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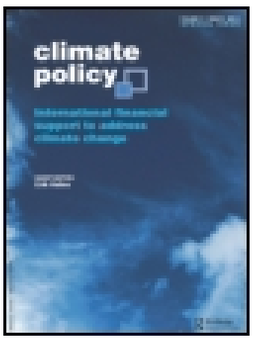

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OUTLOOK ARTICLE

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Targeting carbon dioxide removal in the European Union

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ABSTRACT

In principle, many climate policymakers have accepted that large-scale carbon dioxide removal (CDR) is necessary to meet the Paris Agreement's mitigation targets, but they have avoided proposing by whom CDR might be delivered. Given its role in international climate policy, the European Union (EU) might be expected to lead the way. But among EU climate policymakers so far there is little talk on CDR, let alone action. Here we assess how best to 'target' CDR to motivate EU policymakers exploring which CDR target strategy may work best to start dealing with CDR on a meaningful scale. A *comprehensive CDR* approach would focus on delivering the CDR volumes required from the EU by 2100, approximately at least 50 Gigatonnes (Gt) CO_2, according to global model simulations aiming to keep warming below 2°C. A *limited CDR* approach would focus on an intermediate target to deliver the CDR needed to reach 'net zero emissions' (i.e. the gross negative emissions needed to offset residual positive emissions that are too expensive or even impossible to mitigate). We argue that a *comprehensive CDR* approach may be too intimidating for EU policymakers. A *limited CDR* approach that only addresses the necessary steps to reach the (intermediate) target of 'net zero emissions' is arguably more achievable, since it is a better match to the existing policy paradigm and would allow for a pragmatic phase-in of CDR while avoiding outright resistance by environmental NGOs and the broader public.

Key policy insights

- Making CDR an integral part of EU climate policy has the potential to significantly reshape the policy landscape.
- Burden sharing considerations would probably play a major role, with comprehensive CDR prolonging the disparity and tensions between progressives and laggards.
- Introducing limited CDR in the context of 'net zero' pathways would retain a visible primary focus on decarbonization but acknowledge the need for a significant enhancement of removals via 'natural' and/or 'engineered' sinks.
- A decarbonization approach that intends to lead to a low level of 'residual emissions' (to be tackled by a pragmatic phase-in of CDR) should be the priority of EU climate policy.

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Most modelled emission scenarios that meet the Paris Agreement's objective of limiting global temperature increase to well below 2°C and possibly even 1.5°C include large-scale deployment of carbon dioxide removal (CDR) throughout the twenty-first century (Minx et al., 2018; Smith et al., 2016). While widely applied

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in scenarios, development of negative emissions technologies is in its infancy, and no party to the Paris Agreement is presently pursuing substantial research and development or regulatory support in this area. Informed by both the Fifth Assessment Report and the Special Report on 1.5°C of the Intergovernmental Panel on Climate Change (IPCC), it appears that climate policymakers accept the necessity of CDR to meet the Paris Agreement's targets. But at least so far, they have avoided proposing how and by whom it might be delivered (Fridahl & Lehtveer, 2018; Peters & Geden, 2017).

The history of the international climate change negotiations suggests that the EU might be expected to take leadership in CDR development. Globally, the EU remains one of the largest emitters, EU member states carry a high degree of historical responsibility, and the EU praises itself for climate leadership in the international arena (Oberthür & Groen, 2017). But at the same time, there is currently little talk on CDR among EU climate policymakers, let alone meaningful action. Unsurprisingly, the broader public is largely unaware that CDR will be necessary to meet the objectives of the Paris Agreement.

In June 2018, EU lawmakers struck a deal on the Energy Union Governance Regulation, which contains – among many other things – a call on the European Commission to analyse scenarios for generating negative emissions in the EU in the second half of the century, to be presented in the context of the Commission's proposal for a new EU Long-Term Climate Strategy. This was the result of a broader proposal put forward by the European Parliament in January 2018 which did not lead to any subsequent political debate on CDR. Therefore, it seems premature to already invest much intellectual capital into detailed considerations on how to regulate CDR in the EU (Lomax, Workman, Lenton, & Shah, 2015). The first step should be to create the still-missing political signal that the EU – first and foremost the governments of the 28 (soon 27) Member States – really wants to make CDR an integral part of its climate policy. Therefore, we assess how best to target CDR in the EU.

Hesitating to accept the need for CDR

Integrated Assessment Models (IAMs) currently find that for meeting a 2°C target (defined as a radiative forcing of 2.6 W/m^2 in 2100), global CO_2 emissions will have to reach net zero between 2065 and 2080. *Net-zero emissions* represent a balance between sources and sinks of CO_2 (Anderson & Peters, 2016; Peters & Geden, 2017), implying that there remain some gross positive emissions (*sources*) that need to be offset by gross negative emissions (*sinks*). Gross positive emissions represent continued emissions from fossil fuel use, industrial processes or agriculture that may be prohibitively expensive or even impossible to mitigate (*residual emissions,* see Davis et al., 2018; Luderer et al., 2018). Gross negative emissions could come from both natural (e.g. ecosystem restoration) or engineered sinks (e.g. direct air capture and storage). *Net-negative emissions* occur when the gross negative emissions exceed the gross positive emissions, i.e. when the sinks exceed the sources.

IAMs find that keeping the temperature increase to well below 2°C requires gross negative emissions to start in the 2020s and reach cumulative volumes of around 670 Gt CO_2 [range 320–840] by 2100. The cumulative gross negative emissions for meeting a 1.5°C target are even larger, with around 810 Gt CO_2 by 2100 [range 440–1020] (Smith et al., 2017). These numbers do not represent strict minimum requirements for CDR. They are based on macro-economic and technological assumptions regarding cost-effective mitigation pathways and levels of residual emissions deemed too difficult or even impossible to eliminate (Luderer et al., 2018; Obersteiner et al., 2018; Strefler et al., 2018). Furthermore, the later the global emissions peak, and the slower they decrease thereafter, the more CDR will be needed to make up for a temporary overshoot of carbon budgets or targeted temperature levels (Geden & Löschel, 2017).

So far, in contradiction with its potential role as a leader in this domain of climate policy, the EU seems rather unmoved by technical assessments of the requirement for substantial CDR to meet global climate stabilization objectives. Among policymakers, there is almost no debate on the need for intentional human efforts to remove large amounts of CO_2 emissions from the atmosphere (Minx et al., 2018), let alone on the benefits and risks of individual CDR techniques like bioenergy combined with carbon capture and storage (BECCS), direct air capture and storage, soil carbon sequestration or afforestation/reforestation (European Academies Science Advisory Council, 2018; Fuss et al., 2018; Schäfer et al., 2015; Smith et al., 2016, 2017; The Royal Society & Royal Academy of Engineering, 2018; Williamson, 2016). However, experience shows that transitions of large-scale

energy systems do not solely follow complex modelling studies but result from national or regional political and economic considerations. For example, the failure of the envisaged contributions towards energy sector decarbonization from nuclear energy and CCS technologies is underpinned by factors beyond deficiencies in market design and regulation (Scott, 2013).

To assess whether and how CDR could enter the sphere of EU climate policymaking it is necessary to consider how certain CDR approaches – most of them still largely unknown to policymakers and the larger public – might align with existing European and national political preferences or economic interests. Furthermore, there is also a need to examine how a CDR approach could potentially fit into the EU's policy narrative that emissions reductions 'in line with science', combined with support for low-carbon technologies, will eventually achieve global climate stabilization, and simultaneously deliver green growth (Scott & Geden, 2018).

Making CDR an integral part of EU climate policy has the potential to significantly reshape the landscape of this policy domain, by introducing a new set of technologies, creating new distributional conflicts, and maybe even obstructing conventional mitigation efforts by shifting the focus towards speculative solutions in the distant future (Larkin, Kuriakose, Sharmina, & Anderson, 2018; Minx et al., 2018; Shue, 2018). As a result, progressive EU policymakers appear reluctant to accept the CDR challenge, despite years of modelling studies showing that meeting ambitious temperature targets requires high levels of CDR, even under the most optimistic assumptions regarding lifestyle changes (van Vuuren et al., 2018) or very low energy demand (Grubler et al., 2018). But in real-world policymaking, solutions are rarely derived exclusively from appropriate problem descriptions. Sometimes preferred solutions effectively 'chase' after fitting problems (Beland & Howlett, 2016). If solutions like BECCS or other CDR techniques are seen as politically or economically unattractive, then key actors will tend to reframe the climate policy challenge in ways that avoid discussion about the need for CDR. In policymaking, consistency between talk, decisions and actions might be the cultural norm, but inconsistency is its modus operandi (Brunsson, 2007).

Targeting CDR

The most established way of governing in EU climate and energy policy is to first set specific headline targets (legally binding or only indicative) at the level of heads of state and governments, followed by negotiations on legal acts regulating instruments and incentives (Geden & Fischer, 2014) – the most far-reaching one being the EU's current long-term emissions reduction target of 80–95% by 2050 relative to 1990 emissions. Any introduction of a new macro-policy strategy or a new object of EU climate governance is likely to follow that path. Because of policymakers' widespread reluctance to deal with CDR, the EU is well-advised to look for a way of targeting CDR that does not present a fundamental challenge to its existing climate policy paradigm – the dominant cognitive model of problem-solving that conditions choices and frames potential opportunities by shaping the boundaries of what is thinkable, possible, or acceptable (Burns, Calvo, & Carson, 2009). The choice of a long-term emissions reduction target plays a major role in this respect. Not only does it fulfil an important declarative and symbolic function, but it also gives guidance for appropriate problem-solving activities. Under the current 80–95% target, it is not imperative to discuss CDR politically since this ambition level can in principle be achieved through conventional mitigation measures alone. Only more ambitious targets, essential to achieve the Paris Agreement's temperature goal, can ensure that CDR will enter the EU's climate policy agenda.

Comprehensive CDR approach

IAMs in 2°C scenarios indicate that the EU would be one of the largest CDR contributors over the course of the twenty-first century, delivering cumulative CDR of at least 50 Gt CO_2, more than ten times the EU's current annual emissions, but not more than 10% of the estimated global CDR volumes (Peters & Geden, 2017; Vaughan et al., 2018). A *comprehensive CDR* approach would embrace this challenge by openly acknowledging that the EU would have to reach reduction targets of far more than 100% in the second half of the century to help limit the global temperature increase to no more than 2°C, and that this is only possible with huge amounts of CDR. While there cannot be a scientifically derived, exact number for the EU's 'fair share' of global CDR

deployment, it is clear that aiming for such enormous volumes would have the potential to shift the European climate policy landscape drastically and could render such an approach politically infeasible.

Taking a CDR requirement of at least 50 Gt until 2100 seriously, and given that most CDR techniques are still in their infancy, the EU would have to admit that it is highly uncertain if and how it could meet such a CDR target, including comparatively high costs and under-researched side effects of deploying different technologies (Fuss et al., 2018). Furthermore, suddenly acknowledging the need for such high volumes of CDR means admitting (partial) policy failure, at least at the global level. But even if EU policymakers manage to avoid being blamed for such a failure (Howlett, 2014), then the media and the broader public might ask why the EU itself should carry the burden of becoming a global frontrunner in CDR. If the EU is seen as a front runner in conventional mitigation, then it could be viewed that an aggressive CDR approach essentially consists in offsetting the emissions of laggards (e.g. the United States). It is also highly questionable that the EU would be able to integrate a *comprehensive CDR* approach into its green growth storyline. How could the EU benefit economically from delivering 50 Gt or more of CDR?

Burden sharing considerations would probably play a major role in a political debate on CDR. Within the current paradigm (without considering CDR) the *zero line* – reached by reducing emissions by 100% – is the conceptual reference point beyond which gross positive emissions can no longer be reduced. Some North-Western EU Member States would be expected to reach zero emissions first, with the less advanced economies from Central and Eastern Europe (CEE) eventually obliged to follow. *Convergence towards zero* thus implies a pioneering role for a limited period, not only within the EU but also for the EU as a whole in the international arena. Conceptually expanding the scope of mitigation policy by entering *negative territory* (Meadowcroft, 2013) – assuming that emission reductions of more than 100% are possible and worthwhile – could thus perpetuate differentiated responsibilities.

If the EU agreed to a reduction target of, say, 130% by 2100 compared to 1990, relative latecomers from CEE Member States will very likely continue to expect climate-progressive Member States in the North-Western part of the EU to lead the way – then into negative territory. This does not mean that CEE countries would oppose deploying CDR measures as such. Traditionally, they have highlighted the role of forests as carbon sinks, an already politically challenging issue since it is often seen as an attempt to avoid energy sector decarbonization (Böttcher & Graichen, 2015; Dooley & Gupta, 2017). CEE governments could also be open to the introduction of BECCS via biomass co-firing (Sanchez & Kammen, 2016). But it is unlikely that current CEE governments would see CDR as a possibility to strengthen their overall ambition levels. Instead, they might find CDR – or the promise thereof – attractive as a means to partly substitute conventional mitigation measures.

Similar tensions should also be expected between different economic sectors, such as between electricity generation and transportation. It is not at all clear that taking CDR seriously would result in a distributional logic where every country, sector and company would still reach conventional emissions reductions of (almost) 100%, while some go beyond to effectively deliver the net negative emissions necessary for the EU to reach levels of, say, 130% reductions. The *mitigation disparity* between actors could be much larger, depending on national and sectoral circumstances, cost–benefit assessments and the outcome of political negotiations. Indeed, political discussion of *comprehensive CDR* might well garner support from ulterior motives seeking to exploit CDR conceptually, to gain room for manoeuvre in near-term mitigation obligations.

Recent cost-optimising energy system modelling studies suggest that the EU could already reach CDR levels approaching 1 Gt CO_2 per year by 2050, to be delivered through power sector deployment of BECCS (Bollen & Aalbers, 2017; Solano Rodriguez, Drummond, & Ekins, 2017). Allowing for the cost-effective application of BECCS in an EU emissions scenario that delivers an overall 80% reduction by 2050 would lead to huge mitigation disparities among sectors. While power sector emissions would already decrease by 152%, the transport, buildings and industry sectors would have to deliver reductions of only 10%, 36% and 65% (Solano Rodriguez et al., 2017). While this could be interpreted as an economically efficient approach by some, it is more likely that many in the climate policy community, first and foremost NGOs, would be successful in framing this disparity as a prime example of a 'moral hazard' in EU climate policy: betting on future negative emissions (Anderson & Peters, 2016; Fuss et al., 2014; Kartha & Dooley, 2016) – if not 'geoengineering' (ETC Group, Biofuelwatch, & Heinrich Böll Foundation, 2017) – in one sector, while letting all the others more or less 'off the hook'.

An EU approach that tries to target CDR volumes broadly consistent with global 2°C pathways (be it more than 50 Gt until 2100 or 1 Gt per year by 2050 or with intermediate targets for 2030 and 2040) would be politically more than challenging. If suddenly introduced in the coming years, such a policy may not be attainable and hence not be motivating, because it is unlikely to trigger action in the short to medium term. Given that the European climate policy discourse entails a strong *either/or* distinction (policy will either succeed or fail completely) there is a huge incentive for policymakers to continue to ignore the need for CDR to meet agreed global temperature targets (Geden, 2016). Therefore, it could be politically preferable to opt for an approach that introduces CDR more modestly and keeps both expectations and potential irritations better in check.

Limited CDR approach

Different from global IAM scenarios and IAM-based national carbon budget calculations that apply equity considerations (Robiou du Pont et al., 2017) a *limited CDR* approach would not look at the whole century. Instead it would focus on the path towards 'net zero' emissions. Putting the Paris Agreement's Article 4 target of reaching a balance between emissions and removals in the second half of the century centre stage, the focus would not be on generating 'net negative emissions' (i.e. emissions reductions above 100%) but merely on (domestically) offsetting residual emissions until reaching net zero through comparatively limited amounts of CDR. The need for offsetting residual emissions – assumed to be too expensive or even impossible to eliminate within given timeframes – would probably arise mainly in sectors like (long-distance and heavy-duty) transport, industry or agriculture (Davis et al., 2018; The Royal Society & Royal Academy of Engineering, 2018). Introducing CDR in the context of a net zero pathway would keep a visible primary focus on decarbonization but acknowledge the need for a significant enhancement of removals via 'natural' and/or 'engineered' sinks (Smith et al., 2017).

The volumes of CDR needed for such a *limited* approach in the context of achieving and maintaining a balance of emissions and removals in the EU have not been calculated yet. Modelling of future EU climate policy trajectories has almost exclusively focused on the 80-95% by 2050 range, the target set by EU heads of state and government in 2009. A focus on net zero may bring new complications, as the required CDR would be highly dependent on the – probably politically contested – assumptions on 'residual emissions' and the exact definition of balance between sources and sinks (Fuglestvedt et al., 2018). Nonetheless, it is safe to say that the distributional effects of such an approach would be less significant, at least when compared to the *comprehensive CDR* approach. Keeping the *zero line* as the conceptual reference point for the convergence of actors' emissions reduction efforts (within the EU and globally), thereby avoiding huge mitigation disparities, would help to avoid CDR being framed as 'moral hazard'. It would also allow for extended experimentation regarding technology development, regulation and public deliberation (Bellamy, 2018) since there is much less need to come up with a 'silver bullet' early on (Lomax et al., 2015). Therefore, a *limited CDR approach* could help to integrate the concept of negative emissions into the EU's climate policy paradigm.

Even such an approach would still need considerable EU investment in research and development and at least some regulatory adjustments, first and foremost specific accounting rules for different CDR technologies (Torvanger, 2018; Zakkour, Kemper, & Dixon, 2014). To address concerns that a deliberate policy to incentivise CDR might weaken conventional decarbonization, the EU could split its 'net zero' objective into sub-targets for reducing emissions and for enhancing sinks (Meyer-Ohlendorf & Frelih-Larsen, 2017), e.g. with a 95-5% ratio that could be seen as a smooth extension of the EU's current long-term target.

Focusing on CDR in the context of 'net zero' could facilitate public authorities (perhaps at city or regional levels) and companies re-setting their objectives to go beyond present claims of '100% renewables' and aim for 'climate neutrality'. Such initiatives would probably avoid potentially controversial and complex BECCS facilities, and more likely start with extending current emissions offsetting practices like afforestation/reforestation and introducing other forms of small-scale terrestrial CDR like ecosystem restoration and soil carbon sequestration which could potentially be regulated under the recently introduced EU regulation on land-use, land-use change and forestry (LULUCF), highlighting local ecological or agricultural co-benefits (Griscom et al., 2017; Smith et al., 2017).

A sequential strategy

While a *comprehensive CDR* approach gives a much clearer picture of the challenge ahead, it also presents a significant political challenge for EU policymakers – not only regarding the expected CDR volumes but also the technology portfolios, potential distributional conflicts and 'moral hazard' concerns. A *limited CDR* approach that only addresses the necessary steps to reach the (intermediate) target of net zero emissions is arguably more achievable, since it provides a better match to the existing EU climate policy paradigm. A pragmatic phase-in of CDR would not only help avoid suspicion (if not outright resistance) of 'action deferral' by environmental NGOs and the broader public but also catalyze country- and sector-specific considerations on which technologies are best to use in tackling residual emissions (Davis et al., 2018; Luderer et al., 2018; Karlsson, Delahaye, Johnsson, Kjärstad, & Rootz, 2017; Pye, Li, Price, & Fais, 2017; The Royal Society & Royal Academy of Engineering, 2018).

Conceptually combining CDR with the logic of net zero emissions – regardless of the concrete target year, for which consensual agreement among EU heads of state and government will be difficult to find – would introduce a sequential political strategy. A decarbonization approach that intends to lead to a low level of residual emissions as soon as possible (to be tackled by a pragmatic phase-in of CDR) should be the priority of EU climate policy. Only in a subsequent step would it make sense for the EU to scale-up the deployment of CDR technologies considerably. Aiming for a *comprehensive CDR* approach with net negative emissions (i.e. an EU emissions reduction target of more than 100%) could be an integral part of a global climate recovery strategy that helps to meet the desired temperature target of 1.5-2°C. But to be successful, such a strategy needs to be based on a much enhanced level of regulatory and technical expertise (Nemet et al., 2018) and on a much higher level of trust that CDR can be a credible climate policy approach.

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