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Acknowledgements
The authors thank K. Caldeira for discussion and feedback.

Additional information
Supplementary information is available in the online version of the paper.

Competing financial interests
C.L.Z. began work on this analysis while a researcher at Harvard. She now works for the Open Philanthropy Project, which subsequently became a funder of Harvard's Solar Geoengineering Research Project, co-directed by D.W.K. and G.W.

COMMENTARY:

Catalysing a political shift from low to negative carbon

Glen P. Peters* and Oliver Geden

Policymakers are beginning to understand the scale of carbon dioxide removal that is required to keep global warming "well below 2 °C". This understanding must now be translated into policies that give business the incentive to research, develop and deploy the required technologies.

Following the publication of the IPCC's Fifth Assessment Report, 'negative emissions' came under intense scrutiny. The criticism mainly focused on the conceptual use of immature carbon dioxide removal (CDR) technologies to meet the 2 °C target in Integrated Assessment Models (IAMs), and on the potential risks of deploying CDR technologies at scale[1–5]. Most attention has been placed on bioenergy combined with carbon capture and storage (BECCS), a technology that both produces energy and removes carbon, and which is the CDR technology dominant in most IAMs.

The political implications of large-scale CDR have remained largely out of the debate. In principle, the governments that signed and ratified the Paris Agreement accept the IPCC consensus that CDR cannot be avoided if ambitious climate targets like 1.5 °C or 2 °C are to be met. But so far, there is no debate on the one issue that usually dominates UN climate negotiations — differentiation and burden sharing. Which countries are going to start CDR first? Which countries will deliver the bulk of the CDR? Currently, no countries have mentioned BECCS in their Nationally Determined Contributions, and only about a dozen even mention the key ingredient of carbon capture and storage.

Entering negative territory

In Paris, governments not only agreed on limiting temperature increase to "well below 2 °C" and possibly even to 1.5 °C, they also set a target of reaching a balance between emission sources and sinks in the second half of the century[6]. Officials are now learning that even if they only strive for a balance between sources and sinks, they need CDR to counteract residual emissions in hard-to-mitigate sectors, such as industrial and transport subsectors and CH_4 from agriculture. Since we have emitted so much already, CDR is also required to offset some earlier or ongoing carbon emissions. According to IAMs, CDR starts as early as 2020, reaches 10–20 $GtCO_2$ per year in 2100 (25–50% of current annual emissions), and cumulatively removes 400–800 $GtCO_2$ by 2100, a size comparable to the remaining carbon budget[7]. Most policymakers, heads of state and governments seem to be unaware of the broader political implications[8].

In policymaking, mitigation efforts are often referenced to the percentage reductions from a given base year. The (net) zero line — or reducing emissions by 100% — has been the conceptual reference point. Because UN climate negotiations are generally based on the principle of 'common but differentiated responsibilities' (CBDR), it could be expected that industrialized countries will reach the zero line earlier than emerging economies and developing countries. Aiming at net negative emissions — emission reductions of more than 100% — would probably perpetuate CBDR, both in the timing of net zero and the scale of negative emissions. New or prolonged conflicts about global burden sharing would be inevitable. Emerging and developing countries are likely to demand that industrialized countries invest more in CDR, whilst they themselves might not even reduce their own emissions to zero.

Country and sectoral distribution

Most, if not all, discussions of CDR have been at the global level. This is an unhelpful abstraction, as individual actors must deliver CDR. The next simplest form of abstraction, useful for climate policy negotiations, is the country level. To assess the potential political conflicts, we compared the output from four cost-optimal IAMs[9,10] (Fig. 1). China, the USA, the EU28 and India take the lead in ramping-up BECCS until 2050, with cumulative values of 5–10 $GtCO_2$ up until 2050 (median outcomes: China, 10 $GtCO_2$; the US and EU, 7.5 $GtCO_2$; and India, 6 $GtCO_2$). These countries also provide the largest cumulative contributions over the twenty-first century (median outcomes: China, 80 $GtCO_2$; the US, 60 $GtCO_2$; India and the EU, 50 $GtCO_2$; Brazil, 40 $GtCO_2$; and Russia, 30 $GtCO_2$), but they still represent less than half of the cumulative global CDR total.

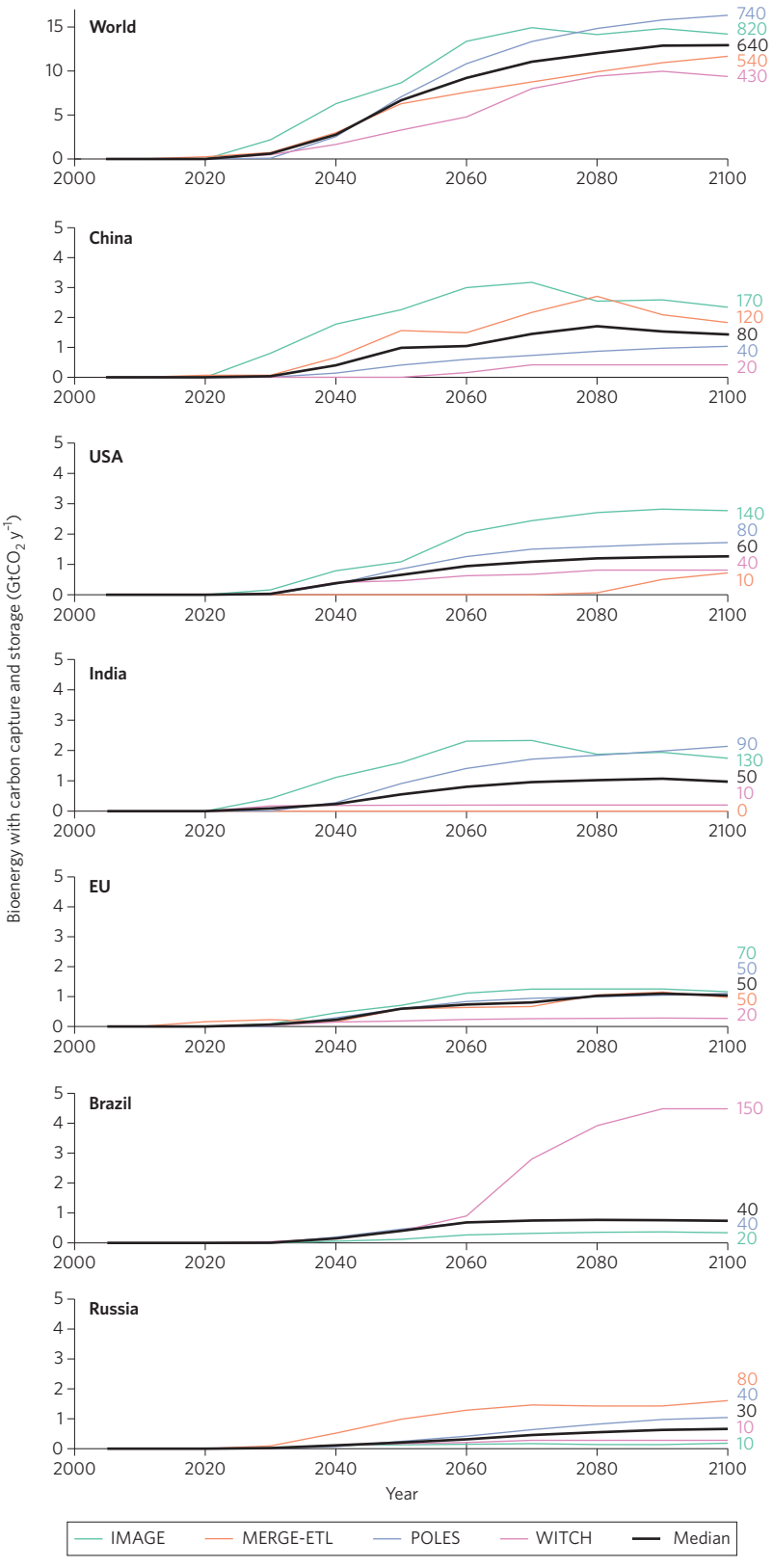

Figure 1 | The scale of bioenergy with carbon capture and storage (BECCS) across different cost-optimal integrated assessment models (IAMs) with globally harmonized climate policies starting in 2010 (refs 9,10). Different colours represent different IAMs and the black line is the median. The numbers to the right of the axis are cumulative values in 2100. Here we only intend to show the scale of the BECCS, and how it varies by country and IAM, to form the basis of policy discussions.

The output from the IAMs gives an indication of cost-optimal pathways, but these may deviate substantially from the politically optimal pathways incorporating CBDR. Even if an operational global carbon-trading system could feasibly transfer costs between countries to make it politically palatable, it is likely that countries such as India would not see it as fair. India and others would rightly argue that they should not provide BECCS at a scale similar to the EU and the US, countries that have a much larger historical contribution to current climate change[11]. Furthermore since different IAMs lead to a variety of BECCS outcomes (Fig. 1), in a political negotiation on BECCS commitments it is likely that countries will put forward modelling results that suit their strategic objectives.

Several aspects compound the distribution concerns even further. At the sector level, scenarios indicate that the power generation will provide most, if not all, the BECCS. While some sectors will continue with positive emissions, only electricity generation has net negative emissions[12] and reaches zero far earlier than at the national level. To meet the global scale required, countries that are the biggest electricity consumers must provide the bulk of the BECCS, as they have the largest capacity to remove CO_2. Countries with the largest potential to produce bioenergy, which may differ to the largest energy consumers, would experience large impacts on their land sector, further exacerbating CBDR issues.

Division of labour

The regional distribution of CDR as indicated by IAMs informs cost-optimal pathways to meet the global demand for CDR. The realized CDR will depend on how climate policies incentivize business to develop and deploy the necessary technologies[13]. Within an IAM, investment decisions are made with long-term, stable, and high carbon prices, perfect knowledge of technology costs, and perfect coordination along the international supply chain, leading to zero risk of investments failing. In practice, investment decisions are made under deep uncertainty, capturing a combination of geopolitical uncertainties, technological uncertainties, and social acceptance. Generous government support in the late 2000s was not sufficient to propel large-scale carbon capture and storage[14], with carbon prices being too low and unstable, and public opposition too high. Bioenergy has also been controversial, and compounds the risks of BECCS even further[3].

BECCS has additional complexities, since the BECCS supply chain may span several countries, requiring some harmonization in policies between countries to get incentives correct[13]. It could be that biomass harvested in Cameroon would be exported to the

UK for combustion and CO_2 capture, and then the captured CO_2 exported to Norway for permanent storage. The current method of reporting does not connect the bioenergy use in the UK with the biomass harvest in Cameroon, making it difficult to assess carbon neutrality[15]. The CO_2 from bioenergy use, currently reported as a memo in the official GHG inventories under the UNFCCC, would need some form of payment to incentivize its capture. But this payment, perhaps from the UK government or a carbon trading system, would need a guarantee that Norway has permanently stored the carbon. An entity also needs to take the liability for a potential leakage from the geological reservoir, or if the biomass is not carbon neutral.

The simple BECCS supply chain outlined here would require a detailed carbon accounting system[13] spanning three countries, over a potential period of decades (biomass growth and permanent storage). This accounting system would need to be coupled to a system of financial transfers to incentivize behaviour[16]. The entire system would require independent measurement, reporting, and verification. The accounting and financial system would have to be robustly applied across countries with vastly different motives and governance levels. Putting aside the technical and socio-political acceptability of BECCS, the governance challenges to incentivize BECCS would require resolving accounting and financial issues that remain sticking points in existing negotiations.

Political conversations

It has become clear that staying "well below 2 °C" will require the large-scale application of CDR. If this is ever to become part of a feasible climate-policy strategy, then questions of differentiated responsibilities among countries and economic sectors will be equally as important as hedging environmental side effects or bending cost curves. We suggest it is necessary to catalyse a political conversation about CDR, covering three key areas.

First, before the next round of updates to the Nationally Determined Contributions, starting with the UNFCCC's 'facilitative dialogue' in 2018, countries should begin negotiating differentiated CDR responsibilities, to indicate potential pathways to net-zero emissions and volumes of CDR that may be achieved. This can be supported by scientific studies more clearly outlining the potential scale of country-level CDR[3].

Second, develop a detailed and functional system of accounting, supported by measurement, reporting, and verification, to track carbon and financial flows along the international CDR value chain to allow governments to incentivize business to research, develop and deploy the necessary technologies.

Third, develop policy portfolios capable of incentivizing CDR, necessarily taking into account support measures that facilitate differentiated responsibilities both across sectors within countries and across countries. Policy portfolios need to go beyond encouraging boutique applications to support the necessary gigatonne scale of CDR required. ❐

Glen P. Peters is at the CICERO Center for International Climate Research, Gaustadalléen 21, 0349 Oslo, Norway. Oliver Geden is at the German Institute for International and Security Affairs, Ludwigkirchplatz 3-4, 10719 Berlin, Germany, and the Institute for Science, Innovation and Society, University of Oxford, 64 Banbury Road, Oxford OX2 6PN, UK.*
**e-mail: glen.peters@cicero.oslo.no*

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Acknowledgements

G.P.P. was supported by the Research Council of Norway (project 261785, Governance of Biomass — CCS).

Published online: 14 August 2017

COMMENTARY:

Climate risks across borders and scales

Andrew J. Challinor*, W. Neil Adger and Tim G. Benton

Changing climates are outpacing some components of our food systems. Risk assessments need to account for these rates of change. Assessing risk transmission mechanisms across sectors and international boundaries and coordinating policies across governments are key steps in addressing this challenge.

Changing climates are projected to result in novel conditions that challenge our ability to adapt. Change is already beginning to outpace the process of breeding crops and having them used by farmers[1]. The rate of change may begin to outpace other components of food systems. We already know that, without mitigation, current rates of change will significantly affect populations across the planet[2]. Keeping pace with risks in changing climates requires research and policy to have sufficient lead time to scan for and act on specific future risks.

National-level assessments of climate-change impacts and adaptation options seek to identify gaps between current policy and the policies needed to minimize