing, but it remains unclear if the best practices developed in European waters will apply equally in other regions. In addition, experts continue to warn against »*putting all our CDR eggs in one basket*«. They point out that even the EU is not able to depend on coastal ecosystem-based mCDR efforts alone – we have relied heavily on Norway and Denmark expanding their sub-seabed carbon storage operations to help us reach our removal targets using DACCS.

So, in sum, when taking stock of where we stand today, we can say we have had »*mixed blue blessings*« when attempting to harness the ocean in our carbon drawdown efforts.

### Feedback

In the first round of feedback, all participants were asked:
***What would you like to hear more about? How could this scenario be made more plausible*?**
A summary of the questions posed and the responses provided by the group is included below.

- *Who was involved in the political polarisation on mCDR? Who/what types of actors were for/against different types of mCDR?* The group responsible for the development of the scenario responded that they did not specify this detail, given that who is for or against the various types of mCDR would not dramatically change the situation, as the polarisation is not a huge driver in this scenario. However, political parties with close ties to coastal communities, fisheries and marine tourism industries were envisaged to be in favour of coastal eco-system based mCDR in this scenario, while those opposing artificial upwelling and alkalinity were groups concerned about whale welfare, the potential effects on weather patterns and the risk of »wasting« taxpayer's money on funding (unpromising) projects.

- *In this scenario, there is a carbon accounting system in place, but monitoring capacity is weak – how would you know about the risks/potentials of different mCDR approaches?* Response: Monitoring is seen as more about long-term capacity to identify and attribute change caused by specific actions. Short-term observation of the risks and benefits of mCDR approaches is envisaged as being possible in this scenario, and there are efforts being made towards improving (long-term) MRV capacity. It was thought that the establishment of regulatory accounting frameworks had led the way, and thus created the incentive to invest in MRV capacity.

- *The energy use for DACCS is not clarified – where is the power coming from?* Response: The assumption in the scenario is that DACCS is powered by renewable energy – probably wind and/or bioenergy to power the capture components inland, and a combination of wind and geothermal energy to power storage components offshore (i.e. in Norway).

In the second round of feedback, all participants were asked to reflect upon the following questions:
***Where were there strategic decision points in the scenario pathway? What types of decisions were made to address the opportunities and threats presented in the scenario?***

- In the resulting discussion, participants highlighted that the severe ecological disasters were a key **threat** which triggered a reaction from the EU – in the form of massive coastal ecosystem restoration efforts. However, there may have been other ways of dealing with this threat. For example there could have been a decision to invest in large dykes, to relocate cities and industries, or simply to accept the ongoing damage to coastal ecosystems. That the decision made at this key turning point was to invest heavily to restore ecosystems as a primary means of coastal protection is based on two underlying assumptions: 1) there is some kind of consensus among EU member states that »nature-based« responses to climate change adaptation are viable and desirable, and 2) that the EU and its member states would still be (economically) strong enough to react in this way to the damage that is happening.

- Another key decision point highlighted in the discussion was the EU entering into a mCDR partnership with the African Union. This was seen as an example of a decision which took the **opportunity** to increase international cooperation with countries with large coasts/marine spaces (including small island developing states) so that they could benefit from research being done in the EU and thus increase the climate resilience and carbon drawdown potential of coastal ecosystems.

## 3.2 Green scenario: Give me the Ocean and I will save the World

### Green scenario description:

Yesterday, two influential groups publically issued conflicting messages on the future of marine carbon dioxide removal. While the heads of multiple EU member states – among them Germany – announced plans to expand their international efforts on Ocean Alkalinity Enhancement (OAE) as a key component of the »global climate strategy to keep 1.5 alive«, prominent scientists from around the world published an open letter reiterating their scepticism about the environmental safety and effectiveness of such efforts. Despite the warnings from science, public opinion in Germany and other EU countries still remains firmly in support of the political »mission« to use OAE and other mCDR methods to help achieve the new 2060 net negative emissions target of minus 135% in comparison to 1990.

| | Description | Projection |
|---|---|---|
| **KU1** | Positive or negative scientific and public experience with pilot deployments of mCDR | Science: »naja...« Public supportive |
| **KU2** | Political polarisation (GER/EU) | Only mCDR, not tCDR methods are perceived to be legitimate tools to combat climate change |
| **KU3** | Social preferences towards tCDR and mCDR methods | tCDR and mCDR methods are perceived as a legitimate tools to combat climate change |
| **KU4** | Sustainably used/useable mCDR methods | Despite (lack of) knowledge they are (un)sustainable, mCDR methods used anyway |
| **KU5** | Existence of MRV technologies, infrastructures and regulatory accounting systems for (marine) carbon (fluxes) | Comprehensive MRV & accounting systems in place |
| **KU6** | Level of CDR governance | Global |

**Table 6:** Green raw scenario framework

| |
|---|
| **Climate crises events, need for large-scale CDR options but land demand high; tCDR scaling potential too small; focus on broader suite of mCDR (incl. OAE).** |
| **New climate target for 2060: -135% (vs. 1990)** |
| **Common OAE practice to work in international waters; local side effects can thus be exported (»implicit« NIMBY);** |
| Science highlights: uncertainty about OAE removal potential and side effects, need for sustainable climate action |
| **Disconnect between *output* (political promises) vs. actual *outcome* (in terms of $CO_2$ sequestration)** |
| **Politicians – we need more: »Give me the ocean and I will save the world«; can't wait for the science to settle** |
| **High energy requirements for CDR on land accepted as an argument to turn to the ocean** |

**Table 7:** Green scenario headlines

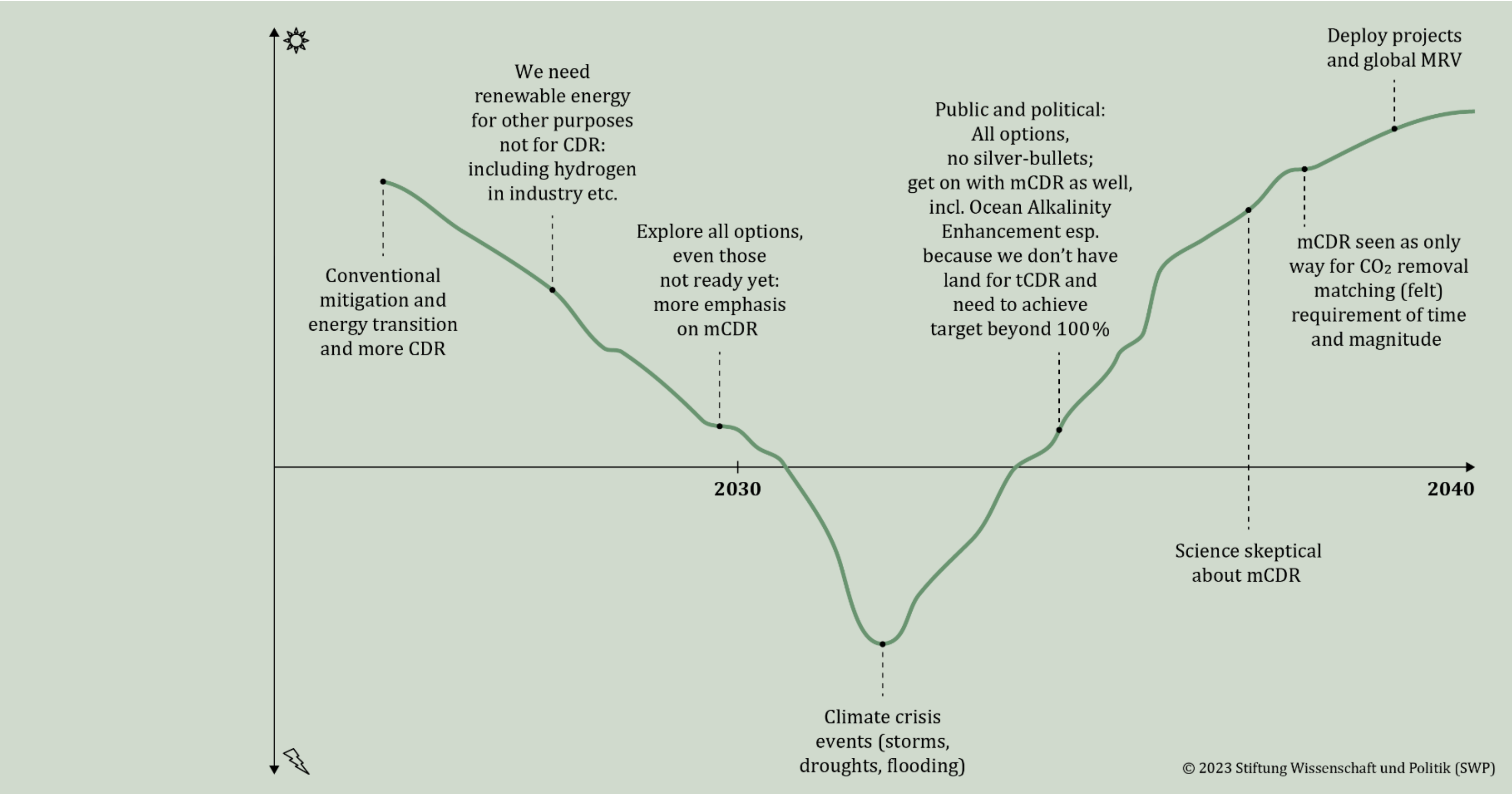



**Figure 3:** Green scenario timeline

The slogan *»Let's do it together!«* that has been so effective in mobilising public support and investment for mCDR efforts around the world is continuing to be more convincing than the calls from scientists to *»Slow down fast!«* and do more research to clarify the remaining uncertainties around OAE.

In hindsight, it is easy to see how we got to this point. In the late 2020s, we were plodding along, slowly but steadily reducing emissions and transitioning our energy systems and industries away from fossil fuels, primarily with increasing shares of green hydrogen. Germany was committed to achieving net-zero emissions by 2045. But it seemed we were not doing enough fast enough. Most of carbon dioxide that had been building up in the atmosphere since the industrial revolution was still there, still warming the planet, irrespective of our incremental efforts to reduce the amount we were adding per year. It became ever clearer that we were going to drastically overshoot the global temperature target set in Paris in 2015. We were failing to act fast enough as a global society, and the effects of our collective failure hit home hard in 2026 – 27, when Europe and other parts of the world was thrown into a state of »climate emergency« by a seemingly endless string of climate-change induced crises; droughts and fires in southern Europe and western USA, multiple *Catarina*-sized hurricanes in the Gulf of Mexico, storm surges battering the Atlantic coastlines. Economic damages and skyrocketing death tolls shocked the world. Calls for fast and decisive action became ever louder – we needed a range of options on the table to enable us to do more, and quickly.

One such option that had been on the table for quite a while was actively *removing* the main source of these climatic events – the accumulated carbon dioxide trapped in the atmosphere. *»Scrubbing the skies*« by drawing down $CO_2$ and thus taking responsibility for cleaning up the mess humanity had cumulatively made over the last 200-odd years gave publics and politicians a much-needed feeling of agency and purpose. But this new found drive and urgency faced several hurdles. First, many proposed carbon removal approaches were energy intensive, or they required large amounts of land. Most renewable energy produced in Germany, however, was needed to cover existing energy demand and power green hydrogen production. In addition, most of the required land in populous EU countries was either covered by housing, used for food production, or protected for environmental or cultural reasons. And even those areas that could be repurposed for removal efforts were close to cities, towns or villages with habitants who – although they wanted to support the climate effort in general – were wary of having such activities happen so close to their homes. The logical step was thus to switch our focus to areas largely devoid of humans – the open oceans. In addition, moving the location of mCDR efforts outside of Germany also made it possible to export the energy demand associated with them to countries with higher capacity for renewables.

In the late 2020s and early 2030s, the oceans thus rapidly became the new »blue frontier« for carbon drawdown hope, with massive mCDR research investment in Germany and other countries with historically high emissions and limited available land. Public and private research funding was accompanied by adaptations to international and national regulatory arrangements to enable large-scale testing and deployment of marine-based carbon removal measures. The London Protocol was amended to exempt many proposed marine CDR measures from the prohibition on »dumping«, and similarly the German »Federal Act on the Prohibition of the Dumping of Waste and other Substances and Objects in the High Seas« was adjusted to define some marine CDR methods – including OAE – as »the introduction of substances is for the purposes of environmental protection« and thus allow them. With the regulatory landscape clarified, many commercial entities began building businesses models around mCDR.

Since then, despite slower-than-hoped-for results from research and continued »scientific hesitancy« about environmental risks and carbon drawdown effectiveness, more and more countries and companies have been advancing plans for scaling up their marine CDR efforts, with a primary focus on OAE.

It is hard not to be swept along with this wave of this hope and hype around mCDR. It feels like the nations of the world are finally mobilising together to do something about climate change. But there remains the niggling knowledge that scientists around the world – although being initially supportive of investigating it – are now sceptical about the carbon removal potential and environmental risks of the politician's and publics' favoured ocean carbon removal approach – OAE. While politicians continue to emphasise that the urgency of the climate problem means they *»can't wait for the science to settle«* before taking decisive action, it remains to be seen whether the carbon sequestration outcomes of OAE will be as effective as the political promises currently being made.

## Feedback

***What would you like to hear more about? How could this scenario be made more plausible?***

- *Where was the turning point at the beginning? What was the trigger point that made the world turn to mCDR?* Drastic climatic events made it clear there was a need for CDR, but national land and energy competition and NIMBY-ism made terrestrial CDR unviable in many industrialised countries. »Offshoring« CDR operations seemed the logical way around these issues.

- *What made the (German) public support mCDR?* The offshore/distant nature the activities themselves. The »offshoring« of CDR efforts meant less need to use German resources, as no (German) land is needed, the (renewable) energy is sourced elsewhere, assuming minerals mining and grinding are not happening in Germany, and the environmental impacts are far from habitable areas, making it less contentious publically.

- *Why was OAE the focus of this scenario?* All mCDR methods are being investigated, but ocean alkalinity enhancement as seen as key largely because it can be done in offshore waters, where people are not directly affected and thus do not care as much.

***Where were there strategic decision points in the scenario pathway? What types of decisions were made to address the opportunities and threats presented in the scenario?***

- The participants highlighted that a **critical juncture** was Germany deciding that renewable energy is better used elsewhere, not for tCDR. This decision fundamentally shaped the further development of the scenario. In addition, this was imagined this as an ongoing juncture – the decision not to go for land-based DACCs is continually reinforced, as is deciding to continue the focus on mCDR.

- In addition, the narrative of this scenario hinges on renewable energy being in limited supply in Germany and other similar countries. The participants discussed that this implied there was either a **missed opportunity** or conscious decision not to invest heavily into more renewables to power land-based CDR in these countries.

- The climate change extreme events which triggered the call for more CDR presented a key **threat** in this scenario. But participants emphasised that the decision to move towards CDR was just one possible plausible response to this threat – an alternative could have been a push for more adaptation to increase resilience in the face of such climate impacts.

### 3.3 Orange scenario: Germany as a frontrunner in carbon sink restoration

#### Orange scenario description:

Today it seems that – after a convoluted and contested period – Germany may be moving from a loner to a leader in marine action on climate change. Back in 2024, this looked quite different. At the UNFCCC COP29 many countries pushed forward a framework to include some biogeochemical mCDR approaches (i.e. OAE) in international climate mitigation and accounting efforts. At that time, Germany was not among these countries, because political and public debate in the country – led primarily by environmental NGOs – was dominated by a call for a precautionary approach towards these emerging methods. In the following years, many mCDR projects went ahead around the world, including the North Sea, with Germany again taking »only« an observing role driven by public scepticism.

Everyone remembers the poignant aerial pictures of people lining up along the North Sea coast line, holding hands, silently protesting the expanding ocean alkalinity pilot studies being carried out in the open ocean by the UK, Norway, the Netherlands and Demark. Rather than perceiving themselves as standing alone against the rest of the world, German publics and some politicians saw themselves as »taking a stand for the sea« itself. They pointed to declining fish stocks in Norwegian waters and coastal ecosystem degradation in the Wadden Sea as evidence that »marine manipulations« were having negative side-effects, and reiterated that Germany should stick to its precautionary stance on all types of CDR.

In contrast, other political parties in Germany lamented that the country was isolating itself by *»missing the boat«* on marine carbon removal, especially when it became clear that Germany was going to fail to meet its climate targets, and German industry entered financial decline – with many companies claiming this was linked to financial losses from drastically increasing carbon prices they had to pay for their residual emissions through the EU ETS.

Then, in 2031, even more fuel was added to this already heated political debate. After large numbers of dead fish and several bloated seal carcasses washed up on the Schleswig-Holstein coastline, a whistleblower revealed that a secret alkalinity enhancement pilot study was being carried out within the Germany Exclusive Economic Zone (EEZ) in the North Sea. After details about the cause of the ecological disaster – a fire on a ship producing alkaline material for distribution in the North Sea using electrochemical splitting that produced hydrochloric acid resulted in a chemical and fuel spill – became public, there was a huge societal backlash within Germany against the incumbent government – which was accused of having prior knowledge of the pilot study. The resulting political fallout was liked by some to the »*Fukushima effect«* and proved to be a major turning point for German politicians, with even those parties who had previously called for a more open stance on mCDR switching to politically prioritizing marine protection. A newly elected German government subsequently announced its intention to become a front runner in developing an alternative approach to combining marine ecosystem protection with climate action.

In 2034 Germany led the creation of a HELCOM–VASAB (Helsinki Commission – Vision and Strategies around the Baltic Sea) marine spatial planning group to establish an unprecedented marine protected area in the Baltic Sea.

| | Description | Projection |
|---|---|---|
| **KU1** | Positive or negative scientific and public experience with pilot deployments of mCDR | Scientific failure, public backlash<br>Side effects of secret pilot study endanger precious ecosystems & release carbon |
| **KU2** | Political polarisation (GER/EU) | High polarization (either/or identities). |
| **KU3** | Social preferences towards tCDR and mCDR methods | No tCDR and mCDR methods are perceived to be legitimate tools to combat climate change |
| **KU4** | Sustainably used/useable mCDR methods | Not enough is known about risks to sustainability etc., and no mCDR is used |
| **KU5** | Existence of MRV technologies, infrastructures and regulatory accounting systems for (marine) carbon (fluxes) | No accounting in place but measuring/monitoring is possible |
| **KU6** | Level of CDR governance | Individual nations (Fragmented) |

**Table 8:** Orange raw scenario framework

| |
|---|
| **The ocean cries – Whistle-blower uncovers ecological crisis as a result of pilot alkalinity study** |
| **mCDR doomed from the start** |
| **Germany misses its climate goals again – do we need to consider mCDR? (push for mCDR by industry)** |
| Norway reports decline in fisheries – scientists consider effects from ecosystem manipulations in Netherlands? |
| **Germany in decline – Is our industry missing out again?** |
| **Atmospheric $CO_2$ still increasing – are diminished natural carbon sinks the cause?** |
| Wadden Sea at risk – are we losing our blue lungs? |
| **Cod returns to its natural habitat – Baltic Sea relives** |
| **Germany proposes to take natural carbon sinks into national accounting for COP50** |

**Table 9:** Orange scenario headlines

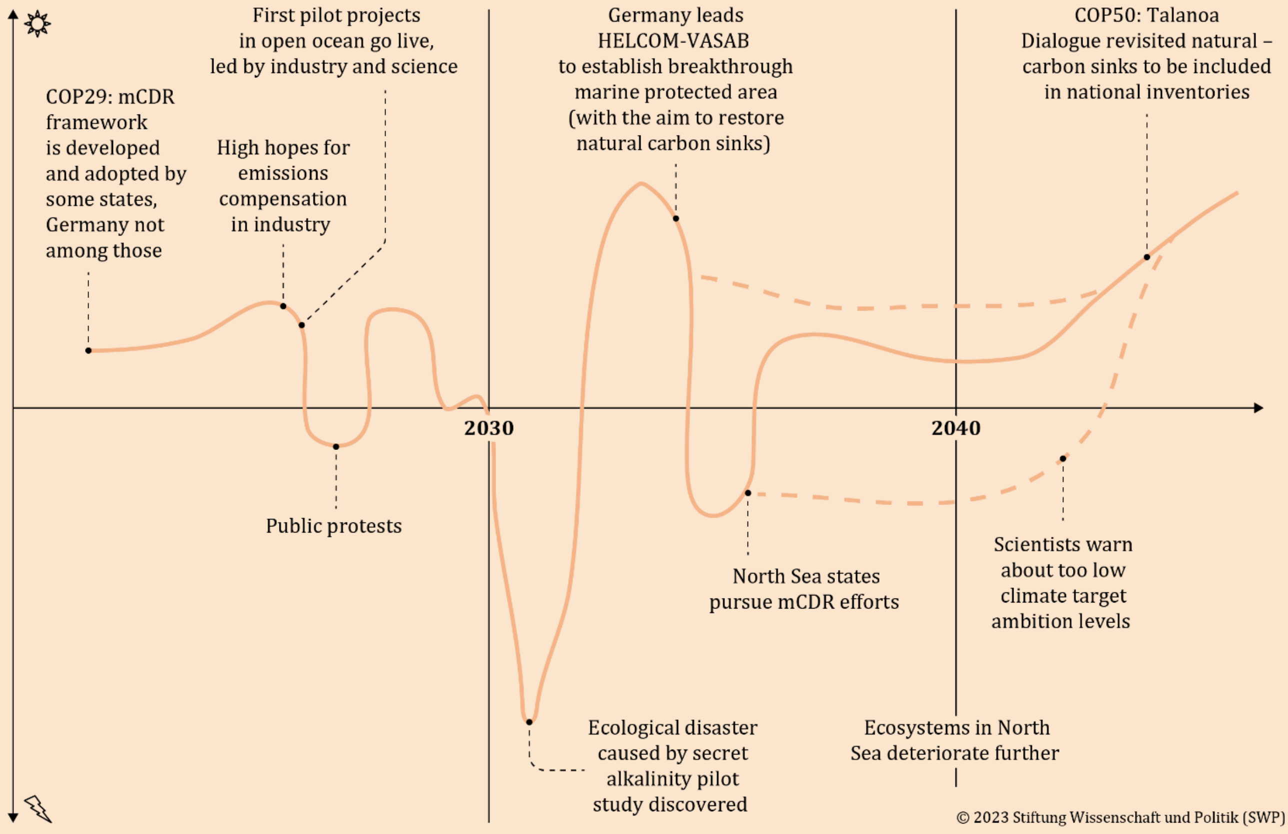



**Figure 3:** Orange scenario timeline

Within this novel Baltic Sea protected area, huge marine ecosystem restoration projects began from 2035 onwards: Wetlands were restored along all coastlines, and stressors for seagrass meadows were actively removed to allow the ecosystems to regenerate and even spread throughout the shallows of the basin.

While North Sea ecosystems continued to deteriorate further (with OAE still happening outside the German EEZ), the Baltic became a poster-child for large-scale ecosystem-based carbon drawdown, with people from around the world visiting to learn about the *»Baltic best-practice«* approach to combining marine ecosystem protection with climate action. But despite these positive developments, it is clear that Germany is not going to be able to meet its 2045 Net-Zero target. Indeed, around the world scientists are still warning that global climate targets are unlikely to be met.

At a Talanoa Dialogue at COP50 in 2040 which sought to break the climate deadlock by encouraging participants to share their local experiences of dealing with climate change, there seemed to be an increasing interest in systematically adopting the *»Baltic Best Practices«* (BBPs) in other areas around the world. The COP negotiators also started to discuss the idea that – as monitoring systems continue to improve – coastal marine carbon sinks may be able to be included in national carbon inventories in the future, thus allowing countries to count marine ecosystem restoration projects towards their carbon removal targets.

## Feedback

***What would you like to hear more about? How could this scenario be made more plausible?***

- *The focus on public protests as a driver of political change is interesting, but assumes a very direct link between these protests and political positions on CDR – is this plausible in the German setting?* Yes, this link is posited as plausible – there is a long history of vocal civil society movements shaping environmental policy in Germany, for example the protests in the wake of the Fukushima disaster led to the German government changing its stance on nuclear energy.

- *Why was it not possible for natural marine carbons sinks be included in national inventories before 2040?* Currently, reporting of emissions and removals from marine ecosystems would have to follow the same logic as LULUCF land categories, i.e. it would be necessary to estimate the carbon stock change/flux from one year to the other. This is already very complicated for terrestrial ecosystems (forests, soils etc.). Based on current knowledge, it would be extremely difficult to do this for underwater ecosystems (including seabed sediments) which we do not have nearly as much experience monitoring – compared to managed terrestrial ecosystems, we have a poor understanding of the carbon dynamics and very limited data. In addition, IPCC guidelines require »complete« reporting of carbon fluxes from a given type of ecosystem – a country could therefore not choose to measure the carbon drawdown taking place in one or two seagrass restoration projects of their choosing – they would need to report gains and losses in all seagrass ecosystems in their EEZ. Therefore, significant advances in large-scale monitoring would be needed before marine carbons sinks could be included in national accounting inventories. In addition, some countries are likely to have a disincentive to include marine carbon fluxes in their inventories, given that – due to degradation – many nations' coastal ecosystems may currently be »net positive« (emitting more carbon than they sequester), and therefore would have detrimental effect on those countries' overall carbon balance if included in their accounting inventories. Therefore it was seen as relatively implausible that this would happen before 2040.

- *Why is not much climate action happening up until 2030 – might this lead to run away climate change?* The assumption is that there is climate action happening – major emissions reductions efforts happening in Germany and other countries around the world, other countries are implementing CDR, and overall climate sensitivity may be lower than anticipated, implying larger emissions budgets and lower risk of runaway climate change events and impacts.

- *Is it plausible that a »secret test« could happen within the German EEZ? Maybe it would make the scenario more plausible to have the ecological disaster happen elsewhere – like with Fukushima?* The assumption is that the secret test was undertaken by a private actor (company) on the edge of the German EEZ, and that the public suspects (some members of) the German government may have had prior knowledge of it. This narrative was chosen because the strong public (and political) reaction is considered more plausible if it is associated with a deeper shock close to home, and if national political figures are implicated.

***Where were there strategic decision points in the scenario pathways? What types of decisions were made to address the opportunities and threats presented in the scenarios?***

- A major turning point was seen to be the ecological disaster, and the political reaction to it. The scale of the **threat** (ecological disaster) was not necessarily large compared to the public backlash – it hits a national nerve, especially due to the extensive media coverage. The historical experience with civil society/public protests around environmental issues in Germany were seen as a precondition for this link between the ecological event and political action.

- Another **threat** that was perceived in this scenario was that Germany was not doing all it could (i.e. also CCS & CDR) to address climate change until quite far in the future, potentially risking run away climate change, and/or relying on others to take climate action.

- **Key decisions** to deal with threats or take advantage of opportunities were being made on a **global level**, i.e. the decision to include some mCDR COP29 (in 2024), and later the discussion at COP50 to change accounting rules to include costal carbon fluxes. But also decision-making on the **regional level** is key – the second major policy/governance action is the creation of novel marine protected area that required regional cooperation among the Pan-Baltic states.

# 4. Comparative reflections

This section documents the final step of the scenario workshop, in which the participants engaged in a comparative reflection processes designed to broaden the analytical lens to include all the scenarios. They were asked to reflect upon and discuss two questions: (1) *What are key context conditions driving (policy) developments across all scenarios?* and (2) *What types of policy developments could help address opportunities and risks presented across (all) the scenarios?* Their discussions are summarized below, followed by a brief reflection on the effects the project aims, design, and group composition may have had on the workshop process and outcomes.

## 4.1 Key context conditions driving (policy) developments across all scenarios

It was highlighted that politics and policy-makers reacting to **public opinion** was a common pattern across all scenarios. In some cases the driver of public opinion was environmental disaster or climate change impacts, which caused publics to call for certain types of action, which in turn led to policy-makers implementing this change. Another example for this type of link was the connection between positive/negative (public) experience with mCDR or other types of marine-based climate action (i.e. coastal ecosystem restoration), and the resulting scope for policy development: The »political possibility space« in the scenarios seemingly expanded when publics had positive experiences and contracted when they had negative experience with marine interventions. This was echoed in the posited link between societal – and thus political – preferences for certain types of mCDR if they offered (local) benefits beyond carbon removal (i.e. increased fisheries production, aquaculture capacity, positive effects on ecotourism). Likewise the potential for negative effects/burdens on society was a factor which influenced decision-making on the type and location of marine-based climate action across the scenarios.

Similarly, it was noted that when external actors or private entities initiated mCDR activities in the scenarios, this caused public/media/civil society reactions, and then politicians and policy-makers had to subsequently position themselves. However, this was only the case if climate change and strategies for dealing with it were assumed to be high on the public/media agenda: If other major issues (i.e. war) had come up during key mCDR decision-making processes in the scenarios, it was presumed that publics may have been distracted from the issue, and thus had less influence on political positions.

However, the discussions highlighted that when conceptualising the link from public opinion to policy-making, we should not forget **politics**. The participants talked about inherently political dynamics that could be driving mCDR policy-making in the scenarios. They flagged that it was important to consider, for example, when events described in the scenarios were happening relative to the national electoral cycle: If key events occurred in the lead up to elections, politicians in the German government and in the opposition may both have been more willing to promise to fulfil public demands. If the scenarios included an incumbent multiparty-coalition national government (as was the case in Germany at the time of the workshop), mCDR decisions might have been reached as the result of bargaining or compromising on other policy issues. Thinking more broadly about international politics, participants pointed out that a key driver of decision-making on mCDR could be what other major countries are doing: If others (i.e. partner countries) were successfully undertaking mCDR already, the (political) risk of Germany doing it might be lower.

The varying roles of **science** in mCDR policy-making across the scenarios was also discussed extensively by the group. Although scientific understanding of marine environments was required in all three scenarios, it seemed that science was not the driving force behind decision-making. In one case, mCDR policy action was even being undertaken despite scientific reservations. The participants reflected on various ways in which scientific knowledge interacted with other drivers in the scenarios – sometimes being harnessed to lend authority to political decisions, sometimes providing input to allow decision-makers to weigh up the risks of »betting on the wrong horse«, sometimes being used as a negative example of how waiting to have all the answers could slow down action. This prompted the group to flag several questions for further reflection: For what is science being strategically mobilized in each of the scenarios? Who is using the science for what end in each scenario?

Although **industry** was not seen as a key driving force across the scenarios, pressure was seen as coming from some industrial sectors to develop (marine & terrestrial) CDR policy to help counterbalance their residual emissions. In addition, the continued energy demand of German industry was one factor expected to influence the amount of (renewable) energy available to power-intensive carbon removal activities across the scenarios. In this vein, the participants reflected that the **cost** of developing mCDR options only appeared in the scenarios in relation to the relative distribution of renewable energy. Despite the fact that cost did not explicitly play a huge role in their scenarios[4], the participants reflected that it would likely be a central factor influencing policy decisions and should be taken into further consideration in future scenario work.

## 4.2 Policy developments which could address opportunities and risks in (all) scenarios

### 4.2.1 Defining mCDR for policy purposes

It became clear to the workshop participants when comparing across all the scenarios there remains a very fuzzy definition of what falls under the mCDR label. May different understandings exist about whether the »marine« element means both the *removal* and the *storage* of carbon happen in the marine environment (i.e. as is the case with OAE) or if i.e. direct air capture on land coupled with subsequent sub-seabed storage could be termed a type of »mCDR«. Likewise the group had differing conceptualisations of where the line between marine ecosystem restoration and ecosystem-based mCDR lay, or if they could be delineated at all. Rather than this being a purely semantic issue, the group discussed the way different definitions would affect policy development across all scenarios. For example, if a given definition of mCDR focused on the »removal« aspect, then a resulting mCDR policy framework would likely only address the carbon removal process itself, while other frameworks (i.e. CCS regulations) may be used to govern sub-seabed storage. This decoupling of components of the same approach may simplify some regulatory processes (requiring less coordination between regulatory bodies on land and at sea) while making others more complicated (i.e. holistic life cycle assessments of the expected distribution of benefits and burdens). An added layer of complexity was highlighted when

[4] See section on reflections on project aims, design, and group composition

discussing the emerging EU CDR Certification Framework, which currently does not expressly differentiate between marine and terrestrial approaches to carbon removal. In addition, it was highlighted that the more specific the definition of mCDR, the more explicit and »binding« a policy can be – conversely the more vague we are about what we are governing, the weaker the regulatory power of the resulting framework is likely to be. The discussions at the workshop thus made it clear that unclear or fuzzy definitions of the »object« of mCDR policy not only make discussions of concrete frameworks more difficult, they also have the power to change the way diverse actors will position themselves in the policy debate. One key take away was therefore that identifying the potential opportunities and threats to be addressed by mCDR policy across various scenarios first requires a joint (working) definition of mCDR itself.

### 4.2.2 Conceptualising science-informed mCDR policy-making

It became clear during discussions of the various scenarios developed at the workshop that the role of scientific knowledge in policy development was not as straight forward as it may seem. When comparing across the scenarios, the participants felt that »evidenced-based policy-making« was not key to their narratives, but rather that »science-informed policy-making« was a more appropriate way of thinking about it. Scientific knowledge played a key role in the scenarios, but it was only one among many other drivers of decision-making. Comparing across the scenarios, the group identified several key *opportunities* for scientific knowledge to inform policy-making processes across the scenarios:

- At the **beginning** of mCDR policy processes described in these scenarios, science can play a key role informing publics (and policy-makers) as they form their initial positions on the approaches: Thorough scientific assessment of the risks and (co)benefits of mCDR options provides publics the chance to form an informed opinion – this was seen as a key *opportunity* for science to support the policy process, especially given that public perception was deemed a key driver of policy development across all scenarios.

- **During** mCDR policy implementation in the scenarios, scientific input is important for establishing regulatory guidelines for measurement, reporting and verification (MRV). Thus science has a key *opportunity* to inform the parameters of the mCDR regulatory requirements set in place and enforced by policymakers.

- Scientific knowledge is also key to establishing criteria for when to **end** certain mCDR activities. It came clear across all scenarios that there the need to take urgent action in the face of the threat of climate change can conflict with the need for precaution when developing new climate response options. Developing adaptive policy frameworks for mCDR with built-in scientific »stop and review« mechanisms was discussed as one way of balancing these *threats and opportunities* across a range of future scenarios.

### 4.2.3 Finding the appropriate level for policy frameworks

Another key cross-cutting discussion which was relevant for all mCDR futures imagined at this workshop was the most suitable level for mCDR policy frameworks. Across the scenarios, individual country level action was secondary to coordinated multi-lateral or regional action, and the participants discussed that an alliance on mCDR policy needs to be »big enough« to have weight, while at the same time not being »too big« to coordinate and regulate effectively.

A suggestion discussed by participants for navigating the middle-ground between the *threat* of gridlock and the *opportunity* for coordinated action in these scenarios were sea-basin-level policy frameworks for mCDR. Those countries who share a »common sea«, perhaps have joint existing marine infrastructure, and have historically interacted on marine governance issues (i.e. marine spatial planning), may be more readily able to find alliances of a critical mass to develop shared mCDR policy frameworks. Such groups of countries would imaginably share the similar understandings of the *opportunities and threats* presented (to ecosystems and local populations) by specific types of mCDR, meaning shared regulatory frameworks might be easier to establish. However, as was illustrated in the scenarios, having larger, overarching supranational (EU) or international (UNFCCC) frameworks was seen as making (nationally) contentious decisions more plausible – if a higher authority stipulated a state had to take a certain kind of marine-based climate action, it would provide additional legitimacy for that type of action on the national level.

## 4.3 Reflections on project aims, design, and group composition

Although the workshop participants were not expressly asked to reflect on the effects the project aims, design, and group composition may have had on the workshop process and outcomes, these issues were raised by participants and organisers alike at various points throughout the event, and are briefly summarised here.

There is an inherent balancing act involved in organising such a participatory foresight process – balancing between providing a structured approach to enable a consistent, robust scenario development process and the need to allow for creativity within that structure. The workshop organisers attempted to maintain this balance by providing a guided, step-by-step process, but at the same time encouraging participants to step outside the bounds of that process – i.e. by adding new factors that had not appeared in the initial horizon scanning exercise, encouraging the workshop participants to define their own key uncertainties and to expand their number of factor projections beyond the originally suggested four.

Another related limiting factor was, as always, **time** – there is never enough time! Participatory foresight processes are collective learning and communication processes, and as such there is always more to say, more to ask, more to debate. Ideally such processes would stretch over several meetings to allow the participants to get to know and trust each other, to build shared understandings of the topic, and enable ongoing discussions of contentious issues. The organisers endeavoured to create this environment to the extent possible within the limited time frame, but recognise that more time would have been helpful.

Due to the scope of the project this event was part of, the workshop was focused on the German and EU context. However, discussions at the workshop made it clear that taking wider international context into account is key. Discussions of how international climate ambition and actions effect German and EU decision making on mCDR are impossible to bracket. As, similarly, are other (influential) states' actions (China, USA) on CDR, which will likely have effects on German/EU decision making. Although these factors did implicitly play a role at this workshop, taking an explicitly wider international view to mCDR policy developments would complement the German/EU focused scenarios developed here.

Scenarios developed in participatory foresight processes such as this one are only as diverse as the people in the room. The workshop organisers aimed to invite a diverse range of participants. The final workshop group included seven representatives from relevant administrative bodies, two from civil society, and five academics (two natural scientists and three social scientists). Only five of the participants did not identify as male. As – following the joint creation of raw scenario frameworks – the participants were free to choose which breakout group they wanted to join, some of the groups responsible fleshing out the scenarios were not gender balanced, nor did all groups contain representatives with the same types of (academic or sectoral) backgrounds. The specific composition of the groups is assumed to have shaped details of the resulting scenarios, but as section two outlines, the participatory scenario development methodology was designed so that the underlying frameworks themselves where jointly produced by the larger group, and each final scenario was also subject to feedback and revision in plenary – both mechanisms for ensuring diverse perspectives were included. That non-withstanding, it cannot be ruled out that gender, seniority and power dynamics played a role in the development of the scenarios presented here.

# 5. Conclusion

This report has detailed the process and reflected upon some of the insights from **one** participatory foresight workshop. It must be stressed that the scenarios developed were explorative thought experiments designed to provoke structured communication on **plausible** mCDR policy futures, and they were produced within the bounds of one foresight methodology by a specific particular group of participants. The resulting scenarios are context-dependent, and **do not predict probable or desirable mCDR futures**. The insights gleaned from this process should therefore not be taken as generalizable. Rather, they form the basis for further future-facing discussion, and demonstrate the utility of such methodologies for exploring complex mCDR policy futures.

The foresight methodology detailed here could be used in follow-up projects to use develop an even wider range of plausible mCDR futures taking different context conditions into account (i.e. zooming in on one local project context, or zooming out to take a more global perspective), and involving varied constellations of participants (i.e. local stakeholders, industry representatives).

As illustrated by the reflections outlined here, exploratory, qualitative foresight processes be a useful tool to help: (1) integrate various forms of relevant knowledge (e.g., natural and social scientific, academic and practice-oriented) to facilitate transdisciplinary communication and learning about the futures of mCDR; and (2) widen understandings of plausible mCDR developments based on the interactions between a broad range of political, economic, technological, and societal factors, (3) identify policy frameworks or instruments which may be robust across a wide range of plausible mCDR futures.

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Dr Miranda Boettcher is a researcher in the ASMASYS project, funded by the Federal Ministry of Education and Research (BMBF).



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