CLIMATE GEOENGINEERING

ENV_R POL 390, Sec. 24

Spring 2024

12.30-1.50pm

Parkes Hall: 212

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Office hours: by appointment via phone or Zoom

Schedule appointments via Calendly:

- 30-minute phone call: https://calendly.com/wil_burns/30min
- 15-minute phone call: https://calendly.com/wil_burns/15min
- 60-minute Zoom session: https://calendly.com/wil_burns/60min
- 30-minute Zoom session: https://calendly.com/wil_burns/30-minute-zoom-call
- 15-minute Zoom session: https://calendly.com/wil_burns/15-minute-zoom-call

rse Overview

Climate change is the keystone environmental issue of this generation, and most likely for many generations to come. While the world community and individual countries have formulated policies to address climate change, these policies are almost universally recognized as being wholly inadequate to effectuate the objective of the Paris Agreement to hold global temperatures to well below 2ºC above pre-industrial levels, and to pursue efforts to limit increases to 1.5ºC.

Indeed, it has become increasingly obvious that achievement of Paris temperature objectives will require both aggressive emission reductions initiatives and large-scale deployment of carbon dioxide removal/negative emissions technologies and processes (CDR), sometimes also referred to as a major sub-category of climate geoengineering. Moreover, many believe that we will also need to deploy solar radiation management (SRM) approaches, which seek to reduce the amount of incoming solar radiation, to buy us time as we decarbonize the world economy.

This course will discuss the exigency of deploying SRM and CDR approaches at scale, including potential benefits and risks of these options. It also will discuss regulatory and governance considerations at both the national and international level, as well as strategies to incentivize large-scale adoption of these approaches.

rning Objectives

After taking this course you should be able to:

- Distinguish between carbon dioxide removal and solar radiation geoengineering approaches;
- Understand the technological aspects of various solar radiation management, potential risks and benefits, and constraints to large-scale deployment;
- Understand the technological aspects of carbon capture and storage, potential risks and benefits, and constraints to large-scale deployment;
- Assess the adequacy of current governance mechanisms for SRM and CDR options and identify gaps in governance;
- Assess the ethics and justice implications of SRM and CDR research and/or deployment

ss Contract

I am pretty "old-school" when it comes to how I view higher education. I do not consider students to be atomistic "customers" purchasing a "product," and I am not simply here to be a vendor of a "product." Rather, by enrolling in this course, you and I are entering into a social contract with each other, and with all the other students in the class, to foster an environment of learning and collaboration. Under the "terms" of this contract, it is my responsibility to always be well-prepared for class, responsive to communications outside of class, and to treat every student with fairness and respect. Consistent with this, I will always try to be accessible and try my best to return graded materials after no more than a week. In turn, by enrolling in the class students agree to: (1) attend classes regularly and punctually; (2) participate by asking questions and joining in class discussions; (3) read the assigned material and complete assignments on time; (4) Regularly consult the course Canvas site for updates and materials intended to facilitate class discussion, including current events pertinent to the topics we will discuss in class; (5) comply with class policies established in this syllabus, and (6) uphold Northwestern University's commitment to academic integrity: https://www.northwestern.edu/provost/policies/academic-integrity/

rse Readings

The readings for the course will be derived from the following sources, designated in the class schedule with the icons listed below:

- E **Electronic readings**, which are available on the course Canvas site for this course. Click on the "Files" link and look for the "Readings" folder.
- O **Online Hyperlinks**, which must be accessed via the online version of the Syllabus on the course Canvas site.

essment/Assignment Schedule

Special Topics Presentations	**Ongoing**	**30%**
Final Examination	**June 3-5 (10am-10am)**	**50%**
Class Participation	**Ongoing**	**20%**

ef Description of Assignments

ecial Topics Presentations [30% of grade]

Students will work in groups of 3-4 to prepare 10-15 minute presentations for class on assigned topics. Please see the "Assignment Guidelines" folder under the Files folder for further instructions.

al Examination [50% of grade]

The final examination will be a 48-hour take-home, comprised of essay questions, with a 3-page limit for each question. More details about the structure of the exam will be provided in class, and see the document in the "Assignments" folder discussing the format of the examination and providing an example question.

ss Participation [20% of grade]

Class participation assessment will be comprised of your participation during lectures, including responses to treaty-interpretation questions and your questions during special topics presentations.

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GRADING:

All grades will ultimately be scaled to a 100-point system: A (94-100); A- (90-93); B+ (87-89); B (83-86); B- (80-82); C+ (77-79); C (73-76); C- (70-72); D (60-69); F (<60).

PLAGIARISM AND THE USE OF AI

Students in this course are required to comply with the policies found in the booklet, "Academic Integrity at Northwestern University: A Basic Guide". All papers submitted for credit in this course must be submitted electronically unless otherwise instructed by the professor. Your written work may be tested for plagiarized content. For details regarding academic integrity at Northwestern or to download the guide, visit: https://www.northwestern.edu/provost/policies-procedures/academic-integrity/index.html

Any form of cheating, including improper use of content generated by artificial intelligence, constitutes a violation of Northwestern's academic integrity policy.

ZOOM ETIQUETTE:

- All students should have their cameras on during all online sessions, including, especially, in classes where we have guest speakers;
- Mute your microphones at all times when not speaking, and please try to minimize potentially distracting background noise;
- Dress like you are coming to class, i.e., no pajamas

RELIGIOUS OBSERVANCE

Northwestern is committed to fostering an academic community respectful and welcoming of persons from all backgrounds. To that end, the policy on academic accommodations for religious holidays stipulates that students will not be penalized for class absences to observe religious holidays. If you will observe a religious holiday during a class meeting, scheduled exam, or assignment deadline, please let me know as soon as possible, preferably within the first two week of class. If exams or assignment deadlines on the syllabus fall on religious holidays you observe, please reach out so that we can discuss that coursework.

ACCOMODATION

Northwestern University is committed to providing the most accessible learning environment as possible for students with disabilities. Should you anticipate or experience disability-related barriers in the academic setting, please contact AccessibleNU to move forward with the university's established accommodation process (e: accessiblenu@northwestern.edu; p: 847-467-5530). If you already have established accommodations with AccessibleNU, please let me know as soon as possible, preferably within the first two weeks of the term, so we can work together to implement your disability accommodations. Disability information, including academic accommodations, is confidential under the Family Educational Rights and Privacy Act.

Writing Center

When working on writing assignments for this class, I encourage you to visit the Writing Place, Northwestern's peer writing center. You will work with juniors and seniors who have been trained to provide you feedback and assistance on any type of writing at any stage in the writing process. They will not edit your work. Rather, they will work with you to brainstorm ideas, organize or outline an essay, clarify your argument, document your sources correctly, or refine grammar and style.

To book an appointment, register for an account at **https://northwestern.mywconline.com/**

	COURSE SCHEDULE
3.25 Live Class Session	**Introduction to the Course** ▪ Instructor introduction ▪ Student introductions ▪ Review of syllabus
SECTION 1	**OVERVIEW OF CLIMATE SCIENCE**
3.27 Asynchronous Class (Video Lecture)	**The Science of Climate Change & The Rationale for Climate Geoengineering** **READINGS:** O IPCC, AR6 Climate Change 2021: The Physical Science Basis 7-35 (2021)
SECTION 2	**Solar Radiation Management (SRM) Approaches**

4.1 Live Class Session

Overview of SRM Options, Part 1

READINGS:

E U.S. National Academies of Sciences, *Climate Intervention: Reflecting Sunlight to Cool Earth* 66-90 (2015)

O Matthews, Dimmer Switch, Prism, November, 2022

O Anthony, Melting point: could 'cloud brightening' slow the thawing of the Arctic?, The Guardian, November 27, 2022

O Keith & Smith, Solar geoengineering could start soon if it starts small, MIT Technology Review, Feb. 5, 2024

O Parson, A Dangerous Disruption, LegalPlanet, Jan. 2, 2023

4.3 Live Class Session

Solar Radiation Management, Part 2: The Role of Legal Institutions

READINGS:

O Marie-Valentine-Florin, Using stratospheric aerosol injection to alleviate global warming: when?, EPFL, Dec. 16, 2021

O U.S. House Appropriations Committee, Consolidated Appropriations Act, 2022, see bottom of p. 233, and top of p. 234

O Text of the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (1976) and its Understandings

STUDENT LEARNING EXERCISE:

Please have access to the **Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques Treaty Interpretation Exercise, and its Understandings,** which can be found in the "Treaty Interpretation Exercises" subfolder, under the Assignment Guidelines folder, under the Files tab, or via the links above.

4.8 Live Class Session

Solar Radiation Management, Part 3: The Role of Legal Institutions

READINGS:

O Climate Overshoot Commission, How Should the World Reduce the Risk of Temperature Overshoot? (scan the site)

O Biermann, et al., *Solar geoengineering: The case for an international non-use agreement*, 13 WIRES CLIMATE CHANGE, e754 (2022)

O Reynolds, *Why the UNFCCC and CBD Should Refrain from Regulating Solar Climate Engineering*, Geoengineering

Our Climate? 137-42 (2019)

O Burns, Climate Geoengineering: Solar Radiation Management and its Implications for Intergenerational Equity, 4 STANFORD JOURNAL OF LAW, SCIENCE & POLICY (2011)

STUDENT PRESENTATION:

Topic: Space-Based Solar Radiation Management ("space mirrors"):

- Boleyn-Fitzgerald
- Yen
- Tunney
- Neuhart

4.10 Live Class Session — Ethics and Justice Considerations: SRM Options

READINGS:

O Stephens, et al., *The Dangers of Mainstreaming Solar Geoengineering: A critique of the National Academies Report*, 32(1) ENVIRONMENTAL POLITICS 157-166 (2021)

E Pamplany, *The Ethical Desirability of Geoengineering: Challenges to Justice*, BIOETHICS 1-11 (2020)

O Parson, Geoengineering: Symmetric Precaution, 374 SCIENCE 795 (2021)

STUDENT PRESENTATION:

American Geophysical Union: Ethical Framework Principles for Climate Intervention Research

- Holquin
- Kanaley
- McQueeny

SECTION 3 Carbon Dioxide Removal Approaches

4.15 Live Class Session — "Nature-Based" Climate Solutions: Forests

READINGS:

E Bastin, *The global tree restoration potential*, 365 NATURE 76-9 (2019)

O Greenfield & Chingono, 'We don't know where the money is going': the 'carbon cowboys' making millions from credit schemes, THE GUARDIAN, Mar. 15, 2024

E Fagan, et al., *How feasible are global forest restoration commitments?,* 13 CONSERVATION LETTERS 1-8 (2020)

E Bond, et al., *The Trouble with Trees: Afforestation Plans for Africa*, 34 TRENDS IN ECOLOGY & EVOLUTION 963-65 (2019)

O Burns, Op-ed: A trillion trees to fight climate change sounds nice. Here's what it misses, IndyStar, Dec. 20, 2020

STUDENT PRESENTATION:

- **Topic: The Potential Role of Agroforestry in Carbon Sequestration**
  - Collins
  - Edwards
  - Tateosian
  - Osbourne

4.17 NO CLASS

4.22 Live Class Session "Nature-Based" Climate Solutions: Soils

READINGS:

E Rumpel, et al., *Put more carbon in soils to meet Paris climate pledges,* 564 NATURE 32-4 (2018)

E Bai, et al., *Responses of soil carbon sequestration to climate-smart agriculture practices: A meta-analysis*, 25(8) GLOBAL CHANGE BIOLOGY 2591-2606 (2019)

E Höglund, Is soil carbon a viable carbon removal solution?, Marginal Carbon, June 21, 2023

O Evich & Monnay, *In rare bi-partisan move, Senate approves bill to help farmers profit on climate action,* Politico June 24, 2021

STUDENT PRESENTATION:

- **Topic: Biochar and Carbon Sequestration**
  - Filstrup
  - Franchere
  - Tapia
  - Lopez

4.24 Live Class Bioenergy and Carbon Capture with Sequestration (BECCS): Overview

READINGS:

E Babin, et al. *Potential and challenges of bioenergy with carbon capture storage as a carbon-negative energy source: A Review*, 146 BIOMASS & BIOENERGY, Art. 105968 (2021)

E Burns, *Human Rights Dimensions of Bioenergy With Carbon Capture and Storage: A Framework for Climate Justice in the Realm of Climate Geoengineering*, in CLIMATE JUSTICE: CASE STUDIES IN GLOBAL AND REGIONAL GOVERNANCE CHALLENGES 149-70 (2016)

E Lefvert & Grönkvist, *Lost in the scenarios of negative emissions: The role of bioenergy with carbon capture and storage (BECCS)*, 184 ENERGY POLICY 1-5 (2024)

STUDENT PRESENTATION:

- **Topic: BECCS with Algae as Biomass Feedstock**
    - Roessner
    - Park
    - Meretsky

4.29 Live Class Session — Direct Air Capture, Part 1

READINGS:

O Webb, et al., *Scaling Direct Air Capture (DAC): A Moonshot or the sky's the limit*, The Oxford Institute for Energy Studies, Dec. 2023, pp. 1-23

O Jacobson, *The health and climate impacts of carbon capture and direct air capture*, 12 ENERGY ENVIRON. SCI. 3567-74 (2019)

O House, et al., Direct air capture: An expensive, dangerous distraction from real climate solutions, Bulletin of the Atomic Scientists, Dec. 15, 2023

O Kusnetz, Carbon Removal Is Coming to Fossil Fuel Country. Can It Bring Jobs and Climate Action?, Inside Climate News, Dec. 4, 2022

STUDENT PRESENTATION:

Topic: The Climeworks Orca Facility

- Rappin
- Roston
- Fransway
- Hettleman

5.1 Live Class Session — Direct Air Capture, Part 2

READINGS:

E Young, et al. *The cost of direct air capture and storage can be reduced via strategic deployment but is unlikely to fall below stated cost targets*, 6 ONE EARTH 1-19 (2023)

E Sovacool, et al., *Climate policy for a net-zero future: ten recommendations for Direct Air Capture*, 17 ENVIRONMENTAL RESEARCH LETTERS 1-19 (2022)

5.6 Live Class Session — Enhanced Rock Weathering

READINGS:

E Beerling, et al., *Farming with crops and rocks to address global climate, food and soil security*, 4 NATURE PLANTS 138 47 (2018)

E Brigham, The no-brainer climate solution — with a big accounting problem, Semafor, Mar. 15, 2024

E Lawford-Smith & Currie, *Accelerating the Carbon Cycle: the ethics of enhanced weathering*, 13 BIOLOGY LETTERS, Art 20160859 (2016)

O Hillsdon, Can enhanced rock weathering weather greater scrutiny as a solution to climate change? REUTERS, Nov. 1, 2023

5.8 Live Class Session

The Oceans and CDR, Part 1: Overview

READINGS:

O Lebling, et al., Toward Responsible and Informed Ocean-Based Carbon Dioxide Removal 32-63 (2022)

E Krause-Jensen, et al., *Sequestration of macroalgal carbon: the elephant in the Blue Carbon room*, 14 BIOLOGY LETTERS, Art. 20180236 (2018)

O Bryce, Marine Carbon Dioxide Removal, Issue Brief 1-8 (2024)

STUDENT PRESENTATIONS:

- **Topic: Electrochemical Ocean CDR**
    - Friedland
    - Herman
    - Lenart

5.13 Live Class Session

The Oceans and CDR, Part 2: Legal Regulation of Ocean-Based CDR Approaches

READINGS:

E Brent, *Marine geoengineering governance and the importance of compatibility with the law of the sea*, in RESEARCH HANDBOOK ON CLIMATE CHANGE, OCEANS, AND COASTS 442-61 (2021)

E Burns & Corbett, *Antacids for the Sea? Artificial Ocean Alkalinization and Climate Change*, 3 ONE EARTH 154-56 (2020)

O Lezaun, *Hugging the Shore: Tackling Marine Carbon Dioxide Removal as a Local Governance Problem*, 3 FRONTIERS IN CLIMATE, Art. 684063 (2021)

STUDENT GROUP EXERCISE:

We will engage in a group treaty interpretation exercise, focused on several marine treaties

	potentially pertinent to ocean-based carbon removal in the "Assignment Guidelines/Resources" folder under the Files tab.
5.15 **Live Class Session**	**The Oceans and CDR, Part 3: Legal Regulation of Ocean-Based CDR Approaches** **STUDENT GROUP EXERCISE:** **We will continue our group treaty interpretation exercise, focused on several marine treaties potentially pertinent to ocean-based carbon removal. You can find those instruments in the "Assignment Guidelines/Resources" folder under the Files tab.**
5.20 **Live Class Session**	**INCENTIVES TO DRIVE CDR RESEARCH AND DEPLOYMENT** **READINGS:** E Honegger, *Who Is Paying for Carbon Dioxide Removal? Designing Policy Instruments for Mobilizing Negative Emissions Technologies*, 3 FRONTIERS IN CLIMATE, Art. 672996 (2021) E Nemet, *Negative Emissions – Part 3: Innovation and upscaling,* 13 ENVIRONMENTAL RESEARCH LETTERS, Art. No. 063003 (2018) **Student Group Presentation: CCS/CDR Support in the U.S. federal budget, and U.S. DOE's Carbon Negative Shot:** ○ Robinson ○ Warfel ○ Wang ○ Nixon
5.22 **Synchronous Online Class Session**	**Some Parting Thoughts: The Current State of Play, and Future, of Climate Geoengineering - Roundtable Panel** ▪ Radhika Moolgavkar, Head of Methodology, Nori Carbon Removal Marketplace, https://nori.com/about ▪ Na'im Merchant, Founder & Managing Director, Carbon Curve LLC, https://carboncurve.substack.com/?utm_source=substack&utm_medium=web&utm_campaign=substack_prof ▪ Edward Parson, Dan and Rae Emmett Professor of Environmental Law, Faculty Co-Director, Emmett Institute on Climate Change and the Environment, UCLA School of Law, https://law.ucla.edu/faculty/faculty-profiles/edward-a-parson **Moderator: Wil Burns**
	Final Examination