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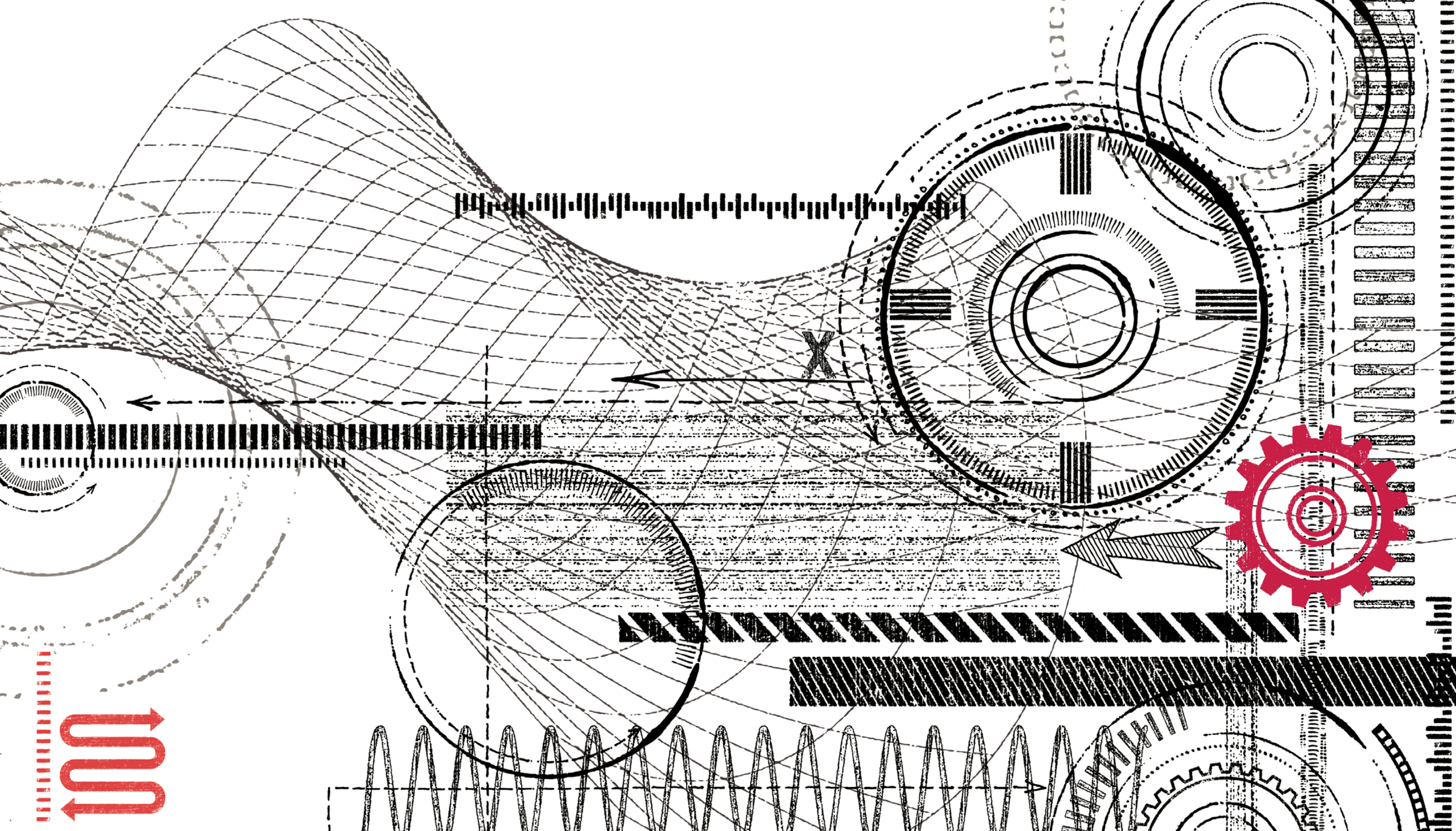
Developing a National Strategy for Climate Engineering Research in Canada

Neil Craik



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About the Author

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Neil's current research examines international law in relation to transboundary and global commons environmental issues. He has particular interests in climate and geoengineering law and governance, deep seabed mining regulation and environmental impact assessment.

Neil is the author of several books, including *Climate Change Policy in North America: Designing Integration* (UTP, 2013), and *The International Law of Environmental Impact Assessment: Process, Substance and Integration* (CUP, 2008), in addition to numerous book chapters and journal articles. He is the co-director of the BSIA/CIGI International Law Summer Institute, and from 2011 to 2017, he served as director of the School of Environment, Enterprise and Development at the University of Waterloo.

About the ILRP

The International Law Research Program (ILRP) at CIGI is an integrated multidisciplinary research program that provides leading academics, government and private sector legal experts, as well as students from Canada and abroad, with the opportunity to contribute to advancements in international law.

The ILRP strives to be the world's leading international law research program, with recognized impact on how international law is brought to bear on significant global issues. The program's mission is to connect knowledge, policy and practice to build the international law framework — the globalized rule of law — to support international governance of the future. Its founding belief is that better international governance, including a strengthened international law framework, can improve the lives of people everywhere, increase prosperity, ensure global sustainability, address inequality, safeguard human rights and promote a more secure world.

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Executive Summary

Climate engineering (CE) is increasingly becoming an area of broad public policy interest within international and domestic climate policy discussions. In addition to receiving greater attention within regulatory contexts, there is a gradual shift toward greater support for nationally supported research programs on CE technologies and assessments. Despite the increased salience of CE, the issue has been largely absent from the Canadian public policy agenda. This paper argues that a national strategy for CE research ought to be developed as part of Canada's broader climate strategy. At the centre of this strategy must be a commitment to ensuring a high level of public trust in the underlying science and a policy process that is open and responsive to public views.

The development of a national CE research strategy is necessary because governance of CE cannot be undertaken in the absence of greater knowledge of CE technologies and their potential impacts. In addition, development of other climate responses, such as mitigation and adaption strategies, will need to be understood in light of the risks of CE, but also the risks associated with forgoing these technologies. As CE technologies become subject to increasing international oversight, the Canadian government needs to develop a greater understanding of these technologies as part of a coherent national position on CE.

The key elements of a national strategy for CE research should include:

- dedicated funding for CE research;
- federal oversight of outdoor research activities that is proportional to the risks; and
- public engagement on the desirability of including different CE technologies as part of Canada's portfolio of responses to climate change.

Introduction

Climate engineering (CE)[1] is shifting quickly from a peripheral issue to a question of broader public policy interest within international and domestic climate policy discussions. In recent years, CE has been the subject of major reviews by national scientific councils, such as the Royal Society (United Kingdom) in 2009 and the National Academies of Sciences (NAS) (United States) in 2015.[2] Ocean fertilization (a proposed form of CE) has been the subject of international regulation under the London Protocol on the dumping of wastes and other matter at sea,[3] a series of non-binding decisions from the Conference of the Parties to the Convention on Biological Diversity,[4] and has begun to form part of the ongoing analysis of climate change by the Intergovernmental Panel on Climate Change (IPCC).[5] In the context of the Paris Agreement, which provides the new global architecture for addressing climate change, the central goal of the agreement that seeks to limit global average temperatures to "well below 2°C" and "to pursue efforts to limit the temperature increase to 1.5°C" is unlikely to be achieved without large-scale implementation of carbon dioxide removal (CDR) techniques, a form of CE.[6]

Research activities on CE are also increasing, albeit slowly, including a recommended shift from computer modelling and laboratory experiments

1 Climate engineering is alternatively referred to as geoengineering.

2 Royal Society, *Geoengineering the climate: Science, governance and uncertainty* (London: Royal Society, 2009); National Academy of Sciences Committee on Geoengineering Climate: Technical Evaluation and Discussion of Impacts, *Climate Intervention: Reflecting Sunlight to Cool Earth* (Washington, DC: NAS, 2015) [NAS SRM Report]; NAS, Committee on Geoengineering Climate: Technical Evaluation and Discussion of Impacts, *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration* (Washington, DC: NAS, 2015) [NAS CDR Report];

3 *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, 29 December 1972, 26 UST 2403, 11 ILM 1294 (entered into force 30 August 1975) [*London Convention*]; Assessment Framework for Scientific Researching involving Ocean Fertilization, 14 October 2010, Annex 4 (the amendment addressing "marine geoengineering" not yet in force) [Oceans Assessment Framework].

4 Conference of the Parties to the Convention on Biological Diversity (2010). Decision X/33, "Biodiversity and climate change," adopted at 10th meeting, 18–29 October 2010, Nagoya.

5 IPCC, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, *Climate Change 2014: Synthesis Report* (Geneva: IPCC, 2014) at 89.

6 Sabine Fuss et al, "Betting on negative emission" (2014) 4 Nature Climate Change 850.

to outdoor research. In 2015, the NAS report called for increased research into CE technologies and their associated risks.[7] The US government has yet to move on this recommendation, but a research team based at Harvard University (led by Canadian researcher David Keith and funded by a variety of non-governmental sources) recently announced a US$20-million research program on solar CE, including a series of small-scale atmospheric field experiments that will inform scientific understanding of solar CE.[8] The British Natural Environment Research Council initiated, in 2017, a modest (£8.6-million) research program on greenhouse gas removal — the first dedicated public research program on this topic in the world.[9] China has also established a CE research program (focused on modelling and governance issues) through its National Program on Key Basic Research.[10]

Despite the salience of CE, the question of CE and CE research has largely been absent from the Canadian public policy agenda.[11] Except for ocean fertilization experiments, where Canada has signed on to the Oceans Assessment Framework,[12] there is no established Canadian position on CE or particular technology types. Nor is there any clearly articulated strategy for conducting or overseeing research or beginning a public dialogue on CE. This paper argues that a national strategy for CE research would be an important and timely element of Canada's broader climate strategy.

At the heart of such a strategy should be the recognition that the public policy debates, both within Canada and internationally, need to be informed by scientific evidence that is credible and legitimate. Given that any future debate on CE will be controversial, it is crucial that the science at the centre of this debate has both scientific support and broad public acceptance. Publicly accepted and scientifically credible research will not resolve the controversy; it is, however, a necessary condition to formulating a Canadian position in this emerging and increasingly important area of climate policy.

7 NAS SRM Report, *supra* note 2, recommendation 4. See also Edward Parson, "Climate policymakers and assessments must get serious about climate engineering" (2017) 114:35 PNAS, DOI/10.1073/pnas.1713456114.

8 See Harvard's Solar Geoengineering Research Program, online: <https://geoengineering.environment.harvard.edu/>.

9 Simon Evans, "UK launches 'world first' research programme into negative emissions", *Carbon Brief*, (21 April 2017), online: <www.carbonbrief.org/uk-launches-world-first-research-programme-into-negative-emissions>.

10 Long Cao, Chao-Chao Gao & Li-Yun Zhao, "Geoengineering: Basic science and ongoing research efforts in China" (2015) 6 Advances in Climate Change Research 188–196.

11 See Parson, *supra* note 7, for a broader discussion of the absence of CE policy discussions.

12 *London Convention*, *supra* note 3 at Annex 4.

Defining CE and CE Research

CE describes a broad constellation of technologies that are loosely united by intent and scale. The broad purpose of CE is to counteract anthropogenic climate change, either through the removal of greenhouse gases, chiefly carbon dioxide, from the atmosphere or by increasing the amount of sunlight that is reflected away from the Earth, and thereby reducing global average temperatures. In order for either set of methods to influence climate change meaningfully, they must be implemented on very large (planetary) scales.

Prominently discussed CDR methods include bioenergy with carbon capture and storage (BECCS), forms of afforestation and reforestation, biochar, ocean fertilization, direct air capture and accelerated weathering. CDR technologies, because they result in the drawdown of atmospheric greenhouse gases, are also referred to as "negative emissions technologies." Solar radiation management (SRM) technologies, such as placing aerosols in the stratosphere or increasing cloud coverage to enhance cloud albedo, address warming by reflecting or scattering incoming sunlight back into space. SRM techniques do not address the buildup of greenhouse gases in the atmosphere, but seek to reduce the adverse consequences of that buildup by reducing the amount of sunlight absorbed by the earth. As a result, this bundle of technologies does not address other impacts from increased carbon dioxide concentrations, such as ocean acidification.[13]

While in some instances it may be helpful to speak of CE in an undifferentiated manner, it is critical

13 But see David Keith, Gernot Wagner & Claire Zabel, "Solar Geoengineering reduces atmospheric carbon budget" (2017) 7 Nature Climate Change 617–619.

to appreciate that each proposed technology raises different levels and types of risk. Treating SRM and CDR technologies as distinct bundles is increasingly common,[14] but the risk profiles of these technologies vary across both CDR and SRM technologies. Some forms of SRM, such as stratospheric aerosol injection and marine cloud brightening, involve less well-understood mechanisms and potentially higher risks when compared with many forms of CDR, which are more mature technologies, albeit at scales much smaller than required to effectively address future climate conditions. That said, there are forms of CDR, such as ocean fertilization or ocean alkalinity experiments, that also pose significant risks.

In the event that any of these technologies move toward large-scale experimentation or deployment — there is no clear point of division — there are broad global implications, but again of differing natures. For SRM, the concerns are very much centred on how states would manage a technology that has such immediate and widespread global impact, in particular where the impacts from deployment may not be evenly distributed and may be hard to attribute directly to specific interventions.[15] SRM deployment in the absence of concurrent emissions reductions or removals is particularly risky, as it would mask the warming effects of an increasing buildup of greenhouse gases. CDR appears less fraught at first blush (in large part because it operates on much longer time scales, since CDR technologies affect climate indirectly through carbon levels), but again when implemented at the scales necessary to achieve meaningful impacts, these technologies are likely to involve significant land and resource consumption (for example, to grow crops for BECCS), which in turn could trigger biodiversity, food security and human rights concerns.[16]

Research activities directed at developing these technologies and understanding their risks are not easily defined or categorized. There is overlap between basic climate and atmospheric science and the research proposed to examine SRM technologies. Two areas of high uncertainty in relation to climate sensitivities relate to the role of aerosols and the role of clouds in climate change processes, which are also key elements that need to be researched in furthering knowledge of stratospheric aerosol injection and marine cloud brightening.[17] In a more applied vein, many elements of CDR technologies are already being examined as part of mitigation strategies. For example, CDR techniques complement existing research on carbon capture and storage, but focus on removing carbon dioxide directly from the atmosphere, as opposed to intercepting end-of-pipe emissions.

This overlap is not to suggest that CE research does not require special consideration — it does. But in doing so, it ought to be recognized that there is no simple solution to distinguishing CE research from other areas of research.

Much CE experimentation is expected to proceed sequentially, with indoor or small-scale experiments preceding larger-scale field experiments, which would proceed only if the risks and scientific merit of proceeding were justified by prior research. One particular challenge is that while the small-scale experimentation being considered is predicted to pose minimal environmental risks, there are a range of indirect risks and concerns that relate to the development of the technologies themselves. For example, there is potential for the prospect of successful CE technologies to create incentives for states and emitters to reduce their mitigation and adaptation efforts on the (misconceived) basis that CE presents an alternative or back-stop technological solution to climate change impacts.[18] In addition, there are concerns that CE technology development may generate commercial or institutional pressures to push ahead with risky (and suboptimal) technology options that might serve narrow interests.[19] Accommodating these concerns in relation to individual research activities presents a challenge in that existing oversight mechanisms tend to

14 For a discussion, see NAS SRM Report, *supra* note 2, box 1.1, "Why There Are Two Separate Reports".

15 Katharine Ricke, M. Granger Morgan & Myles Allen, "Regional climate response to solar-radiation management" (2010) 3 Nature Geoscience 537.

16 Pete Smith et al, "Biophysical and economic limits to negative CO2 emissions" (2016) 6 Nature Climate Change 42; see also William Burns, "The Paris Agreement and Climate Geoengineering Governance: The Need For a Human-rights Based Component" CIGI, CIGI Papers No 111 October 2016.

17 NAS SRM Report, *supra* note 2.

18 Christopher Preston, "Ethics and geoengineering: reviewing the moral issues raised by solar radiation management and carbon dioxide removal" (2012) 4:1 Wily Interdisciplinary Reviews: Climate Change 23–27. See also Albert Lin, "Does Geoengineering Present a Moral Hazard?" (2013) 40:3 Ecology LQ 673–712.

19 Jane Long & Dane Scott, "Vested Interests and Geoengineering Research" (2013) XXIX:3 Issues in Science and Technology 45–52.

focus on direct physical impacts of a certain threshold, but requiring individual researchers to bear the weight of broader societal and ethical concerns over technology development choices places considerable burdens on those researchers.

Demand for CE Research in Canada

The Canadian government, in its *Mid-Century Long-Term Low-Greenhouse Gas Development Strategy*, acknowledges that CDR (referred to as negative emissions in the document) is fundamental to achieving global emissions targets that will contribute to limiting the increase of global average temperature to 2°C.[20] Similarly, a Carbon Management Canada (CMC) report on deep decarbonization pathways acknowledged the need to push for net negative emissions.[21]

Recourse to CDR as part of a long-term climate strategy is consistent with a similar approach by the IPCC, which incorporates BECCS into many of its integrated assessment models that show pathways consistent with the goal of restricting global average temperature increases to no more than 2°C.[22] In effect, what the IPCC models show is that even where fairly aggressive mitigation measures are taken, the international community will likely overshoot the 2°C target, requiring CDR in order to bring carbon dioxide levels back into line with global objectives (see Figure 1).

Thus, CDR technologies are already on the table as part of global and Canadian strategies for achieving the Paris goals and objectives. However, because the IPCC included BECCS in its scenarios with little fanfare or analysis, and Canada's acknowledgement of this reliance is similarly below the radar,[23] there is a significant research gap on understanding the feasibility or desirability of these technologies. This point, that was stressed in the CMC report, the authors noted, the need for CDR to meet climate goals was acknowledged but the CDR scenarios were not modeled. "This is a high priority frontier of Canadian climate policy knowledge. Indeed, understanding net negative emission sources is a trend that will only grow in importance in a deeply decarbonized world."[24]

This research gap ought to be of concern to policy makers because there remains a high level of uncertainty associated with the technical feasibility, scalability and cost of key CDR technologies,[25] leading to questions about how much reliance ought to be placed on technologies that are, as yet, unproven at the scales necessary to achieve the desired outcomes.

Since the implementation of CDR technologies at the scales contemplated to meet international objectives are accompanied by significant environmental, social and economic costs, a key area of research is assessing these impacts and considering approaches that may avert or mitigate these effects.[26]

A number of CDR technologies propose to directly intervene in ocean ecosystems, which, given Canada's position as a major coastal state, ought to generate special interest in these activities. CDR activities such as ocean fertilization, increases to ocean albedo and ocean alkalinity measures could have profound impacts on marine ecosystems,

20 Government of Canada, *Canada's Mid-Century Long-Term Low-Greenhouse Gas Development Strategy* (Ottawa: Environment and Climate Change Canada, 2016) 9.

21 Chris Bataille, David Sawyer & Noel Melton, *Pathways to Deep Decarbonization in Canada* (Sustainable Development Solutions Network and Institute for Sustainable Development and International Relations, 2015).

22 Discussed in T Gasser et al, "Negative emissions physically needed to keep global warming below 2°C" (2015) 6 Nature Communications, DOI 10.1038/ncommm8958. See also Fuss, *supra* note 6.

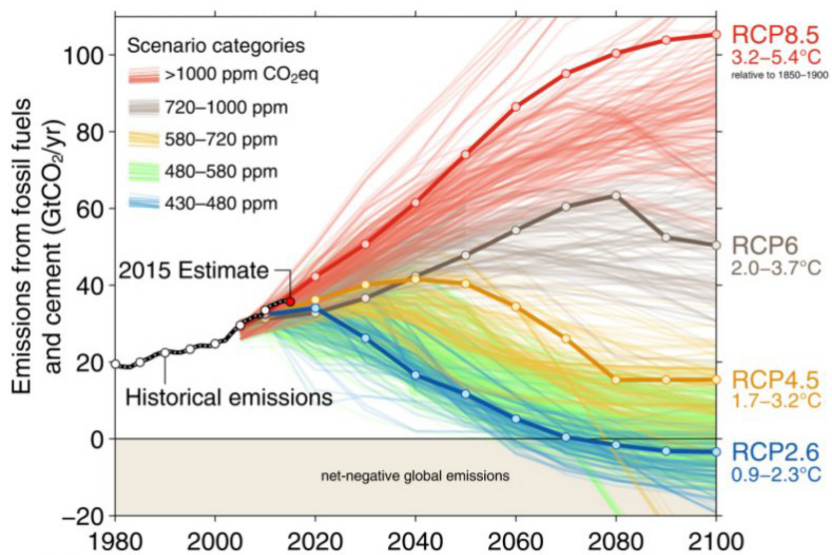
23 For a critical commentary on the IPCC AR5 models, see Andy Parker & Oliver Geden, "No fudging on geoengineering" (2016) 9 Nature Geoscience 859–860.

24 Bataille, Sawyer & Melton, *supra* note 21 at 40.

25 Parson, *supra* note 7.

26 For example, the land use requirements for even modest reductions of carbon dioxide (i.e., in the order of three gigatonnes) are in the range of 400 to 700 million acres, which is equivalent to seven to 25 percent of global agricultural land. There are other predicted impacts on water, nutrient and energy consumption that are also of significance. See Smith et al, *supra* note 16; see also Phil Williamson, "Emissions reduction: Scrutinize CO_2 removal methods" (2016) 53 Nature 153.

Figure 1: Carbon Dioxide Emission Pathways until 2100 and the Extent of Net Negative Emissions and BECCS in 2100



Source: Fuss et al.

including fisheries.[27] Concerns not only involve activities based within Canadian maritime zones, but may also include activities of Canadian companies or scientists operating elsewhere.[28] These concerns are not abstractions, as vividly illustrated by an unauthorized ocean fertilization experiment conducted off the coast of British Columbia, which resulted in worldwide attention and condemnation (see Box 1).

While analysis of these issues at global levels is beginning to be undertaken, consideration of the feasibility of specific technological pathways and their implications for Canada will require evidence-based assessments and consultation.

SRM research is at a very early stage of development, compared with many CDR technologies. As a set of hypothesized technologies, SRM scenarios have been modelled on computer simulations, and are informed by research into natural analogues, such as volcanoes. The proposed field research focuses on small-scale process studies that are directed toward understanding particular processes or interactions that underlie SRM methods. Consequently, the research demand in Canada is more diffuse, and relates principally to developing the capacity to contribute and respond to policy discussions and governance demands in this area.

One area of developing interest that may have particular salience for Canada is whether some SRM methods could be implemented so that the cooling effects are regional in nature. The higher susceptibility of the Arctic to the effects of climate change, such as higher temperature increases, sheet ice and sea ice loss, as well as concern over feedbacks such as increased loss

27 The risks associated with oceans-based geoengineering, and ocean iron fertilization in particular, have been the subject of much debate in the Conference of the Parties to the Convention on Biological Diversity, as well as the London Protocol. For a summary, see Convention on Biological Diversity, "Climate-related Geoengineering and Biodiversity: Technical and regulatory matters on geoengineering in relation to the CBD", online: <www.cbd.int/climate/geoengineering/>; International Maritime Organization, "Ocean Fertilization under the LC/LP," online: <www.imo.org/en/OurWork/Environment/LCLP/EmergingIssues/geoengineering/OceanFertilizationDocumentRepository/OceanFertilization/Pages/default.aspx>; see also Phillip Williamson et al, "Ocean fertilization for geoengineering: A review of effectiveness, environmental impacts and emerging governance" (2012) 90:6 Process Safety & Environmental Protection 475.

28 Jeff Tollefson, "Iron-dumping ocean experiment sparks controversy", *Nature* (23 May 2017), online: <www.nature.com/articles/n-12306030> (describing concerns over a Vancouver-based company's proposed ocean fertilization activities in Chile).

Box 1

The carrying out of an unauthorized ocean fertilization experiment off the coast of British Columbia and involving a Canadian First Nation demonstrates the need for proactive consideration of CE activities. The incident, which occurred in 2012, involved the deposition of roughly 100 tonnes of iron sulphate into the Pacific Ocean for the ostensible purpose of salmon restoration. However, the project proponents also indicated their intention to generate carbon credits on the basis of carbon dioxide sequestered through the ocean fertilization activity. No authorization was sought by the proponents, notwithstanding a (non-binding) Canadian policy requiring an assessment of such activities. The incident generated international headlines and a Canadian investigation, but no charges were ever laid against the project principals, notwithstanding that the activity was clearly contrary to the intentions of the London Protocol on Dumping at Sea, an international treaty to which Canada is a party.

The case was not without legal ambiguity (in relation to both international and Canadian law), and the parties to the London Protocol subsequently adopted a formal amendment to the protocol, making unauthorized ocean fertilization experiments illegal. Canada voted in favour of adopting the amendments, but has not yet ratified the change. The incident itself points to a couple of important features. First, CE experimentation will not necessarily be publicly funded and could be undertaken in attempts to generate commercial profits. Second, classifying an activity as CE may not always be clear. In this case, the experiment was framed as being directed to salmon stock restoration. And finally, while international legal institutions can provide some direction for coordinated state behaviour, domestic regulatory control is critical for compliance.*

* See Neil Craik, Jason Blackstock & Anna-Maria Hubert, "Regulating Geoengineering Research through Domestic Environmental Protection Frameworks: Reflections on the Recent Canadian Ocean Fertilization Case" (2013) 7:2 Carbon and Climate L Rev 117.

of ice albedo effects from diminishing ice or the release of methane due to thawing permafrost, have led scientists to consider the potential of tailored CE methods, such as stratospheric aerosol injection or marine cloud brightening, to specifically address Arctic climate issues.[29]

At present, it is difficult to assess Canada's research activity in relation to CDR and SRM research, as there has been no dedicated natural science research program directed at these areas or assessments of Canadian research capacity.

Certainly, Canadian researchers are involved in areas of relevance to CDR, such as carbon capture and storage technologies, and biomass fuels. There is an existing direct air capture demonstration facility located in British Columbia, owned by a Canadian company, that is actively developing technologies with commercial potential in this area. There are no SRM field experiments being proposed in Canada, but there are some Canadian scientists developing modelling expertise in relation to SRM scenarios.

29 Ken Caldeira & Lowell Wood, "Global and Arctic climate engineering: numerical model studies" (2008) 366:1882 Philosophical Transactions of the Royal Society A 4039–4056; Alan Robock, Luke Oman & Georgiy Stenchikov, "Regional climate responses to geoengineering with tropical and Arctic SO_2 injections" (2008) 113:D16 J Geophysical Research 101; John Latham et al, "Marine cloud brightening: regional applications" (2014) Philosophical Transactions of the Royal Society A, DOI:10.1098/rsta.2014.0053; Ben Kravitz et al, "Process-model simulations of cloud albedo enhancement by aerosols in the Arctic" (2014) Philosophical Transactions of the Royal Society A, DOI:10.1098/rsta.2014.0052. Another approach that has been examined involves pumping sea water to the sea surface, where it would freeze and increase sea ice levels, as a method to maintain Arctic sea ice levels and their associated (albedo) effects on the climate. The proposal suggests using millions of pumps powered by wind turbines, and projects a cost of $500 billion. See Steven Desch et al, "Arctic ice management" (2017) 5:1 Earth's Future 107–127.

Why the Need for a National Strategy for CE Research?

Governance and Research Must Co-evolve

There has been a "chicken-and-egg" debate around the extent to which a robust international research regime must precede research activities.[30] The difficulty with insisting on a prescriptive, international research governance regime prior to experimentation is that, at present, the subject of regulation is poorly understood. Creating rules respecting CE research under conditions of high uncertainty make agreement and adherence to the rules more of a challenge and run the risk of calcifying a set of rules that end up being poorly suited to subsequent technological developments. A preferred approach would be to treat governance and research in a more iterative fashion, working toward a framework that ensures transparency and assessment that is proportional to the risks of the proposed activities as they evolve.

Requiring sequential research activities that are structured to reduce uncertainty of future research activities and that clearly identify conditions under which larger-scale experimentation would proceed is desirable from a risk mitigation perspective, but also better ensures that research activities do not proceed ahead of the required regulatory environment and public acceptability. The need for research activities to account for and apply emerging CE research norms suggests that research activities in this area will need to be coordinated in a deliberate manner. The recent decision of the Canadian government to name a chief science adviser should strengthen Canada's capacity to structure scientific activity, particularly research such as CE research, which is directed toward policy outcomes.

30 Debate discussed in Andy Parker, "Governing solar geoengineering research as it leaves the laboratory" (2015) 372:2031 Philosophical Transactions of the Royal Society A, DOI:10.1098/rsta.2014.0173.

The Need for Integration

At present, CE technology research and assessment exists outside the main climate policy structures in Canada. In part, this isolation is a result of the view shared by many in the climate policy community that CE technologies will divert attention and funding from critical mitigation and adaptation activities. However, at the same time, there is a growing recognition in the scientific and policy communities that mitigation alone is likely to be insufficient to meet Canada's (and global) mid-century long-term climate objectives, requiring at a minimum that long-term planning efforts integrate CDR assessments to begin to analyze the feasibility and associated risks of these technologies as part of a broader portfolio of climate responses. Given the scaling and commercialization requirements for CDR will themselves require a long lead time, attention to these issues and potential pathways for implementation are near-time requirements. To some degree, the assessment of CE technology risks must be understood in relation to the climate risks associated with forgoing these technologies.

CDR technologies are likely to be subject to greater scrutiny as progress toward the Paris goals is assessed under the global stock taking exercises and the IPCC's special report, ***Global Warming of 1.5°C***, due to be completed in 2018. Carbon dioxide removal falls within the current scope of the Paris Agreement, which includes enhancement of carbon "sinks and reservoirs" in its mitigation objectives,[31] and CDR methods could eventually be integrated into the nationally determined contributions required under the Paris Agreement, and will likely need to be subject to monitoring, verification and reporting structures that meet international requirements.[32]

With the exception of the London Protocol, there are no specific international legal requirements governing CE, although CE has been the subject of discussion and some non-binding decisions in the Convention on Biological Diversity. CE is clearly salient to the United Nations Framework Convention on Climate Change (UNFCCC), the

31 *Paris Agreement*, 22 April 2016, art 5 (entered into force 4 November 2016), online: <https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf>.

32 Neil Craik & William Burns, "Climate Engineering under the Paris Agreement: A Legal and Policy Primer" CIGI, Special Report, 1 November 2016.

Montreal Protocol (sulphate aerosols could affect ozone levels in the stratosphere), as well as to the mandate of numerous UN agencies, but has yet to enter onto official agendas as a matter of formal discussion. This is likely to change in the near term.

It will also be beneficial to assess SRM in the context of a portfolio of climate responses in light of the common research requirements and the importance of ensuring that SRM research is not used to provide a basis for lower emission reduction ambitions. There is very little public discussion of SRM within national governments, including Canada, and within international organizations, including the UNFCCC, notwithstanding the global governance requirements (whether SRM approaches are pursued or abandoned).[33] Developing a coherent national position on SRM will be necessary as these discussions in international venues begin to unfold. This, in turn, requires the Canadian government to develop greater technical understanding of SRM technologies and their broader implications, including potential security implications,[34] to effectively participate in these discussions.

Science Legitimacy Will Be Fundamental to Future Policy Discussions

The aims and ethics of CE and CE research are divisive, making public trust in the science surrounding CE a central consideration. Scientists and research processes have their own codes for establishing credibility that rely on established expertise, objectivity and peer review to make determinations on the validity of scientific claims. However, in areas where the research has clear public policy salience and where those policy decisions involve value disputes, there is increased pressure to open up scientific processes to greater public scrutiny and input.[35]

Legitimacy in this context requires taking steps to ensure that experiments pose well-understood and acceptable risks to the public and public resources, that research plans and their assessment are publicly disclosed and subject to appropriate consultation, that those carrying out or supporting (funding) the research are transparent about their interests and motivations, and that the results (and potentially the supporting data) are publicly disclosed.[36]

Legitimacy is crucial to the sequential unfolding of research activities. Decisions on future larger-scale experiments will in part be determined by the research results of small-scale field and indoor experiments, but the ability of scientific research to influence policy processes will depend in part on the public's acceptance of the authoritativeness of those results.[37] CE, as an issue of the public's imagination, is already the subject of concerns and conspiracies about creating a "slippery slope" toward deployment. In this context, research transparency and other legitimacy-enhancing measures are essential for promoting a decision-making environment that is properly informed by science, but is responsive to public views.

33 But see Carnegie Climate Geoengineering Governance Initiative, a research and engagement project that has as its primary goal to catalyze discussions on CE within the broader global policy community, online: <www.carnegiecouncil.org/programs/ccgg>.

34 Paul Nightingale & Rose Cairns, "The Security Implications of Geoengineering: Blame, Imposed Agreement and the Security of Critical Infrastructure" (2014) Climate Geoengineering Governance Working Paper Series No 18.

35 Sheila Jasanoff, "Technologies of Humility: Citizen Participation in Governing Science" (2003) 41:3 Minerva 223–244; Jack Stilgoe, Richard Owen & Paul MacNaghten, "Developing a framework for responsible innovation" (2013) 42:9 Research Policy 1568–1580.

36 Steve Rayner et al, "The Oxford Principles" (2013) Climate Geoengineering Governance Working Paper Series No 1.

37 Neil Craik & Nigel Moore, "Disclosure-based Governance for Climate Engineering Research" CIGI, CIGI Papers No 50 November 2014, online: <www.cigionline.org/publications/disclosure-based-governance-climate-engineering-research>.

Key Elements of a National Strategy for CE Research

Dedicated Funding

While there has been a great deal of public anxiety regarding CE research over the past 10 years, our understanding of CE, in particular SRM, has not significantly advanced. Dedicated research funding to support both CDR and SRM research programs is key to developing Canadian policy capacity in this area. In the absence of greater scientific knowledge, in particular field tests that will inform better models and provide a much clearer idea of environmental risks, development of sensible policies is frustrated. In 2013, this point was made emphatically in an op-ed in *Foreign Affairs*: "The result [of the absence of scientific funding] is that the scientific community knows little more than it did four years ago about how geoengineering would actually work or what its consequences would be. These technologies might not be well understood when and if they are needed, and could be deployed prematurely. In the growing efforts to regulate geoengineering, governments and activists are flying blind as they conjure up new regulations."[38] Four years have passed since that comment was made, but publicly funded CE science remains at very low levels.

With a strong commitment to climate mitigation and strong capacity in related research areas, Canada is well-positioned to contribute leadership in this area. This may be particularly the case as the United States enters a period of retrenchment in climate policy that could constrain its ability to lead on CE.[39]

A research program would likely be fairly small to start and would not appreciably detract from existing resources for mitigation and adaptation research, but identifying CE funding as a distinct source may alleviate concerns regarding CE research funding supplanting other climate funding. The NAS, in its review of SRM technologies, emphasized the importance of prioritizing areas of SRM research that would have co-benefits for basic climate science. This may have some advantages in terms of public acceptability, but runs the risk of ignoring questions that are necessary to inform critical knowledge in this field. Private funding may be more focused on commercialization opportunities, which may be suitable for some (mostly CDR) technologies, but certainly not all.

Oversight

Given the legitimacy demands in this research area, clear but proportional oversight is required. The sources of oversight in the near term are more likely to be domestic, as small-scale experiments are less likely to trigger international legal rules. The regulatory environment in Canada is complicated by the split (federal/provincial) jurisdictional authority over environmental regulation. CE research can be understood as an extension of jurisdiction over climate, an area that most commentators feel the federal government has broad authority to regulate.[40] The international dimensions of CE also militate in favour of federal oversight. There will, however, be some activities that involve land use that will engage provincial authority and might require a cooperative approach to regulation. (The experimental lakes program in Northern Ontario may provide some useful parallels, in that it was a complicated joint effort that involved ongoing environmental perturbation.) Within the federal government, CE research oversight could cut across multiple ministries and departments, including Environment and Climate Change; Fisheries and Oceans; Innovation, Science and Economic Development; Natural Resources; and Global Affairs, necessitating some intra-governmental coordination, or identifying a lead agency.

A further complication will be the constitutional requirements to consult Aboriginal groups whose rights under section 35 (of the Constitution Act, 1982) are potentially impacted by CE research activities. Again, the limited impacts of small-scale

38 David Victor et al, "The Truth About Geoengineering: Science Fiction and Science Fact", *Foreign Affairs* (27 March 2013), online: <www.foreignaffairs.com/articles/global-commons/2013-03-27/truth-about-geoengineering>.

39 Nell Greenfieldboyce, "Scientists Who Want to Study Climate Engineering Shun Trump", NPR (29 March 2017), online: <www.npr.org/2017/03/29/521780927/scientists-who-want-to-study-climate-engineering-shun-trump>.

40 Nathalie Chalifour, "Canadian Climate Federalism: Parliament's Ample Constitutional Authority to Legislate GHG Emissions through Regulations, a National Cap and Trade Program, or a National Carbon Tax" (2016) Ottawa Faculty of Law Working Paper No 2016–18, online: <https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2775370>.

experimentation may not engage Aboriginal rights immediately, but land intensive and ocean-based CDR methods are likely to have Indigenous rights implications that would require consultation. Early involvement of Indigenous groups in broader policy discussions around CE may be legally required, even where physical impacts are not imminent, and would in any event be politically sensible as research and policy discussions advance.

A core oversight mechanism that has been repeatedly recognized is environmental assessment, but small-scale experiments may pose very low environmental risks and may not be caught by Canadian environmental assessment legislation.[41] The approach under the London Protocol was to make all ocean fertilization experiments involving depositions (regardless of predicted levels of harm) subject to assessment requirements. Requiring assessments (by designating certain CE research activities as requiring a federal assessment, regardless of the likelihood of a significant environmental impact) for perturbative experiments, such as small-scale atmospheric process tests, would be a positive step that would better ensure identification of risks and uncertainties associated with experiments that aligns with international expectations.

The other main form of research accountability that has been identified is the necessity for research transparency mechanisms. Transparency is fundamental to maintaining public trust in research activities, and would likely require disclosure of research activities and funding sources, as well as research results. Environmental assessment processes, if required to apply, would partially address the need for transparency, but these assessments do not address back-end disclosure (after the activity is complete). An important component of research disclosure would be ensuring results are publicized and, perhaps, contextualized for the public and policy makers. There is no clear, existing avenue for research disclosure, such as research registries or a clearinghouse in Canada, although there have been discussions (but no concrete plans) around the creation of such a mechanism to track research internationally. Canada currently has a national system of disclosure for weather modification that could provide a model for CE.[42] Notably, this system is disclosure driven, requiring both prior notification and subsequent reporting. There is also a transboundary agreement with the United States requiring an exchange of information where weather modification activities occur within 200 miles of the border.[43]

Public Engagement

A further element of a research strategy for CE is establishing the means to engage the public on this topic. The development of science policy in areas of high contestation and high uncertainty cannot treat science as an external and neutral input that can simply be projected into policy discussions when expertise is required. Traditional forms of credibility assessment, such as peer review and scientific objectivity, are necessary but inadequate to promote public acceptance. Instead, scientific processes themselves must become more inclusive and reflective. That is, they should be permeable to public views on the value and implication of the technologies being examined, and may require justification of experimentation that is responsive to public concerns.[44] Given the current low levels of public knowledge on CE, public education and awareness will be a significant element to engendering informed debate on CE research.

The modalities for public engagement on science policy are not well institutionalized in Canada, but the kinds of options being proposed include deliberative fora of citizens who are invited to obtain an understanding of the science and its implication and deliberate (not necessarily by consensus) on broad policy questions related to the technology, as well as more informal opportunities, such as science cafés, for interested citizens to engage scientists in discussions about their research. The federal government can draw on similar experiences in public engagement on technologies such as genetically modified organisms and nanotechnology. In some instances, the engagement can focus on a particular experiment, but may also focus more generally on the process of technology development. These consultation efforts may be government-led or may be led by arms-length entities that may be viewed as a more neutral arbiter.

41 *Canadian Environmental Assessment Act, 2012*, SC 2012, c 19.

42 *Weather Modification Information Act*, RSC 1985, c W-5.

43 *Agreement Between Canada and the United States of America Relating to the Exchange of Information on Weather Modification Activities*, CTS 1975, No 11.

44 See William Burns & Jane Flegal, "Climate Geoengineering and the Role of Public Deliberation: A Comment on the U.S. National Academy of Sciences' Recommendations on Public Participation" (2015) 5 Climate Law 252–294; see also Stilgoe, Owen & MacNaghten, *supra* note 35.

As a starting point, there may be more traditional avenues of public consultation that may initiate a public discussion among interested groups and citizens. Reports by the Canadian Council of Academies can play a catalytic role in providing baseline information, as well as soliciting input into assessments on emerging issues of public policy importance. As noted, assessments of CE have been undertaken by the Royal Society and the NAS,[45] but there may be merit in a Canadian review of this issue, including an assessment of CE research activities and capacities in Canada, as well as identifying areas of specific concern within the Canadian public sphere.

Conclusion

If there is one top-line message from this paper, it is that the issue of CE can no longer be treated as peripheral and best left to expert communities. A national strategy for CE research allows for some deliberate and anticipatory consideration of CE in the broader context of Canadian climate policy and its role in climate discussions on the global stage. Research and discussion of CE will not bring those technologies into existence, but will provide a framework for responsible assessment of these potential climate management tools.

Canada is moving toward global climate leadership, but in doing so it ought to be accounting for the full range of options within a portfolio of climate responses. As with all areas within climate policy, the decisions taken must be informed by scientific evidence, which in turn must be seen as being broadly responsive to public risk preferences and views on acceptable pathways. To this end, this paper recommends that the Canadian government begin to formulate a national research strategy on both CDR and SRM that supports research in a transparent, consultative and regulated environment.

45 The European Commission also funded a wide-ranging assessment prepared by a large consortium of European institutions under the EuTRACE (European Transdisciplinary Assessment of Climate Engineering) program. See Stefan Schafer et al, *The European Transdisciplinary Assessment of Climate Engineering (EuTRACE): Removing Greenhouse Gases from the Atmosphere and Reflecting Sunlight away from Earth*, online: <www.iass-potsdam.de/sites/default/files/files/rz_150715_eutrace_digital.pdf>.

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