covertly, so participants know they will be held to account by other states, civil society actors and their own citizens if they fail to comply.

While this transparency may discourage faint-hearted politicians from signing up to fossil fuel bans in the first place, it also exposes them as free-riders if they don't. Such exposure will render them more vulnerable to the kinds of domestic political pressures and international social costs discussed above. In this way, transparency, domestic political mobilization and international norm diffusion combine to make fossil fuel bans a potent instrument in the climate policy toolkit. ❐

Fergus Green
London School of Economics and Political Science, London, UK.
e-mail: R.F.Green@lse.ac.uk

Published online: 14 May 2018
https://doi.org/10.1038/s41558-018-0172-3

References

1. Somanathan, E. et al. in *Climate Change 2014: Mitigation of Climate Change* (eds Edenhofer, O. et al.) Ch. 15 (IPCC, Cambridge Univ. Press, 2014).
2. March, J. G. & Olsen, J. P. in *The Oxford Handbook of Public Policy* (eds Goodin, R., Moran, M. & Rein, M.) Ch. 34 (Oxford Univ. Press, Oxford, 2006).
3. Green, F. in *Trends in Climate Change Legislation* (eds Averchenkova, A., Fankhauser, S. & Nachmany, M.) Ch. 5 (Edward Elgar, London, 2017).
4. McAdam, D. *Ann. Rev. Polit. Sci.* **20**, 189–208 (2017).
5. Ansolabehere, S. & Konisky, D. M. *Cheap and Clean* (MIT Press, Cambridge, 2014).
6. Cheon, A. & Urpelainen, J. *Activism and the Fossil Fuel Industry* (Routledge, New York, 2018).
7. Green, F. *Climatic Change* https://doi.org/10.1007/s10584-017-2134-6 (2018).
8. Collier, P. & Venables, A. J. *Oxford Rev. Econ. Pol.* **30**, 492–512 (2014).
9. Green, F. & Denniss, R. *Climatic Change* https://doi.org/10.1007/s10584-018-2162-x (2018).

Acknowledgements

For helpful comments I am grateful to R. Finighan and to participants in the Governance & Legislation Workshop at the LSE's Grantham Research Institute on Climate Change and the Environment.

Competing interests

The author declares no competing interests.

International law poses problems for negative emissions research

New international governance arrangements that manage environmental risk and potential conflicts of interests are needed to facilitate negative emissions research that is essential to achieving the large-scale CO_2 removal implied by the Paris Agreement targets.

Kerryn Brent, Jeffrey McGee, Jan McDonald and Eelco J. Rohling

Carbon dioxide removal (CDR) geoengineering refers to activities to counteract climate change by removing CO_2 from the atmosphere on a large scale. CDR geoengineering activities are aimed at achieving 'negative emissions', or a net reduction in GHG emissions in a given time period. A path of rapid decarbonization might still achieve the Paris Agreement's target of stabilizing global temperature increase at 1.5–2 °C above pre-industrial levels[1,2]. However, many of the integrated assessment models used for this target range — summarized in the IPCC's Fifth Assessment Report — suggest that on top of mitigation, negative emissions will need to commence by 2030 and occur at large scale by 2050[3]. Similar arguments have been made about reducing warming to demonstrably safe Holocene levels, rather than the more arbitrary 1.5–2 °C bounds[4].

Reliance on future negative emissions to meet the Paris Agreement targets is a risky strategy. It assumes that CDR proposals will be developed, tested and implemented at scale within the next decade. Some, such as reforestation, afforestation and soil restoration, have discrete capacities that are ready to be exploited[5]. However, only limited progress has been made in developing and testing technologies to remove CO_2 from the atmosphere and store it in terrestrial or oceanic sinks. Such reliance also assumes that large-scale implementation of CDR will be socially acceptable. Social acceptability will be influenced by the level of openness and responsibility of CDR research during the development phase, and especially by the level of direct public engagement with such research.

Not all geoengineering proposals carry the same risks. CDR proposals such as reforestation and direct air capture involve less obvious risks to the Earth system than solar radiation management strategies such as stratospheric aerosol injection (see page 97 of ref. [6]). Many CDR activities nevertheless present significant risks and uncertainties. For example, terrestrial CDR proposals (such as bioenergy with carbon capture and storage) may conflict with land use for food production and biodiversity conservation[7]. Marine-based CDR proposals such as ocean fertilization may alter ocean chemistry, with potentially significant impacts on the marine food web that remain poorly understood (see page 61 of ref. [6]).

It is critical that governance arrangements continue to emphasize the need to drastically mitigate global GHG emissions. CDR cannot be considered as a substitute for mitigation because current emissions (almost 10 gigatonnes of carbon per year, or 37 gigatonnes of CO_2 per year) are so high that even widespread — largely untested — application of all conceivable CDR options today could offset only about a third of emissions[8]. In parallel to the requirement for emission reductions, urgent research and development is needed into the long-term negative emissions potential of CDR and its risks. For this purpose, modelling and laboratory-based testing of CDR proposals need to progress to incremental field-testing and demonstration projects[9]. Robust international governance arrangements will also be needed to minimize the negative effects and manage the remaining risks of CDR strategies[10]. Finally — and most importantly — governance must take into account the wider risk of failing to advance CDR research. In other words, it needs to minimize the risk that international climate policy will continue to expect significant negative emission capacity to be available by 2030, without understanding the feasibility for it to be implemented at the scale required.

Given that international law will need to both allow and facilitate responsible CDR research, the current legal position is concerning. Several international laws may be incidentally relevant to CDR,

including obligations to protect and preserve the marine environment under the UN Convention on the Law of the Sea, and rules concerning prevention of transboundary harm under customary international law[11]. There have been two specific advances to govern CDR research by international law, both of which predate the Paris Agreement. We focus on these attempts as they provide the only firm indication of how CDR research has so far been treated under international law.

The first came in 2010, when the UN Convention on Biological Diversity (CBD) passed a decision inviting all countries and international organizations to prohibit geoengineering activities (including research) that may negatively impact biodiversity[12]. This prohibition is intended to last until there is adequate science to justify geoengineering and a better understanding of the risks and associated impacts. Small-scale scientific research is permitted, but only in controlled settings (that is, not in the open ocean or the atmosphere) and provided it can be justified to gather specific scientific data. This prohibition is non-binding, so a state cannot be sued for breaching it, but it is nevertheless important because it sets the stage for how the international community should approach the issue of geoengineering research. The CBD reaffirmed the prohibition in 2012[13] and again in 2016[14].

The second development came in 2013, when the international regime governing the dumping of waste at sea (the London Convention and Protocol)[15,16] adopted a legally binding prohibition on ocean fertilization (Resolution LP.4(8) that is yet to come into effect)[17]. This prohibition was in response to controversial proposals for ocean fertilization that were aimed at creating emission reduction credits for sale on emerging carbon markets[18]. Like the CBD, the London Protocol's prohibition contains an exception for scientific research activities. Yet it goes further in providing a detailed framework to help states identify when activities are 'legitimate scientific research'[19]. The framework allows for researchers to be paid for their work and to seek patents on technologies. But the framework states that ocean fertilization research activities are prohibited if their 'design, conduct and/or outcome' is influenced by economic interests, or leads to direct economic gains. At face value, therefore, the London Protocol prohibits any ocean fertilization research that is aimed at or leads to economic gains, such as carbon trading, an approach that may be applied to other marine geoengineering research in the future (see page 2 paragraph 5, art 6bis and annex 5 of ref. [17]).

The framework for legitimate scientific research gives states greater certainty in identifying which research activities should be allowed. However, it is important to bear in mind that these rules were primarily developed with environmental protection in mind, rather than spurring research[20]. The restrictive nature of the London Protocol prohibition is reflected in the fact that there have been no known scientific ocean iron fertilization field tests since 2009[21].

It is time to rethink the initial stance of international law towards CDR research as it leaves little room for carbon trading, subsidies or other economic incentives to play a role in advancing CDR research. Such measures will give greater investment certainty and encourage research and development activity. To be clear: economic interests or gains should not be the primary driver for CDR research and testing. Nor should the personal commercial interests of CDR researchers be mixed with research activities[22], as they may be detrimental to geoengineering research and public confidence[23]. But an approach to governance that precludes any economic interests from influencing — and any direct economic gains from — CDR research is now too restrictive. There is already evidence of some CDR research pushing the boundary on the role of economic interests[24]. For CDR research to progress as needed, international law must avoid the problem of conflicts of interest, while becoming more accommodating of economic interests that facilitate research.

A shift in the stance of international law has already been anticipated. The 2017 Emissions Gap Report from the UN Environment Programme highlights the benefits of expanding CDR research, and states that governments might have an important role to play in incentivizing research[25]. Carbon trading systems, also contemplated under the Paris Agreement, have been suggested as means to incentivize CDR research[26]. Similarly, tax incentives and government subsidies could encourage private sector investment in research[27], which will be required at large scales. Rules requiring transparency and disclosure of economic and financial interests may strike a more appropriate balance between facilitating scientific research, minimizing risk and avoiding personal conflicts of interest.

In conclusion, there is a mismatch between the current position of international law with regards to CDR research and the need to advance CDR research and associated technological developments to help meet the Paris Agreement targets. The current stance, although not yet legally binding for states, is primarily aimed at preventing harm to biodiversity and the marine environment[28]. Risk management measures are important, and the CBD and London Protocol have the capacity to further develop these rules, but they are unlikely to propose rules to govern the incentive schemes or carbon trading mechanisms that will be necessary to advance CDR technologies. Other areas of international law, such as the UN Framework Convention on Climate Change, might be better suited to developing this structure for CDR research. If not, a new international treaty may be needed to match international law on CDR research governance with the expectations of international climate change policy. International policymakers must urgently advance such reforms, to ensure that international law is more facilitative of CDR research. ❐

Kerryn Brent[1]*, Jeffrey McGee[1,2,3], Jan McDonald[1,3] and Eelco J. Rohling[4,5]

[1]Faculty of Law, University of Tasmania, Hobart, Tasmania, Australia. [2]Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia. [3]Centre for Marine Socioecology, University of Tasmania, Hobart, Tasmania, Australia. [4]Research School of Earth Sciences, Australian National University, Canberra, Australian Capital Territory, Australia. [5]Ocean and Earth Science, University of Southampton, National Oceanography Centre, Southampton, UK.

**e-mail: K.A.Brent@utas.edu.au*

Published online: 30 May 2018
https://doi.org/10.1038/s41558-018-0181-2

References

1. Rockstom, J. et al. *Science* **355**, 1269–1271 (2017).
2. Goodwin, P. A. et al. *Nat. Geosci.* **11**, 102–107 (2018).
3. Anderson, K. & Peters, G. *Science* **354**, 182–183 (2016).
4. Hansen, J. et al. *Earth Syst. Dynam.* **8**, 577–616 (2017).
5. Griscom, B. W. et al. *Proc. Natl Acad. Sci. USA* **114**, 11645–11650 (2017).
6. National Research Council *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration* (National Academies, 2015).
7. Dooley, K. & Kartha, S. *Int. Environ. Agreem.* **18**, 79–98 (2018).
8. *Summary of Solutions by Overall Rank* (Drawdown, 26 February 2018); http://www.drawdown.org/solutions-summary-by-rank.
9. Lomax, G., Lenton, T. M., Adeosun, A. & Workman, M. *Nat. Clim. Change* **5**, 498–500 (2015).
10. Pasztor, J., Scharf, C. & Schmidt, K. *Science* **357**, 231 (2017).
11. Scott, K. N. *Mich. J. Int. Law* **34**, 309–358 (2013).
12. *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting: X/33 Biodiversity and Climate Change* UNEP/CBD/COP/DEC/X/33 8(w) (Convention on BiologicalDiversity, UNEP, 2010).
13. *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Eleventh Meeting: XI/20 Climate-related geoengineering* UNEP/CBD/COP/DEC/XI/20 (CBD, UNEP, 2012); https://go.nature.com/2w2M4Pe
14. *Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity: XIII/14 Climate-Related Geoengineering* CBD/COP/DEC/XIII/14 (CBD, UNEP, 2016); https://go.nature.com/2rdL6K0
15. *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972* (International Maritime Organization, 1972); https://go.nature.com/2KekHUs

16. *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972* (International Maritime Organization, 2006); https://go.nature.com/2wGqHDJ
17. *Resolution LP.4(8) on the Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities* LC 35/15 Annex 4 (International Maritime Organization, 2013).
18. Ginzky, H. & Frost, R. *Carbon Clim. Law Rev* **8**, 82–96 (2014).
19. *Assessment Framework for Scientific Research Involving Ocean Fertilization* LC 32/15 Annex 6, 2.2.2 (International Maritime Organization, 2010).
20. *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 and its 1996 Protocol: Statement of Concern Regarding Iron Fertilization of the Oceans to Sequester CO_2* LC-LP.1/Circ.14 (International Maritime Organization, 2007).
21. *Nature* **458**, 562 (2009).
22. Blackstock, J. *Nature* **486**, 159 (2012).
23. *Nature* **485**, 415 (2012).
24. Bourzac, K. *Nature* **550**, S66–S69 (2017).
25. Fuss, S. et al. in *The Emissions Gap Report 2017* 58–66 (UNEP, 2017).
26. Peters, G. P. & Geden, O. *Nat. Clim. Change* **7**, 619–621 (2017).
27. *Priority Three: Governance of Carbon Removal Technologies* (C2G2, 24 February 2018); https://go.nature.com/2w665V1
28. McGee, J., Brent, K. & Burns, W. *Aust. J. Mar. Ocean Aff.* **10**, 67–80 (2018).

Acknowledgements

K.B. was supported by a scholarship from the Institute for the Study of Social Change at the University of Tasmania, Australia. E.J.R. acknowledges Australian Laureate Fellowship FL120100050.