SWP Research Paper

Oliver Geden and Felix Schenuit

Unconventional Mitigation

Carbon Dioxide Removal as a New Approach in EU Climate Policy

Stiftung Wissenschaft und Politik
German Institute for International and Security Affairs

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- If the EU wants to achieve *net zero emissions* by 2050, enacting *conventional* climate change mitigation measures to avoid emissions of greenhouse gases will not be enough. To compensate for unavoidable residual emissions, *unconventional* measures to remove CO_2 from the atmosphere will also be necessary — for example, through afforestation or the direct capture of CO_2 from ambient air.
- Not all member states and economic sectors will have achieved greenhouse gas neutrality by 2050; some will already need to be below zero by then. The option of CO_2 removal from the atmosphere will allow greater flexibility in climate policy, but will also raise new distributional issues.
- Avoiding greenhouse gas emissions should be given political priority over the subsequent removal of CO_2. *Net zero targets* should be explicitly divided into emission reduction targets and removal targets, instead of simply offsetting the effects of both approaches.
- The future development of an EU CO_2 removal policy should be structured by adequate policy design. Whether the EU chooses a *proactive* or *cautious* entry pathway in the medium term will depend not least on the *net negative targets* it assumes for the period after 2050.
- In the coming years, the EU should focus on investing more in research and development of CO_2 removal methods and gaining more practical experience in their use.
- Only if the EU and its members actually succeed in convincingly combining *conventional* emission reductions and *unconventional* CO_2 removals to reach *net zero* will the EU be able to live up to its status as a pioneer in climate policy.

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Unconventional Mitigation: Carbon Dioxide Removal as a New Approach in EU Climate Policy

The European Union (EU) sees itself as a pioneer in international climate policy, basing its actions on the latest scientific findings. Following the tightening of the long-term temperature goal in the 2015 Paris Agreement, the results of the latest Special Reports of the Intergovernmental Panel on Climate Change, and the protests of the Fridays for Future movement, the EU has raised its greenhouse gas reduction target for 2050: from 80—95 percent to *net zero emissions*. However, not all emission sources can be completely eliminated by 2050. In particular, aviation, certain industrial sectors and agriculture are likely to continue to contribute *residual emissions* beyond the middle of the century. To bring the overall balance to *zero*, it will therefore not be sufficient to take *conventional* climate change mitigation measures to avoid emissions. The EU will also have to implement *unconventional* measures for the targeted removal of carbon dioxide (CO_2) from the atmosphere — to the amount of several hundred million tonnes per year.

Up until now, the removal of atmospheric CO_2 has played only a minor part in the EU climate policy debate. This is partly due to the state of development of the relevant methods. Apart from the already established option of re/afforestation, methods for CO_2 removal such as the combination of bio-energy and carbon capture and storage, increased carbon sequestration in soils, or the direct capture of CO_2 from ambient air have been insufficiently researched or are not yet at the stage of market maturity. However, the fact that the carbon removal approach has considerable potential for causing irritation is much more significant. This applies not only to the problem-solving paradigm prevalent in EU climate policy, but also to the associated narrative whereby science-based emission reduction targets and support for low-carbon technologies contribute to stabilising the global climate system while generating “green growth” in Europe. The future debate will therefore not only focus on evaluating specific methods, but also on the conceptual role of the carbon removal approach.

This study investigates the question of how the currently still *unconventional* carbon removal approach can be integrated into EU climate policy. The answer depends not only on the technological and economic potentials of each method, but also on the assessment of central actors as to who, under a shifting paradigm, would have more responsibility for achieving the European climate mitigation goals, and who would have less.

The debate will be significantly shaped by the fact that not all member states and sectors need to have achieved greenhouse gas neutrality by 2050. Those with a high proportion of residual emissions, unfavourable economic conditions or above-average negotiating power will voice their expectation that there will continue to be both leaders and laggards in EU climate policy. This could mean, for example, that countries such as Poland or Ireland would be allowed to have their emissions above the zero line in 2050, while pioneers such as Germany, France or Sweden would be called upon to reduce their emissions already by more than 100 percent, i.e. to remove more CO_2 from the atmosphere than they still emit.

It is difficult to anticipate which path the EU will choose in the coming decade to start deliberately removing CO_2, and what part the relevant methods will play in EU climate policy in the long term. Therefore, it would be premature to draw up very detailed regulatory proposals at this point. In its drafts for an EU climate strategy 2050 and an EU climate law, the Commission has indeed begun to give significant attention to CO_2 removal. However, which member states, party groups, economic sectors, companies, and NGOs want to promote the removal approach, and which methods they prefer, is only beginning to emerge.

Anticipated political resistance will be directed at the removal approach itself, not only because of the distributional effects described above, but also because of fears that it could call conventional mitigation measures into question. However, there will also be resistance to individual methods, usually based on specific risk perceptions and presumably occurring along the already established dividing line between ecosystem-based and technological removal methods.

The EU's climate policy must be expanded, and for this to be successful, it must prioritise avoiding greenhouse gas emissions over the subsequent removal of CO_2. Moreover, the impression that individual member states and sectors benefit disproportionately from the conceptual integration of CO_2 removal should be avoided. Two steps are of particular importance here: devising the specifics of *net zero targets* and designing the policy.

To safeguard the primacy of conventional mitigation measures and to communicate them visibly, it is advisable to split *net zero targets* into emission reduction targets and removal targets, instead of offsetting the effects of both approaches, i.e. in the order of 90:10 percent. If the 90 percent was understood to be the minimum target, breakthroughs in CO_2 removal methods would not lead to a decrease in emission reductions, but to *net zero* or *net negative emissions* being achieved earlier.

The relationship between leaders and laggards should also be regulated at an early stage. If, for understandable reasons, individual countries and sectors reach the zero line later than the EU average, that difference should at least be limited in time or correlate with financial compensation. The EU should not allow any member state to reach *net zero* more than 10-15 years later than the average. As for the relationship between sectors, however, it will not be possible in the foreseeable future to establish a similar obligation; there are technical feasibility limits in agriculture, in particular. Here, it is important to ensure that sectors which have to be allowed residual emissions as a matter of principle are themselves responsible for CO_2 removals, regardless of whether they purchase certificates from other sectors or invest directly in CO_2 removal methods.

The Removal of Atmospheric CO_2 as a Global Challenge

Mitigation of anthropogenic climate change requires the concentration of carbon dioxide and other greenhouse gases (GHG) in the atmosphere to be stabilised. This can be achieved in two fundamental ways. International climate policy has always focused on emission sources and thus on the avoidance of greenhouse gas emissions, for example from the power sector, industry, transport, or land-use changes.

To achieve global climate goals, methods for the removal of carbon dioxide from the atmosphere must be used.

However, there has also always been a second strand of climate change mitigation policy, which focuses on the preservation and enhancement of emission sinks, i.e. the removal of carbon dioxide (CO_2[1]) from the atmosphere, for example through programmes for re- or afforestation or the restoration of ecosystems. Since global emissions of greenhouse gases have continued to rise almost continuously since the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, the *conventional* mitigation approach, which is aimed at avoiding emissions, has lost nothing of its urgency — quite the contrary. However, to achieve the global climate targets adopted by the UNFCCC, *unconventional* mitigation methods involving the deliberate removal of CO_2 from the atmosphere[2] must also be used, and to a considerable extent. There is now a broad consensus on this in climate research.[3] This can be achieved not only by enhancing the sink function of ecosystems, but also using technological processes such as the direct capture of CO_2 from ambient air, whereby the CO_2 is subsequently geologically stored. The capture and storage of CO_2 (Carbon Capture and Storage, CCS) from the use of fossil fuels in power plants or in industrial processes is a conventional mitigation method because the stored CO_2 has not been taken from the atmosphere.[4] The approach of large-scale CO_2 removal has been discussed in climate science since the beginning of the millennium and, over the past decade, has become an integral part of the mitigation scenarios assessed by the Intergovernmental Panel on Climate Change (IPCC). The scenarios in the IPCC Special Report on the 1.5 degree target are based on the removal of vast quantities of CO_2 (Carbon Dioxide Removal, CDR) — 730 billion tonnes (gigatonnes, Gt) by 2100, almost 15 times the current annual GHG emissions.[5] Yet the issue of CDR has still gained only marginal importance both on the global climate policy agenda and in debates within the signatory states of the Paris Agreement. Moreover, given

1 Methods of removing other greenhouse gases (such as methane, nitrous oxide or F-gases) from the atmosphere have so far hardly featured in the debate.

2 As much as possible, we avoid the term *negative emissions* in this study, because it often leads to misunderstandings, especially due to an implicit equation with the term *net negative emissions*. The latter describes a status (globally, or in a subsystem such as the EU, a country, sector or company) where more CO_2 is removed from the atmosphere than is still emitted in greenhouse gases. The fact that CO_2 removal methods are used does not in itself indicate whether total net emissions are above, below or exactly at zero.

3 Intergovernmental Panel on Climate Change (IPCC), *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (Geneva, 2018).

4 Jan C. Minx et al., "Negative Emissions — Part 1: Research Landscape and Synthesis", *Environmental Research Letters* 13, no. 063001 (2018); Sabine Fuss et al., "Negative Emissions — Part 2: Costs, Potentials and Side Effects", *Environmental Research Letters* 13, no. 063002 (2018).

5 Joeri Rogelj et al., "Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development", in IPCC, *Global Warming of 1.5°C. An IPCC Special Report* (see note 3), 122.

the current state of research and development, it is uncertain how great the potential of individual CDR methods actually is and how quickly they could be deployed at scale.[6]

CO_2 Removal in Climate Policy

The necessity to remove carbon from the atmosphere stems from two different functional logics. First, by generating net negative emissions,[7] CDR theoretically makes it possible to compensate at a later point in time for initially overshooting the CO_2 budget that the world has left to reach a given temperature target.[8] Second, CDR is already needed to achieve net zero emissions, since not all GHG emissions can be completely eliminated, be it for technological, economic or political reasons. Since the remaining carbon budget for the lower end of the Paris Agreement target corridor of 1.5 to 2°C is much smaller than for the upper end, 1.5°C compatible emission pathways reach net zero much earlier than pathways compatible with 2°C (see Figure 1).

In the political debate on carbon removal, the fact that it compensates for an interim overshooting of the CO_2 budget has so far been foregrounded. For critics, what is problematic is not only the vast CDR volumes assumed by mitigation scenarios, and the unintended negative side effects that individual methods might have when implemented, but above all that the CDR-enabled possibility of achieving net negative emissions masks the fundamental contradiction between a limited CO_2 budget and real-world emissions that continue to rise.[9]

Nobody fundamentally doubts that there are unavoidable emission sources which will have to be balanced by sinks.

More attention has recently been paid to the use of CDR to offset *residual emissions* (mainly methane and nitrous oxide from agriculture and CO_2 from industrial processes and aviation), especially within global or national net zero targets, which are becoming increasingly popular in climate policy.[10] One reason for this is the Paris Agreement, Article 4 of which explicitly includes the target "to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century"[11] — which would at least stabilise global temperature.[12]

6 Gregory F. Nemet et al., "Negative Emissions — Part 3: Innovation and Upscaling", *Environmental Research Letters* 13, no. 063003(2018): 1—30.

7 Due to the very small remaining CO_2 budget, all illustrative model pathways in the IPCC Special Report on the 1.5°C target assume that net negative emissions must be achieved in the second half of the century.

8 Due to the roughly linear relationship between the cumulative amount of CO_2 emissions and the global average temperature increase, each temperature target can be converted into a remaining CO_2 budget. Since the 5th Assessment Report of the IPCC (2013/14), the (remaining) carbon budget has been considered a central category in climate research and climate policy, see Joeri Rogelj et al., "Estimating and Tracking the Remaining Carbon Budget for Stringent Climate Targets", *Nature* 571 (2019): 335—42; Bård Lahn, "A History of the Global Carbon Budget", *Wiley Interdisciplinary Reviews [WIREs]: Climate Change* 11, no. e636 (2020).

9 Oliver Geden, Modifying the 2°C Target. Climate Policy Objectives in the Contested Terrain of Scientific Policy Advice, Political Preferences, and Rising Emissions, SWP Research Paper 5/2013 (Berlin: Stiftung Wissenschaft und Politik, June 2013); Oliver Geden, "Climate Advisers Must Maintain Integrity", *Nature* 521 (2015): 27—28; Kevin Anderson and Glen Peters, "The Trouble with Negative Emissions", *Science* 354, no. 6309 (2016): 182—83; European Academies Science Advisory Council (EASAC), *Negative Emission Technologies: What Role in Meeting Paris Agreement Targets?* (Halle: EASAC, February 2018); Alice Larkin et al., "What if Negative Emission Technologies Fail at Scale? Implications of the Paris Agreement for Big Emitting Nations", *Climate Policy* 18, no. 6 (2018): 690—714; Nils Markusson, Duncan McLaren, David Tyfield, "Towards a Cultural Political Economy of Mitigation Deterrence by Negative Emissions Technologies (NETs)", *Global Sustainability* 1, no. E10 (2018): 1—9.

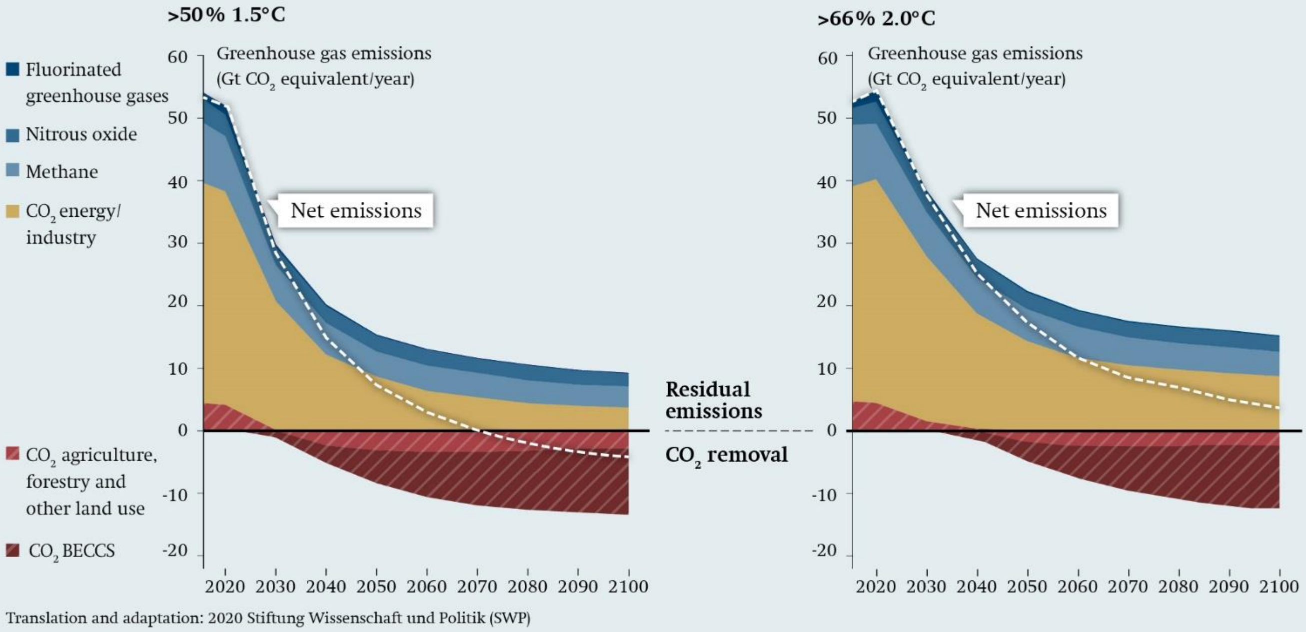
10 Oliver Geden, "An Actionable Climate Target", *Nature Geoscience* 9 (2016): 340—42; Steve Pye et al., "Achieving Net-zero Emissions through the Reframing of UK National Targets in the post-Paris Agreement Era", *Nature Energy* 2, no. 3 (2017): 17024; United Nations Environment Programme (UNEP), *The Emissions Gap Report 2019* (Nairobi, November 2019).

11 United Nations Framework Convention on Climate Change (UNFCCC), *Adoption of the Paris Agreement*, 12 December 2015.

12 Jan S. Fuglestvedt et al., "Implications of Possible Interpretations of 'Greenhouse Gas Balance' in the Paris Agreement", *Philosophical Transactions of the Royal Society. Series A, Mathematical, Physical, and Engineering Sciences* 376, no. 2119 (2018): 1—17.

Figure 1

Global mitigation scenarios to limit global warming to 1.5 or 2°C



Source: Committee on Climate Change (CCC), *Net Zero – The UK's Contribution to Stopping Global Warming* (London, 2019), 77, based on IPCC SR1.5 scenario database

Since the publication of the IPCC Special Report on the 1.5-degree target, it has also become increasingly apparent that nation states, cities and companies are each discussing and deciding on individual net zero targets.[13] As a result, the compensatory function of CO_2 removal is increasingly coming into focus. Although the level of residual emissions assumed in global and national climate mitigation scenarios is certainly the subject of criticism,[14] no one in the debate fundamentally doubts that there are unavoidable emission sources which will have to be balanced by sinks. This puts the spotlight on the question of which CDR methods could be used in the future.

13 See for example the Energy & Climate Intelligence Unit's *Net Zero Tracker*. For examples in the context of UNFCCC negotiations, see Stefan C. Aykut et al., *The Accountant, the Admonisher and the Animator: Global Climate Governance in Transition*, (Hamburg: Center for Sustainable Society Research, February 2020).

14 Duncan P. McLaren et al., "Beyond 'Net-Zero': A Case for Separate Targets for Emissions Reduction and Negative Emissions", *Frontiers in Climate* 1, no. 4 (2019): 1–5.

Selected CO_2 Removal Methods

In global mitigation scenarios, two main removal methods have so far been used: afforestation and, to a far greater extent, the use of biomass for energy generation in combination with carbon capture and storage (BECCS). This limitation to two methods is mainly due to pragmatic considerations in climate-economic modelling and existing gaps in knowledge. However, the range of possible CO_2 removal methods is much wider. Should the CDR volumes assumed in global mitigation scenarios ever be realised, we should not expect it to happen with a (globally co-ordinated) recourse to only two methods. Since many methods are still in an early phase of research and development, estimates of removal potentials and costs are subject to great uncertainty. Furthermore, each method could be applied in several variants. The actual use of removal methods in individual countries will depend not only on their effectiveness and cost, but also on the different geographical conditions, economic structures and political preferences.[15]

Numerous studies on CO_2 removal methods have been published in recent years with the aim of pooling the existing body of knowledge and identifying gaps in research.[16] We will provide a brief overview of the research results on the most important methods below. Our focus is on those factors that are likely to significantly shape or influence the political debate on further research, the launch of pilot projects, and the large-scale deployment of the various methods. These criteria include the methods' specific functional mechanisms, availability, global removal potentials, cost, permanence of CO_2 storage, and possible risks.[17]

Re/Afforestation

In this approach, CO_2 from the atmosphere is captured in wood biomass through photosynthesis by the planned expansion of forest areas on land that has not been covered by trees during the last 50 years (afforestation) or on more recently deforested land (reforestation). Since the extraction potential of a forest decreases significantly in the long term (saturation), the age of tree stands and the available land areas are of great importance. The additional global CO_2 removal potential is estimated to be 0.5 – 3.6 Gt CO_2 in 2050. This can be increased by long-term use of the harvested wood, for example as building material. The cost estimates for 2050 are $5 – 50 per tonne of CO_2 removed.[18]

Forests cannot be fully protected against natural and human disturbances such as drought, pests and fire.[19] The permanent storage of the extracted CO_2 is therefore highly uncertain. Negative side effects include high land and water use, a possible reduction in biodiversity (depending on how the respective land use changes), and reduced reflection of solar radiation (albedo) in forest areas at northern latitudes. Afforestation and reforestation are already established as methods for CO_2 removal.

Soil Carbon Sequestration

The soil organic carbon content can be increased in various ways, including by changing agricultural practices, such as refraining from deep ploughing, incorporating harvest residues or sowing cover crops. The removal potential is 2 – 5 Gt CO_2. However, it is limited by the medium to long-term carbon saturation of the soil. The costs are estimated at $0 – 100 per tonne of CO_2.

Permanence of CO_2 storage is quite uncertain. It depends inter alia on how the land is managed or used in the long term. Positive side effects of increasing the soil carbon content are improvements in capacity for water and nutrient retention and increases in soil fertility. Land-use conflicts are not expected, since agricultural use of respective soils could continue despite the increased CO_2 enrichment. Methods for increasing carbon sequestration in soils could be applied immediately.

Bio-energy with Carbon Capture and Storage (BECCS)

BECCS combines energy production from fast-growing biomass with capture and storage of the resulting CO_2. Since biomass takes up CO_2 from the atmosphere during its growth, the combination of both processes is equivalent to a net removal of CO_2. The potential

15 Rob Bellamy and Oliver Geden, "Govern CO2 Removal from the Ground Up", *Nature Geoscience* 12, no. 11 (2019): 874 – 76.

16 Pete Smith et al., "Biophysical and Economic Limits to Negative CO_2 Emissions", *Nature Climate Change* 6, no. 1 (2016): 42 – 50; UNEP, *The Emissions Gap Report 2017* (Nairobi, November 2017); Fuss et al., "Negative Emissions — Part 2" (see note 4); Royal Society and Royal Academy of Engineering, *Greenhouse Gas Removal*, London 2018; Gernot Klepper and Daniela Thrän, *Biomasse im Spannungsfeld zwischen Energie- und Klimapolitik. Potenziale – Technologien – Zielkonflikte* (Munich, 2019); Deutsche Forschungsgemeinschaft (DFG), *Climate Engineering and Our Climate Targets – A Long-overdue Debate*, Schwerpunktprogramm 1689 (Bonn, 2019); International Energy Agency (IEA), *Energy Technology Perspectives 2020: Special Report on Clean Energy Innovation* (Paris 2020; forthcoming); other methods discussed in the literature include restoring peatlands and marine habitats, burial of biomass, and use of CO_2 in durable materials such as carbon fibre composites.

17 Estimates for removal potentials and costs have so far been carried out almost exclusively at global level; no EU-specific data are available.

18 The values for all methods given in this study are annually realisable values. Like the cost estimates (in 2011 US dollars), they always refer to the year 2050. These data are taken from a comprehensive meta-study that evaluates over 2,000 articles, see Fuss et al., "Negative Emissions — Part 2" (see note 4).

19 On a global scale, land use and forestry are currently still emission sources, i.e. they emit more CO_2 than is bound by re/afforestation (see Figure 1, p. 9).

of BECCS is estimated at 0.5 — 5 Gt CO_2. The amount depends on the availability of sustainably produced biomass whose cultivation competes with other uses. The estimated cost per tonne of CO_2 extracted is $100 — 200.

The removal can be made permanent by storing the CO_2 geologically underground. A positive side-effect of BECCS is that, unlike most other removal methods, it generates energy (electricity, biofuels or hydrogen). A disadvantage is that the necessary cultivation of biomass is land-intensive (but less per negative tonne of CO_2 than afforestation), requires water and fertiliser, and thus potentially conflicts with food production and biodiversity more than most other removal methods. The individual components of the process, energy generation from biomass and CCS, are each considered sufficiently researched and tested. So far, the two sub-processes have only been combined in a single commercial plant (for biofuel production, in the US); two demonstration plants in the power and in the heating sector were commissioned in the UK and Sweden in 2019. To use BECCS on a large scale in the future, infrastructures for the transport and storage of the captured CO_2 would also have to be created.

Biochar

The heating of biomass, for example plant residues, in the absence of oxygen prevents the organic material from decomposition and thus from releasing CO_2. Biochar produced in this process can be mixed into arable soils. The potential of biochar as a CO_2 removal option is about 0.5 — 2 Gt CO_2. The cost per tonne of CO_2 is estimated at $30 — 120.

Depending on the process chosen, the production of biochar offers the possibility of storing CO_2 in a stable way for several centuries. Land-use conflicts over biomass can be limited by recycling plant waste. Using biochar as a soil amendment also has a positive effect on the quality of soils. Producing and burying biochar is already practiced, but only to a very limited extent due to the lack of specific incentive systems. There is a lack of experience with large-scale plants and the corresponding production and supply chains for biomass.

Direct Air Carbon Capture and Storage (DACCS)

CO_2 can also be filtered from ambient air by chemical processes (Direct Air Capture, DAC) and then stored underground. The potential of DACCS is in principle unlimited. Since not much land is required for DAC systems, any number of units could theoretically be put into operation, as long as they are in relative proximity to established geological CO_2 storage facilities. The potential of this method is limited by the large amounts of energy it requires — which would have to be supplied from low-CO_2 sources — as well as the location and volume of global storage capacities. Due to the small number and size of the facilities built so far, development of DAC technology is far from complete. Upscaling production capacities can therefore be expected to reduce costs significantly, down to $100 — 300 by the middle of the century.

The first DAC plants are being operated in Switzerland, Italy, Iceland, the USA and Canada. For economic reasons, the captured CO_2 has so far usually not been stored underground but used further (carbon capture and utilisation, CCU), for example in the beverage industry or in the production of synthetic fuels. If CO_2-free energy sources are used, these DAC projects are at best greenhouse gas neutral, since the CO_2 is emitted again when the products are used. To permanently remove CO_2 from the atmosphere with DAC, it will have to be permanently stored.

Enhanced Weathering on Land and in the Ocean

This procedure accelerates natural CO_2-binding processes in the weathering of minerals. Carbonate and silicate rocks are mined, ground and spread over agricultural land or ocean surfaces. By the middle of the century, the method's potential is estimated to be 2 — 4 Gt CO_2, at $50 — 200 per tonne of CO_2 removed.

Compared to other removal methods, the negative side effects are considered to be low. The distribution of the ground rock on agricultural land would not cause any conflicts of use and could contribute to improving soil quality. Spreading the ground rock in oceans could counteract increasing acidification. However, for large-scale use, an extensive infrastructure for the extraction, transport and application of the minerals would have to be created. Specific processes of enhanced weathering have not yet been sufficiently researched experimentally and are therefore not yet ready for use.

Ocean Fertilisation

This method aims to increase the nutrient content of the ocean, preferably by adding iron. This would encourage plankton growth, which in turn would bind more atmospheric CO_2. Estimates of the future removal potential and associated costs are subject to much greater uncertainty than with other methods.

How permanently the removed CO_2 could be stored is a controversial issue, since only a small part of the additionally absorbed CO_2 would be stored in sea floor sediment. So far, two negative side effects are known. There is a fundamental risk of over-fertilisation, which could result in strong plankton blooms withdrawing a great deal of oxygen from the affected ocean areas. Over-fertilisation would also lead to an increase in nitrous oxide, which would run counter to the goal of removing greenhouse gases from the atmosphere. Due to its negative side effects, the extent of which is almost impossible to estimate, and its low efficiency as a CO_2 removal method, ocean fertilisation is now rarely treated as a serious option in research.

Integration of CO_2 Removal into European Climate Policy

The global emission reduction scenarios assessed by the IPCC, which outline compliance with the target corridor agreed in Paris (1.5 – 2°C), include extraordinarily large quantities of CO_2 removal from the atmosphere. However, with the exception of the United Kingdom, no UNFCCC Party has yet made serious efforts to develop a comprehensive CDR research and demonstration programme, or dedicated regulatory instruments. Following the latest IPCC Special Reports on the 1.5°C target and on Climate Change and Land, it is now generally accepted by policymakers and public officials that using CDR will be essential if the Paris long-term temperature goal is to be met. So far, however, the UNFCCC has avoided a serious debate about which methods, and above all which actors, should generate the corresponding amounts of CO_2 removal.[20]

The experience of past international climate negotiations suggests that the EU could take a leading role on CDR. The European Union is still the third largest emitter of greenhouse gases in the world; Europe has a high degree of historical responsibility for climate change; and the EU constantly emphasises its leadership within the global climate regime.[21] Climate-economic models for global emission reductions assume that the EU will be one of the largest "producers" of CDR in the 21st century, contributing about 50 Gt – more than 10 times its current emissions but at the same time less than 10 percent of the total global CDR volume.[22] These numbers would increase substantially if criteria of international fairness were applied.[23] If the global community is to achieve net negative emissions on the way to meeting the Paris target corridor, the EU will have to set itself long-term emission reduction targets of more than 100 percent. But so far, the removal of atmospheric CO_2 has only played a minor part in the EU's climate policy debate.

An Irritation to the EU's Climate Policy Paradigm

Although the EU has committed itself to a science-based climate policy, its reluctance to date on the subject of CO_2 removal should not come as a surprise. Plans for transforming economic sectors and actual restructuring processes – for example of national energy systems – do not usually follow the optimisation assumptions of complex global mitigation scenarios. To assess how the *(unconventional)* approach of CO_2 removal from the atmosphere could be integrated into European climate policy, we must not only examine how CDR fits into existing political preferences, economic interests and national infrastructures. It is equally important to analyse how the new approach relates to the climate policy paradigm that is prevalent in Europe. In the last two decades, this paradigm has been characterised by a narrative that science-based targets for emission reductions and the

20 Mathias Fridahl, "Socio-political Prioritization of Bioenergy with Carbon Capture and Storage", *Energy Policy* 104 (2017): 89 – 99; Glen P. Peters and Oliver Geden, "Catalysing a Political Shift from Low to Negative Carbon", *Nature Climate Change* 7, no. 9 (2017): 619 – 21; Mathias Fridahl and Mariliis Lehtveer, "Bio-energy with Carbon Capture and Storage (BECCS): Global Potential, Investment Preferences, and Deployment Barriers", *Energy Research & Social Science* 42 (2018): 155 – 65.

21 Lisanne Groen and Sebastian Oberthür, "The European Union and the Paris Agreement: Leader, Mediator, or Bystander?" *WIREs Climate Change* 8, no. 1 (2017): e445.

22 Peters and Geden, "Catalysing a Political Shift from Low to Negative Carbon" (see note 20); Naomi E. Vaughan et al., "Evaluating the Use of Biomass Energy with Carbon Capture and Storage in Low Emission Scenarios", *Environmental Research Letters* 13, no. 4 (2018): 044014.

23 Carlos Pozo et al., "Equity in Allocating Carbon Dioxide Removal Quotas", *Nature Climate Change* 10 (2020): doi: 10.1038/s41558-020-0802-4.

promotion of climate-friendly technologies would help to stabilise the global climate system whilst generating "green growth" in Europe.[24]

This cognitive problem-solving model, shared by the main EU actors,[25] has been relatively stable for at least two decades, and the instruments created for it have accordingly achieved a high degree of institutionalisation. The central actors in this policy domain (European Commission and member states in North-Western Europe) are also among the most influential forces in the EU as a whole. At the same time, over the past ten years the veto power of Poland and the *Visegrád Group* has weakened noticeably. Not least because the *Green Growth Group* of climate-progressive member states is increasingly willing to use the opportunity for qualified majority decisions in the Council, no longer seeking consensus on every fundamental question by delegating decisions to the European Council.[26] The European Parliament (EP) has also accrued greater weight in the legislative procedures since 2014.

CDR holds considerable potential for becoming an irritation to Europe's climate success story.

EU climate policy is *polycentrically* organised[27] and has been supported by a broad constellation of actors beyond the EU institutions for more than 20 years. This includes a comparatively environmentally friendly population and powerful non-governmental organisations (NGOs), allowing scientists a strong role in policy formulation, and relying on companies that invest massively in low-carbon technologies. Moreover, there are now hardly any relevant actors who fundamentally reject an ambitious climate policy. Energy-intensive industry, for example, no longer questions ambitious long-term targets per se. Its criticism is usually limited to questioning the scope of their planned contribution to achieving these targets. Despite fears to the contrary ahead of the 2019 European elections, and in contrast to the US or Australia, even climate change deniers have so far failed to exert any significant political influence in the EU; there is thus no competing paradigm or powerful climate policy counter-narrative in the EU.[28]

It is hard to deny that the EU's climate policy approach has been comparatively successful in the past. Emissions already fell by more than 20 percent between 1990 and 2018,[29] putting the EU far ahead of Western industrialised countries and legitimising its claim to being a leader in international climate policy.[30] Since there is a broad interest within the EU in continuing this European success story — not least in order to counteract the rampant perception of an EU that is shaken by crisis or has only a limited capacity to act — climate policy actors tend to be risk-averse. Debating how to systematically remove atmospheric

24 Vivian Scott and Oliver Geden, "The Challenge of Carbon Dioxide Removal for EU Policy-Making", *Nature Energy* 3, no. 5 (2018): 350—52.

25 Marcus Carson, Tom Burns and Dolores Calvo, eds., *Paradigms in Public Policy. Theory and Practice of Paradigm Shifts in the EU* (Frankfurt: Peter Lang, 2012).

26 E.g. in negotiations on the reform of emissions trading, see Torbjørg Jevnaker and Jørgen Wettestad, "Ratcheting Up Carbon Trade: The Politics of Reforming EU Emissions Trading", *Global Environmental Politics* 17, no. 2 (2017): 105—24. The possibility of using qualified majority voting changes the balance of power in the Council of the EU to the detriment of potential veto users, even if consensus decisions are ultimately reached, see Stéphanie Novak, "The Silence of Ministers: Consensus and Blame Avoidance in the Council of the European Union", *Journal of Common Market Studies* 51, no. 6 (2013): 1091—1107.

27 Tim Rayner and Andrew Jordan, "The European Union: The Polycentric Climate Policy Leader?" *WIREs Climate Change* 4, no. 2 (2013): 75—90.

28 It is true that right-wing populist parties in Europe have recently increasingly incorporated elements of climate change scepticism into their communication. However, the issue is not central to their agenda. It merely serves to emphasise their anti-elitism. Here, the difference between the EP and the Council of the European Union is remarkable. The representatives of right-wing populist parties, who are usually marginalised in the Parliament, often express strong climate change denial (see Stella Schaller and Alexander Carius, *Convenient Truths. Mapping Climate Agendas of Right-wing Populist Parties in Europe* (Berlin: adelphi, 2019). However, when representatives of these parties become part of member states' governments (e.g. the PiS in Poland or, until 2019, the FPÖ in Austria), they do not stand out in the Council of the European Union with climate-sceptical positions.

29 The latest available statistics for 2018 show a reduction of 23.3 percent for the EU28. With the United Kingdom leaving the EU, the relative performance of the EU27 decreased by about 3 percentage points due to the above-average emission reductions of the UK since 1990, see European Environment Agency (EEA), *Trends and Projections in Europe 2019: Tracking Progress towards Europe's Climate and Energy Targets* (Copenhagen, 2019).

30 Groen and Oberthür, "The European Union and the Paris Agreement" (see note 21).

CO_2 does not directly call into question the dominant paradigm, which is geared to avoiding dangerous climate change caused by anthropogenic emissions; however, CDR has considerable potential for becoming an irritation to Europe's climate policy success story.

If the EU suddenly acknowledges the need to remove CO_2 from the atmosphere on a large scale, including net negative emissions in the long-term, this is tantamount to admitting that there have been fundamental failures in (largely EU-driven) global climate policy which cannot be compensated for by *conventional* mitigation measures alone. The EU may be able to defend its domestic climate policy record against the impression of failure. But this raises the question of why the EU in particular should bear the burden of becoming an international pioneer in CDR. Would this simply be an expression of its global political responsibility, or could Europe's economies also benefit from an *unconventional* climate policy approach, at least in the long term? It is highly doubtful that comprehensive EU programmes for CO_2 removal methods such as BECCS and re/afforestation would be able to fulfil the promise of positive side effects that are closely linked to current climate policy (e.g. "green" growth, more jobs, improved local air quality, and reduced dependence on energy imports).

One decisive factor in determining whether and how the concept of deliberate CO_2 removal will be integrated into EU climate policy is likely to be the patterns of interpreting CDR, which will shape the mitigation debate in the medium term. Such influence, which should not be underestimated, will come from the status of CDR in future UNFCCC negotiations; from (perceived) experiences with CDR programmes and methods in other G20 countries; from the role of CO_2 removal in IPCC scenarios; and last but not least from the positioning of European environmental NGOs and companies. Will CDR primarily be seen as a fit-for-purpose response to climate change, as a meaningful extension of the existing climate policy portfolio, and possibly even as an implementation of the *precautionary principle* which is often invoked in European environmental policy in the sense of forward-looking risk management? Or will the approach of removing atmospheric CO_2 be interpreted as undermining an ambitious mitigation policy, and as a dubious attempt to postpone necessary emission reductions further into the future in the vague hope that future generations will find new technical solutions?[31] Such assessments would not, of course, develop in a political or societal vacuum. New ways of describing problems or approaching solutions will always have an impact on the relevance of previously used policy instruments or on the relationships between the actors concerned.[32] For this reason, the issue of which groups of actors would be ascribed more responsibility to achieve Europe's climate protection targets under a shifting paradigm, and which ones less, will be a central factor in the considerations of governments, climate policymakers, industry associations, businesses, and NGOs.

Normalising the CO_2 Removal Approach

With the exception of forestry measures,[33] European climate policy cannot rely on mature CDR methods, making it hard to assess how much their implementation would cost and who would benefit from their use. As with global debates, the European debate will initially focus on conceptual aspects of CO_2 removal and only at a later stage on specific methods, i.e. initially far more on questions of "why" and "how much" than on "how".

31 Michael Obersteiner et al., "How to Spend a Dwindling Greenhouse Gas Budget", *Nature Climate Change* 8 (2018): 7–10; Nils Markusson, Duncan McLaren and David Tyfield, "Towards a Cultural Political Economy of Mitigation Deterrence by Negative Emissions Technologies (NETs)", *Global Sustainability* 1, no. E20 (2018): 1–9.

32 David Béland and Michael Howlett, "How Solutions Chase Problems: Instrument Constituencies in the Policy Process", *Governance* 29, no. 3 (2016): 393–409.

33 Since 2000, the EU28 has achieved an average net CO_2 removal of 0.32 Gt per year in the emission category Land-Use, Land-Use Change and Forestry (LULUCF), with a slight downward trend. Although this net sink is equivalent to roughly 5 percent of 1990 EU emissions, it has so far not been included in the calculation of the EU emission reduction target (20 percent from 1990 to 2020). In the coming regulatory phase (2021–2030), this will be possible for the first time, but only to a very limited extent, see Hannes Böttcher et al., *EU LULUCF Regulation Explained. Summary of Core Provisions and Expected Effects* (Freiburg: Öko-Institut, June 2019).

A serious discussion on the need for *net negative emissions* has not yet taken place at the EU level.

The fact that a debate on CDR has not taken place in the EU and among its member states is also due to the fact that Europe was late in adapting its emission reduction targets to the IPCC's global mitigation scenarios. The EU reduction target of 80 – 95 percent by 2050, which was adopted by the European Council in 2009, drew its political legitimacy from an explicit reference to a table in the 4th IPCC Assessment Report of 2007, which presented 80 – 95 percent as an appropriate contribution from industrialised countries. As the 5th IPCC Assessment Report in 2013 did not include such a table, there was no subsequent discussion in the EU about adjusting the 2050 climate target.[34] This only changed after the Paris Agreement. While European NGOs initially argued that the establishment of a global 1.5°C target would require the EU to tighten its reduction target to 95 percent, the IPCC Special Report 2018 established a new type of target which has quickly become the benchmark for all climate policy actors in industrialised countries: *net zero emissions* or *greenhouse gas neutrality.*[35] In the public debate, individual countries, cities, sectors and businesses are now differentiated based on the year by which they should achieve net zero. But the IPCC now restricts itself to giving global averages, not distinguishing between groups of countries so as not to pre-empt genuine political negotiations. For there to be at least a 50 percent chance of stabilising global warming at 1.5 degrees by 2100, GHG emissions would have to reach net zero by 2067 (and CO_2 emissions, which are easier to reduce, by 2050) — and then move deep into "negative territory".[36] The EU Commission and member states deduce from the IPCC figures that the EU should have achieved greenhouse gas neutrality by 2050 (see Figure 1, p. 9, and Table 1, p. 16).[37] However, the majority of European NGOs are calling for a GHG-neutral EU by 2040 at the latest. No serious debate on the need for Europe to achieve *net negative emissions* thereafter has yet taken place at the EU level — even though the Regulation on the Governance of the Energy Union already includes it as a long-term option.[38]

Table 1

Target years for achieving net zero emissions

	Only CO_2 (global, IPCC SR1.5[i])	*All GHG (global, IPCC SR1.5[i])*	*All GHG (EU, Commission[ii])*
1,5°C	**2050**	**2067**	**2050**
2°C	**2070–2085**	**after 2100**	**ca. 2060[iii]**

i Intergovernmental Panel of Climate Change (IPCC), *Global Warming of 1.5°C.* (see note 3), Table 2.4.
ii European Commission, *In-Depth Analysis in Support of the COM(2018) 773* (Brussels, 28 November 2018).
iii This value is based on an extrapolation of the emission reduction pathway of 80 – 95 percent by 2050.

34 Brigitte Knopf and Oliver Geden, "A Warning from the IPCC: the EU 2030's Climate Target Cannot Be Based on Science Alone", *energypost.eu*, 26 June 2014, https://energypost.eu/warning-ipcc-eu-2030s-climate-target-based-science-alone/ (accessed 7 February 2020).

35 Even though the two terms are often used synonymously, *greenhouse gas neutrality* cannot be simply equated with the (broader) concept of *climate neutrality*. This distinction becomes politically relevant, for example, in aviation, where the climate impacts of long-haul flights at high altitudes go beyond GHG emissions, see Jan S. Fuglestvedt et al., "Implications of Possible Interpretations of 'Greenhouse Gas Balance' in the Paris Agreement" (see note 12); Lisa Bock and Ulrike Burkhardt, "Contrail Cirrus Radiative Forcing for Future Air Traffic", *Atmospheric Chemistry and Physics* 19, no. 12 (2019): 8163 – 74.

36 James Meadowcroft, "Exploring Negative Territory Carbon Dioxide Removal and Climate Policy Initiatives", *Climatic Change* 118, no. 1 (2013): 137 – 49.

37 This has so far been reflected in all key documents from EU institutions: in the Commission's draft for the EU's long-term climate strategy of November 2018; in the Commission's Communication on the European Green Deal of December 2019; in the European Council conclusions presented the following day; in the Commission's draft for an EU climate change law presented in March 2020; and in the EU's long-term strategy submitted to the UNFCCC by the Council and the Commission shortly afterwards.

38 Article 15 of the Regulation states, albeit in a somewhat convoluted form, that the binding obligation to establish national and EU long-term strategies serves to achieve "long-term greenhouse gas emission reductions and enhancements of removals by sinks in all sectors […] so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases within the Union as early as possible and, as appropriate, achieve negative emis-

The fact that the climate policy debate is refocusing on net zero targets has a (largely unintended) side effect: CO_2 removal is beginning to *normalise*. While an 80 – 95 percent target could certainly be achieved without CDR, this becomes impossible with a reduction target of 100 percent – whatever the target year (see Figure 1, p. 9). All climate policy actors (including environmental NGOs) accept in principle that even in a greenhouse gas-neutral EU there will still be residual emission sources that cannot be eliminated or can only be eliminated at very high costs – for example in agriculture, the steel and cement industry, or aviation.[39] These residual emissions can only be physically compensated by using CO_2 removal methods.[40]

New Rules, Similar Game

Not only will the implementation of a net zero target result in a Europe-wide tightening of climate policy targets, the normalisation of CO_2 removal will also create a new resource for flexibility. Net zero will for the first time put the focus of climate policy on *all* sectors and member states, including politically assertive sectors such as agriculture, or member states with very low per capita income such as Bulgaria and Romania. All emitters will come under increased pressure to justify their actions, even those that previously implicitly assumed that their greenhouse gas emissions would fall largely into the 5 – 20 percent that an EU reduction target of 80 – 95 percent by 2050 would leave. Yet the *net zero* target will also accelerate a debate on the nature and extent of residual emissions, and their compensation through deliberate CO_2 removals. Many governments, industries and companies, which are under increasing pressure to change in order to achieve ever more ambitious emission reduction targets, will initially see CDR primarily as a new resource for political flexibility, without necessarily planning to use CDR themselves. At the same time, a gradually developing political and economic demand for CDR will also attract potential CDR suppliers who are confident that they can exploit the arising market opportunities.

CO_2 removal from the atmosphere will expand the field of climate policy.

The integration of CDR into a programme to achieve a net zero target will thus not be accompanied by a fundamental paradigm change in EU climate policy, nor will it lead to fundamental changes in the interaction between key players.[41] However, CO_2 removal from the atmosphere will expand the field of climate policy by increasing the number of variables. Once the concept of deliberate removal of CO_2 from the atmosphere has become normalised, it raises immediate questions of convergence and equity, primarily between member states and between emission sectors or industries: who will be allowed to stay above the zero line for longer or even permanently? Who will organise CO_2 removals, and who will pay for them?

sions thereafter", see *Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action*.

39 David Gernaat et al., "Understanding the Contribution of Non-carbon Dioxide Gases in Deep Mitigation Scenarios", *Global Environmental Change* 33 (2015): 142 – 53; Steven J. Davis et al., "Net-zero Emissions Energy Systems", *Science* 360 (2018): eaas9793; Gunnar Luderer et al., "Residual Fossil CO2 Emissions in 1.5 – 2°C Pathways", *Nature Climate Change* 8 (2018): 626 – 33; Julio Friedman et al., *Low-Carbon Heat Solutions for Heavy Industry: sources, options, and costs today.* (New York: Columbia/SIPA Center on Global Energy Policy, October 2019); Christopher G. F. Bataille, "Physical and Policy Pathways to Net-zero Emissions Industry", *WIREs Climate Change* 11, no. 2 (2020): e633.

40 Compensating for residual emissions, at least on the balance sheet, would also be conceivable for the time being if European governments and companies were once again allowed to use credits from international mitigation projects to meet their legal emission reduction obligations. In the EU this is no longer possible due to the negative experience with such mechanisms, which were laid down in the Kyoto Protocol. A change in *offsetting policy* will only be decided in the EU after a successful conclusion of the negotiations on international market mechanisms provided for in the Paris Agreement (Article 6). If such project-based credits are once again accessible to actors within the EU, a considerable part will come from the use of CDR methods, not least from re/afforestation projects, see Matthias Honegger and David Reiner, "The Political Economy of Negative Emissions Technologies: Consequences for International Policy Design", *Climate Policy* 18, no. 3 (2018): 306 – 21.

41 Due to the much larger CDR volumes, EU climate policy would be under far greater pressure to change in the event of a comprehensive, but currently not pursued, net negative strategy, see Oliver Geden, Glen P. Peters and Vivian Scott, "Targeting Carbon Dioxide Removal in the European Union", *Climate Policy* 19, no. 4 (2019): 487 – 94.

If CO_2 removal makes it possible to compensate for residual emissions so as to achieve net zero emissions, then it is obviously also conceivable that individual states or sectors (for example those with a low proportion of residual emissions or favourable conditions for the use of CDR methods) will remove significantly more CO_2 from the atmosphere than they still emit. This actor-specific net negative option would give other countries or sectors (such as those with a high proportion of residual emissions, unfavourable conditions for the use of CDR methods, or difficult economic conditions) the option of not (yet) having to reduce their emissions by 100 percent as part of an EU-wide net zero GHG emissions target.[42] When the European Council first adopted the climate neutrality target for 2050 in December 2019, Poland thus pushed through the formulation that "One Member State, at this stage, cannot commit to implement this objective as far as it is concerned".[43]

In publishing its draft EU climate change law, the Commission has taken this position into account by not proposing that all member states must be climate-neutral by 2050, but by defining climate neutrality as a target "at Union level" to be achieved by the EU as a *whole.*[44] These clauses, which are not easy to interpret for the general public interested in climate policy, allow the progressive member states of the Green Growth Group to evade, for the time being, the question of whether they are prepared to commit themselves to national reduction targets for 2050 of above 100 percent for the benefit of Poland and other potential laggards. If they did, it is questionable whether they could ever derive an economic advantage from their lead in the development of CDR methods, and if so when. An obvious solution would be to set EU-wide financial incentives for the generation of negative CO_2 and to make the resulting credits usable across countries and economic sectors. Ultimately, however, this would mean that states and companies with objectively more difficult starting conditions would have to bear higher costs. Moreover, given the current structure of EU climate policy — which organises the emission reduction obligations of states and companies by clearly allocating them to three regulatory pillars (emissions trading, effort sharing between member states, and land use/forestry) — it would have to be determined in advance which groups of actors would be obliged to supply surpluses of negative CO_2 in the long term.

42 A similar dispute may occur at the international level in the medium to long term. If the international community does indeed make serious efforts to achieve net zero GHG emissions globally, emerging and developing countries will point to the principle of *Common but Differentiated Responsibilities and Respective Capabilities* (CBDR-RC) enshrined in the UNFCCC, and expect industrialised countries to lead the way by bringing their emissions well below zero.

43 European Council, *Meeting of the European Council (12 December 2019) – Conclusions*, EUCO 29/19 (Brussels, 12 December 2019), 1.

44 *Proposal for a Regulation of the European Parliament and of the Council Establishing the Framework for Achieving Climate Neutrality and Amending Regulation (EU) 2018/1999* (European Climate Law) COM(2020) 80 final (Brussels, 4 March 2020).

Actors and Their Positions

Since the EU claims to base its climate policy on the climate science consensus developed in IPCC reports, it will no longer be concerned with whether to use CDR or not, but only how. However, in the coming years the integration of CO_2 removal may essentially remain limited to the conceptual level of modelling and not (yet) be reflected in corresponding actions — which is a widespread phenomenon in climate policy.[45] The first important window of opportunity will open up as part of the decision on tightening the EU climate target for 2030 — be it in strategic decisions on the level and structure of the target, or in the subsequent legislative procedures for amending the EU's three most important legal acts on climate policy: the Emissions Trading Directive, the Effort Sharing Regulation, and the Regulation on Land-Use, Land-Use Change and Forestry (LULUCF).

Currently, only a limited assessment is possible of how CDR will be integrated into European climate policy.

Currently, only a limited assessment is possible of how the integration of CDR into European climate policy will proceed, because many of the relevant actors in this field (the EU Commission, member states, European Parliament, neighbouring states with regulatory links to the EU, companies, and environmental NGOs) have not yet developed a substantial — and thus potentially stable — position on the role of CO_2 removal. Nor have there been any meaningful studies on public acceptance of CDR or individual CDR methods in the EU.[46]

European Commission

The Commission is one of the driving forces behind the integration of CDR into EU climate policy. More than a decade ago, it advocated for including CO_2 removal from the atmosphere in the IPCC's global mitigation scenarios. Since then, it has been instrumental in establishing the underlying modelling infrastructures in climate economics.[47] However, for a long time deliberate CO_2 removal played no part in EU-internal mitigation scenarios. This only changed in late 2018 with the presentation of a draft for a new long-term EU climate strategy, the formal launch for member states' discussions on a new EU climate tar-

45 Oliver Geden, "The Paris Agreement and the Inherent Inconsistency of Climate Policymaking", *WIREs Climate Change* 7 (2016): 790—97.

46 Surveys on the public acceptance of CDR generally suffer from the fact that the approach and individual methods are barely known and must first be explained in the surveys, with the type of explanation given in turn strongly influencing the respondents' answers. Respondents also lack a decisive point of orientation, namely the perceptible positioning of political and corporate actors with regard to CDR. Presumably the most valid statements can be made for BECCS, since its two components, bio-energy and CCS, have been part of the energy and climate policy debate for several years. Here, however, there are clear differences between European countries: for example, CCS is rated more positively in the UK than in Germany, and BECCS is rated more positively in both countries than fossil CCS, see Elisabeth Dütschke et al., "Differences in the Public Perception of CCS in Germany Depending on CO_2 Source, Transport Option and Storage Location", *International Journal of Greenhouse Gas Control* 53 (2016): 149—59; Gareth Thomas, Nick Pidgeon and Erin Roberts, "Ambivalence, Naturalness and Normality in Public Perceptions of Carbon Capture and Storage in Biomass, Fossil Energy, and Industrial Applications in the United Kingdom", *Energy Research & Social Science* 46 (2018): 1—9; Rob Bellamy, Javier Lezaun and James Palmer, "Perceptions of Bio-energy with Carbon Capture and Storage in Different Policy Scenarios", *Nature Communications* 743 (2019): 1—9.

47 Richard Moss et al., *Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies. Intergovernmental Panel on Climate Change Expert Meeting Report, 19–21 September 2007* (Geneva: IPCC, 2008); Beatrice Cointe, Christophe Cassen and Alain Nadaï, "Organising Policy-Relevant Knowledge for Climate Action — Integrated Assessment Modelling, the IPCC, and the Emergence of a Collective Expertise on Socioeconomic Emission Scenarios", *Science & Technology Studies* 32, no. 4 (2019): 36—57.

get for 2050.[48] With this strategy paper, the Commission not only anchored the net zero vision in EU climate policy, it also explicitly declared CO_2 removals to be one of its strategic priorities in pursuing a net zero policy. The main focus of future mitigation efforts will certainly continue to be on avoiding GHG emissions. However, the amounts of residual emissions and corresponding CO_2 removals in 2050 will be considerable (see Figure 2).

As far as technological CDR methods are concerned, the Commission so far relies only on BECCS and DACCS, which are to be used from 2035.

By combining two different net zero scenarios (one with higher levels of technology-based CDR, and one with relatively low levels), the Commission's accompanying technical analysis assumes[49] that residual emissions of over 550 million tonnes (Mt) will be offset by CDR in 2050, which is the equivalent of about 10 percent of EU emissions in 1990. The Commission's strategy document envisages that CO_2 removals from land use and forestry should be increased again, contrary to the current trend, and that the land sink should be fully counted towards the EU climate target in the future. In emissions reporting by the EU and its member states, the (net negative) LULUCF emissions are shown separately. Until 2020, they will not be counted at all towards meeting the EU emission reduction target (20 percent). For the 2030 target (currently at 40 percent), they will be included to a small extent, but only if individual member states choose to use the individually determined maximum levels of LULUCF credits for meeting their obligations under the Effort Sharing Regulation. As far as technological CDR methods are concerned, the Commission has so far referred exclusively to BECCS and DACCS, which are expected to be deployed from 2035 onwards.[50]

While the Commission has thus conceptually upgraded the status of CDR, it is not yet possible to estimate what effect this will have in political and administrative practice. In its communication on the *European Green Deal*, CDR-relevant initiatives are not mentioned with one exception: the development of a new EU forestry strategy.[51] By contrast, the Commission's draft of the European Climate Law explicitly refers to the necessary use of "natural and technological" removal methods to achieve the goal of GHG neutrality throughout the EU.[52] Recently, measures for CO_2 removal were taken into account within the European Commission's Circular Economy Action Plan. It focuses on removal measures described as 'natural' and announces a regulatory framework for the certification of carbon removal methods by 2023.[53] This initiative was also taken up in the EU Commission's "Farm to Fork" strategy, in which the certification proposal has been complemented by the idea of using money from the Common Agriculture Policy to reward farmers and foresters who sequester carbon.[54] Large CDR research projects are already being funded under the EU's *Horizon 2020* research framework programme. The Commission is also providing political support for new projects on CO_2 capture, transport and geological storage (*Port of Rotterdam* and *Northern Lights*). It has also announced that it will support pilot and demonstration plants for CCS and CDR from the approximately €10 billion Innovation Fund, which will be part of the Emissions Trading System (ETS) from 2021.

Member States

So far, member states have given few hints on how they intend to deal strategically with CDR in the future. This will change during the negotiations on the EU Climate Law. However, member states that have already adopted national greenhouse gas neutrality targets have generally done so without detailed

48 Oliver Geden and Felix Schenuit, *Climate Neutrality as Long-term Strategy. The EU's Net Zero Target and Its Consequences for Member States*, SWP Comment 33/2019 (Berlin: Stiftung Wissenschaft und Politik, August 2019).

49 European Commission, *In-Depth Analysis in Support of the COM(2018) 773: A Clean Planet for All – A European Strategic Long-term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy* (Brussels, 28 November 2018), Table 9.

50 See ibid., 188ff.; Pantelis Capros et al., "Energy-system Modelling of the EU Strategy towards Climate-neutrality", *Energy Policy* 134 (2019): 110960.

51 European Commission, *The European Green Deal*, COM(2019) 640 final (Brussels, 11 December 2019).

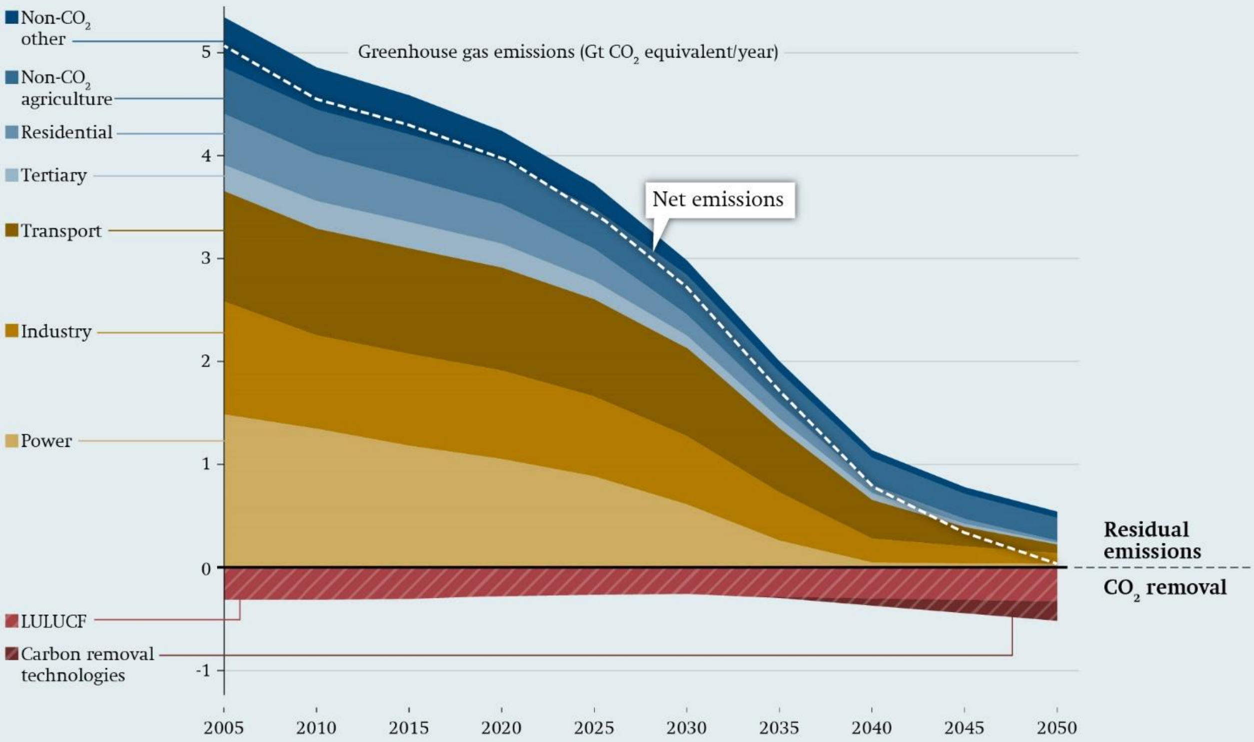
52 European Commission, *Proposal for EU Climate Law* (see note 44).

53 European Commission, *A New Circular Economy Action Plan: for a Cleaner and More Competitive Europe*, COM(2020) 98 final (Brussels, 11 March 2020).

54 European Commission, *A Farm to Fork Strategy for a Fair, Healthy and Environmentally-Friendly Food System*, COM(2020) 381 final (Brussels, 20 May 2020).

Figure 2

Illustrative emissions pathways to achieve a net-zero target in the EU



Source: European Commission, *A Clean Planet for All. A European Strategic Long-term Vision for a Prosperous, Modern, Competitive and Climate-neutral Economy*, COM(2018) 773 (Brussels, 28 November 2018).

consideration of the level of residual emissions that can be expected in the first net zero year, or how the corresponding CO_2 removals are to be realised. So far, announcing a national net zero target has been primarily an act of political marketing. Although the governments of Sweden (2045), Portugal (2050), France (2050), Finland (2035), Germany (2050) and Austria (2040) have already decided on national net zero targets, none of these countries has a plan for a dedicated national CDR policy yet. Accordingly, there is also a lack of active positioning on this issue at the EU level.[55]

However, governments often also develop their position reactively, in relation to specific Commission plans or the positions of other member states. Particular importance is likely to be attached to the future stance of those member states whose current emis-

55 National Energy and Climate Plans (NECP), whose submission by the end of 2019 was mandatory as part of the Regulation on the Governance of the Energy Union, only have a time horizon of 2040 for emission projections, and generally contain only brief references to deliberate CO_2 removal policies. While technological CDR options are barely mentioned, the (potential) sink performance of land use and forestry plays a far greater part, albeit mostly in the context of meeting national commitments under the LULUCF Regulation. Draft NECPs had to be submitted by the end of 2018 and were subsequently evaluated by the Commission. The European Council's commitment to a European *net zero target* for 2050, first made on 12 December 2019, had no influence on the NECPs, which were submitted on time by the end of 2019 and usually comprise several hundred pages. Even the NECPs which were submitted, significantly late, in the first half of 2020 make only cursory references to the EU-wide GHG neutrality target. Germany and Luxembourg submitted their plans six months late, by 11 June 2020. Only Ireland has not yet submitted its final NECP.

sion profiles indicate comparatively high levels of residual emissions, and those that for political or economic reasons are unwilling to commit to achieving net zero emissions as early as 2050. The first group includes *Ireland*, where 33 percent of total emissions come from agriculture, a large proportion of which are methane and nitrous oxide, which, if current production structures are maintained, will be difficult or impossible to eliminate. Ireland is likely to find it very difficult to fully offset the expected high levels of residual emissions with CO_2 removals,[56] all the more so since it currently belongs to the very small group of member states for which LULUCF is not a net sink but a source of emissions. In the not unlikely event of Ireland declaring itself unable to achieve net zero emissions on its national territory, the expectation would be that net negative emissions will be generated in other member states.

The second group is currently led by *Poland*, whose government, in the European Council conclusions on the net zero target for 2050, stated that it “cannot commit to implement this objective as far as it is concerned”. The Polish government has repeatedly argued in the negotiations that a national net zero level is unlikely to be achieved before 2070. From today’s perspective, this would also mean that emissions by other EU member states would have to be net negative by the middle of the century — and considerably so — due to the relatively large volume of Polish emissions.[57] For both Ireland and Poland, there are good reasons why achieving the net zero target is more challenging than for the EU average. Whether this will be recognised, and if so under what conditions, is primarily a question of the negotiating power of the governments concerned.

The fact that some EU member states — especially those in the north and west — are making greater efforts in mitigation than others is by no means new. However, the expectation, which seems paradoxical from today’s perspective, that some countries should go *below zero* before 2050 so that others can stay *above zero* (for the time being), is likely to be challenged by member states expected to be frontrunners — especially if no economic benefits can be achieved by using removal methods. However, a closer look at those countries and governments that have already adopted net zero targets shows that CDR planning is still in its infancy.

In *Austria*, the new governing coalition announced a surprisingly ambitious climate neutrality target for 2040 at the beginning of 2020, but did not outline whether the national emissions pathway should be below zero by 2050. To compensate for residual emissions, Austria will give priority to LULUCF sinks.[58] In *Finland*, the government, which took office in 2019, has agreed on a net zero target for 2035 as an intermediate step towards net negative emissions. However, the NECP does not yet contain specific measures to meet this self-imposed target. To compensate for residual emissions, Finland has declared its intention to expand sinks from land use and forestry, and has announced a separate sub-target for CO_2 removal.[59] *France* is the only EU member state to have announced in its NECP that it will use a technological CO_2 removal method to achieve its zero emissions target. In 2050, 10 Mt are to be contributed from BECCS. However, the government in Paris has not yet specified how the corresponding capacities could be built up and where the CO_2 would be stored.[60] In *Portugal*, the government committed itself in 2016 to making the country GHG-neutral by 2050, and in 2019 outlined possible ways to achieve this in a national long-term strategy. It envisages using only the LULUCF sink to compensate for residual emissions.[61]

With its Climate Change Act of December 2019, *Germany* has also expressly committed itself to the net zero target for 2050. However, it is not yet clear to what extent CO_2 removals will be necessary, and what

56 A similar problem exists in New Zealand, where the government has therefore refrained from legislating on a net GHG target for 2050. *Net zero* there refers only to long-lived greenhouse gases (such as CO_2 or nitrous oxide), while biogenic methane from agriculture is to be reduced by only 24—47 percent between 2017 and 2050.

57 After the UK left the EU, Poland became its second largest emitter, behind Germany and ahead of France and Italy.

58 ÖVP and Die Grünen, *Aus Verantwortung für Österreich. Government Programme 2020–2024* (Vienna, 2020).

59 Ministry of Economic Affairs and Employment of Finland, *Finland’s Integrated Energy and Climate Plan* (Helsinki, 20 December 2019).

60 10 Mt CO_2 corresponds to about 2 percent of France’s emissions of 1990, see Ministère de la Transition écologique et solidaire, *Projet de Plan National Integré Énergie-Climat de la France* (2019).

61 Ministry of the Environment and Energy Transition of Portugal, Fundo Ambiental and Portugese Environment Agency (APA), *Roadmap for Carbon Neutrality 2050 (RNC2050). Long-term Strategy for Carbon Neutrality of the Portuguese Economy by 2050* (Lisbon, 2020).

methods will be used to achieve them.[62] While the Climate Change Act highlights the role of LULUCF, the final NECP mentions the necessity of both biological and technical CDR methods to "close the carbon cycle" in industrial processes, but without going into detail.[63] Responses by the German government to parliamentary questions on this issue[64] suggest that the current preference is for expanding the LULUCF sink. The reason for this is not only that this sink currently accounts for only about 2 percent of 1990 emissions, far below the EU average,[65] but also the low levels of public acceptance of geological CO_2 storage in Germany, which would hinder the deployment of BECCS and DACCS.[66] The German Ministry for Education and Research recently launched two major research programmes for both marine and terrestrial CDR.

The most advanced CDR debate within the EU so far is in *Sweden*. In 2016 the country already set itself a net zero emissions target for 2045, making explicit, like Finland, its intent to generate net negative emissions thereafter. Yet when announcing the net zero target, the government only specified that 85 percent would be achieved with conventional mitigation measures. A government commission was formed in 2018 to draw up proposals on how the remaining 15 percent could be achieved. Discussions are underway, for example, on making greater use of LULUCF sinks, including the use of international project-based credits or incentivising technological CDR methods. The corresponding report was submitted in January 2020,[67] and a fundamental decision by the Swedish government on how to deal with CDR is still pending. The Climate Action Plan, which the government presented at the end of 2019, already announces a commitment to promoting BECCS. This process could be used in Sweden not only in biomass-fired power and heat plants, but also in pulp and paper plants, which are responsible for a large share of Sweden's industrial emissions.[68] If Sweden were to start counting its CO_2 removals from land use and forestry fully towards meeting its national climate target, the country could achieve net zero emissions before 2030.[69]

Neighbouring Countries with Regulatory Links

The EU's climate policy not only regulates the emission sources and sinks of its current 27 member states. It also has direct and indirect effects on a number of neighbouring European countries via regulatory links. For example, Iceland and Norway, as members of the European Economic Area (EEA), are also part of the EU Emissions Trading Scheme. From 2021 Norway, with its own national targets, will also be included in the effort sharing and LULUCF regulations. The national emissions trading system of the non-EEA member Switzerland has been linked to the EU ETS since 2020. In the case of the United Kingdom, it is considered likely that the country will be interested

62 Usually, the German Ministry for the Environment, Nature Conservation and Nuclear Safety and the German Ministry for Economic Affairs and Energy each independently commission macroeconomic mitigation scenarios. The established modelling consortia have not yet published any studies for a net 100 percent reduction by 2050.

63 See German Bundestag, "Gesetz zur Einführung eines Bundes-Klimaschutzgesetzes und zur Änderung weiterer Vorschriften, vom 12. Dezember 2019", *Bundesgesetzblatt*, part I, no. 48 (17 December 2019): 2513—21, and Bundesministerium für Wirtschaft und Energie (BMWi), *Integrierter nationaler Energie- und Klimaplan* (Berlin, June 2020).

64 German Bundestag, *Drucksache 19/7400*, 29 January 2019; idem., *Drucksache 19/14052*, 15 October 2019.

65 In 2018 the net LULUCF sink in Germany was 27 Mt.

66 Not using CCS is the position taken, for example, by the German Environment Agency (UBA), which has published the only study to date on the achievement of a net zero target for 2050 in Germany, and in which it states a priori that this target must be achieved without CCS. In its most ambitious scenario, the UBA authors assume zero macroeconomic growth from 2030, which clearly contradicts the currently dominant climate policy paradigm, Umweltbundesamt, *Resource-Efficient Pathways towards Greenhouse Gas Neutrality – RESCUE: Summary Report* (Dessau-Roßlau, November 2019); see also Dütschke et al., "Differences in the Public Perception of CCS in Germany" (see note 46).

67 Among the three options mentioned CDR is considered to have the largest potential, especially BECCS and biochar. International project credits should be possible, but as of 2045 only from CDR projects, see Statens offentliga utredningar, *Vägen till en klimatpositiv framtid* (Stockholm, 2020).

68 Anton A. Hansing and Mathias Fridahl, "European and Swedish Point Sources of Biogenic Carbon Dioxide", in *Bioenergy with Carbon Capture and Storage. From Global Potentials to Domestic Realities*, ed. Mathias Fridahl (Stockholm and Brussels: The European Liberal Forum, 2018), 31—44.

69 Sweden's emissions in 2017 were 52.7 Mt without LULUCF. If the LULUCF sink of 43.7 Mt had been fully included, the emissions would have been only 9 Mt. Compared to 1990, this would already have represented an 87 percent reduction in emissions.

in linking its new nationally organised emissions trading with that of the EU. Moreover, it is likely that a European net zero policy will also bring into focus the very large CO_2 storage capacities that Norway and the UK have under the seabed of the North Sea.[70] Due to these diverse interdependencies, an EU CDR policy will be directly and indirectly influenced by steps taken in these neighbouring countries. If Switzerland, Norway or the UK make CO_2 removal an integral part of their climate policy, this will promote similar developments within the EU.

In 2019 the *Swiss* government adopted a net zero target for 2050. The details of the new Swiss climate strategy are to be worked out in the course of 2020. In its announcement, the Swiss government already pointed out that to compensate for residual emissions, "technologies will also be used that permanently extract greenhouse gases from the atmosphere and store them" alongside international project credits and biological CO_2 sinks, and that domestic industry and research institutions will play an important role in the development of such technologies.[71] The Swiss government is thus trying to integrate CDR directly into the dominant climate policy paradigm and make it compatible with the promise of future green growth. By doing so, it is implicitly emphasising the role of *Climeworks*, a company that emerged from ETH Zurich and is one of the world's leading manufacturers of direct air capture systems.

The *UK* is currently the world's leader in integrating CDR into climate policy. This is probably due to two main factors: first, the institutionalised integration of scientific expertise into the UK's policy process, which is guaranteed by the UK Climate Change Act of 2008; and second, the traditionally high degree of technological openness in the country's climate policy. The independent Committee on Climate Change (CCC), which advises government and parliament on all aspects of climate policy and submits proposals for national emissions budgets in five-year increments,[72] already suggested in 2016 that CDR methods, and in particular BECCS, should be widely used to achieve an 80 to 90 percent reduction target by 2050.[73] The first interdisciplinary CDR research programme was launched in 2017. In the same year, the government explicitly included CDR technologies in its *Clean Growth Strategy*, while the CCC commissioned a detailed catalogue of progress indicators for CDR.[74] Not surprisingly, a CCC study commissioned by the government on the possibilities of achieving net zero at the national level by 2050 recommends the extensive use of CO_2 removal methods.[75] Following the official adoption of this target in June 2019, the government announced the following autumn that it would set up a programme to support CDR demonstration projects worth the equivalent of almost 40 million euros.[76] In contrast with other European countries, the UK already has a wealth of studies on the technical potential and regulatory incentives for the use of various CO_2 capture methods.[77] Nevertheless, the British government has not

70 These capacities would be relevant not only for CO_2 from BECCS and DACCS, but also for captured CO_2 from industrial processes, such as steel and cement production. Norway has been positioning itself as a potential recipient of CO_2 from the EU for several years now, but this would require the development of an adequate transport infrastructure, see Jo-Kristian S. Røttereng, "When Climate Policy Meets Foreign Policy: Pioneering and National Interest in Norway's Mitigation Strategy", *Energy Research & Social Science* 39 (2018). 216—25. Contrary to media reports, Norway has not yet adopted a national net zero target. There is only a parliamentary resolution to this effect, which is not considered binding by the minority government in office, see Erlend A. Hermansen, Glen Peters and Bård Lahn, "Climate Neutrality the Norwegian Way: Carbon Trading?" *CICERO* [Oslo], 17 September 2019, https://cicero.oslo.no/no/posts/nyheter/climate-neutrality-the-norwegian-way-carbon-trading (accessed 11 February 2020).

71 Swiss Federal Council, "Bundesrat will bis 2050 eine klimaneutrale Schweiz", *Federal Council press releases* (Bern, 28 August 2019).

72 Felix Schenuit and Oliver Geden, "Ein deutsches Klimaschutzgesetz nach britischem Vorbild: Voraussetzungen einer Realisierung", *Energiewirtschaftliche Tagesfragen* 68, no. 10 (2018): 16—18.

73 Committee on Climate Change (CCC), *UK Climate Action Following the Paris Agreement*, CCC Report (London, 2016).

74 UK Government, *Clean Growth Strategy. Leading the Way to a Low Carbon Future*, London 2017; Tom Berg, Goher-Ur-Rehman Mir and Ann-Kathrin Kühner, *CCC Indicators to Track Progress in Developing Greenhouse Gas Removal Options. Final Report* (Utrecht: Ecofys Netherlands, 2017).

75 Its study assumes conventional emission reductions of 89 percent by 2050 and correspondingly large CDR volumes of more than 100 Mt, see CCC, *Net Zero – The UK's Contribution to Stopping Global Warming* (London, 2019).

76 United Kingdom Research and Innovation (UKRI), *UKRI Greenhouse Gas Removal Demonstrators Call for Proposals* (Swindon, 2019), https://bbsrc.ukri.org/documents/ukri-call-for-proposals-spf-ggr-demonstrators-2019-2020/.

77 See Pete Smith, R. Stuart Haszeldine and Stephen M. Smith, "Preliminary Assessment of the Potential for, and Limitations to, Terrestrial Negative Emission Technologies yet indicated which methods it intends to prioritise or which incentive systems it intends to establish.[78]

European Parliament

Although the European Parliament is one of the more progressive players in EU climate policy, it has so far made little progress on the issue of CDR. During the negotiations on the Regulation on the Governance System for the Energy Union, which was concluded in 2018, it was the EP which succeeded in getting the Council to explicitly mention the long-term option of a European net negative emissions pathway. However, this did not result in any noticeable action on the part of the EP with regard to CDR. In its own-initiative reports, CO_2 removal has not been given priority to date. Nor has a firm CDR approach played any role in recent legislative procedures — for example, in the amendments to the Emissions Trading Directive, the Effort Sharing Regulation, and the revision of the LULUCF Regulation during the last legislative period. Currently, there is no solid evidence of how the EP in its current composition will position itself on CDR. The first indication will be the EP's negotiation position on the EU Climate Law.

Business

Within the European climate policy paradigm, business actors are addressed in two ways: as (emitting) parties responsible for the problem, and as potential drivers of innovation with green growth opportunities. The same applies to the issue of CO_2 removal. The implementation of the net zero target in almost all European countries brings with it new responsibilities, first of all the expectation that every business will explore ways of eliminating its emissions as far as possible and compensate for the remainder.[79]At the same time, there is at least an implicit assumption that there will be a significant future demand for CO_2 removal, which will also offer market opportunities to innovative companies, which far exceed their own need for offsetting residual emissions.

Apart from a few exceptions, European companies and industry associations have not yet taken a position on the CDR approach and the regulatory framework required for it.[80] One exception is the Swiss-based DAC manufacturer *Climeworks*, whose business model — filtering carbon dioxide from ambient air — can only be successful if CDR becomes an integral part of the climate policy of industrialised and emerg-

in the UK", *Environmental Science: Processes & Impacts* 18, no. 11 (2016): 1400—05; Devon Platt, Mark Workman and Stephen Hall, "A Novel Approach to Assessing the Commercial Opportunities for Greenhouse Gas Removal Technology Value Chains: Developing the Case for a Negative Emissions Credit in the UK", *Journal of Cleaner Production* 203 (2018): 1003—18; Habiba A. Daggash et al., *Bio-energy with Carbon Capture and Storage, and Direct Air Carbon Capture and Storage: Examining the Evidence on Deployment Potential and Costs in the UK* (London: UK Research Centre, April 2019); Renewable Energy Association, *Going Negative – Policy Proposals for UK Bio-energy with Carbon Capture and Storage (BECCS)*, REA Position Paper (London: Renewable Energy Association, 2019).

78 In contrast to the CCC's recommendation, the British government does not exclude the use of international project credits, but has not yet taken a position on what share these could have in achieving the target. Possible incentive systems and regulatory options for removal methods were examined by the Department for Business, Energy and Industrial Strategy (BEIS) in 2019, see Vivid Economics, *Greenhouse Gas Removal (GGR) Policy Options – Final Report* (London, 2019).

79 This is already reflected in many corporate announcements on the (imminent) achievement of carbon or climate neutrality, for example by *Bosch* (2020), *Siemens* (2030), *Mars* (2040) or *Shell* (2050). Such announcements are based on self-defined system boundaries and generally provide for the inclusion of international emission credits that are currently only weakly regulated. They are based on a voluntary approach and are thus an expression of *corporate social responsibility*. This must be strictly distinguished from future EU legislation, which will be binding as to which CO_2 removal activities and which international credits are eligible, see Burkhard Huckestein, "Klimaneutrale Unternehmen und Verwaltungen: Wirksamer Klimaschutz oder Grünfärberei?", *GAIA – Ecological Perspectives for Science and Society* 29, no. 1 (2020): 21—26.

80 The world's most ambitious announcement to date comes from *Microsoft*, which aims to achieve net negative emissions by 2030, including its entire supply chain, and without recourse to international emission reduction credits. The plans — although voluntary — envisage CO_2 removals of 5 Mt by 2030, using a broad portfolio of biological and technological methods. By 2050, *Microsoft* wants to have offset all the emissions it has caused since it was founded, see Brad Smith, "Microsoft Will Be Carbon Negative by 2030", *Official Microsoft Blog*, 16 January 2020, https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/ (accessed 11 February 2020).

ing countries. Since there are as yet no effective incentive systems for geological CO_2 storage, DAC plants can currently only be used commercially if the CO_2 removed from the air is reused, for example in the beverage industry or in refineries.[81]

Politically, companies that want to make CO_2 removal an integral part of long-established business models carry far more weight. These are found primarily in countries with net zero targets and advanced CDR debates. *Stockholm Exergi*, for example, the Swedish capital's electricity and district heating provider, is not only planning the extensive decarbonisation of its already predominantly biomass-fuelled production, but also wants to bring emissions below zero in the medium term with the help of BECCS and biochar.[82] In the UK, the operator of what used to be the country's largest coal-fired power plant, the *Drax Group*, has announced that it will gradually switch its electricity generation completely to biomass and generate net negative emissions with the help of BECCS by 2030.[83] Both companies already operate BECCS demonstration plants, but argue that government support will be required to launch commercial operations. While *Drax* expects to be able to store the captured CO_2 on UK territory, *Stockholm Exergi* plans to transport its CO_2 to Norway.

It is to be expected that companies in the energy sector would be among the CDR pioneers. The option of using BECCS in power plants still dominates CDR portfolios in climate-economic scenarios. Of the European Commission's two net zero emission scenarios, the more technology-orientated one similarly assumes that the European power sector will already remove 141 Mt CO_2 from the atmosphere in 2050. However, its industry association has not yet adopted this view: *Eurelectric's* long-term vision assumes that the European power sector can achieve net zero emissions by 2045, based on renewables and nuclear energy, but without CDR. So far, the relevant strategy documents have made no mention of the possibility that the power sector would subsequently move below zero.

The extent to which the sector could benefit financially from the use of CDR largely depends on how the relevant regulation is designed, how technology develops, and what price per negative ton of CO_2 can be obtained in the ETS. For example, the technology-orientated Commission scenario assumes that in 2050 emissions in the entire ETS will be at minus 50 Mt. Sectors such as the steel, cement, chemical and aviation industries will still be allowed some residual emissions, which the power sector will (over)compensate for with CO_2 removal.[84] Outside the emissions trading system, agriculture would also be a major consumer of negative CO_2. Emissions that are difficult or unavoidable in this sector could be offset by removal methods such as biochar or increased carbon sequestration in soils but above all by the much larger sinks in forestry.[85] Whether viable business ideas and solutions can be derived from this *modelled* constellation, is almost impossible to predict from today's perspective.[86] Nevertheless, it is foreseeable that the option of CO_2 removal will change future climate policy expectations of economic sectors and companies.

Non-governmental Organisations

Environmental NGOs do not deny that the zero emissions vision they share contains a net element, i.e. residual emissions and CDR. However, there is widespread fear among them that upgrading the CDR approach could undermine the integrity of European climate policy — either on a conceptual level or by using methods that NGOs consider problematic, especially BECCS and DACCS. Compared to the European Commission and national governments, NGOs generally advocate earlier net zero target dates and lower volumes of residual emissions or CDR. The umbrella organisation of European climate policy NGOs, *CAN Europe*, for example, is calling for a target year of

81 Christoph Beuttler, Louise Charles and Jan Wurzbacher, "The Role of Direct Air Capture in Mitigation of Anthropogenic Greenhouse Gas Emissions", *Frontiers in Climate* 1, no. 10 (2019): 1—7.

82 Fabian Levihn et al., "Introducing BECCS through HPC to the Research Agenda: The Case of Combined Heat and Power in Stockholm", *Energy Reports* 5 (2019): 1381—89.

83 "British Power Plant Promises to Go Carbon Negative by 2030", *BBC News*, 10 December 2019, https://www.bbc.com/news/business-50712500 (accessed 11 February 2020).

84 See European Commission, *In-Depth Analysis* (see note 49), Table 9.

85 To reduce the pressure on the agricultural sector, national and European agricultural associations now often attribute forestry sinks to their own sector, and sometimes also emission reductions from biomass cultivation, see, e.g., Copa-Cogeca, *Copa and Cogeca Position on Climate Action* (Brussels, September 2019).

86 *Puro.earth* is a trading platform for certified CO_2 removal credits, which has so far focused on biochar and the storage of CO_2 in durable products, with low trading volumes.

2040 and extensive decarbonisation of all emission sectors. With reference to the concept of "*nature-based* solutions" that has become popular in recent years,[87] *CAN Europe* wants to see the use of CO_2 removal methods limited to "proven" practices such as the restoration of ecosystems or increasing CO_2 storage in soils.[88] Technical methods such as BECCS or DACCS are usually not mentioned at all in position papers or are rejected as "artificial" and "risky".[89] The politically constructed dividing line between "natural" and "artificial" CDR methods is a defining element of the European NGO discourse. Only a few national organisations have dropped this line of argument, such as the British section of the *World Wildlife Fund for Nature* (WWF), in whose net zero scenario for 2045 technological methods such as BECCS and DACCS generate higher CDR volumes than ecosystem-based approaches.[90]

87 For a justification of this approach, which made it possible for NGOs to refer positively to CDR in the first place, see Bronson W. Griscom et al., "Natural Climate Solutions", *Proceedings of the National Academy of Sciences of the United States of America* 114, no. 44 (2017): 11645—50; for a discussion of the concept, see Rob Bellamy and Shannon Osaka, "Unnatural Climate Solutions?" *Nature Climate Change* 10 (2020): 98—99.

88 Climate Action Network Europe (CAN), *CAN Europe Position on Long Term Targets* (Brussels, 4 October 2018).

89 The German section of Fridays for Future does not explicitly reject technological sinks, but — in contrast with the IPCC — excludes them from the outset when defining *net zero*. The glossary for its list of demands, which includes GHG neutrality by 2035, states: "net zero: only the amount of greenhouse gases that is recaptured by natural processes (e.g. plant growth) is emitted", https://fridaysforfuture.de/forderungen/glossar/ (accessed 2 February 2020).

90 See the report by Vivid Economics, *Keeping it Cool: How the UK Can End Its Contribution to Climate Change* (London, 2018). Although the German WWF section believes there are outstanding questions on the sustainability of CCS, it does not reject CCS in principle, see WWF Deutschland, *Klimaschutz in der Industrie. Forderungen an die Bundesregierung für einen klimaneutralen Industriestandort Deutschland* (Berlin, 2019).

The CO_2 Removal Approach: Entry Pathways, Target Structure and Policy Designs

If the EU truly wants to meet its own climate policy goals, it will not be able to avoid pursuing the *unconventional* mitigation approach of CO_2 removal from the atmosphere — in addition to far-reaching conventional emission reduction measures. The general public will most likely only realise that the use of CDR methods is necessary when the EU, or at least some of its environmentally progressive member states, starts to adopt net negative targets. The removal of atmospheric CO_2 is, however, already indispensable for achieving the EU's agreed net zero target by 2050, since not all emission sources can be completely eliminated (e.g. in agriculture, the steel and cement industry, or aviation) and because these *residual* emissions must be compensated for by CDR methods.

The Commission has begun to devote significant attention to the concept of CO_2 removal. So far, however, there have at best been vague indications as to which member states, party groups, industries, businesses, and NGOs want to promote a CDR approach, what coalitions are emerging, and which methods are preferred. Since it is also difficult to predict how the individual removal methods will develop in the coming decade in terms of technology and costs, it is currently impossible to predict how the transition to a European CDR policy will take place, or how quickly.[91] Consequently, it would also be premature to draw up very detailed regulatory proposals for the EU.

Removal of atmospheric CO_2 is indispensable for attaining the EU's agreed net zero target by 2050.

The following section therefore outlines two typical variants, one cautious and one proactive, of developing an EU CDR policy in the coming decade. Our focus is on (climate) policy decisions and initial approaches to implementing them in regulation. Reliable estimates of the CDR volumes that can be realised in each case cannot be made here. Inter alia, this is due to the fact that the material effects of integrating CDR into climate policy would probably not be fully felt until the 2030s, especially with technological CDR methods such as BECCS, DACCS or enhanced weathering.

Among the governance mechanisms of EU climate policy, setting quantified medium and long-term goals is paramount, regardless of whether these are legally binding or (initially) only indicative and symbolic in nature.[92] A determining factor for whether or not the EU chooses to embark on a targeted CO_2 removal policy is therefore likely to be the following, politically still unanswered, question: which emission reduction pathway is the EU aiming for once net zero

91 See Nikolaos Zahariadis, "Ambiguity and Choice in European Public Policy", *Journal of European Public Policy* 15, no. 4 (2008): 514—30; Aleh Cherp et al., "Integrating Techno-economic, Socio-technical and Political Perspectives on National Energy Transitions: A Meta-theoretical Framework", *Energy Research & Social Science* 37 (2018): 175—90; Cameron Roberts and Frank W. Geels, "Conditions for Politically Accelerated Transitions: Historical Institutionalism, the Multilevel Perspective, and Two Historical Case Studies in Transport and Agriculture", *Technological Forecasting and Social Change* 140 (2019): 221—40.

92 Oliver Geden and Severin Fischer, *Moving Targets. Negotiations on the EU's Energy and Climate Policy Objectives for the Post-2020 Period and Implications for the German Energy Transition*, SWP Research Paper 3/2014 (Berlin: Stiftung Wissenschaft und Politik, March 2014); Claire Dupont and Sebastian Oberthür, eds., *Decarbonization in the European Union. Internal Policies and External Strategies* (London: Palgrave Macmillan, 2015).

emissions have been reached? While a net zero target logically entails the use of CDR, climate policy communication barely mentions this fact. A net negative vision, which goes one step further and is already set out in the Governance Regulation for the Energy Union, can be divided into two illustrative pathways (see Figure 3).

On the one hand, CDR volumes could be kept stable in the decades after achieving the net zero target, i.e. EU climate policy could follow a *limited CDR approach.* If residual emissions continued to decline initially (due to technical progress or changing consumption patterns),[93] EU net emissions would stabilise quite quickly. Alternatively, the EU could try to keep steadily reducing its own net emissions in line with the Paris Agreement and the IPCC's global mitigation scenarios by means of ever more CDR — i.e. to move deeper and deeper into negative territory to an extent hardly conceivable today. By pursuing a *comprehensive CDR approach*, the EU would make an important contribution to the success of international climate policy, in line with its historical responsibility and current economic potential. The EU would thus at least help to achieve the global net zero GHG emissions target (Art. 4 of the Paris Agreement) by giving emerging economies and developing countries more time to bring their emissions down to zero.[94] Should the world actually reach the global *net zero* target in the second half of the century, this would at least stop the global temperature rise.[95]

93 Detlef P. Van Vuuren et al., "Alternative Pathways to the 1.5°C Target Reduce the Need for Negative Emission Technologies", *Nature Climate Change* 8, no. 5 (2018): 391—97; Bataille, "Physical and Policy Pathways to Net-zero Emissions Industry" (see note 39).
94 Glen P. Peters et al., "Measuring a Fair and Ambitious Climate Agreement Using Cumulative Emissions", *Environmental Research Letters* 10, no. 100504 (2015): 1—9.
95 However, it is highly probable that such a stabilisation would be above 1.5°C, see Rogelj et al., "Mitigation Pathways" (see note 5). By pursuing a net negative strategy, the EU could make a significant contribution to decreasing atmospheric CO_2 concentrations again, to keep the duration of the overshoot of the targeted temperature threshold as short as possible, see Kirsten Zickfeld, Vivek K. Arora and Nathan P. Gillet, "Is the Climate Response to CO_2 Emissions Path Dependent?" *Geophysical Research Letters* 39, no. 5 (2012): 1—6; Oliver Geden and Andreas Löschel, "Define Limits for Temperature Overshoot Targets", *Nature Geoscience* 10, no. 12 (2017): 881—82; Kate L. Ricke, Richard J. Miller and Douglas MacMartin, "Constraints on Global Temperature Target Overshoot", *Scientific Reports* 7, no. 14743 (2017): 1—7.

The integration of the currently still unconventional CO_2 removal approach into climate policy will ultimately only succeed if its potential for being an irritation to the prevailing climate policy paradigm is minimised, i.e. if the paradigm is supplemented rather than undermined. In essence, therefore, neither the description of the central cause of the climate change problem nor the existing allocation of responsibility for contributions to solving the problem must change. Since emissions of greenhouse gases (and especially CO_2) are at the core of the problem, avoiding them must be given political priority over their subsequent removal. Moreover, the impression must be avoided that some member states and sectors benefit disproportionately and at the expense of other actors from the conceptual integration of CDR. By contrast, however, the EU's climate policy narrative, which has been successful so far, may need to be adapted. Two areas are of particular importance for a "paradigm-sustaining" integration of CDR into EU climate policy: the specific design of the net zero target, and the development of a basic policy design.

Entry Pathways

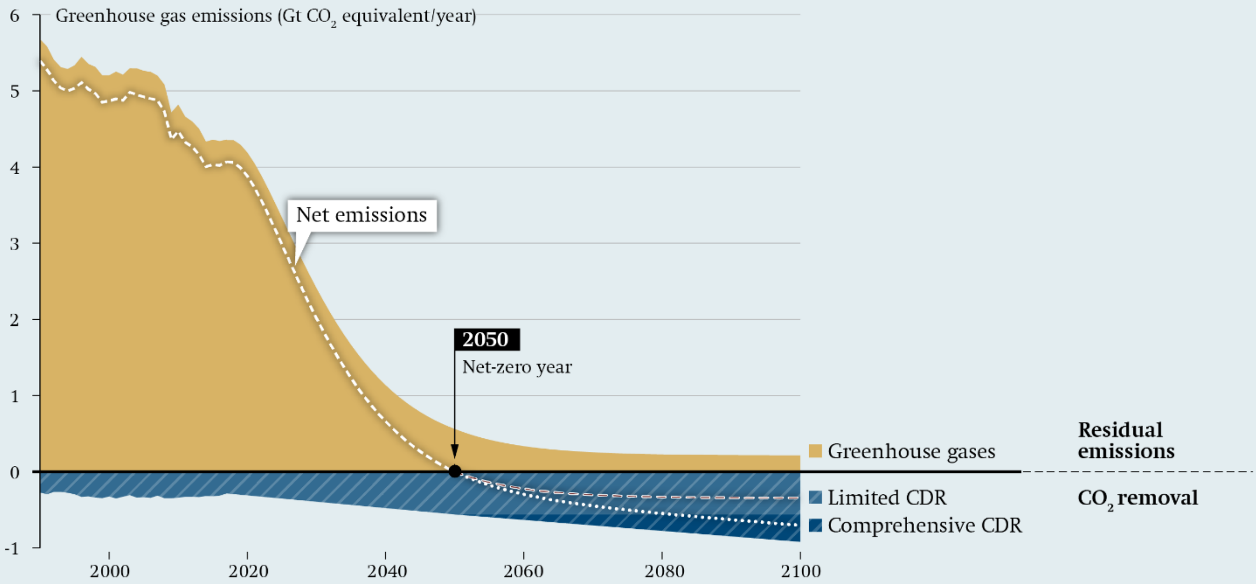
Proactive Entry

An EU climate policy that takes the goals of the Paris Agreement seriously would have to develop a proactive attitude towards CO_2 removal from the atmosphere. On a symbolic level, this could be most clearly illustrated by the EU and its member states adopting explicitly net negative targets for the second half of the century. Since the planning and implementation periods for far-reaching economic transformations are very long, a start must be made in the mid-2020s to go beyond the current planning horizon of 2050.[96] Such a decision by the European Council, the choice of such a time horizon in EU climate legislation, and the specifics of such projection periods for the NECPs in the governance regulation are conceivable. Even if the time horizon were only slightly extended, the signalling effect would be enormous. An EU target of

96 In 2009 the European Council decided for the first time on a EU emission reduction target (80—95 percent) for the year 2050, i.e. more than 40 years ahead. Many EU member states have since orientated themselves on this long-term target, and the EU's interim targets for 2020 and 2030 were also set with reference to it, though not always consistently.

Figure 3

Illustrative emissions pathways in the EU in the second half of the century



Translation and adaptation: 2020 Stiftung Wissenschaft und Politik (SWP)

Source: based on Oliver Geden, Glen P. Peters and Vivian Scott, "Targeting Carbon Dioxide Removal in the European Union", *Climate Policy* 19 (2018), 487—4, updated with data from the European Commission, *In-Depth Analysis in Support of COM(2018) 773* (Brussels, 28 November 2018).

minus 110 percent by 2060 (supplemented by member state targets) would make it obvious that the Union will have to pursue a far-reaching CDR approach.[97] It would then not only be easier to justify integrating CDR into EU climate policy in the 2020s, but also to help allay fears that the debate on CO_2 removals only serves to postpone or even defer conventional measures to reduce emissions.

An upgrading of CDR would already need to be reflected in a redefinition of the EU climate target for 2030. The EU's Nationally Determined Contribution (NDC) will be strengthened under the Paris Agreement — the EU is being put under great pressure by internal and international expectations[98] — and its key legal acts on climate policy will subsequently be amended. As part of these processes, the CO_2 removals envisaged under the LULUCF Regulation could for the first time be fully credited towards the fulfilment of the EU climate target. The fact that, on the basis of current projections, the 2030 target could be increased by four to five percentage points due to this change alone will make it even easier for the Commission and the member states to take such a decision.[99]

97 In the modelling that accompanied the Commission's draft for an EU long-term strategy, such an emission reduction pathway was already set out, see European Commission, *In-Depth Analysis* (see note 49), Table 9. Shortly before the start of the legislative process, several references to the net negative option were included in drafts of the Commission proposal for a European climate law. In the version that was finally published on 4 March 2020, no such references remain.

98 Susanne Dröge and Vijeta Rattani, *After the Katowice Climate Summit. Building Blocks for the EU Climate Agenda*, SWP Comment 9/2019 (Berlin: Stiftung Wissenschaft und Politik, February 2019).

99 Commission President Ursula von der Leyen announced even before her election that she would propose an initial increase of the EU's emission reduction target by 10 percentage points by 2030 (from 40 to 50 percent) and later examine the extent to which 55 percent is also possible. This is necessary given the strengthened 2050 target, but politically it is extremely ambitious, especially in the context of the economic upheavals caused by the COVID 19 pandemic, see

If this numerical integration of CO_2 removals into EU climate policy were to take place transparently — i.e. if the CDR share in the achievement of future EU climate targets was always made explicit — this would not only have an international and intra-European signalling effect. It would also help to legitimise specific measures to regulate CO_2 removal techniques. Definitions would be needed here both of the accounting rules and of how to integrate rising CDR volumes into the key legal acts on climate policy (ETS, ESR, LULUCF) and their interplay. Furthermore, it would have to be decided how the use of already available biological CDR methods could be stimulated in the short term; how research, development and market introduction of technological removal methods could be promoted in Europe; and how the expansion of extensive capacities for transporting and geologically storing CO_2 could be pushed forward rapidly.

Cautious Entry

It may seem appropriate for the EU to develop a proactive CO_2 removal policy if it wants its claim of pursuing a science-based climate policy to be taken seriously. However, it is equally conceivable that the EU will take things step-by-step. It is possible that the CDR approach will not (yet) be convincingly integrated into the dominant climate policy paradigm, because of extensive, and initially irresolvable, political resistance. This could, for example, focus on reservations against certain CDR methods or the (justified) fear that some of the most vocal proponents of the CDR approach will be motivated primarily by wanting to shift their responsibility for ambitious conventional emission reductions onto other actors or the distant future. Uncertainty as to whether the CDR quantities assumed in global 1.5—2°C emission scenarios are even remotely realistic or whether the (mandatory) use of CDRs will actually bring about opportunities for green growth in the long term could also prevent the EU from prioritising CDR in the coming decade. Faced with such resistance, the EU would initially refrain from an early formulation of its targets in the second half of the century. In this case, the ambiguous standard formula already in use today, *net zero by 2050, net negative thereafter*, is likely to establish itself at the EU level — even if individual progressive member states go beyond this and adopt national mitigation targets higher than 100 percent.

In this scenario, the introduction of a CDR policy would be primarily incremental. Although the importance of sinks would be more strongly emphasised, additional initiatives would essentially be limited to so called 'nature-based solutions'. The importance of LULUCF should be expected to increase only gradually in the readjustment of EU climate policy until 2030, not least because of political differences regarding accounting for ecosystem-based emission sources and sinks. Instead, international project-based credits (including those from CDR projects) are likely to become more important again in meeting European climate targets. The promotion of CCS infrastructure would essentially remain limited to emissions from industrial production processes. Although research and development of technological CDR methods would certainly be supported to a limited extent, impetus for their market launch would probably depend primarily on breakthroughs in other regions of the world. Comprehensive regulatory adjustments at the EU level would not be necessary for the time being.

Designing the Net Zero Target

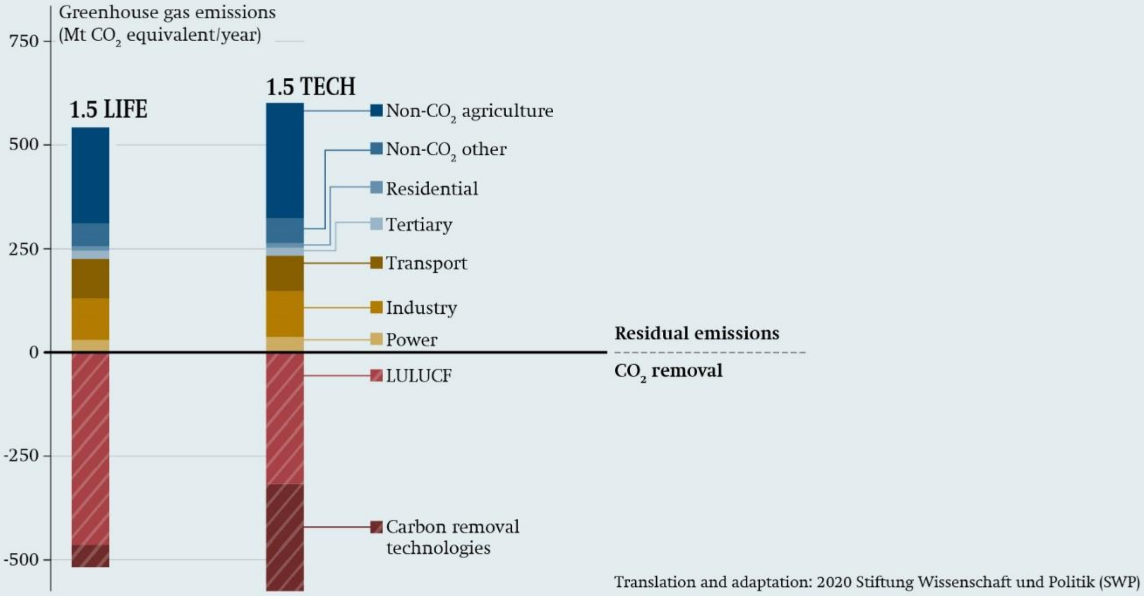
The setting of net zero targets all over the world will considerably focus the attention of climate policymakers on the emission structure of the respective target year, i.e. the relationship between residual emissions and CO_2 removals. The debate will centre, on the one hand, on the question of which sectors should be granted residual emissions, and which CDR options can be used to offset them. Structurally, this debate will not differ from the debate on setting priorities for conventional emission reduction measures, which has been ongoing for more than two decades.[100] It should lead to a "normalisation" of the CO_2 removal approach within a few years, not least due to graphical representations in the form of opposing bars or bars mirrored at the zero line (see Figure 4, p. 32). While representatives of the economic sectors concerned will argue that the scenarios drawn up

Geden and Schenuit, *Climate Neutrality as Long-term Strategy* (see note 48).

100 In these debates, there is a tendency to outline problems in such a way that they fit the preferred approaches to solving them, see Arno Simons and Jan-Peter Voß, "The Concept of Instrument Constituencies: Accounting for Dynamics and Practices of Knowing Governance", *Policy and Society* 37, no. 1 (2018): 14—35.

Figure 4

Residual emissions and CO_2 removal in the EU in 2050



Source: European Commission, *In-Depth Analysis in Support of COM(2018) 773* (Brussels, 28 November 2018), Figure 91.

by the EU Commission and national governments are setting too low a volume for residual emissions, they are likely to be thought too high by NGOs. The estimates of CDR volumes are likely to replicate such perceptions. Both sides will support their positions with their own scenarios. Again, this would mirror today's climate policy debate. However, the debate could develop into a serious problem for the political and public acceptance of the CO_2 removal approach and the international reputation of EU climate policy if the impression is created that the (planned) use of CDR methods serves above all to massively weaken the previous (planned) emission reduction pathways.

This impression, which would be fatal for climate policy, could best be countered by splitting net zero targets into emission reduction targets and removal targets, instead of simply offsetting the effects of both approaches. The continued primacy of conventional mitigation measures could thus be assured and visibly communicated.[101] However, this does not yet resolve the question of which ratio would be the most sensible to aim for, especially as the answer will vary from one member state to another and from one sector to another. Since conventional emission reductions of 80—95 percent by 2050 have so far been targeted at the EU level, a consensus would probably lie within a corridor of 80:20 percent to 95:5 percent. The scenarios of the European Commission's long-term strategy are in the order of 90:10 percent. If the 90 percent were to be understood as a minimum target for GHG reductions, any breakthroughs in CDR methods would not lead to a lowering of *conventional* emission reductions, but rather to net zero or net negative emissions being achieved earlier. With this approach, CO_2 removals would no longer seem a potentially questionable element of a covert attempt to reduce climate policy ambitions, but as a key component in increasing them.

A ratio of 90:10 could be incorporated fairly straightforwardly into the EU's climate policy narrative. Such an integration of the CDR approach into

101 Geden, Peters and Scott, "Targeting Carbon Dioxide Removal in the European Union" (see note 41); McLaren et al., "Beyond 'Net-Zero'" (see note 14). Should the EU decide to allow credits from international climate mitigation projects again, it would be worth considering only credits from CDR projects, especially those based on technological removal methods. As these have barely been used worldwide so far, the criterion of *additionality*, which was often a debatable issue under the Kyoto regime, could also be met more easily.

the EU's problem-solving paradigm could be accompanied by a new narrative element, whereby the achievement of *net zero* marks the point in time when the EU and its member states no longer use the atmosphere as a "dumping ground" for emissions.[102] This would amount to equating CO_2 and other greenhouse gases with largely avoidable waste, a small part of which can be reused and an unavoidable remainder of which must be balanced by compensatory measures. Viewing greenhouse gas emissions as a *waste management problem* could certainly be persuasive,[103] but only if the narrative can also point to a reasonably convincing practice. The EU's contribution to global problem solving could thus be decoupled in political and moral terms from the practice of less ambitious actors, under the motto "Ending our contribution to global warming".[104] In the transition from net zero to net negative emissions, the EU would then begin the phase of taking back the "waste" already released into the atmosphere.

The Main Features of Policy Design

A wide range of measures is conceivable for creating incentives for targeted CO_2 removal. Dedicated regulatory steps at the EU level will be taken in the coming decade, not least at the instigation of proactive member states and companies. Nevertheless, it makes sense not only to shape the development of an EU CO_2 removal policy in response to bottom-up initiatives, but also to steer it into productive channels through carefully prepared policy design. For example, it is certainly sensible to provide additional funds for research and development and to design innovation processes;[105] to take additional measures to expand the sink potential in land use and forestry;[106] to create financial incentive systems for CO_2 removal;[107] or to promote the embedding of technological CDR methods in global governance structures[108] — yet the strategic frameworks for this do not exist. This applies first and foremost to the question of how responsibilities will be distributed among member states and among individual sectors, but also to possible decisions on which CO_2 removal methods are (provisionally) preferred. While the European Commission recently announced plans for concrete steps (e.g. developing a framework for carbon removal certification in the land sector, and payments for farmers and foresters), these initiatives are not being politically discussed, let alone implemented.

The EU should not allow any member state to reach *net zero* more than 10–15 years later than the average.

If *net zero* at the EU level does not mean that all member states and sectors have to be at zero in the collective target year, the relationship between leaders to laggards should be defined. Even if there are good reasons why individual countries and sectors reach the zero line later than the EU average, any deviation from the average should at least be limited or compensated for financially. Since it should be possible for all member states to bring their emissions to at least *net zero* in the long term, the EU should start to limit the delay, i.e. not allow any member state to reach *net zero* more than 10 — 15 years later than the average. The success of the *net zero* project must not be jeopardised by the fact that citizens in the pioneering European states are getting the impression that they are — to continue the *waste management* metaphor — permanently responsible for cleaning up the waste of other EU member states.

102 Ottmar Edenhofer, Christian Flachsland and Steffen Brunner, "Wer besitzt die Atmosphäre? Zur Politischen Ökonomie des Klimawandels", *Leviathan* 39 no. 2 (2011): 201 — 21.
103 Klaus S. Lackner and Christophe Jospe, "Climate Change Is a Waste Management Problem", *Issues in Science and Technology* 33, no. 3 (2017).
104 The UK Committee on Climate Change has successfully focused on the slogan "Ending the UK's contribution to global warming" in its net zero study (see note 75). However, by doing so, the CCC downplays the dimension of historical emissions which, due to the longevity of CO_2, will still have an impact on the climate even after *net zero* has been reached.
105 Nemet et al., "Negative Emissions — Part 3" (see note 6); Max Åhman, Jon Birger Skjærseth and Per Ove Eikeland, "Demonstrating Climate Mitigation Technologies. An Early Assessment of the NER 300 Programme", *Energy Policy* 117 (2018): 100 — 107; Per Ove Eikeland and Jon Briger Skjærseth, *The Politics of Low-Carbon Innovation. The EU Strategic Energy Technology Plan* (Cham: Palgrave Macmillan, 2020).
106 Gert-Jan Nabuurs et al., "By 2050 the Mitigation Effects of EU Forests Could Nearly Double through Climate Smart Forestry", *Forests* 8, no. 484 (2017): 1 — 14.
107 Platt, Workman and Hall, "A Novel Approach" (see note 77).
108 Asbjørn Torvanger, "Governance of Bio-energy with Carbon Capture and Storage (BECCS): Accounting, Rewarding, and the Paris Agreement", *Climate Policy* 19, no 3 (2019): 329 — 41.

As for the relationship between *sectors*, however, it will not be possible in the foreseeable future to establish a similar obligation for all laggards. While the steel, cement and aviation industries are likely to be primarily concerned in the long term with the cost level of technical decarbonisation options like 'green hydrogen' (whose marketability will depend not least on the level of CO_2 pricing and other support measures),[109] there are technical feasibility limits in agriculture, in particular.[110] Here, care must be taken to ensure that sectors which in principle must be allowed residual emissions are themselves responsible for the corresponding CO_2 removals, regardless of whether they purchase certificates from other sectors (e.g. electricity or forestry) or invest directly in CO_2 removal methods, which is particularly appropriate in the agricultural sector.[111]

The allocation of responsibilities must be organised and regulated via the established pillars of emissions trading, member state effort sharing (for non-ETS sectors such as transport, buildings and agriculture), and land use/forestry. While emissions trading is harmonised across Europe and controlled by a single reduction factor for certificates and the resulting prices, the other two pillars still have politically negotiated targets that can differ substantially across member states. There is currently only limited flexibility between the three pillars, and the (political and financial) abatement costs for an additional tonne of CO_2 vary widely. If the EU does not want to move to emissions trading for nearly all sectors in the long term — which cannot be in the political interest of the member states lagging behind as long as they are able to negotiate advantageous national targets — it will sooner or later have to define which pillars (and thus, which groups of actors) will primarily be in charge of organising CO_2 removals from the atmosphere.

In the short term, such a complex decision could be postponed if the EU relied exclusively on expanding LULUCF sinks, possibly with more stringent national minimum targets as early as 2030. Such a preference for biological sinks could reasonably be justified with the argument that CDR methods already in use are ready for application (afforestation, restoring ecosystems, increased sequestration of carbon in soils), and also with reference to the presumably higher levels of public acceptance for these methods compared to technological sinks — the recent announcements by the Commission point towards this development.[112] In the medium term, however, the EU will not be able to avoid integrating technological sinks into its climate policy. Based on the current state of the debate and the first demonstration plants in individual member states, these will probably mainly involve BECCS and DACCS, but possibly also enhanced weathering of mineral rocks. Any preferences could be governed by differentiating a CO_2 removal target into specific sub-targets for ecosystem-based and technological processes. Reservations against individual CDR methods need not result in explicit exclusions. It would be enough not to define accounting rules for them.[113]

For many observers — especially those who are not primarily concerned with climate policy — it may

109 Davis et al., "Net-zero Emissions Energy Systems" (see note 39); Yoichi Kaya, Mitsutsune Yamaguchi and Oliver Geden, "Towards Net Zero CO_2 Emissions without Relying on Massive Carbon Dioxide Removal", *Sustainability Science* 14, no. 6 (2019): 1739—43; Bataille, "Physical and Policy Pathways to Net-zero Emissions Industry" (see note 39).

110 Given current production structures and consumption patterns, this especially applies to methane emissions from livestock. The extent to which far-reaching changes can be expected in this area cannot be predicted. Trying to bring about a significant reduction in meat consumption through climate policy measures is likely to reach the limits of feasibility, see Jessica Jewell and Aleh Cherp, "On the Political Feasibility of Climate Change Mitigation Pathways: Is It Too Late to Keep Warming Below 1.5°C?" *WIREs Climate Change* 10, no. e621 (2019).

111 E.g. by processes such as increased carbon sequestration in soils, biochar burial, or the application of minerals for enhanced weathering, see Pete Smith et al., "Land-Management Options for Greenhouse Gas Removal and Their Impacts on Ecosystem Services and the Sustainable Development Goals", *Annual Review of Environment and Resources* 44, no. 1 (2019): 255—86.

112 The acceptance of individual CDR options is likely to vary significantly between member states or even between regions.

113 It is already possible to operate BECCS plants, for example to produce electricity. However, under the current ETS rules, an operator would receive no compensation for the CO_2 removed from the atmosphere. To make this possible, new crediting rules would have to be established, which differentiate not only between individual BECCS processes, but also between the specific life-cycle emissions of the biomass used in each case. The latter differ considerably depending on whether the biomass is grown and imported for energy purposes or is a residue from domestic forestry, see Mathilde Fajardy et al., *BECCS Deployment: A Reality Check*, Briefing paper no. 28 (London: Grantham Institute, January 2019).

seem audacious to start thinking now about what emissions pathway the EU should follow after 2050. However, it makes a significant difference when looking at the challenge of integrating CDR today, because it influences the decision between a proactive and a cautious pathway. Since CO_2 sequestration in soils and forests is associated with natural saturation effects, it cannot simply be assumed that a biological sink performance achieved in 2050 can be repeated in each subsequent year. Even if the EU "only" wanted to achieve net zero emissions in the long term, it is unlikely that the additional land required for this purpose would be available throughout the second half of the century. Moreover, along with rising temperatures comes a risk that the capacity of ecosystems to act as a CO_2 sink will decline. If Europe wants to live up to its responsibility for achieving global climate targets and therefore pursue an ambitious net negative strategy in the long term, there will be no way around the increased use of more easily scalable technological CDR methods and permanent geological CO_2 storage.[114] While climate policymakers and public officials should always take this into account when planning to set up and expand CO_2 removals, they must also avoid overburdening the public and non-specialist politicians with extremely ambitious net negative targets, which would mean challenging the largely successful problem-solving paradigm. The straightforward necessity of making CO_2 removal an integral part of EU climate policy as part of a net zero strategy offers an opportunity for proceeding sequentially.[115] The first priority should be to invest more in research and development of CO_2 removal methods, to gain more practical experience of their use, and to "normalise" CDR discursively and practically. Only if the EU and its member states actually succeed in convincingly combining conventional emission reductions and unconventional CO_2 removals on the road to *net zero* will Europeans one day dare to pursue an ambitious net negative strategy as a second step, i.e. to expand CO_2 removals to an extent not yet imaginable.

114 Royal Society and Royal Academy of Engineering, *Greenhouse Gas Removal* (see note 16). Given the relatively high land requirements associated with afforestation measures, the question of the *land footprint* of alternative removal methods is likely to become a key issue, including the extent to which land from non-EU states should be used, for example for growing the biomass required for BECCS, cf. Mathilde Fajardy, Solene Chiquier and Niall Mac Dowell, "Investigating the BECCS Resource Nexus: Delivering Sustainable Negative Emissions", *Energy & Environmental Science* 11 (2018): 3408–30.

115 Geden, "An Actionable Climate Target" (see note 10); Joeri Rogelj et al., "A New Scenario Logic for the Paris Agreement Long-Term Temperature Goal", *Nature* 573 (2019): 357–63.

Abbreviations

BECCS	Bio-energy with Carbon Capture and Storage
CCC	Committee on Climate Change (UK)
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CDR	Carbon Dioxide Removal
CO_2	Carbon Dioxide
DAC	Direct Air Capture
DACCS	Direct Air Carbon Capture and Storage
EEA	European Economic Area
ESR	Effort Sharing Regulation
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse Gases
Gt	Gigatonnes
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change and Forestry
Mt	Megatonnes
NECP	National Energy and Climate Plan
UNFCCC	United Nations Framework Convention on Climate Change