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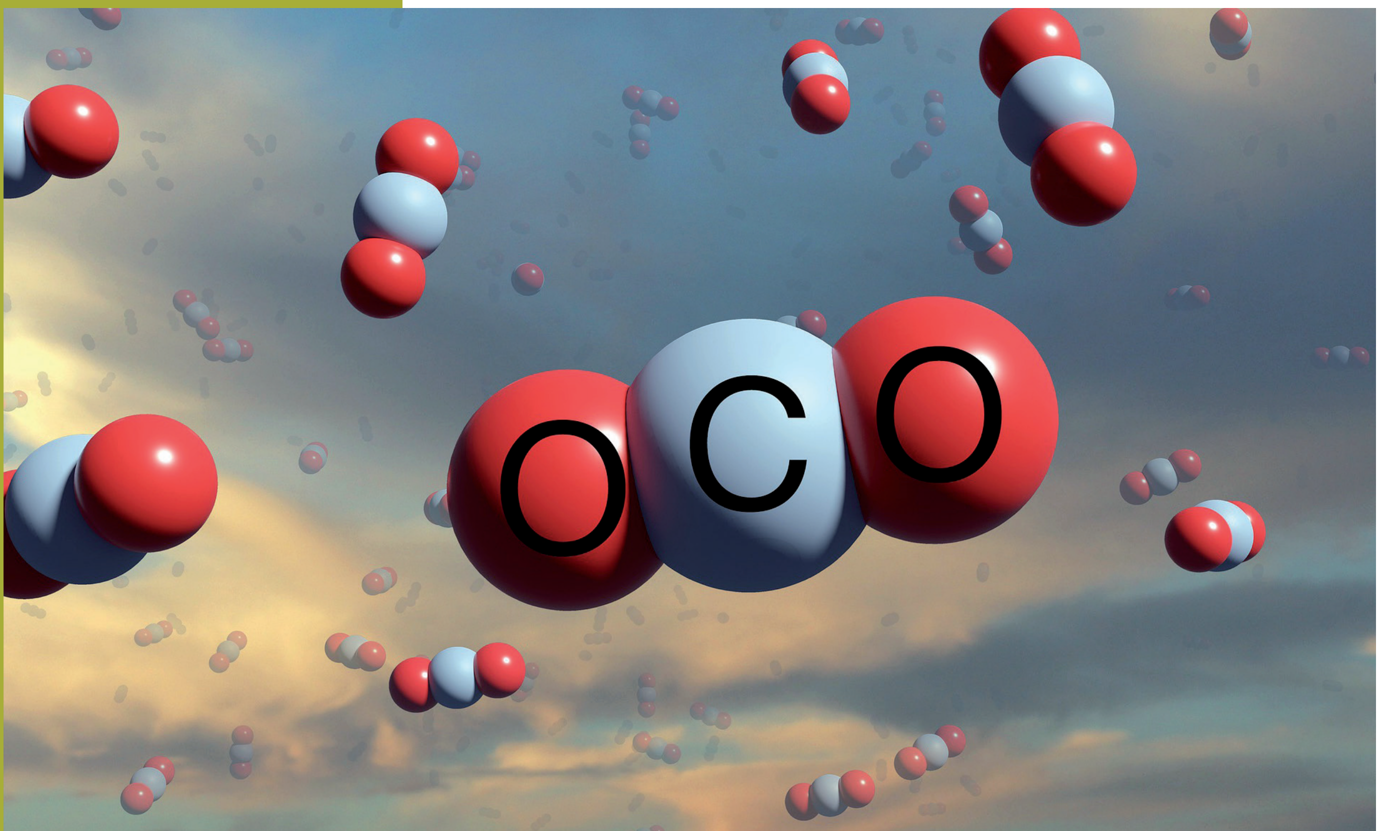
ECOLOGY

E-PAPER

Geoengineering in the European Union

EU-financed projects and their implications for the European Green Deal



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About the author

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Contents

Glossary

BASRECCS	Baltic Sea Region network for CCS
BECCS	Bioenergy with carbon capture and storage
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCUS	Carbon Capture, Utilisation and Storage
CO_2	Carbon dioxide
DAC	Direct Air Capture
DKK	Danish krone
EEA	European Environmental Agency
EEPR	European Energy Programme for Recovery
EGD	European Green Deal
EOR	Enhanced Oil Recovery
ETS	Emission Trading System
EU	European Union
FP	Framework Programs
GE	Geoengineering
GHG	Greenhouse Gas(es)
HRK	Croatian kuna
NDCs	Nationally Determined Contributions
NECPs	National Energy and Climate Plans
NER300	New Entrants' Reserve programme, funded from the sale of 300 million ETS allowances
NRRPs	National Recovery and Resilience Plans
SRM	Solar Radiation Management

Introduction

The notion of geoengineering includes a wide array of technologies that seek to intervene in and alter earth systems on a large scale – a "technofix" to climate change. Most geoengineering tech falls into two categories. The most contentious is solar radiation management (SRM), which aims to reflect more sunlight back into space to cool the planet by creating brighter and more reflective clouds or by injecting sun-dimming aerosols into the stratosphere to mimic a huge volcanic eruption. The other major category of geoengineering – large-scale carbon dioxide removal (CDR) from exhaust fumes or the atmosphere – is more prominent in the debate. It includes ideas like carbon capture from exhaust and underground storage (CCS) as well as carbon use (CCU), but also CDR in marine environments, such as artificial upwelling. CCS and CCU are an integral component of many geoengineering schemes and many climate models currently envision them on large-scale. This paper takes a comprehensive approach and considers all geoengineering approaches that have been studied and are policy relevant in the EU context.

There are many reasons to be wary of these technologies. They do not address the underlying causes of climate change themselves, anthropogenic greenhouse gas emissions, thereby delaying the implementation of a transition away from fossil fuels. As they are very pricy, they redirect funding and investments away from real climate solutions. Some geoengineering proposals require vast amounts of energy, nullifying any potential benefit. There are also geopolitical and social concerns: technologies could have transboundary impacts or be weaponized, e.g., SRM, or use up vast amounts of land, e.g., BECCS. Indigenous peoples have a particular vulnerability, for example due to potential displacements or changes in agricultural opportunities. Lastly, they are largely unproven und their actual impact on the climate system is difficult - for some approaches: impossible – to test without potentially irreversible consequences.

Geoengineering approaches figure prominently in net zero plans and pledges, of both governments and corporations, in particular. This contributes to an environment where urgent choices about decarbonization of industry, transport, and power production are postponed. To be relevant to 'net zero', the geoengineering technologies must be deployed at very large scale. Failure of these technologies would lock in several degrees of warming, with a catastrophic impact.

In the European context, the debate on "net zero" has only started. While – after tough negotiations – the EU institutions agreed on an Climate Law to enshrine the overarching objective of the European Green Deal, climate neutrality by 2050[1], and even net negative emissions thereafter into law, the question how much emission reductions could be achieved via technologies and not natural sinks remains open.[2] Many of the relevant actors in this field (the EU institutions Commission, neighboring states with regulatory links to the EU, companies, NGOs) have not yet developed a substantial and stable position on the issue.

1 It is important to recall that the objective to become climate neutral only in 2050 and to reduce emissions by net. 55 % by 2030 is per se against the principle of common bur differentiated responsibilities and therefore not compatible with the Paris Agreement target of limiting global average temperature rise to 1.5°C.

2 For the 2030 target priority is given to natural sinks, in large parts due to purely physical factors as technological solutions cannot contribute significantly in the short term.

The Climate Law itself uses cautious language and sees responsibility with Member States to decide whether they want to rely on such technologies. CCS and CCU are especially relevant in the debate around so-called "low-carbon gases" because they play a role in important policy files, such as the Hydrogen Strategy and the Taxonomy for Sustainable Finance. In 2022, the European Commission will make a legislative proposal on carbon removal certification.

Against this background, the policy brief on hand provides an overview and critical evidence-based analysis of both the role of the EU in financing geo-engineering projects and the role of geo-engineering in relevant EU policies under the umbrella of the European Green Deal. It ought to feed into the debate of how the EU can reach the long-term objective of carbon neutrality by 2050. It seeks to answer the following questions: Where does the EU stand in the debate on geo-engineering? Are there striking differences among the member states? Which role do the above technologies play in the European Green Deal and the overarching goal to become climate neutral by 2050 and achieve net negative emissions thereafter? In which policy files is the bet on CDR especially relevant? Which projects on GE has the EU funded? And which actors have had an influence in that debate? As such, it aims to inform decision-makers, civil society actors and journalists about players and their positions in the area, financial expenses and opportunity costs of such projects, and the overall relevance of geo-engineering projects in climate policy making.

The report is structured around the following themes: The first three chapters examine the role of geoengineering (GE) in relevant EU policies, focusing primarily on GE technologies mentioned under the umbrella of the European Green Deal in the context of the transition to climate neutrality. The interactive geoengineering map, generated by the Heinrich Böll Foundation and ETC Group, allows a detailed insight into GE activities in the European context. Based on the available information in the map, the fourth chapter analyses the role of the European Union (EU) in financing GE projects. The fifth chapter provides an overview of the EU member states' approach to GE by summarising the role of GE technologies in the national strategic plans as well as the member states' experiences with GE technologies to date. The sixth chapter provides insights into the geoengineering lobby and the extent to which the EU has helped shape the existing lobby structures. The final chapter questions whether geoengineering is a suitable instrument for implementing the goals of the European Green Deal.

Climate policy context

Climate has become a top policy priority for the institutions of the European Union. The European Parliament declared a climate emergency in November 2019 and one month later, the European Commission under President von der Leyen communicated on its flagship project: the European Green Deal. Its main objectives are economic growth decoupled from resource use, a zero-pollution environment, halting biodiversity loss and – above all - no net emissions of greenhouse gases by 2050. The EU's first Climate Law, passed in June 2021, enshrined the goal of a climate-neutrality for the EU as whole by 2050 into law. After 2050, the EU aims for negative emissions – but how the EU will remove more greenhouse gases from the atmosphere than it emits is still unclear. The Climate Law also raised the EU emissions reduction target from 40% to at least 55% by 2030 compared to 1990 levels. The 2030 target is a net target, as natural

CO_2 sinks, such as forests, peatlands or soils, are allowed to contribute to meeting the climate target. However, natural CO_2 sinks are capped at 225 million tonnes of CO_2. In addition to natural sinks, policy makers also consider technical solutions to achieve future targets, for example carbon capture and storage. The European Commission will propose an action plan to promote carbon removals from forests, agricultural practices or engineered mechanisms and develop a regulatory framework for the certification of such carbon removals by late 2022.

1. The European Green Deal mentions CCS and CCU as possible measures to implement the declared climate targets

Among the goals of the European Green Deal is that the EU should be climate neutral by 2050. Proposed for implementation are also measures that do not combat the causes of climate change but seek to reduce the concentration of greenhouse gases in the atmosphere.

In the European Green Deal, published in late 2019, the European Commission points to climate and environmental problems – such as the rise in atmospheric temperature, the loss of species and the pollution of oceans and forests – and sets the goals to become climate neutral by 2050. Besides, the European Green Deal "*aims to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts".* In order to achieve the climate-related goals, various instruments are to be used, including "*carbon pricing*", "*removing subsidies for fossil fuels*", and "*the phasing out of fossil fuels, in particular those that are most polluting*". In section 2.1.2 on "*supplying clean, affordable and secure energy*", as one of a number of measures, the European Green Deal recommends the introduction and promotion of carbon capture, storage and utilization. The EC's staff working document "Impact Assessment – Stepping up Europe's 2030 climate ambition" defines carbon capture and storage (CCS) as "*a set of technologies aimed at capturing, transporting, and storing CO_2 emitted from power plants and industrial facilities*" and elaborates that "*the goal of CCS is to prevent CO_2 from reaching the atmosphere, by storing it in suitable underground geological formations*". *Carbon capture and utilisation (CCU) is defined as a "process of capturing carbon dioxide (CO_2) to be recycled for further usage".* The European Green Deal section 2.1.3 on "mobilising industry for a clean and circular economy" lists CCS and CCU among the "climate and resource frontrunners" that are expected "to develop the first commercial applications of breakthrough technologies in key industrial sectors by 2030", such as carbon-free steel making.

CCS as a mean to achieve climate targets has already been addressed in previous communications of the European Commission. The 2018 communication "A Clean Planet for all" identified CCS as one of four main pathways to a sustainable energy system in 2050 and describes CCS as a mean to reduce emissions. Back in 2013, the communication on the Future of Carbon Capture and Storage in Europe outlined that "*fossil fuels are likely to continue to be used in Europe's power generation as well as in industrial processes for decades to come*" as well as a scenario for the deployment of CCS – "*with 7% to 32% of power generation using CCS by 2050 [...], if commercialized*".

CCS and CCU are both so-called geoengineering technologies that are an integral component of many geoengineering schemes. The scale at which they are currently envisioned in many of the climate models would make them geoengineering as such. The term geoengineering (GE) refers to deliberate, usually large-scale, interventions in the Earth' climate system with the aim of reducing or masking the effects of climate change. Rather than addressing the underlying causes auf climate change, anthropogenic greenhouse gas emissions, the proposed GE technologies primarily attempt to reduce the concentration of greenhouse gases in the atmosphere, or to reflect more sunlight back to space.

2. The European Union has not met its own targets for testing CCS – yet CCS is regarded as a *"climate and resource frontrunner"* under the European Green Deal

The European Council committed to testing the feasibility and economic viability of CCS. Up to twelve large-scale demonstration projects were to be conducted under two different funding programmes. In the end, only seven of these projects were planned, but none was implemented. Nevertheless, the European Union and the European Green Deal continue to back CCS – even though the self-imposed targets for testing CCS have not been achieved.

In 2007, the European Council committed to support up to twelve large-scale demonstration CCS projects by 2015. For implementation, support for CCS was made possible through two financing instruments – the European Energy Programme for Recovery (EEPR) and the European NER300 funding programme.

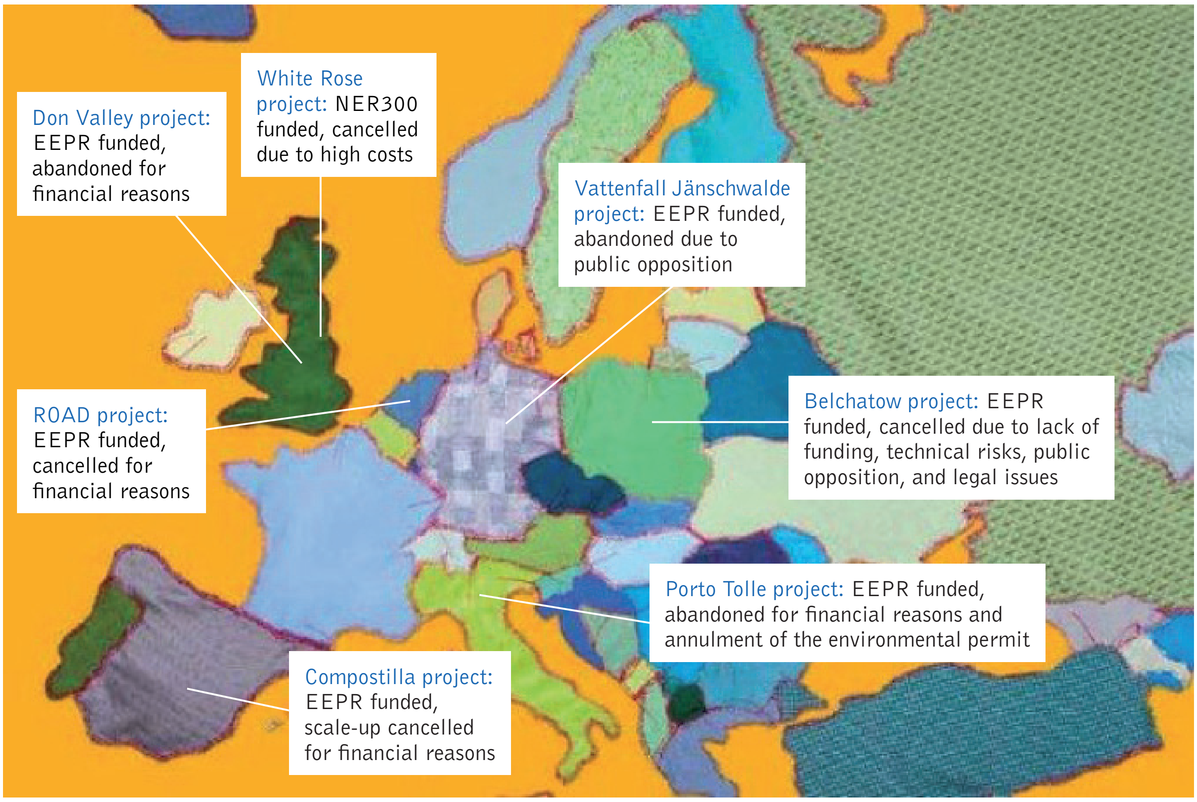
In 2013, six years later, a communication on the Future of Carbon Capture and Storage in Europe from the European Commission stated that

— *"the need for large scale demonstration and deployment of CCS, in view of its commercialisation, has not receded and has only become more urgent";*

— *"investment in CCS demonstration is required to test whether the subsequent deployment and construction of CO_2 infrastructure is feasible. The first step on this path is therefore to ensure a successful commercial-scale demonstration of CCS in Europe that would confirm CCS's technical and economic viability as a cost-effective measure to mitigate GHG in the power and industrial sector."*

A 2018 European Special Report, produced by the European Court of Auditors, explains that the two programs introduced to support the twelve large-scale demonstration CCS projects have not succeeded in deploying the projects. The following map provides an overview of the planned projects and the respective reasons for failure:

Figure 1: The European Council committed to support up to 12 large-scale demonstration projects to test CCS. In the end, seven projects were planned, but none of the projects were implemented.



The EEPR programme was launched in 2009 and aimed to support nine offshore wind projects with €565 million as well as six CCS projects with €1 billion. Regarding the CCS projects, the EEPR had the target of making CCS technology commercially viable by the end of the decade. Although a total of €424 million was spent on the CCS projects, with an additional €150 million in national funding in the case of the ROAD project, this target was missed. In spite of this high cost to the taxpayer, none of the EEPR CCS projects reached commercial status, but all were abandoned.

The NER300 funding programme aimed *"to successfully demonstrate environmentally safe carbon capture and storage (CCS)"* and to demonstrate *"a wide range of CCS technologies"*. During the first call, in 2012, none of the CCS projects were considered for funding, because they *"were not confirmed by the Member States concerned"*. During the second call, in 2014, only one CCS proposal was submitted, but cancelled in 2015. The unspent funds will be reinvested in the NER300 successor programme, the Innovation Fund. The funding instrument aims to invest up to €10 billion to advance *"breakthrough technologies for renewable energy, energy-intensive industries, energy storage, and carbon capture, use and storage".* The Innovation Fund launched its first call for large-scale projects in July 2020, with the second call expected in October 2021. The proportion of large-scale projects related to geoengineering cannot yet be viewed – 66 applications were submitted in June 2021 and grants will be awarded at the end of 2021.

Although the targets to test the feasibility and economic viability of CCS have not been met, the EU continues to rely on CCS, *"because a significant amount of power generation and industry will continue to rely on fossil fuels also in the future".* A Commission report, issued in 2020, summarized: *"although the financial support of EEPR was not sufficient to prompt companies to realise commercial-scale CCS demonstration projects, the Commission still considers CCS important for decarbonisation"*. It remains inexplicable how a technology that has yet to be tested and assessed for feasibility and viability can turn into a *"climate and resource frontrunners"* and a *"breakthrough technology"* in the European Green Deal.

3. The European Hydrogen Strategy relies on blue hydrogen in the short and medium term – and thus on an immature technology with high GHG emissions

The European Hydrogen Strategy intends to introduce blue hydrogen – produced from fossil fuels and combined with CCS – as a large-scale interim solution. If this proposal is implemented, the combustion of fossil fuels will not only be prolonged, but also enlarged. Moreover, with CCS, the EU is relying on a technology that, despite long development cycles and extensive public funding, is still in its infancy, incurs high costs, and cannot guarantee safe storage of captured CO_2.

The European Hydrogen Strategy calls for hydrogen to play a key role in achieving a climate-neutral Europe. Currently, hydrogen makes up only a small share of the EU's energy mix – which is predominantly produced from fossil fuels and generates large amounts of CO_2. The EU aims to expand renewable hydrogen ("green hydrogen"), produced with renewable energies such as wind or solar energy, on a large scale. In the short and medium term, however, forms of so-called *"low-carbon hydrogen"* are also to be used, i.e., hydrogen produced with fossil energy is to be combined with CCS ("blue hydrogen"). The Commission justifies this transitional phase, which allows the continued use of fossil energy sources for hydrogen production, as follows: *"an incentivising, supportive policy framework needs to enable renewable and, in a transitional period, low-carbon hydrogen to contribute to decarbonisation at the lowest possible cost".*

The Hydrogen Strategy will be pursued in three phases. In the first phase, from 2020 – 2024, a regulatory framework for a hydrogen market will be created, including *"bridging the cost gap between conventional solutions and renewable and low-carbon hydrogen and through appropriate State aid rules".* In the second phase, from 2025 – 2030, projects are to be financed, e.g., *"retrofitting of existing fossil-based hydrogen production with carbon capture".* In the third phase, from 2020-2030, approximatively € 11 billion will be invested *"in retrofitting half of the existing [hydrogen] plants with carbon capture and storage".* The Hydrogen Strategy concludes by stating that *"low-carbon hydrogen can contribute to reduce greenhouse gas emissions ahead of 2030".* On what grounds this statement was made, since the intended CCS tests did not take place, is uncertain. The European Environmental Agency (EEA) stated in 2017 that CCS solutions *"are expected to contribute to overall climate efforts but it is unclear whether or not they can be implemented at the scale needed and be viable and truly sustainable in the long term".* In 2020, the EEA adds that *"currently, there are around 80 large scale CCS projects at various stages of development around the world but only a few are operational. There are as yet no large-scale CCS plants in operation which cover all three elements of the CCS chain – the capture, transport and storage of CO_2."* As already observed in the previous chapter, the EU is thus relying on a technology that has not yet been proven. Nevertheless, blue hydrogen is scheduled for short- and medium-term use. There are several reasons to question the undertaking and investments in the billions:

- **On the state of development of CCS technology:** A recent European Commission communication on the potential of offshore renewable energy reports that in 1991, off the coast of Denmark, the world's first offshore wind farm was installed and that "*30 years later, offshore wind energy is a mature, large-scale technology providing energy for millions of people across the globe.*" In 1996, the world's first CO_2 injection project was set up off the coast of Norway, but compared to wind power, CCS is still in its infancy. This raises the question of whether the planned investments in CCS as an interim solution should not rather be used for solutions that already work or that make sense in the long run.

- **On the cost of CCS – technology:** The European Commission communication on the potential of offshore renewable energy in the EU states, that "*today, offshore wind produces clean electricity that compete with, and sometimes is cheaper than existing fossil fuel-based technology.*" In contrast, many CCS projects have not been realised, because they are too expensive, despite heavy public funding.

- **On the GHG footprint of blue hydrogen:** The European Hydrogen Strategy describes blue hydrogen as "*low-carbon hydrogen*". A recently published peer-reviewed study proves that the term "low-carbon" is misleading by examining the lifecycle greenhouse gas emissions of blue hydrogen accounting for both carbon dioxide and unburned fugitive methane. It finds that heating with blue hydrogen leaves a 20% larger GHG footprint compared to heating with fossil fuels such as natural gas or coal. In comparison to diesel oil, blue hydrogen even causes about 60% higher emissions. Equipping fossil fuel combustion plants with CCS increases their fuel consumption by up to 40%. The release of fugitive methane also dismisses blue hydrogen as a means for climate mitigation. For the study's conservative default assumptions for methane emissions, total carbon dioxide equivalent emissions for blue hydrogen are only 9%-12% less than for gray hydrogen. In a sensitivity analysis in which the methane emission rate from natural gas is reduced to a low value under 2 %, greenhouse gas emissions from blue hydrogen are still greater than from simply burning natural gas. The analysis assumes that captured carbon dioxide can be stored indefinitely, an optimistic and unproven assumption. Thus, the study concludes: "*We see no way that blue hydrogen can be considered 'green'.*"

- **On the environmental risks of CCS – technology:** As CCS is very energy-intensive, large-scale deployment of blue hydrogen means that more fossil fuels have to be exploited. In addition, the European Hydrogen Strategy assumes that underground storage of CO_2 is safe. However, this has not been proven and the possibility of leaks due to faulty construction, earthquakes or other underground movements argue against it.

4. EU funding increasingly plays a role in financing geoengineering projects

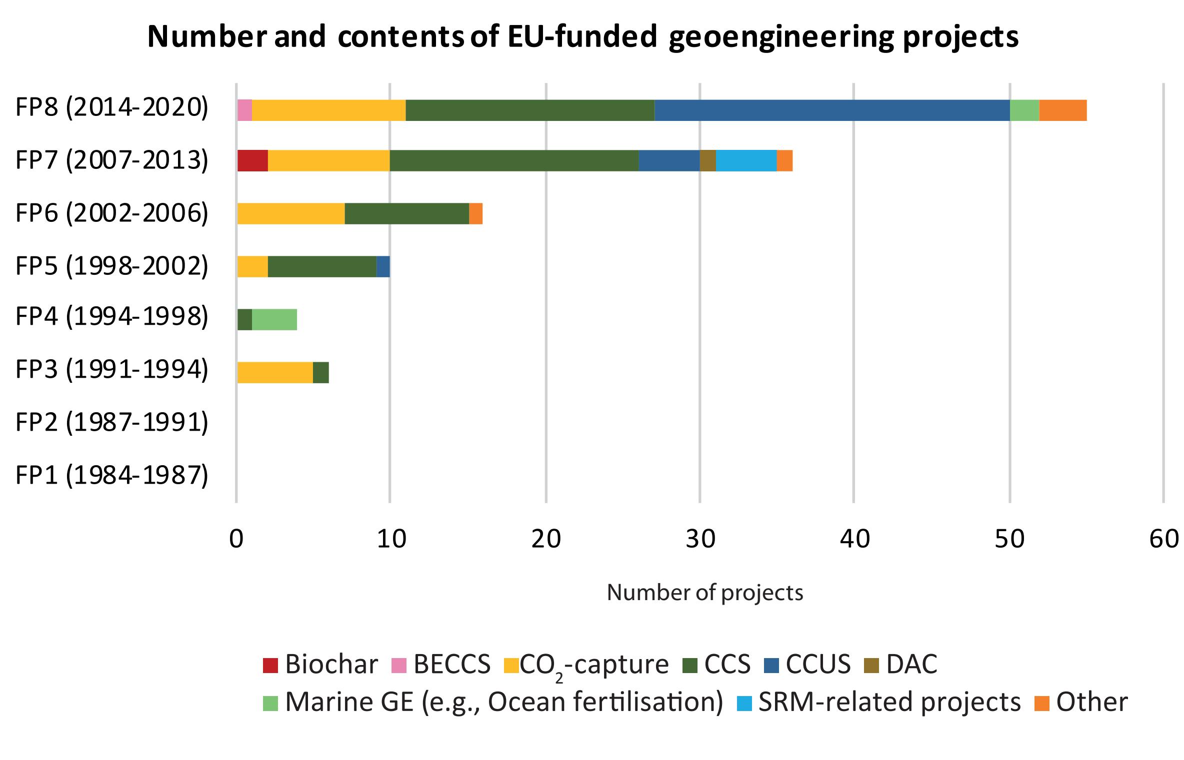
During the first four EU multi-annual Framework Programmes, research projects on geoengineering played little or no role. Especially during FP7 and FP8, the number of EU-funded geoengineering projects and the funding allocated to them increased significantly. With regard to its content, this trend will continue in FP9, even though the proposed geoengineering technologies have no track record, are associated with significant risks, and do not address the root causes of climate change.

Starting in 1984, the European Union has bundled its research, technological development and demonstration programs into multi-annual Framework Programmes (FP). FP1 (1984-1987) and FP2 (1987-1991) have no reference to the subject of geoengineering in terms of content. FP1 includes several studies on the circulation of CO_2 in the atmosphere, in oceans and on a global scale.[3] An examination of anthropogenic influences on the climate begins in the context of individual research projects in FP2.[4] In FP3 (1991-1994) and FP4 (1994-1998) the EU funded the first research projects on the technical and economic feasibility of CO_2 capture from fossil fuel derived flue gas, on CO_2 fixation in marine environments, as well as an initial study on the feasibility of geological CO_2 storage. Figure 2, based on annex 1, shows how the number of geoengineering projects in the Framework Programmes has developed and provides an overview of the programme contents. The data analysed and presented in annex 1 not only confirm that the number of research projects on geoengineering has increased more than fivefold over the past decades, but also that the number of GE experiments has multiplied. Within FP8, with 55 known EU-funded GE projects, more than 40 field trials were conducted, including demonstration sites for CO_2 capture and CCUS, CO_2 injection sites, and marine offshore trial sites.

3 European Commission (2021) CORDIS database – FP1 projects: Interdisciplinary study of the carbon cycle – to study the temporal variations of atmospheric trace gases, Global climate and atmospheric carbon dioxide: role of circulation, Global climate and atmospheric carbon dioxide: role of ocean circulation, Interdisciplinary study on the carbon cycle – simulation of carbon cycle and CO_2-concentration in the atmosphere, Global climate and CO_2: The role of oceanic circulation

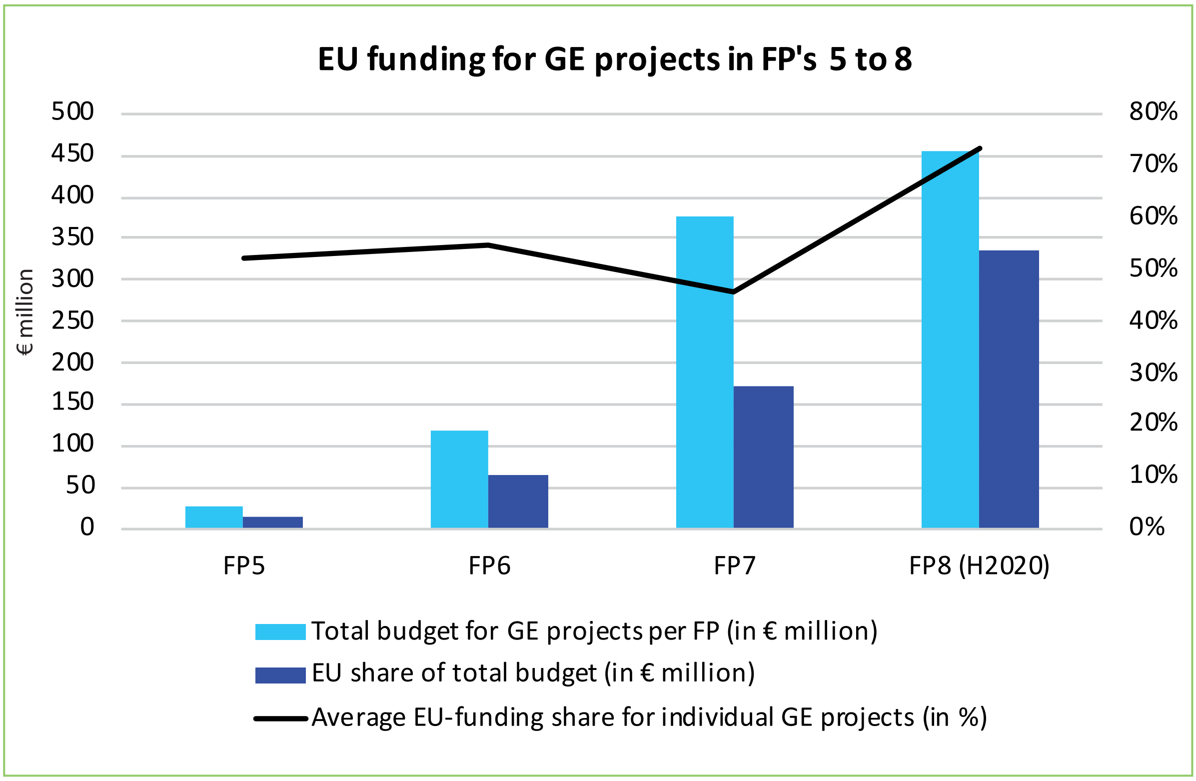
4 European Commission (2021) CORDIS database – FP2 projects: Emissions of greenhouse gases from coal-fired plants, Biochemical carbon cycling in coastal zones, The global carbon cycle and its perturbation by man and climate, The global carbon cycle and its perturbation by man and climate, The greenhouse effect and European economic growth

Figure 2: The number of EU-funded projects on geoengineering has increased significantly in FP7 and FP8. Please see Annex 1 for further details.



Information on the budgets of geoengineering projects and the funding shares allocated by the European Union are available for the Framework Programmes FP5 to FP8. Figure 3 and the data presented in annex 2 show that funding for geoengineering projects in FP8 has increased more than fifteenfold compared to FP5. At the same time, the volume of funding for geoengineering projects, measured against the total budget of each Framework Programme, has increased almost fivefold. The share of EU funding for individual projects has also climbed: In FP5, FP6 and FP7, the EU covered on average 50% of the project costs. In FP8, this share increased to 73.4%.

Figure 3: EU funding for geoengineering projects has increased in several ways: The funding volume in the individual FPs has grown as well as the percentage of EU-funding per project. Please see annex 2 for further details.



FP8, also named Horizon 2020, is now being replaced by FP9, aka Horizon Europe. The European Green Deal stipulated that "*at least 35% of the budget of Horizon Europe will fund new solutions for climate*". Horizon Europe has a total budget of €95.5 billion. In Pillar II, Cluster 5 – Climate, Energy and Mobility, FP9 aims to accelerate the development of various geoengineering approaches. The 2021-2022 Work Programme for Cluster 5 includes CO_2 capture technologies, CCUS in the power sector and energy intensive industries, CCUS possibilities in hubs and clusters, so-called "low-carbon" hydrogen from natural gas with CCUS, DAC approaches, CCS, geological CO_2 storage, and biochar. It can therefore be assumed that the amount of EU funding for GE-relevant research projects will not decrease in FP9, but rather increase. This is also supported by the fact that in February 2020, the European Parliament confirmed five pan-European CCS/CCUS networks as "Projects of Common Interest", even though the geoengineering technologies in question have no track record, pose significant risks and do not address the root causes of climate change. The selected CCS/CCUS networks include the Dutch projects ATHOS and PORTHOS , the Irish Ervia Cork CCS, the Longship CCS in Norway and the British Acorn CCS. Inclusion in the list of Projects of Common Interest means that projects can apply for priority funding, but there is no guarantee of funding.

5. The role of geoengineering in nationally elaborated climate plans gaps widely

The national strategy plans take very different positions on geoengineering technologies: some do not mention them at all, while in one case a GE approach is described as a *"breakthrough technology"*, others assume that geoengineering technologies will become interesting in 10 to 20 years at the earliest. Where geoengineering technologies are mentioned, mostly CCS and/or CCUS, they are to be tested and further developed, the latter mainly to reduce their high costs. An additional concern is the very high energy consumption of CCS and CCUS, adding to the consumption of fossil fuels. As a result, many proposed GE projects are suspected of generating extra emissions.

To outline the role of geoengineering at the national level, climate relevant national strategic plans of the EU member states, Iceland, Norway, Switzerland and the United Kingdom were reviewed – to understand which forms of GE matter and to what extent. The National Energy and Climate Plans (NECPs) and the National Recovery and Resilience Plans (NRRPs) submitted to the European Commission were examined, where available, as well as the Nationally Determined Contributions (NDCs) submitted to the UNFCCC secretariat. In the NECPs, the EU member states provide information on national energy and climate targets for the period 2021 to 2030, based on Regulation (EU) 2017/1999 on the Governance of the Energy Union and Climate Action. In order to be eligible for the European Recovery and Resilience Facility, EU member states must submit a NRRP that allocates at least 37% of spending to climate-related investments. The NDCs are based on the Paris Agreement, article 4, paragraph 2, and outline post-2020 climate action at national level. In addition to the information in the National Strategic Plans, the available date in the Geoengineering Map was used to examine what experiences the individual countries have gained to date with the geoengineering technologies identified in their National Strategic Plans.

The results in annex 3 demonstrate that four countries – Luxembourg, Malta, Portugal and Switzerland – make no reference to researching or using geoengineering technologies in their national strategic plans. In the case of Malta and Luxembourg, no experience with geoengineering technologies has come to light to date. However, Portuguese and Swiss research institutions and companies have participated in pan-European research projects on geoengineering. In Switzerland, public funding has been made available for geoengineering projects on several occasions, and spin-offs of the ETH Zurich develop and commercialise geoengineering technologies, including outside Switzerland.

The national strategic plans of the other countries address up to three geoengineering technologies, including CCS, CCU, CCUS, BECCS and DAC. CCS is mentioned most often, 23 times, CCU/CCUS second most often, 18 times, and DAC and BECCS two to three times each.

The views on the future role of the aforementioned geoengineering technologies differ widely. The Austrian NECP describes CCUS as a *"breakthrough technology for industry"*, although there is little experience on CCUS at national level. The Cypriot NECP did not consider CCU technologies *"due to the lack of available data"*. In the context of CCUS, it is important to mention that CCUS products are not a permanent CO_2 storage. Moreover, CCUS is very energy- and cost-intensive, especially the process of CO_2 capture. As a result, there is a risk that CCUS generates additional climate-related emissions instead of avoiding them.

With CCS, the energy and cost issues are similar, and in addition, the underground storage of CO_2 is associated with high risks. As a result, more than 50% of known CCS proposals in Germany have been cancelled due to public opposition. Nevertheless, the German NECP states with regard on CCS that a *"vast majority of studies and scenarios have now confirmed that from today's perspective, CCS technology is vital for the achievement of greenhouse gas neutrality by 2050"*. The Finnish NRRP describes CCS as an *"important technology"* with *"the potential to grow into a huge market"*, although the only known Finnish CCS project was discontinued due to technological and financial risks. The Dutch NECP considers CCS *"as an inevitable transition technology for reducing CO_2 emissions in sectors where no cost-effective alternative is available in the short term"*. The Polish NECP points out that CCS technology is *"recommended by the European Commission"*, but *"despite a wide-ranging research effort, it will be extremely difficult for CCS technologies to become commercially mature"*. In addition, the Polish NECP states that *"CCS technologies have proved to be very difficult to apply widely"* and, that *"it is not a foregone conclusion when these technologies will be commercially available, given that the last 10 years have not brought any significant progress, especially in terms of cost reduction"*. The Hungarian and Slovenian NECPs assume that CCS will become interesting in 10 to 20 years at the earliest. The results of CCS projects to date confirm this: Major CCS projects worldwide, which were highly praised by the industry in their early days, are struggling with major technical and financial problems – despite very substantial public funding in the millions, e.g., the Australian Gorgon CCS project, the US Petra Nova project and the Canadian Sask-Power project. Apart from the fact that the safety of underground storage of captured CO_2 has not been proven, the captured CO_2 is often used for Enhanced Oil Recovery – thus extracting more oil and producing extra emissions.

The NDCs of Norway and the UK barely mention geoengineering technologies. However, this contrasts with the scale of public funding programmes for geoengineering – both countries have significant public funding available, including for the Longship CCS project in Norway and the HyNet North West project in the UK. In the European context, these two countries have had the most extensive experience with CCS, but many projects have failed, mostly due to high costs. Or fossil fuel companies have been unwilling to undertake CCS projects without substantial public funding, as in the case of the Logannet project.

Some countries have been more specific regarding the expenditure or projects that will be implemented in relation to geoengineering: The Belgian NRRP announced €10 million to demonstrate CCS and CCUS. The Croatian NECP envisages a national feasibility study to assess CCS and CCUS; the costs of the study are estimated at HRK 1 million. The Danish NRRP proposes DKK 200 million *"for a subsidy scheme to support the development and demonstration of CO_2 storage sites in depleted oil and gas fields in the Danish part of the North Sea"*. The Finnish NRRP will set up a €156 million programme to encourage *"the scaling up of hydrogen production using clean energy and its utilisation and of carbon dioxide capture and use/storage"*. The Romanian NRRP includes support for two gas-fired power plants with CO_2 capture. Both projects, Halanga and Constanta, plan to channel the captured CO_2 into greenhouses, which means that the captured CO_2 will be released back into the atmosphere after a short period of time. As CO_2 capture consumes more natural gas, additional emissions are generated – an issue that applies to the entire CCUS/CCS sector.

6. The number of geoengineering actors in the EU is increasing

The number of lobbying organisations working on geoengineering in the EU has doubled within the last few years. Some of the organisations have been initiated and financially supported by the European Commission. It seems that the natural gas industry in particular is strongly committed in order to continue using fossil fuels, but in combination with CCS. Many members of the advocacy organisations have been involved in EU-FP projects on geoengineering – their share of project partners from industry was almost 50%.

In Europe, there are at least 20 larger and smaller organisations actively promoting the use of geoengineering technologies. Of these, half have been founded only recently – within the last five years. The organisations most frequently advocate for CCS, CCUS and so-called "low-carbon gases/low-carbon hydrogen" (please see annex 4).

Four of the initiatives were launched with EU funding, including the CCUS Projects Network and CO_2GeoNet. The CCUS Projects Network aims to support industrial CCUS/CCS projects and "*works closely with the European Commission and the Network's Steering Committee to ensure that members' needs and interests are provided for while supporting the EU's climate action ambitions*". In its early years, the network received €3 million in funding under an EU FP7 project and continues to receive EU support. However, it is led by its members, including Gassnova, Tata Steel, Drax and the Port of Rotterdam. CO_2GeoNet advocates for CCS and aims to be the preferred source of "*information and advice for the European Union, industry, regulators, the general public and other CCS stakeholders*". The network emerged from an eponymous EU FP6-project and was funded with €6 million. Public funding has also been spent in the UK to finance geoengineering initiatives, including the CCUS Advisory Group. This group is to support the implementation of the CCUS-UK Action Plan and includes representatives from Shell, BP, Tata Steel and Drax.

No less than six organisations are campaigning for "low-carbon hydrogen" with CCS. Their members are mainly companies from the natural gas sector that seek to develop a hydrogen economy based on existing infrastructures. One of the organisations is Hydrogen Europe – a lobbying platform with nearly 200 industry members. In addition to its lobbying activities, Hydrogen Europe is simultaneously working with the European Commission as a research body in a joint undertaking on hydrogen. This close link between industry and research can also be observed in the research projects on geoengineering in the European framework programmes. There, the share of project partners from industry is almost 50%. The majority of industrial partners come from the energy sector or from energy-intensive industries. The companies that have participated most frequently in EU-funded FP projects, more than ten times, include ALSTOM Power, RWE Power AG, Shell, Statoil and Vattenfall. Among the research institutions, the most frequent participants, more than 15 times, were SINTEF (Norway), TNO (Netherlands), CSIC (Spain), Centre National de la Recherche Scientifique (France), Bureau de Recherches Géologiques et Minières (France), and the British NERC. The EU-funded research projects on geoengineering were not evenly distributed across the EU. Research institutions and industrial partners from the UK, Germany, France, the Netherlands, Norway and Italy were most frequently involved and coordinated more than two thirds of the projects.

7. Geoengineering is not compatible with the goals of the European Green Deal – and may even make it more difficult to achieve them

The European Green Deal aims to address climate and environmental challenges. Geoengineering is not an appropriate response to these challenges, as the proposed geoengineering technologies pose unmanageable risks for the environment and may even hinder the implementation of the European Green Deal goals. One example is the very high energy consumption of CO_2 capture processes underlying many geoengineering technologies. The high consumption can lead to both increased fossil fuel extraction and a delayed phase-out of fossil fuels.

The following table provides selected examples of why the use of geoengineering is more detrimental than beneficial to the goals under the umbrella of the European Green Deal.

Table 1: Geoengineering technologies and their inconsistencies with the targets under the umbrella of the European Green Deal

Targets to be implemented under the umbrella of the European Green Deal	Inconsistencies with the European Green Deal arising from the use of geoengineering technologies
The European Green Deal demands the *"phasing out of fossil fuels"*.	**Prolonged/increased use of fossil fuels**: The combination with CCS/CCUS, is intended to justify the continued use of fossil fuels. However, the CO_2 capture process is very energy-intensive, which leads to a significantly higher consumption of fossil fuels. The higher consumption delays the phase-out of fossil fuels. The high energy consumption of many of the GE-approaches would lead to increased extraction and combustion of fossil fuels. Yet, according to the EEA, the EU is already importing about 50% of its domestic energy consumption and *"the EU's dependence on fossil fuel imports has increased"*. The extra combustion of fossil fuels due to the deployment of GE technologies would lead to added climate-related emissions along the entire fossil fuel value chain.
The European Green Deal *"aims to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts"*. The Zero Pollution Action Plan calls *"improving air quality to reduce the number of premature deaths caused by air pollution by 55%"*.	**Air pollution:** GE technologies focus on the capture of CO_2. But the combustion of fossil fuels also releases methane and air pollutants. Methane is not only an important greenhouse gas, but can also reacts with other chemicals in the atmosphere to form ozone and to reduce the amount of "detergent" available to clean other types of pollutants. With further use of natural gas in particular, e.g., to produce blue hydrogen, fugitive methane emissions will increase. The air pollutants include nitrogen oxides, sulfur oxides, non-methane volatile organic compounds, and particulate matter. The high energy usage of many GE technologies, such as CCS, can translate into more fossil fuels being combusted and more pollutants being released into the environment. This applies to power plants but also to many other energy-intensive industries. The pollutants may cause different and also multiple damages. One example is black carbon, which is formed during the incomplete combustion of fossil fuels. The EEA describes black carbon as particularly harmful to health and climate *"as it represents a mixture of very fine, partly carcinogenic particles, small enough to enter the bloodstream and reach other organs"*; and *"In the atmosphere the carbon-containing pollutant effectively absorbs solar radiation leading to a warming of the atmosphere. When it settles on snow or ice, the darker colour absorbs more heat, accelerating melting."*. Not only with regard to CO_2, but also with regard to air pollutants, neither prolonged nor increased burning of fossil fuels is compatible with the goals of the European Green Deal. But this is exactly where the use of energy-intensive GE technologies can lead.

Targets to be implemented under the umbrella of the European Green Deal	Inconsistencies with the European Green Deal arising from the use of geoengineering technologies
The New European Strategy on Adaptation to Climate Change finds that *"The EU committed to climate neutrality by 2050 and a more ambitious emissions reduction target of at least 55% by 2030, compared to 1990. A climate emergency has been recognised by the European Parliament, by several Member States, and by over 300 cities. The European Council has concluded that climate change is "an existential threat"."*	**CO_2 storage safety:** No geoengineering technology can guarantee safe and long-term CO_2 storage. The safety of geological CO_2 storage sites is not proven – leakages cannot be excluded, e.g., due to underground movements. Moreover, captured CO_2 is often used for EOR, leading to the extraction of more fossil fuels and even greater emissions. If the injected CO_2 were to escape, humans, animals and nature could be harmed. The leaked, anthropogenically emitted CO_2 degrades only very slowly. After 1,000 years, up to 40% is still in the atmosphere. However, the entire decomposition process takes several hundred thousand years.
	Effective response to the climate emergency: Geoengineering technologies cannot be deployed quickly on a large scale, are associated with unmanageable risks and also with high investment and energy costs. Thus, they are not a suited to respond to the climate emergency declared by the European Parliament.
	Increase in GHG emissions: According to the EEA, the EU imports about 50% of its domestic energy consumption and *"the EU's dependence on fossil fuel imports has increased"*. The large energy consumption of many GE processes, such as CCUS and CCS, would exacerbate this trend and lead to additional climate-relevant emissions along the entire fossil fuel value chain. This cannot be an appropriate response to the declared climate emergency.
EU strategy to reduce methane emissions (Communication from the European Commission).	**Methane emissions (and safety of proposed CO_2 storage sites):** *"In the energy sector, methane leaks from fossil fuel production sites, transmission systems, ships and distribution systems [...] contribute to 50% of the energy sector's emissions"*. Abandoned mines, oil and gas sites can have significant levels of emission, *"however, at present, there are no EU-wide rules on checking, measuring or utilising methane leakage or emissions from coalmines or oil and gas wells after their closure."* If the deployment of energy-intensive GE technologies delays the phase-out of fossil fuels, methane emissions will endure. A recent study points to the large number of methane leaks from fossil extraction sites. The same structures are proposed for underground storage of CO_2 – casting further doubt on the safety of underground storage. Even with very strict regulations for the oil and gas sector, methane emissions will remain a problem: The Climate & Clean Air Coalition's (CCAC) Scientific Advisory Panel estimates that a maximum of 70% of methane emissions from fossil fuels can be abated. This means that blue hydrogen will always face a methane problem, which will not be solved by CCS and CCU.
Chemicals Strategy for Sustainability. Towards a Toxic-Free Environment (Communication from the European Commission).	**Production and disposal of chemicals:** Many technical approaches to CO_2 capture require very large quantities of toxic chemicals. These chemicals not only have to be produced, but also transported and disposed of. Geoengineering would therefore complicate the path to a toxic-free environment.
On a new approach for a sustainable blue economy in the EU. Transforming the EU's Blue Economy for a Sustainable Future (Communication from the European Commission).	**Conservation and security of marine ecosystems:** The EC's Communication on a Sustainable Blue Economy highlights the importance of marine ecosystems. The *"oceans hold 97% of all our water and 80% of all life forms"*, *"food for almost half of humanity, and critical resources for human health, not to mention a web of economic interactions"*. Some geoengineering proposals are to be implemented directly in the marine environment. The effectiveness of these proposals has not been proven, and the associated risks, e.g., for marine food chains, are incalculable. But a delayed phase-out of fossil fuels, due to energy-intensive GE technologies, is also associated with drawbacks for the marine environment, such as oil spills, acidification, changes in water temperature, and biodiversity loss.
European Green Deal: *"All EU policies should contribute to preserving and restoring Europe's natural capital"* new EU Strategy on Adaptation to Climate Change: *"implementing nature-based solutions on a larger scale would increase climate resilience and contribute to multiple Green Deal objectives"*.	**Land usage:** Geoengineering technologies that rely on biomass, such as BECCS and biochar, would consume a great deal of land if introduced on a large scale. This would not only create competition with food production, but also jeopardise the desired conservation and restoration of natural capital.

All of the proposed geoengineering technologies carry unmanageable risks, and many of the proposals are very costly and energy-intensive. One of the biggest risks, however, is that geoengineering technologies create a false sense of security, even though none of the proposed technologies have been proven to work - despite decades of research and extensive funding.

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Annexes

Annex 1 (chapter 4, figure 2): Number and contents of EU-funded geoengineering projects

FP	No. of (known) projects	Biochar	BECCS	CO_2-capture	CCS	CCUS	DAC	Marine GE (e.g., Ocean fertilisation)	SRM-related projects	Other	Number of trial sites
FP1 (1984-1987)	0	0	0	0	0	0	0	0	0	0	0
FP2 (1987-1991)	0	0	0	0	0	0	0	0	0	0	0
FP3 (1991-1994)	6	0	0	5	1	0	0	0	0	0	0
FP4 (1994-1998)	4	0	0	0	1	0	0	3	0	0	3
FP5 (1998-2002)	10	0	0	2	7	1	0	0	0	0	4
FP6 (2002-2006)	16	0	0	7	8	0	0	0	0	1	5
FP7 (2007-2013)	36	2	0	8	16	4	1	0	4	1	13
FP8 (2014-2020)	55	0	1	10	16	23	0	2	0	3	41

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Annex 2 (chapter 4, figure 3): EU funding for GE projects in FP's 5 to 8

Framework Programme (FP)	Number of (known) GE-related projects	Total FP budget in Billion €	GE-Projects: Total Budget in Million €	GE-Projects: EU-share in Million €	GE-Projects: EU-share in %	EU funding: share of the known GE projects in total FP budget
FP1	0		0	0	0	0
FP2	0		0	0	0	0
FP3	6		not available	not available	not available	not available
FP4	4		not available	not available	not available	not available
FP5	10	15.00	28.07	14.65	52.17%	0.10%
FP6	16	17.50	119.12	65.10	54.65%	0.37%
FP7	36	50.50	377.40	172.54	45.72%	0.34%
FP8 (H2020)	55	70.20	456.77	335.21	73.39%	0.48%

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Annex 3 (chapter 5): The role of geoengineering in national strategic plans

Country	Geoengineering technologies addressed in national strategic plans	The role of geoengineering technologies in national strategic plans (NECPs, NRRPs, NDCs, where available)	Experience with the geoengineering technologies identified in the national strategic plans
European Member States			
Austria	CCU	The Austrian NECP (12/2019) proposes CCUS as a *"breakthrough technology for industry"* and suggests *"greater consideration should be given to the key opportunities offered by Carbon Capture and Utilisation (CCU) for European industry"*.	The Austrian company AVL List GmbH participates in the EU-funded EcoFuel project; the project aims to develop fuels based on captured CO_2.
Belgium	CCS, CCUS	The Belgian NECP (12/2019) proposes the large petrochemical clusters in Flanders as *"an ideal region for developing new cooperation and integrating innovative systems allowing tens of millions of tonnes of CO_2 to be offset, collected or sequestered, or transformed into useful products"* and announced studies in this context as well as to examine CO_2 capture at waste incineration facilities, aiming to use the captured CO_2 *"as a raw material in a circular economy"*. The Belgian NRRP (06/2021) announced € 10 M to demonstrate CCS/CCUS as well as investments in the infrastructure for / production of hydrogen in combination with CCS/CCUS.	Belgian companies and research institutions conducted several EU-funded research projects on CCUS and on CO_2 capture. The pan-European project STEELANOL is currently constructing a CCUS pilot plant at ArcelorMittal's steel plant in Gent. At the same site, ArcelorMittal and LanzaTech aim to demonstrate CO_2 capture for the production of ethanol and further CO_2 -based chemicals.
Bulgaria	BECCS	The Bulgarian NECP (undated, accessed: 08/2021) considers biomass plants with CCS for electricity generation.	Bulgarian research institutions participated in pan-European research projects on CCS and CO_2 capture. Experiences in connection with BECCS have not yet been reported.
Croatia	CCS, CCUS	The Croatian NECP (12/2019) proposes a platform for CCS and CCUS, to evaluate *"a) availability of a suitable location for storage, b) transport facilities are technically and economically feasible and c) upgrade of facilities for CO_2 capture is technically and economically feasible"*. A National Feasibility Study will look at *"emission sources, transport, injection and storage of CO_2, and the interconnection of the CO_2 transport system with other EU countries"* and *"plans to inform the public about carbon dioxide capture and storage technology"*. The costs of the study are estimated at HRK 1 million.	Croatian research institutions participated in pan-European research projects on CCUS and CO_2 storage. There are plans to establish a CCS project at the geothermal plant AAAT Geothermae in Draškovec.
Cyprus	CCS, CCU	The Cypriot NECP (01/2020) proposes to *"assess the exploitation of CCS and CCU technologies"* and adds: *"However, it has been noted that emerging technologies like hydrogen and carbon capture and storage have not been considered in the above scenario due to the lack of available data"*.	The Electricity Authority of Cyprus participated in a pan-European research project on CO_2 capture technologies.
Czechia	CCS, CCU	The Czech NECP (11/2019) proposes to consider *"a combination of natural gas with CCS or CCU"*.	Czech companies and research institutions participated in several pan-European research projects related to CO_2 capture and CCS. The depleted oilfield LBr-1, in Moravia, is serving as a test site for CO_2 injections, e.g., for the pan-European ENOS project. Plans for a CCS project in Vresova have been cancelled.

Country	Geoengineering technologies addressed in national strategic plans	The role of geoengineering technologies in national strategic plans (NECPs, NRRPs, NDCs, where available)	Experience with the geoengineering technologies identified in the national strategic plans
European Member States			
Denmark	BECCS, CCS, CCUS	The Danish NECP (12/2019) states that *"CCS needs to be demonstrated at scale"* and that *"Bioenergy should be used in high-value sectors (transport), and sustainability remains a challenge"*. The Danish NRRP proposes DKK 200 million *"for a subsidy scheme to support the development and demonstration of CO_2 storage sites in depleted oil and gas fields in the Danish part of the North Sea"*. The NRRP adds that *"CCS is foreseen to contribute significantly to the achievement of Danish greenhouse gas reduction targets"* and that *"storage sites for CO_2 in depleted Danish oil and gas fields could play an important role in storage of CO_2 from other EU member states"*. *"CCUS is expected to be a growing industry."*	Danish research institutions coordinated various pan-European research projects on CCS. A new CCS project, a proposal with onshore CO_2 capture and offshore injections, has concluded a first feasibility study. Former plans for an onshore CCS project have been cancelled. The Danish Union Engineering markets CCUS technology for recovering CO_2 from fermentation processes in breweries. Experiences in connection with BECCS have not yet been reported.
Estonia	CCS, CCUS	The Estonian NECP (12/2019) states that *"according to current knowledge, Estonia does not have suitable geological conditions for storing CO_2"*. Currently, a study is conducted *"to assess the suitability of different carbon capture technologies and develop scenarios for implementing these technologies in the Estonian oil shale industry"*. The NECP proposes to look into *"cooperation opportunities of the Nordic countries and Baltic States […] for the development of future technologies (energy storage, CCUS, hydrogen, etc.)"*.	Estonian companies and research institutions participated in various pan-European research projects on CCS and CCUS. Estonia is a member of the BASREC-CS Network.
Finland	CCS, CCU	The Finnish NRRP (2021) describes CCU and CCS as *"important technologies"* with *"the potential to grow into a huge market"*. A € 156 million programme will be set up to encourage *"the scaling up of hydrogen production using clean energy and its utilisation and* of carbon dioxide capture and use/storage". There was no reference to the use of geoengineering technologies in the European NDC or the Finnish NECP (12/2019).	Finish research institutions and companies participated in various pan-European research projects on CO_2 capture, CCUS and CCS. The Finish government financed research on biochar, DAC and CCUS and Finish companies developed CCUS and DAC technology. Plans for a CCS project have been cancelled.
France	BECCS, CCS, CCUS	The French NECP (03/2020) states that *"carbon capture and storage will only compensate for residual non-energy emissions and the residual emissions from fossil fuels that are still used for certain means of transport (aviation)"* and that *"in 2050, these technologies would make it possible to avoid around 6 $MtCO_2$/year in industry and to achieve a dozen or so $MtCO_2$ each year in negative emissions for biomass energy generation installations (BECCS)"*. The French NRRP (2021) proposes to decarbonize industry by *"deploying decarbonised processes and carbon capture and storage or recovery"*. In addition, the French NECP identified the following research and innovation requirements, among others: *"carbon capture, storage and reuse solutions"*.	French research institutions and companies coordinated more than 15 pan-European and EU-funded research projects on CO_2 capture, CCUS and CCS, and conducted field tests to trial CO_2 capture and CO_2 injections. French public funds financed additional projects, mainly on CCS, but also on BECCS and CCUS. A number of CCS projects have been implemented with the participation of companies in the energy sector. A CCUS pilot trial is conducted by Vicat.

Country	Geoengineering technologies addressed in national strategic plans	The role of geoengineering technologies in national strategic plans (NECPs, NRRPs, NDCs, where available)	Experience with the geoengineering technologies identified in the national strategic plans
European Member States			
Germany	CCS, CCU, DAC	The German NECP (2019) proposes to further develop *"CCU/CCS options"*. It states that a *"vast majority of studies and scenarios have now confirmed that from today's perspective, CCS technology is vital for the achievement of greenhouse gas neutrality by 2050"*and that *"technologies which separate carbon out of industrial exhaust gases and in particular the atmosphere are needed for this"* The NECP adds that *"research into carbon separation, transport, storage, long-term sequestration and use technologies will be stepped up so that domestic companies and research institutions can assume a pioneering role in this area"*.	Germany research institutions and companies coordinated more than 15 pan-European and EU-funded research projects on CO_2 capture, CCUS and CCS. The German public sector financed further projects, mainly on CCUS, CCS and DAC, often at industrial sites, in some cases also outside Germany, e.g., in Chile. Most pilot tests and demonstration projects were conducted by industry, e.g., in aviation, cement and further energy-intensive sectors. More than 50% of known CCS projects in Germany have been cancelled due to public opposition.
Greece	CCS, CCUS	The Greek NECP (12/2019) proposes research to develop *"CO_2 capture, storage and use technologies" and "ensuring the capture, storage and utilisation of carbon dioxide from power generation plants using conventional fuels and industrial uses"*. The Greek NRRP (04/2021) *"contains a measure to develop Greece's first carbon capture, utilisation and storage investment by developing transportation and storage on CO_2 into geological features."*	Greece research institutions coordinated five pan-European projects on CO_2 capture technologies and participated in various other pan-European research projects on CCS and CCUS. A hydrogen plant with CCS in Northern Greece has been proposed.
Hungary	CCS	The Hungarian NECP (2019) states, that *"power stations with CCS will be available only after 2030"* and that *"until CO_2 capture and storage become economical it will probably not be profitable to build conventional coal-fired power plants in Europe"*.	Hungarian research institutions participated in several pan-European research projects on CCS, CCUS and DAC.
Ireland	CCS	The Irish NECP (2019) proposes to *"examine the feasibility of the utilisation of CCS in Ireland and to develop policy in the area"* and *"states that Carbon Capture and Storage (CCS) is recognised as a potential bridging technology that could support the transition to a low carbon economy"*. The NECP adds that *"Ireland adopted a 5-year CCS review process, which will inform any decision to commit resources to put regulatory and permitting systems in place" and "is currently assessing a project at feasibility stage promoted by Ervia"*. The NECP proposes funding for various research areas, among them *"carbon capture & storage (CCS)"*.	The Irish Department of Environment, Climate and Communications participated in a pan-European research project on CCS. A CCS project has been proposed by fossil-fuelled power companies.

Country	Geoengineering technologies addressed in national strategic plans	**The role of geoengineering technologies in national strategic plans** (NECPs, NRRPs, NDCs, where available)	Experience with the geoengineering technologies identified in the national strategic plans
European Member States			
Italy	CCS, CCU	The Italian NECP (12/2019) proposes to "*promote the geological capture of CO_2 […] both in the electricity and industrial sectors*" and to employ CO_2 "*in power-to-liquid […] with CO_2 captured from the air or derived from waste*".	Italian research institutions coordinated more than five pan-European projects on CCUS and CO_2 capture technologies and participated in further pan-European research projects on CCS and CCUS. Several pilot projects are located in Italy, including a CCS test site for the pan-European ENOS project.
Latvia	CCS, CCU	The Latvian NECP (11/2020) proposes "*innovative solutions for capturing and reuse of carbon*" and states that "*in addition, future technologies (energy storage, CCU, hydrogen, etc.) will be sought in cooperation with the Nordic countries and the Baltic States*".	Latvian research institutions participated in pan-European research projects on CCS and CCUS.
Lithuania	CCS, CCU	The Lithuanian NECP (2019) states that it is "*necessary to further develop carbon capture, use and storage technologies and to analyse their applications in Lithuania*". The proposed analysis will cover an "*assessment of CO_2 capture, use and storage chain alternatives*" as well as "*a feasibility study on the application of CO_2 capture, use and storage technologies in Lithuania*". The NECP also proposes "*a detailed analysis of the feasibility and usefulness of projects implemented with other countries of the EU common economic area (to the geological structures of which the CO_2 captured in Lithuania could be exported)*".	Lithuanian research organisations participated in pan-European research projects on CCS and CCUS.
Luxembourg	-	There is no reference to the use of geoengineering technologies in the European NDC, the Luxembourgian NECP (12/2018) and the Luxembourgian NRRP (06/2021).	Information on geoengineering-related research activities in Luxembourg has not yet been reported.
Malta	-	There is no reference to the use of geoengineering technologies in the European NDC, Malta's NECP (12/2019) and Malta's NRRP (2021).	Information on geoengineering-related research activities in Malta has not yet been reported.
The Netherlands	CCS, CCU	The Dutch NECP (11/2019) states that CCS is regarded "*as an inevitable transition technology for reducing CO_2 emissions in sectors where no cost-effective alternative is available in the short term*". The NECP proposes national "*grants for CO_2-reducing measures*", to combine CCS with hydrogen production, and to work "*with other Member States to achieve […] the joint development of CCU/CCS*".	Dutch research institutions and companies coordinated about 15 pan-European projects on CCS, CO_2 capture technologies and CCUS, and participated in many other pan-European research projects. Over the past decade, five Dutch CCS projects have been cancelled, including two in the Rotterdam Port area. Meanwhile, there are new proposals for CCS projects, including the Porthos project at Rotterdam Port. Dutch companies and research institutions conducted various trials, e.g., a CO_2 capture testing campaign at a Tata Steel plant.

Country	Geoengineering technologies addressed in national strategic plans	The role of geoengineering technologies in national strategic plans (NECPs, NRRPs, NDCs, where available)	Experience with the geoengineering technologies identified in the national strategic plans
European Member States			
Poland	CCS, CCU	The Polish NECP (2019) points out that CCS technology is "*recommended by the European Commission*", but adds that "*however, CCS technologies have proved to be very difficult to apply widely*" and that "*a greater potential is seen in the development of carbon processing technologies*". The NECP also states that "*it is not a foregone conclusion when these technologies will be commercially available, given that the last 10 years have not brought any significant progress, especially in terms of cost reduction*" and "*as no industrial installation of this type has yet been put into operation*". The NECP adds that "*despite a wide-ranging research effort, it will be extremely difficult for CCS technologies to become commercially mature*".	Polish research institutions and companies participated in about 20 pan-European research projects on CCS, CO_2 capture technologies, CCUS and biochar. Polish coal seams and a marine site have been used as pilot sites for CO_2 injections in pan-European research projects, e.g., the Barbara coal mine.
Portugal	-	There is no reference to the use of geoengineering technologies in the European NDC, the Portuguese NECP (12/2019) and the Portuguese NRRP (04/2021).	Portuguese research organisations and companies participated in pan-European research projects on CO_2 capture, CCS and CCUS and led the pan-European research project COMET on CO_2 transport and storage in the west Mediterranean.
Romania	CCUS	The Romanian NRRP (05/2021) includes support for two gas-fired power plants with CO_2 capture in Halanga and Constanta. The captured CO_2 is to be fed into greenhouses. There is no reference to the use of geoengineering technologies in the European NDC and the Romanian NECP (04/2020).	Romanian research organisations participated in pan-European research projects on CO_2 capture, CCS and CCUS. Plans for a CCS project have been cancelled.
Slovakia	CCS	The Slovakian NECP (12/2019) proposes "*projects to convert other suitable geological structures into underground gas storage facilities, respectively to use them in another way for energy-related purposes (CCS)*".	Slovakian research organisations participated in pan-European research projects on CCS and CCUS.
Slovenia	CCS	The Slovenian NECP (02/2020) states that "*there are possibilities for CCS at existing power sites and also in energy-intensive industry*" in Slovenia and assumes that CCS technologies will only become commercially interesting, "*but this is not expected before 2040*", if emission allowance prices rise significantly and electricity demand is not replaced by renewable, nuclear, or gas-fired power plants. The NECP stresses that "*under the current legislation […], the injection and storage of carbon dioxide is prohibited in Slovenia*".	Slovenian research organisations and companies participated in pan-European research projects on CCS, biochar and CCUS. A Slovenian coal mine was used as a test site for CO_2 injections.

Country	Geoengineering technologies addressed in national strategic plans	The role of geoengineering technologies in national strategic plans (NECPs, NRRPs, NDCs, where available)	Experience with the geoengineering technologies identified in the national strategic plans
European Member States			
Spain	CCS	The Spanish NECP (01/2020) proposes "*the integration of CO_2 capture technologies to reduce emissions*". It suggests "*promoting the construction of CO_2 capture and geological storage projects*", through the NER 300 programme.	Spanish research institutions and companies coordinated more than five pan-European projects on CCS, CCUS and CO_2 capture technologies and participated in further pan-European research projects. Spanish industrial and research sites served as tests sites for CCS and CCUS trials, e.g., the Compostilla power station and the IMDEA Energy Institute.
Sweden	CCS	The Swedish NECP (01/2020) states that "*capture and storage of carbon dioxide of fossil origin must be included in the measures*" to enable Sweden to achieve its emission targets and adds that "*CCS must be demonstrated on a large scale*". A "*three-year demonstration project for carbon capture and storage (CCS) at the Preem refinery in Lysekil*" will investigate "*the possibility of setting up a full-scale CCS plant*".	Swedish research institutions and companies coordinated pan-European projects on CCS, CCUS and CO_2 capture technologies and participated in further pan-European research projects.
Iceland, Norway, Switzerland and the UK			
Iceland	CCS, DAC	The Icelandic NDC (02/2021) proposes to increase "*carbon removals from the atmosphere*", including by "*carbon capture and mineralization in rock formations (Carbfix)*".	Reykjavik Energy led the pan-European research projects CarbFix and GECO and conducted CO_2-injection trials, e.g., at the Húsmúli site. The projects combine DAC and CCS and there are plans to trial the approach on a larger-scale.
Norway	CCS	The Norwegian NDC (02/2020) states that "*economic measures like CO_2- taxes and emission trading are central to Norwegian climate policy*". The NDC proposes to support the "*development and adoption of low emissions technologies, including carbon capture and storage technologies*".	Norwegian research institutions and industry coordinated more than 15 pan-European research projects on CCS, CCUS and CO_2 capture technologies and have carried out several CCS projects, including Sleipner and Snøhvit. A new CCS project is in preparation.
Switzerland	-	There is no reference to the use of geoengineering technologies in the Swiss NDC.	The ETH Zürich participated in pan-European research projects on geoengineering, e.g., on BECCS and CO_2 storage, and spin-offs of the ETH developed DAC and CCUS technology.
The UK	CCU (?)	The British NDC (12/2020) states that "*the Welsh Government is investing in people to develop the skills needed for a low-carbon, circular economy*" and adds that Northern Ireland plans a "*transition to a low-carbon circular economy*". Beyond this, there is no evidence that geoengineering technologies could play a role in the UK. However, this contrasts with the scale of public funding programmes for geoengineering.	UK research institutions and industry have coordinated more than 20 pan-European and EU-funded research projects on CCUS, CCS and CO_2 capture technologies, and have participated in many further pan-European research projects on geoengineering. Nationally, there are numerous further programmes and centres in the UK to research, promote and establish geoengineering, including the UK Carbon Capture and Storage Research Centre, the UK CCS Infrastructure Fund, and the Centre of Climate Repair. One of the most extensive publicly funded programmes is the UK Greenhouse Gas Removal Programme. Although more than 10 CCS projects have already failed in the UK, major CCS projects are in the pipeline, supported by public funds, including the Acorn CCS project and HyNet North West project.

Annex 4 (chapter 6): European lobby groups working on the issue of geoengineering

Lobby group	Founded in	Head office	Advocates for the following GE technologies	Goals	Members/ funding	Further information
BASRECCS	2014/15	various: http://basrec.net/basrec-members/	CCS in the Baltic Sea countries	Initiated by BASREC (Baltic Sea Region Energy Cooperation). The networks' goal is to support the exploration and gradual implementation of CCS in the Baltic Sea countries and to strengthen regional cooperation.	Funding: Global CCS Institute, CCSP-Carbon Capture and Storage Program, Nordic Council of Ministers, Baltic Sea Region Energy Cooperation (BASREC)	https://www.bcforum.net/, https://map.geoengineeringmonitor.org/ggr/basreccs-baltic-sea-region-network-for-ccs
Carbon Drawdown Initiative Carbdown GmbH	2020	Registered in Fürth, Germany	BECCS, CCUS (synfuels) DAC, Enhanced weathering	The corporation aims to ensure that projects in the following geoengineering fields are (further) developed: DAC, Enhanced weathering with olivine or serpentine, BECCS, and CO_2-based synfuels. To achieve these goals, the company grants financial support to geoengineering companies. In addition, the corporation is involved in public and political work, e.g., as a founding member of the Negative Emissions Platform.	Founded by Dirk Paessler and directed in cooperation with Ralf Steffens. Information on the funding is not available.	https://www.carbon-drawdown.de/home-en, https://map.geoengineeringmonitor.org/other/carbon-drawdown-initiative-carbdown-gmbh
Carbon Removal Advocacy Europe	2020/21	Based in UK	BECCS, DAC	The group aims to "*advocate for policy change to provide critical research and deployment incentives to scale up carbon removal; coordinate among funders, ENGOs, industry, and government to build a thriving European CDR ecosystem; engage with the public and community leaders to explore the benefits and potential risks of CDR and enable well-informed decision making*". The organisation "*already raised over £ 2,700,000 in funding commitments and built a network of partners and allies across Europe.*"	Funding & expert partners: Carbon180, Quadrature Climate Foundation, Climate Pathfinders Foundation, Grantham Environmental Trust, Oxford NetZero, Oxford University.	https://cdradvocacy.org/?utm_medium=email&_hsmi=121470622&_hsenc=p2ANqtz-_QiF0F_PrIz9VxpQtcRXGVd-wSAXpu8_zweSxYslIspPYG-R982IxGbr0PyRY28gpN60U3tIWCD9BSK2xsL4Xcfnv Zhg&utm_content=121471195&utm_source=hs_email

Lobby group	Founded in	Head office	Advocates for the following GE technologies	Goals	Members/ funding	Further information
CCUS Projects Network	Formed as "European CCS Demonstration Project Network" in 2009; renamed in 2018.	Not available	CCS, CCUS	The network aims to support industrial projects related to CCS and CCUS, e.g., by sharing information and learning from each other. The networks secretariat "*works closely with the European Commission and the Network's Steering Committee to ensure that members' needs and interests are provided for while supporting the EU's climate action ambitions*".	The European Union has provided financial support to the network through an FP7 project and appears to continue its financial support. In the early years, the network was managed by the Australian-based Global CCS Institute. Today the network is managed by its members, which include SINTEF, TNO, Gassnova, Tata Steel, Drax, Port of Rotterdam, CarbFix, Leilac,… (https://www.ccusnetwork.eu/network-members)	https://www.ccusnetwork.eu/about-network, FP7-project: https://cordis.europa.eu/project/id/296013, https://map.geoengineeringmonitor.org/other/ccus-projects-network
CCUS – UK Action Plan & CCUS Advisory Group	Since 2018, advisory group since 2019.	UK ministry for Energy and Clean Growth	CCUS	The UK Ministry for Energy and Clean Growth launched the "*UK Action Plan*" for CCUS. In 2019, the Ministry announced the formation of a CCUS Advisory Group, to help deliver the CCUS action plan. The Group consists of experts in industry, finance, and policy and includes representatives from Shell, BP, Tata Steel, Drax, and National Grid.	The CCUS Advisory Group received £ 1 M of funding from the UK Government and industry.	https://www.gov.uk/government/publications/the-uk-carbon-capture-usage-and-storage-ccus-deployment-pathway-an-action-plan, https://map.geoengineeringmonitor.org/other/ccus-uk-action-plan
Centre for Climate Repair at Cambridge (CCRC)	Launched in 2019	Cambridge University, UK	DAC, Ocean fertilization, Marine cloud brightening, Enhanced freezing	The CCRC states the following goals: to reduce greenhouse gas emissions, remove greenhouse gases from the atmosphere and restore broken climate systems. In order to reach these goals, the centre looks into geoengineering technologies such as DAC, Ocean fertilization, Marine cloud brightening or Enhanced freezing. In June 2021, the CCRC founded the Climate Crisis Advisory Group (CCAG). The CCAG aims to advice the public, governments and financial institutions.	Launched by Cambridge University. £ 2.1 million gift from Jamie Arnell in May 2021.	https://www.climaterepair.eng.cam.ac.uk/, https://map.geoengineeringmonitor.org/other/centre-for-climate-repair-at-cambridge-(ccrc)

Lobby group	Founded in	Head office	Advocates for the following GE technologies	Goals	Members/ funding	Further information
Coalition for Negative Emissions	2020	Based in the UK	BECCS, Biochar, DACCS, Enhanced weathering	*"The Coalition for Negative Emissions has the expertise, experience and skill to deliver negative emissions on a global scale. We are calling on those that can support us to do so."*	Drax, Velocys, Carbon Engineering, Carbon Removal Centre, CBI, Carbon Capture and Storage Association, Climeworks, Energy U.K., Heathrow, International Airlines Group, U.K. National Farmers Union,…(https://coalitionfornegativeemissions.org/who-we-are/)	https://coalitionfor-negativeemissions.org/who-we-are/, http://biomass-magazine.com/articles/17440/drax-velo-cys-help-launch-co-alition-for-nega-tive-emissions
CO_2GeoNet	EU-funded project: 2004. Associ-ation: 2008.	Project: Natural Envi-ronment Research Council, UK. Today, the asso-ciation is based in Orléans Cedex, France.	CCS, geolog-ical storage of CO_2	*"CO_2GeoNet is the European scientific body on CO_2 geological storage."* Among the ambitions: *"Be the preferred source of impartial scientific and technical information and advice for the European Union, industry, regulators, the general public and other CCS stakeholders".*	The association started as a pan-European FP6 research initiative, funded with € 6 million (total budget: € 9.18 million). The association currently comprises 27 research institutes from 21 European countries, among them ETH Zürich, SINTEF, TNO, Helmholtz Centre Potsdam, Imperial College London, IFPEN,… (http://www.co2geonet.com/about-us/)	http://www.co-2geonet.com/about-us/, https://map.geo-engineeringmonitor.org/other/co2geon-et-network
ECCSEL-RICO network	2015	Estab-lished by the EU, registered in Norway, at the Norwegian University of Science and Tech-nology (NTNU), Trond-heim, Norway.	CCS, CCUS	ECCSEL *"is the European Research Infrastructure for CO_2 Capture, Utilisation, Transport and Storage (CCUS). Our vision is to enable low to zero CO_2 emissions from industry and power generation to combat climate change. Our aim is to enhance European science, technology development, innovation and education in the field of CCUS."* (ECCEL = European Carbon Dioxide Capture and Storage Laboratory Infrastructure, ERIC = European Research Infrastructure Consortium)	Established with EU funding (€ 3.25 million, FP8-H2020). Five member countries: France, Norway, Italy, the Netherlands, UK. Among the members: TNO, IFPEN, CNRS, EDF, TOTAL, SINTEF. Members: https://www.eccsel.org/about-eccsel/eccsel-highlights/	https://www.eccsel.org/, https://map.geoengineering-monitor.org/other/eccsel-rico-network

Lobby group	Founded in	Head office	Advocates for the following GE technologies	Goals	Members/ funding	Further information
Eurogas	~30 years old	Brussels, Belgium	CCS, low-carbon gas	"*Eurogas engages actively with its stake-holders to discuss and develop EU policy and legislation related to energy. To this end the member compa-nies and associations join forces in expert committees and task forces to bring strong arguments and con-structive proposals to the table.*" The organ-isation is lobbying for "*decarbonised gas and CCS technologies*".	Among the members: EON, ENI, Equinor, Shell, Uniper,… (https://eurogas.org/about-eurogas/our-members/)	https://eurogas.org/
European Biochar Industry Consortium (EBI)	2019	Freiburg im Breisgau, Germany	Biochar	The organisation aims to promote the use of biochar in Europe, to employ biochar to fight climate change, and "*support/ initiate adaptation of legal regulations regarding production and usage of biochar*".	Member organisations, please see: https://www.biochar-industry.com/about/	https://www.biochar-industry.com/about/, https://map.geoengineeringmonitor.org/ggr/european-biochar-industry-consortium-(ebi)
European Clean Hydrogen Alliance (ECH2A)	March 2020	Not available	Low-carbon hydrogen, based on CCS and pyrolysis (biochar)	"*The European Clean Hydrogen Alliance aims at an ambitious deployment of hydro-gen technologies by 2030, bringing to-gether renewable and low-carbon hydrogen production, demand in industry, mobility and other sectors, and hydrogen transmission and distribution. With the alliance, the EU wants to build its glob-al leadership in this domain, to support the EU's commitment to reach carbon neutrality by 2050.*"	Initiated by the European Union, the European Clean Hydrogen Alliance brings together industry, national and local public authorities, civil society and other stake-holders. Please see: https://ec.europa.eu/docsroom/documents/46392, among the members are: ArcelorMittal, Alstom, BP Europa, RWE, Schlumberger, Shell, Siemens, SINTEF, Uniper, Vattenfall.	https://www.ech2a.eu/, https://ec.europa.eu/growth/industry/policy/european-clean-hydrogen-alliance_en, https://ec.europa.eu/docsroom/documents/46392
European Zero Emissions Technology & Innovation Platform	Not available	Brussels, Belgium	CCS, CCUS	"*ZEP is the technical adviser to the EU Commission on the deployment of CCS and CCU*"	Among the members: BP, ENI, Equinor, ExxonMobil, Port of Rotterdam, Shell, SINTEF, Northern Lights, TNO, Total, Bellona Foundation (https://zeroemissionsplatform.eu/about-zep/members/)	https://zeroemissionsplatform.eu/about-zep/zep-structure/

Lobby group	Founded in	Head office	Advocates for the following GE technologies	Goals	Members/ funding	Further information
GIS-Gas Infrastructure Europe	Not available	Brussels, Belgium	*"Low carbon hydrogen"* with CCS	Among the objectives: *"development of the hydrogen economy with the existing gas infrastructure and via the development of innovative project"*, *"low-carbon gases"*. *"GIE closely collaborates with many stakeholders in the community to ensure a responsible and sustainable future for the European infrastructure industry, and to increase our positive contributions."*	*"67 member companies from 27 countries, encompassing operators of gas infrastructures across Europe"* https://www.gie.eu/dna/members/	https://www.gie.eu/
GasNaturally	Not available	Not available	*"Low carbon hydrogen"* with CCS	*GasNaturally is a partnership of eight associations from across the whole gas value chain.* The organisation advocates for *"clean hydrogen and CCS for Europe"* and for large-scale deployment of CCS in Europe.	Members: Eurogas, European Gas Research Group, Gas Infrastructure Europe (GIE), International Association of Oil and Gas Producers (IOGP),International Gas Union (IGU), Liquid Gas Europe, Marcogaz, NGVA Europe	https://gasnaturally.eu/about-gas/clean-hydrogen-and-ccs-for-europe/
Hydrogen Council	2017	Brussels, Belgium	*"Low carbon hydrogen"* with CCS	Aims to supply low-carbon hydrogen at scale. According to the Hydrogen Council *"low-carbon hydrogen supply at scale is economically and environmentally feasible"*.	Lobbying platform with ~100 industry members, among them AirLiquide, ALSTOM, BP, Equinor, Linde, Microsoft, Shell, Siemens, Total, ThyssenKrupp, Uniper,...	https://hydrogencouncil.com/en/
Hydrogen Europe	Since 2014, possibly longer	Brussels, Belgium	*"Low carbon hydrogen"* with CCS	Hydrogen Europe presents the interests of *"the industry and national association members covering the entire hydrogen value chain."* At the same time, it partners with the European Commission as a research body, in the European Joint Undertaking on Hydrogen. Hydrogen Europe members contributed to the research activities.	Lobbying platform with nearly 200 industry members.	https://www.hydrogeneurope.eu/

Lobby group	Founded in	Head office	Advocates for the following GE technologies	Goals	Members/ funding	Further information
Negative Emissions Platform (NEP)	2020	Registered in Brussels, as a Belgian company	BECCS, Biochar, CCUS (fuels, chemicals, materials), DAC/DACCS, Enhanced weathering on land and in the oceans	NEP aims to draw the attention of policy makers and the public to the aforementioned geoengineering approaches and calls for further research to investigate the potential, costs and side effects of the approaches as well as (financial) incentives for so-called "negative emissions".	Among the members: Climeworks, Carbon Drawdown Initiative, Carbon Engineering, Carbyon, Global Thermostat, Fieldcode, Air Capture, CarbonFuture, Drax, Carbfix, Project Vesta, European Biochar Industry, ClimatePartners, Stockholm exergi, 44.01, Repair CO_2 capture,...	https://www.negative-emissions.org/, https://map.geoengineeringmonitor.org/other/negative-emissions-platform
OHB's geoengineering network	2021	OHB SE, Bremen, Germany	*"Space-based geoengineering"*	*"OHB System AG, a subsidiary of the German space and technology group OHB SE, has joined forces with eight research institutes from five different countries to establish a competence network on the subject of space-based geoengineering." "The research areas that are covered range from aerospace engineering, atmospheric research and climate modelling to communication sciences and ethics. In addition to building up sound knowledge on climate change and geoengineering, the objectives of the consortium also include the exchange and open discussion with other experts, political decision-makers and the general public."*	*"Participating institutions include the University of Bremen (Center of Applied Space Technology and Microgravity (ZARM) and Institute for Theoretical Philosophy), the Alfred Wegener Institute Bremerhaven (Paleoclimate Dynamics), Cranfield University (Astrodynamics and Mission Design), TU Delft, the University of Patras (Applied Mechanics Laboratory), NHL Stenden (Communications and Multimedia Design), the University of Utrecht (Institute of Marine and Atmospheric Research) and the University of Applied Sciences Wiener Neustadt (Aerospace Engineering)."*	https://www.ohb.de/en/news/2021/ohb-establishes-geoengineering-network
Scottish Carbon Capture & Storage (SCCS) partnership	2005	Edinburgh, UK	CCS, CCUS	*"We carry out strategic and innovative research across the full CCS chain, including CO_2 capture engineering, transportation, storage, utilisation and impact analyses. Our researchers are engaged in economic, legal and regulatory studies and consultation work." "Enhancement and promotion of SCCS research and development capacity and knowledge exchange to a global audience of researchers, industry and governments."*	Funded by the Scottish Funding Council (SFC), the European Regional Development Fund (ERDF), Scottish Government. Some members of the advisory board are affiliated with TOTAL UK and Shell.	https://sccs.org.uk/, https://map.geoengineeringmonitor.org/other/scottish-carbon-capture-storage-(sccs)

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