

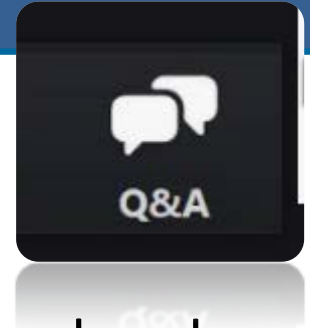
The National Academies of
SCIENCES • ENGINEERING • MEDICINE

A RESEARCH STRATEGY FOR OCEAN CARBON DIOXIDE REMOVAL AND SEQUESTRATION

Welcome!

Workshop Series Part 1: Setting the Stage
January 19, 2021

Virtual Logistics



- If you are watching the webinar, submit questions or comment through Q&A!
- Committee members and panelists, please use the raise hand function or submit questions through the chat
- Presentations and recording will be posted on our project website:

<https://www.nationalacademies.org/our-work/a-research-strategy-for-ocean-carbon-dioxide-removal-and-sequestration>

- For assistance, please contact Trent Cummings, tcummings@nas.edu

Background

- NASEM Consensus Study
- Sponsored by the ClimateWorks Foundation
- Exploring 6 Ocean-based CDR Strategies:
 - Identify the most urgent unanswered scientific and technical questions needed to: assess the benefits, risks, and sustainable scale potential CDR approaches
 - Define the essential components of a research and development program and specific steps that would be required to answer these questions;
 - Estimate the costs and potential environmental impacts of such a research and development program to the extent possible in the timeframe of the study.
 - Recommend ways to implement such a research and development program that could be used by public or private organizations.

Workshop Series

- **January 19, 2021** - Part 1: Setting the Stage
- **January 27, 2021** - Part 2: Technological and Natural Approaches to Ocean Alkalinity Enhancement and CO₂ removal
- **February 2, 2021** - Part 3: Ecosystem Recovery and Seaweed Cultivation
- **February 25, 2021** - Part 4: Nutrient Fertilization and Artificial Upwelling and Downwelling

The Committee

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Ken Buesseler

Jane Flegal

Debra Iglesias-Rodriguez

Kate Moran

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UC Santa Barbara

Ocean Networks Canada

GEOMAR

Heriot-Watt University

University of Vermont

UC Los Angeles

UC Santa Barbara

Columbia Law School

University of Hawai'i

Agenda

12:00pm	Welcome
12:05pm	Global Role for Carbon Removal Strategies
12:30pm	Legal and Political Aspects of Ocean-based CDR
1:30pm	BREAK
1:45pm	Social Acceptance and Ethical Considerations
2:45pm	Financial and Economic Considerations
3:45pm	BREAK
4:00pm	Parallel Efforts in Advancement of Ocean-based CDR Strategies
5:00pm	Adjourn

Global Role for Carbon Removal Strategies

SWP

Dr Oliver Geden

NASEM Committee on Ocean-Based CDR, 19 January 2021



Stiftung Wissenschaft und Politik
Deutsches Institut für
Internationale Politik und Sicherheit

Quick overview

- 3 different strategic approaches (visual representations)
 - what should CDR be used for?
 - who are the imagined and/or real-world actors?
 - [implicitly] how would ocean-based CDR options fit in?

1. *Global Temperature Target Focus*

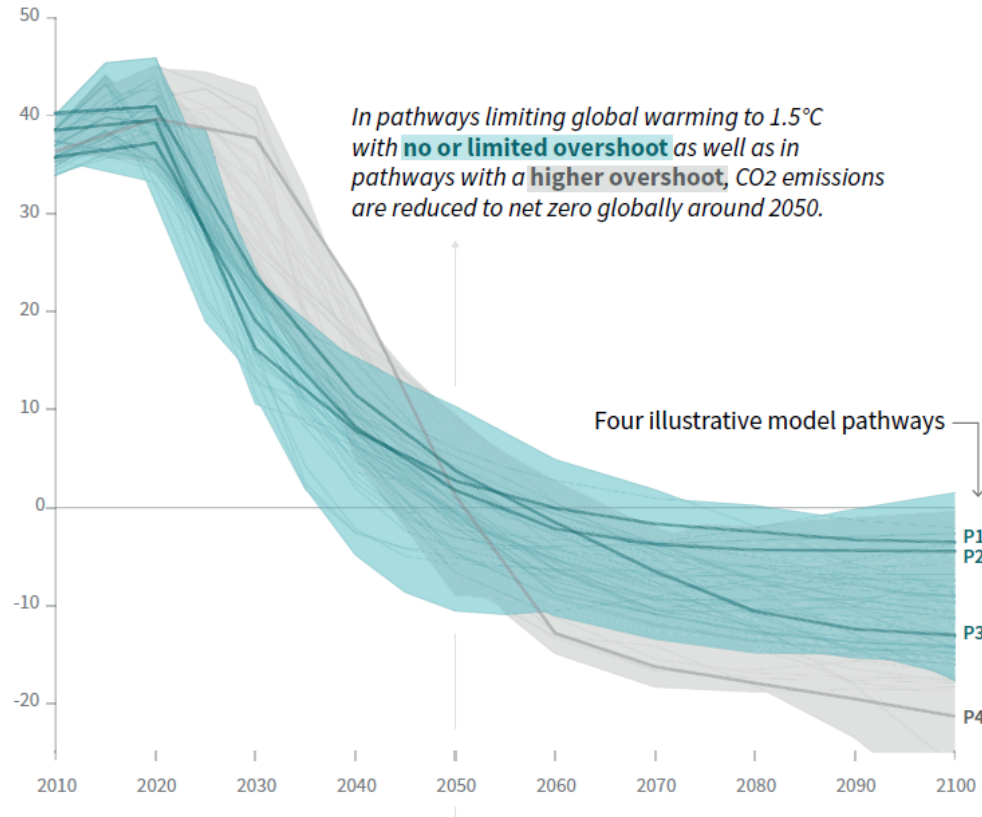
2. *Global Risk Hedging Focus*

3. *(National/Regional) Emissions Target Focus*

Global Temperature Target Focus I

Global total net CO₂ emissions

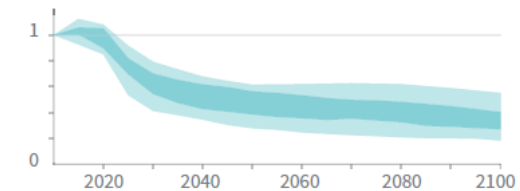
Billion tonnes of CO₂/yr



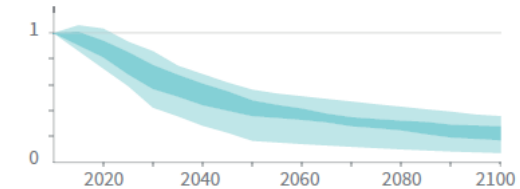
Non-CO₂ emissions relative to 2010

Emissions of non-CO₂ forcers are also reduced or limited in pathways limiting global warming to 1.5°C with **no or limited overshoot**, but they do not reach zero globally.

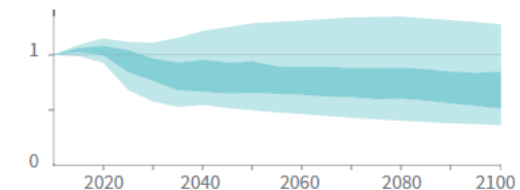
Methane emissions



Black carbon emissions

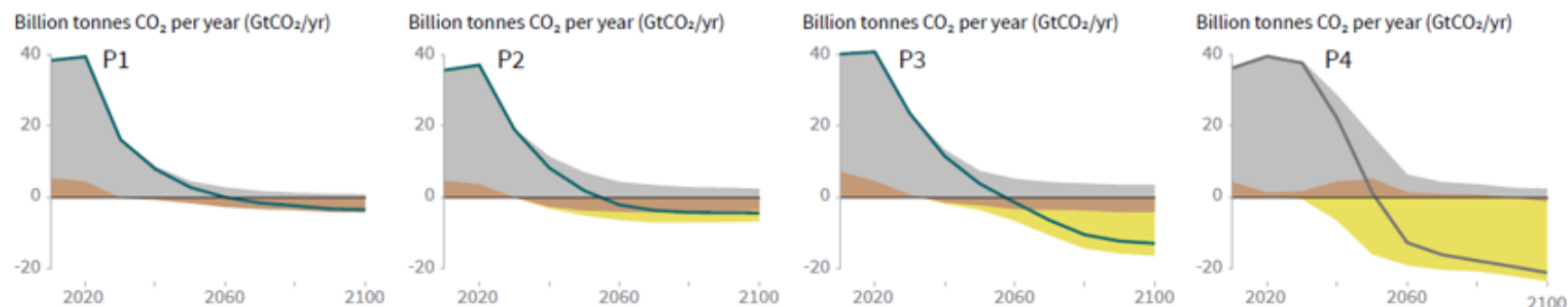


Nitrous oxide emissions



Global Temperature Target Focus II

● Fossil fuel and industry ● AFOLU ● BECCS



P1: A scenario in which social, business, and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A down-sized energy system enables rapid decarbonisation of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

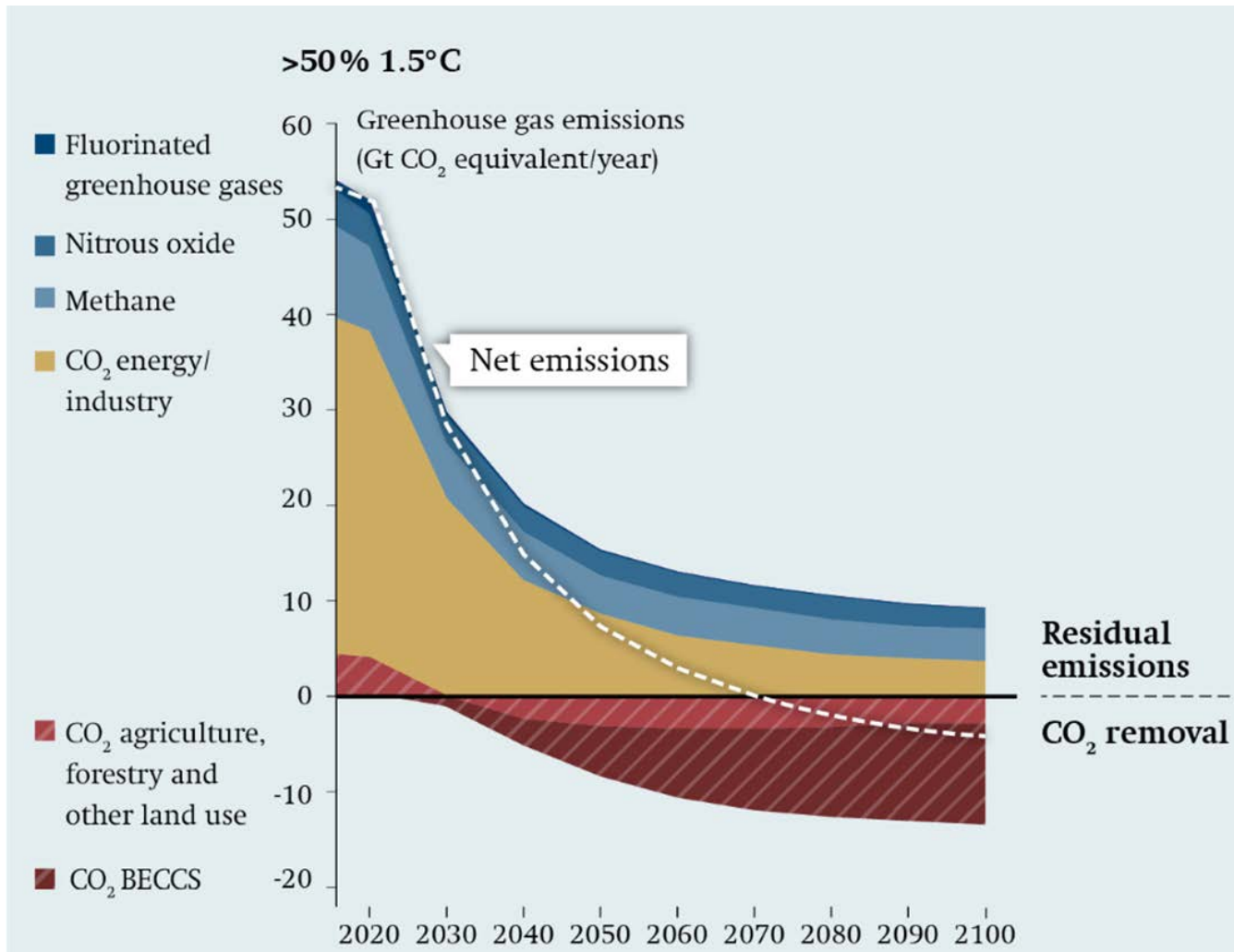
Global indicators

Pathway classification

	P1	P2	P3	P4	Interquartile range
Pathway classification	No or low overshoot	No or low overshoot	No or low overshoot	High overshoot	No or low overshoot

IPCC Special Report 1.5 °C – SPM

Global Temperature Target Focus III

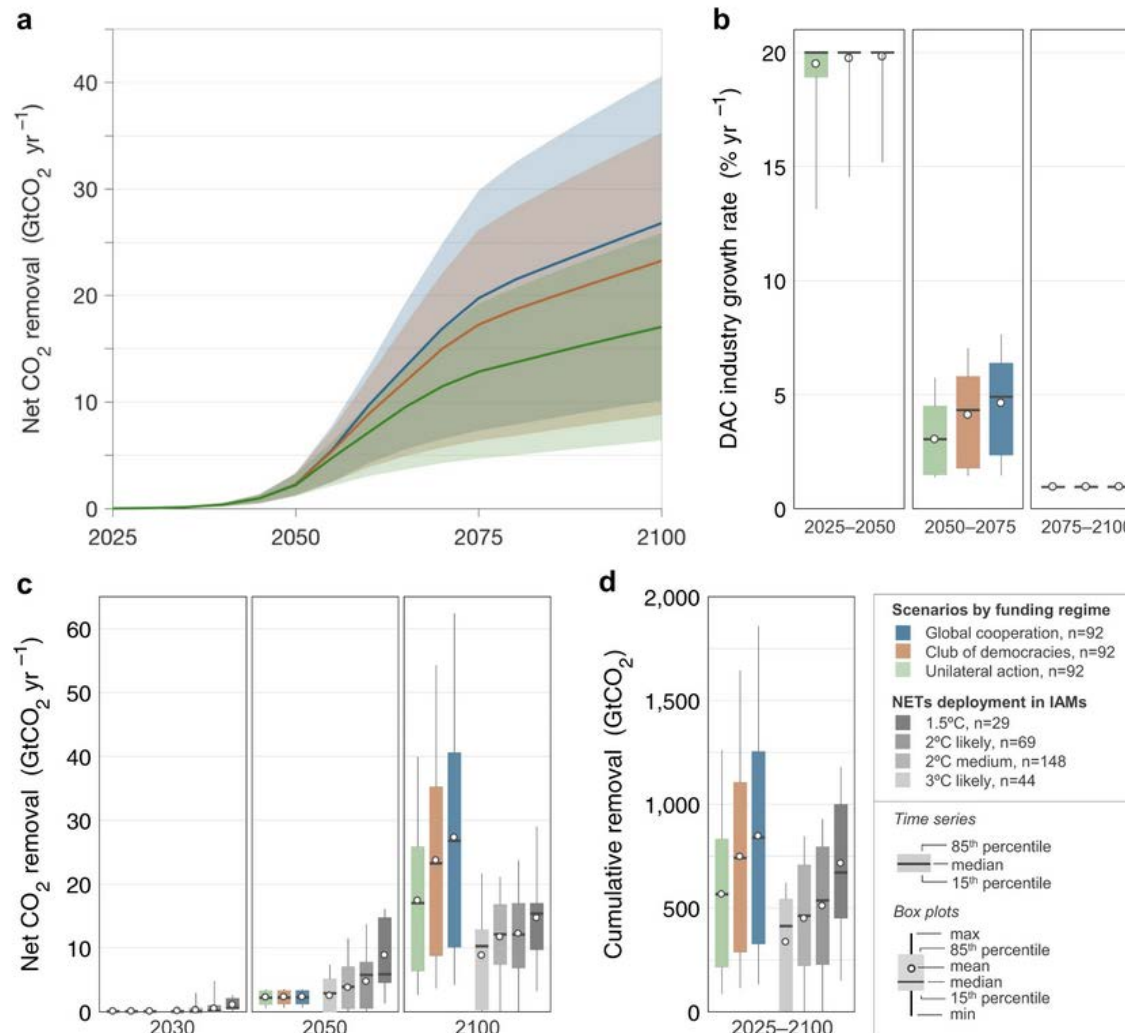


Geden/Schneuit: Unconventional Mitigation (2020)

Global Risk Hedging Focus I

Fig. 3: Net CO₂ removal by funding regime.

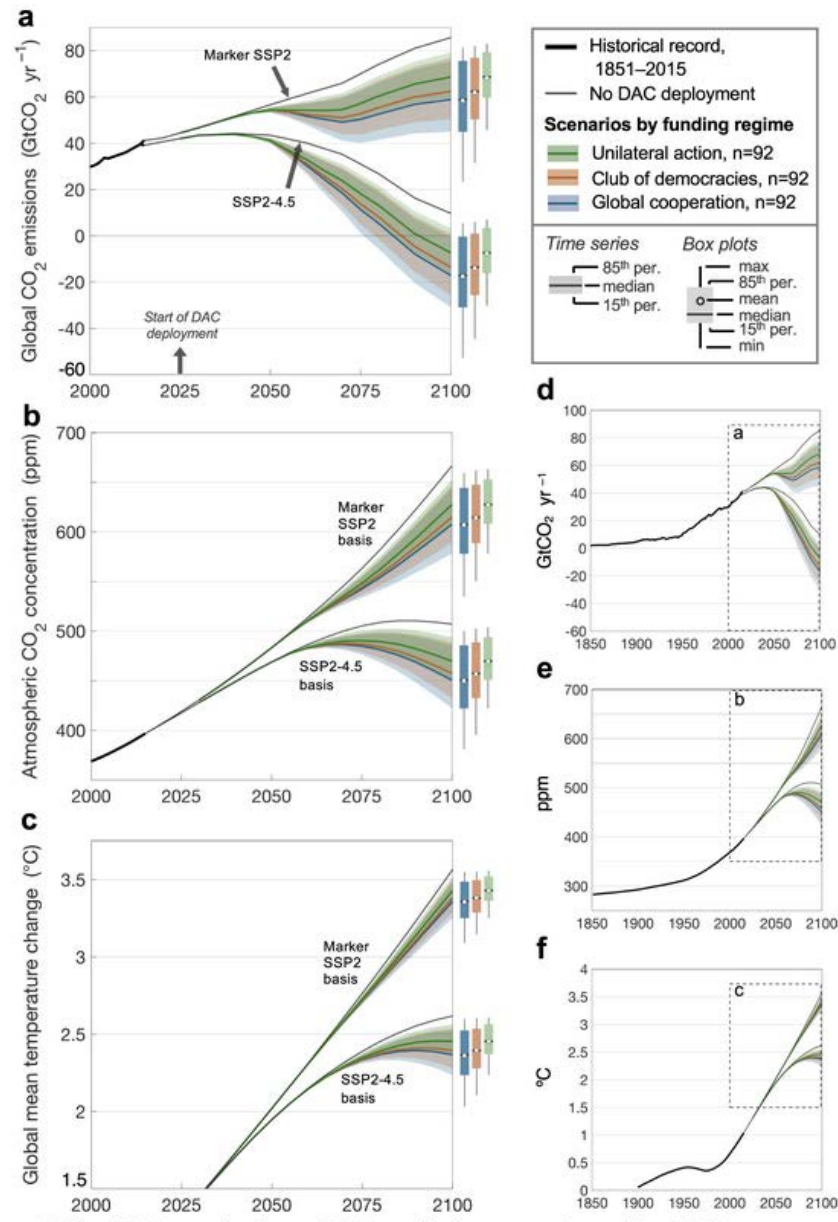
From: Emergency deployment of direct air capture as a response to the climate crisis



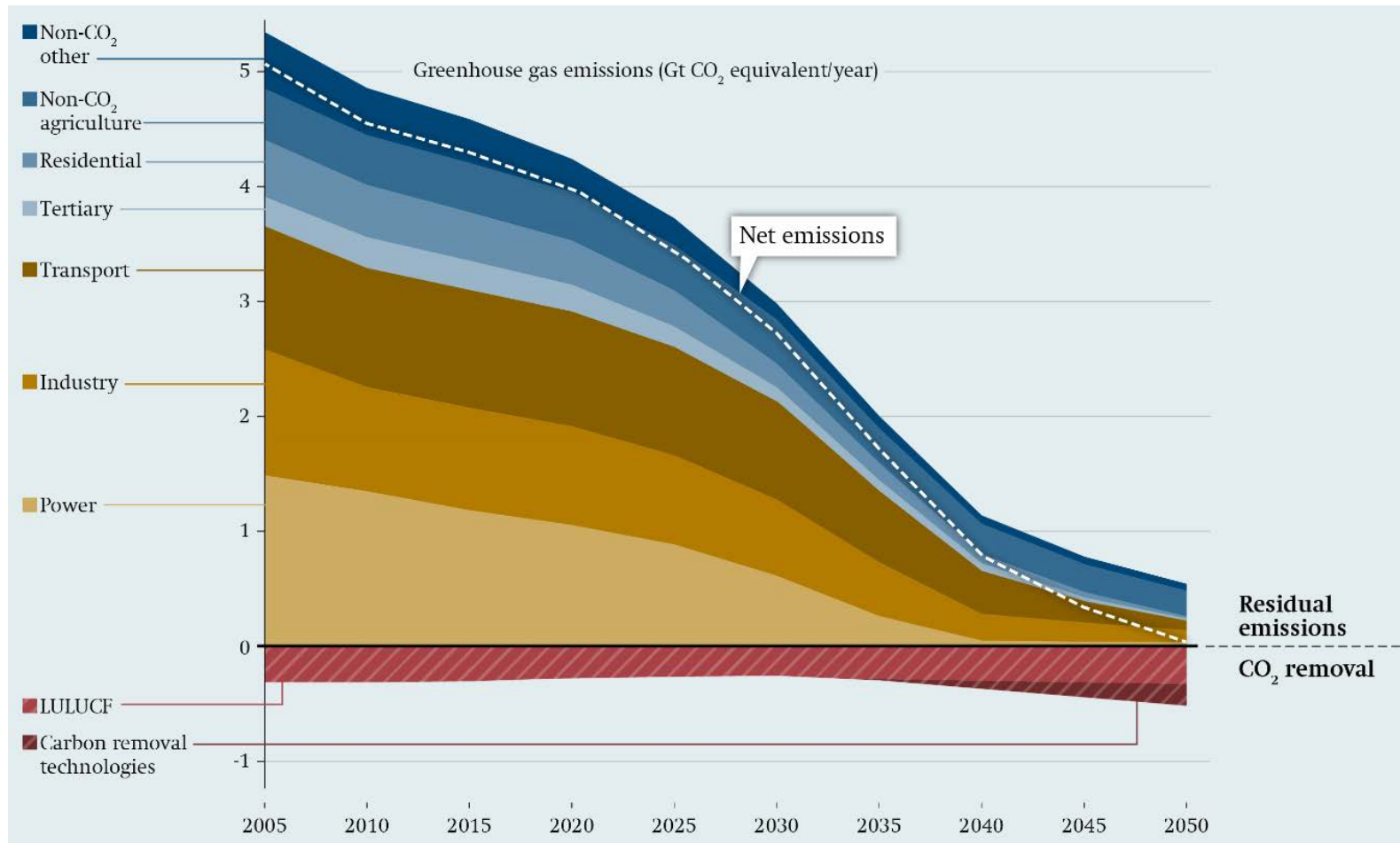
Hanna et al.: Emergency deployment of direct air capture as a response to the climate crisis (2021)

Global Risk Hedging Focus II

Hanna et al.: Emergency deployment of direct air capture as a response to the climate crisis (2021)

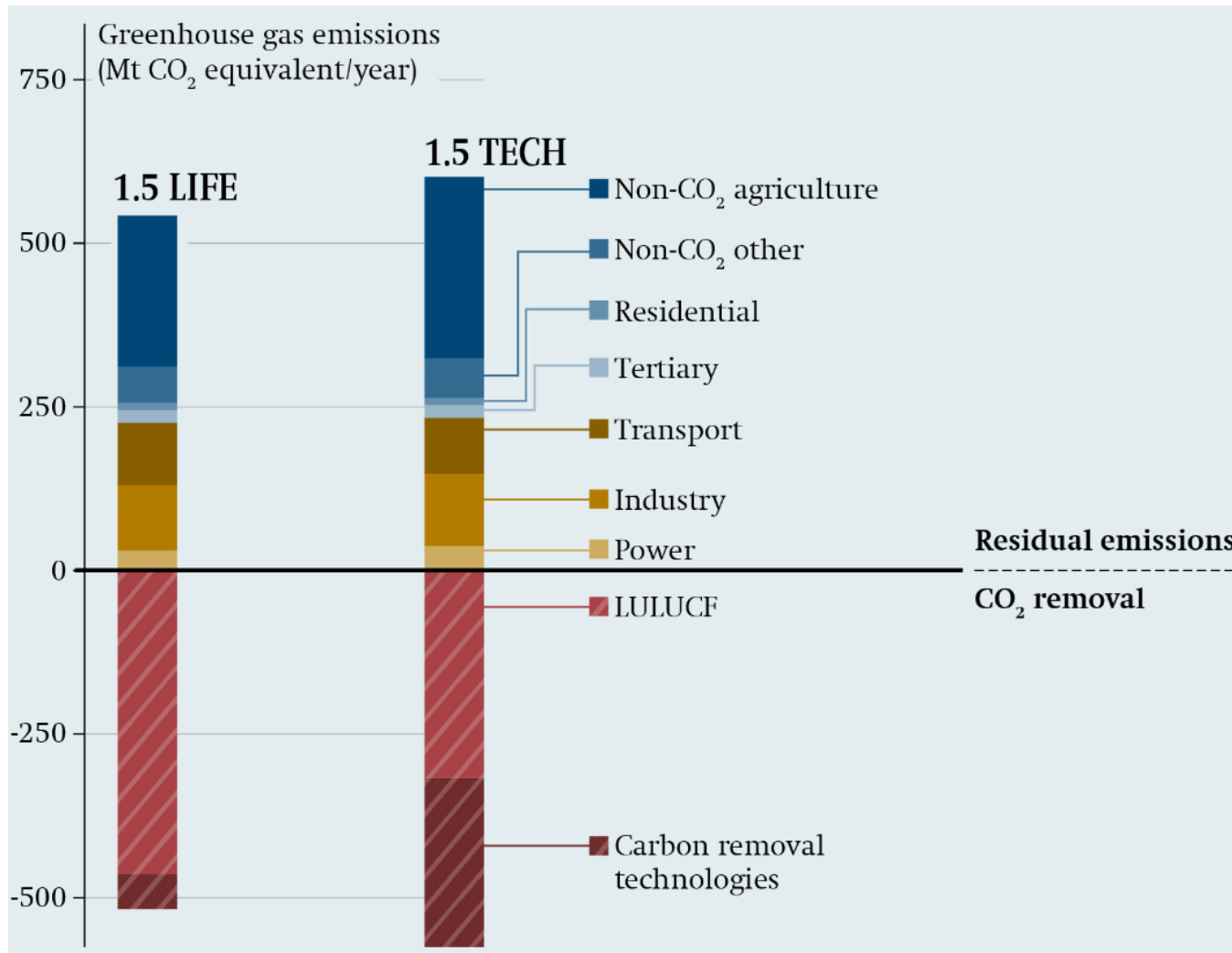


(EU-28) Emissions Target Focus I



Geden/Schneuit: Unconventional Mitigation (2020)

(EU-28) Emissions Target Focus II



Geden/Schenuit: Unconventional Mitigation (2020)

Some conclusions

- If a strategy doesn't have actors who are willing and capable of making it happen in the real world, then it's not really a strategy, it's wishful thinking (*imagined* vs. *existing* policymakers)
- Influenced by IPCC's global macro-economic optimization scenarios, it's now accepted among climate policymakers that CDR will be needed globally to achieve the Paris Agreement's long-term temperature goal (1.5 - <2°C). But there's not even serious talk who's actually going to deliver it.
- In coming years, CDR debate will shift from „if or if not“ to policy discussions about which CDR options should be deployed by whom, by when, at which volumes and in which ways.
- Main conceptual framework for CDR policy will be (national) net-zero GHG targets (*residuals* vs. *removals*). Only based on practical experience a serious debate on large-scale CDR will emerge (*global net-zero* and *actor-level net negative*, then *global net negative*)

Research areas, or: Issues to think about

Under the assumption that it is possible to incentivize (some) Ocean-Based CDR responsibly...

- What are (future) policy/politics 'problems' that Ocean-Based CDR options might be the (preferred) 'solution' for? For which actors?
- [in a given country:] How do Ocean-Based CDR options rate in the 'socio-political merit order'? Or: What are the mitigation options they are competing against (in terms of political preferences, societal acceptance, economics, efficacy)?
- How do Ocean-Based CDR options fit into the usual categorization (nature/ecosystem-based – hybrid – technological/geochemical)? Will they stabilize the politically emerging *nature vs. tech* dichotomy, or help to overcome it?

Literature

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- Schenuit, F. (2021): Carbon Dioxide Removal policy in the making: Assessing developments in 9 OECD cases. *Frontiers in Climate* (under review)

Thank you very much!

...and don't forget to review IPCC AR6 WG3 SOD (CDR mainly in chapters 12, 7 & 3)

<https://apps.ipcc.ch/comments/ar6wg3/sod/register.php>
(until 14 March)





International Governance of Marine Geoengineering Approaches

Wil Burns, Co-Executive Director

NASEM Workshop on Ocean-based CDR Opportunities and Challenges

January 19, 2021



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LAW AND POLICY

MARINE GEOENGINEERING

Dozens of approaches have been proposed to store carbon dioxide in or below the oceans, or to alter seas to cool the planet. No method has been rigorously tested scientifically.

FOAMS

Films or foams on the surface could reflect sunlight



CLOUD SEEDING

Ships spraying seawater might help to form reflective clouds



ALKALINIZATION

Chalk-like powder could absorb CO₂ chemically



IRON FERTILIZATION

Dissolved iron might encourage phytoplankton growth



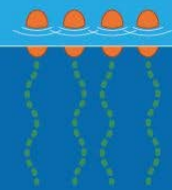
ARTIFICIAL UPWELLING

Pumping water from depth might cool the surface



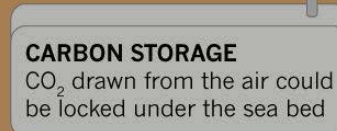
MACROALGAE CULTIVATION

Carbon absorbed by growing seaweed might be stored at depth



CARBON STORAGE

CO₂ drawn from the air could be locked under the sea bed



©nature



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London Dumping Convention (1972)

RESOLUTION LC-LP.1(2008) ON THE REGULATION OF OCEAN FERTILIZATION

3. AGREE that in order to provide for legitimate scientific research, such research should be regarded as placement of matter for a purpose other than the mere disposal thereof under Article III.1(b)(ii) of the London Convention and Article 1.4.2.2 of the London Protocol;
4. AGREE that scientific research proposals should be assessed on a case-by-case basis using an assessment framework to be developed by the Scientific Groups under the London Convention and Protocol . . .
8. AGREE that, given the present state of knowledge, ocean fertilization activities other than legitimate scientific research should not be allowed. To this end, such other activities should be considered as contrary to the aims of the Convention and Protocol and not currently qualify for any exemption from the definition of dumping in Article III.1(b) of the Convention and Article 1.4.2 of the Protocol; [emphasis added]





London Dumping Convention (1972)

ASSESSMENT FRAMEWORK FOR SCIENTIFIC RESEARCH INVOLVING OCEAN FERTILIZATION (2010)

■ Elements of environmental assessment:

- Problem formulation
- Site selection and description
- Exposure assessment
- Effects assessment
- Risk Characterization
- Risk Management
- Decision Making
- Results of Monitoring





Resolution LP.4(8) on the Amendment to the London Protocol of Matter for Ocean Fertilization and Other Marine Geoengineering Activities (2013)

- Expanded potential purview of regulation to all potential “marine geoengineering” activities, i.e. “deliberate intervention in marine environment to manipulate nature processes;”
- Mandated issuance of permits by Parties before such activities occurred, including the mandate to limit or reduce pollution as far as “practicable;”
- In case of OIF (and by implication, other geo. options), permits only to be issued for “legitimate scientific research” and projects not intended for commercial gain;
- Establishment of an assessment framework similar to 2010 voluntary framework, including elements for ongoing consultation with other Parties potentially affected in areas in their jurisdiction or the global commons, assessment of potential impacts of activities, risk management to minimize potential impacts, monitoring, and reporting to the Secretariat, and subsequently to other Parties.





CBD, 10TH COP (2010)

X/33. Biodiversity and climate change

(w) Ensure . . . in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting in accordance with Article 3 of the Convention, and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment; [emphasis added]





UNCLOS

Article 238 Right to conduct marine scientific research

All States, irrespective of their geographical location, and competent international organizations have the right to conduct marine scientific research subject to the rights and duties of other States as provided for in this Convention.

Article 239 Promotion of marine scientific research

States and competent international organizations shall promote and facilitate the development and conduct of marine scientific research in accordance with this Convention.



Article 245 Marine scientific research in the territorial sea

Coastal States, in the exercise of their sovereignty, have the exclusive right to regulate, authorize and conduct marine scientific research in their territorial sea. Marine scientific research therein shall be conducted only with the express consent of and under the conditions set forth by the coastal State.

Article 257 Marine scientific research in the water column beyond the exclusive economic zone

All States, irrespective of their geographical location, and competent international organizations have the right, in conformity with this Convention, to conduct marine scientific research in the water column beyond the limits of the exclusive economic zone.

Article 263 Responsibility and liability

1. States and competent international organizations shall be responsible for ensuring that marine scientific research, whether undertaken by them or on their behalf, is conducted in accordance with this Convention.
2. States and competent international organizations shall be responsible and liable for the measures they take in contravention of this Convention in respect of marine scientific research conducted by other States, their natural or juridical persons or by competent international organizations, and shall provide compensation for damage resulting from such measures.
3. States and competent international organizations shall be responsible and liable pursuant to article 235 for damage caused by pollution of the marine environment arising out of marine scientific research undertaken by them or on their behalf. [emphasis added]

Article 194: Measures to Prevent, Reduce and Control Pollution of the Marine Environment

1. States shall take, individually or jointly as appropriate, all measures consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source, using for this purpose the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavour to harmonize their policies in this connection.

Article 1(1)(4): Use of Terms

(4) "pollution of the marine environment" means the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life . . .

Article 235

1. States are responsible for the fulfilment of their international obligations concerning the protection and preservation of the marine environment. They shall be liable in accordance with international law.
2. States shall ensure that recourse is available in accordance with their legal systems for prompt and adequate compensation or other relief in respect of damage caused by pollution of the marine environment by natural or juridical persons under their jurisdiction. [emphasis added]

4. Measures such as area-based management tools, including marine protected areas

4. Objectives of area-based management tools, including marine protected areas

The text would set out objectives of area-based management tools, including marine protected areas, in areas beyond national jurisdiction for the conservation and sustainable use of marine biological diversity.

5.Environmental impact assessments

5.1 Obligation to conduct environmental impact assessments

Drawing from article 206 of the Convention and customary international law, the text would set out the obligation for States to assess the potential effects of planned activities under their jurisdiction or control in areas beyond national jurisdiction.

Paris Agreement (2015)

Article 4

2. Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions. [emphasis added]



UNFCCC (1992)

Article 4: Commitments

2. The developed country Parties and other Parties included in Annex I commit themselves specifically as provided for in the following:

(a) Each of these Parties shall adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs. [emphasis added]



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Paris Agreement (2015)

Preamble

Acknowledging that climate change is a common concern of humankind, Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights... [emphasis added]

Emphasizing the intrinsic relationship that climate change actions, responses and impacts have with equitable access to sustainable development and eradication of poverty . . . [emphasis added]



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Governing Marine CDR

Anna-Maria Hubert, Assistant Professor University of Calgary, Faculty of Law, Associate Fellow, InSIS, University of Oxford

19 January 2021

Geoengineering Research Governance Project (GRGP)

www.ucalgary.ca/geoengineering-governance



- ❖ Aim to engage with academics from relevant disciplines, together with experts from government, intergovernmental and non-governmental organizations, and other stakeholders to seek their views and integrate this feedback into a revised document
- ❖ Expert peer review by legal scholars, online call for comments, interviewing expert stakeholders, international workshop

IASS WORKING PAPER

Institute for Advanced Sustainability Studies (IASS)
Potsdam, May 2015

An Exploration of a Code of Conduct for Responsible Scientific Research involving Geoengineering

Introduction, Draft Articles and Commentaries

Anna-Maria Hubert and David Reichwein



CODE OF CONDUCT FOR RESPONSIBLE GEOENGINEERING RESEARCH

October 2017

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The Human Right to Science and
Its Relationship to International
Environmental Law

Anna-Maria Hubert*^o

Abstract

This article explores the potential contribution of international human rights law – specifically, the oft-neglected ‘right to science’ – to the interpretation, operation and progressive development of international environmental law. Science and its applications play a critical role in environmental protection. At the same time, society faces persistent controversies at this interface. Environmental regimes may lack sufficient norms and tools for regulating upstream science and innovation processes because they tend to focus narrowly on physical harms to the environment and may not address the wider ethical, legal, social and political concerns. The human right to science, which is codified in various international and regional human rights instruments, may serve to augment international environmental law and contribute to more effective, equitable and democratically legitimate and accountable processes and outcomes in relation to the application of science and technology in environmental regimes. The article begins by outlining the scope and contents of, as well as the limitations on, the right to science, focusing on Article 15(1)(b) of the International Covenant on Economic, Social and Cultural Rights (ICESCR) and its overlaps with the norms of international environmental law.¹ It then analyses the ways in which the right to science may influence the development of international environmental law by elucidating mechanisms for the integration of a human rights perspective in science and technology and by outlining its potential substantive contributions to the development of international environmental law.



Cracking the code: how discursive structures shape
climate engineering research governance

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ABSTRACT

There is increasing interest in developing anticipatory governance of climate engineering (CE) research. Discourse is the source code with which contested futures are written, shaping how future governance options can be imagined, designed and institutionalized. ‘Cracking the code’ underpinning the CE research governance debate can, therefore, help anticipate and critically reflect upon the ongoing constitution of governance. I present a sociology-of-knowledge-based discourse analysis (SKAD) of a series of interviews with governance experts from the US, the UK and Germany about a proposed Code of Conduct for climate engineering research. I illustrate how – by shaping what is defined as the object(s) of governance, why governance is considered necessary, and who is assigned the authority to govern – the underlying discursive structure of a given governance debate can shape governance development.

KEYWORDS Discourse analysis; sociology of knowledge; anticipatory governance; climate engineering; expert interviews



A Code of Conduct for Responsible
Geoengineering Research

Anna-Maria Hubert
University of Calgary, and
University of Oxford

Abstract

This article explores the potential contribution of the development of a code of conduct to serve as a near-term governance instrument to guide the responsible conduct of geoengineering research. This idea is grounded in the observation that geoengineering research and development processes are emerging within a polycentric governance landscape. A key feature of such systems is the recognition of an overarching system of rules which, inter alia, set out the key objectives to be achieved. To this end, the article presents the results of a multi-year, transdisciplinary study that seeks to identify and describe salient legal concepts, norms, and processes relevant to the geoengineering research governance, and discusses how the interpretation and application of these may be promoted through the adoption of a flexible, voluntary instrument promulgated by various state and non-state actors operating at different levels.

Policy Implications

- There is a strong need to promote the responsible conduct of geoengineering research through the development of flexible, near-term governance frameworks within the context of a polycentric governance landscape.
- Geoengineering research governance could be promoted through the development and promulgation of a Code of Conduct to serve as one near-term element in a broader governance landscape for geoengineering measures.
- There is no need to reinvent the wheel: the design of geoengineering research governance should take into account relevant legal concepts, norms, and processes as the basis for policy experimentation and innovation.
- The process of developing geoengineering research governance must involve awareness, discussion, and engagement on the part of different experts representing a full range of disciplines, government and intergovernmental representatives, civil society, and the lay public about geoengineering research and its governance.

Despite a large and proliferating literature on the topic, it seems that there is no foreseeable end to discussions on the governance of geoengineering. This state of affairs is perhaps unsurprising given the controversial nature, variety, and scale of proposals to deliberately intervene in nature to counteract anthropogenic climate change,¹ involving many different sectors, actors, and geographical areas; the diversity and relative independence of bodies and actors at various levels with rule-making authority; and the need to facilitate policy experimentation to address the more novel features of these technological proposals. The fact that there are so many divergent, yet meritorious governance avenues to explore may be descriptive of the underlying conditions of governance in this emerging area of climate law and policy. Much like climate change governance writ large, the geoengineering governance landscape is emerging within a ‘polycentric’ system populated by a variety of public and private actors and institutions operating at multiple scales (see Nicholson et al., 2018; Reynolds, 2018). This concept is even more salient to the governance of geoengineering research since science itself is also described as a ‘real-world’ example of polycentricity (Feyerabend, 1975; Polanyi, 1951).

Definitions abound, but polycentric governance is generally understood as ‘a social system of many decision centers having limited and autonomous prerogatives and operating under an overarching set of rules’ (Aligica and Tarko, 2012, p. 237). Embedded in this theory is the understanding that a key feature of such systems is ‘an overarching system of rules’ (or ‘rule of law’) for the functioning of the polycentric order within the existing institutional and cultural framework. In other words, at its core, ‘polycentricity is not just a discussion about multiple decision-making centers and monopolies of power, but also a discussion about rules, constitutions, fundamental political values, and cultural adaptability in maintaining them’ (Aligica and Tarko, 2012, p. 246; see further Fuller, 1978; Ostrom, Tiebout, and Warren, 1961; Polanyi, 1951). This idea of polycentric systems being bound by a set of overarching rules is ‘found in almost all definitions of polycentric governance’ (Jordan et al., 2018, p. 19), and distinguishes polycentric governance from other forms of governance that are analogous to the polycentric order (Aligica and Tarko, 2012, p. 245 commenting on Ostrom et al., 1961). The role of overarching rules within the

A Polycentric Governance Landscape

- ❖ Marine CDR is variety of public and private actors and institutions operating at multiple scales
- ❖ “Polycentricity” refers to “a social system of many decision centre having limited and autonomous prerogatives and operating arching set of rules’ (Aligica and Tarko, 2012, p. 237), and is apt as a theoretical framework for analysing the governance of marine CDR, including R&D in this field
- ❖ Governance considerations include:
 - ❖ Controversial nature, variety, and scale of proposals to deliberately intervene in the marine environment to counteract anthropogenic climate change, involving many different sectors, actors, geographical areas and jurisdictional considerations
 - ❖ Diversity and relative independence of bodies and actors at various levels with rule-making authority
 - ❖ Need to facilitate policy experimentation to address the more novel features of these technological proposals

While a well-developed theorization of significance and role of overarching rules in polycentric governance systems is beyond the scope of this article and is a discussion that requires further elaboration, this feature of polycentric orders being governed by an overarching system of rules may have at least two important implications for scholarship on the governance of geoengineering research. First, it highlights the role for research in identifying and describing norms relevant to this field. Specifically, it invites an enquiry into whether such 'overarching rules' are present, and, if so, what form and function they may take. Second, from a prescriptive standpoint, it prompts scholars and other stakeholders to reflect on the 'most desirable rules, norms and organizations' to be established for the field (Jordan et al., 2018, p. 20).

These conditions usefully frame the aims and purposes of the Geoengineering Research Governance Project (GRGP), which is the focus of this article (Hubert, 2016). The idea for this project emerged several years ago in connection with

— Hubert, *Global Policy*, 2020

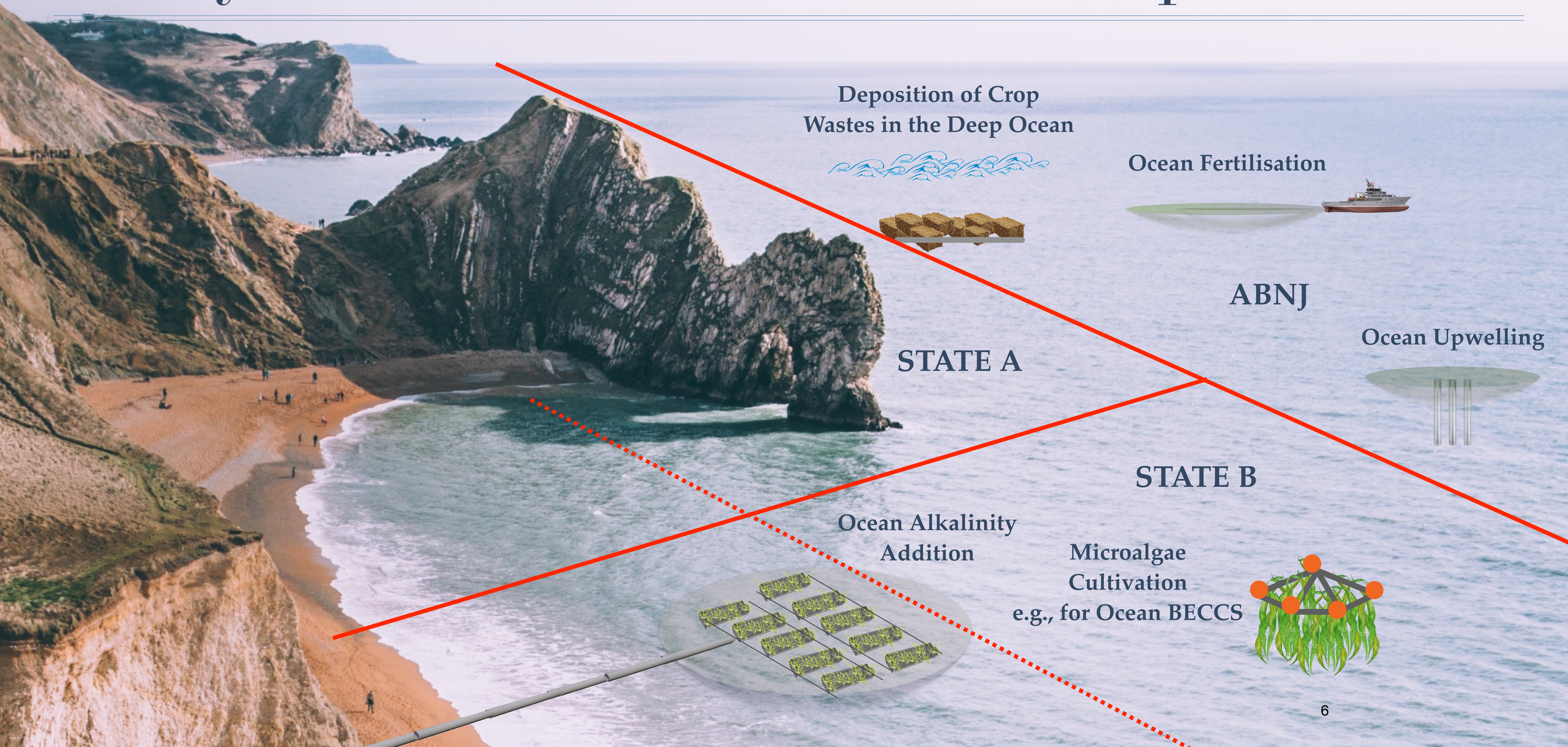
Descriptively, what norms and processes are relevant to the governance of marine CDR?

Context specific enquiry with some ambiguity:

- ❖ *How* can the activity be characterised?
- ❖ *Who* is undertaking the activity?
- ❖ *Where* is the activity taking place?

Prescriptively, taking the existing legal and institutional framework into account, how should marine CDR be governed?

A Polycentric Governance Landscape



Existing Legal and Institutional Landscape

- ❖ International law

- ❖ Law of the sea: including regimes on protection and preservation of the marine environment, such as pollution by dumping, by seabed activities, and land-based sources; fisheries; shipping and installation of platforms and structures; marine scientific research
- ❖ International environmental law: including intersection with regimes on the conservation of marine biodiversity and climate law, customary law regime on transboundary harm, general principles
- ❖ International human rights law: including Art 15(1)(b) ICESCR on the so-called “human right to science”
- ❖ Others...

Existing Legal and Institutional Landscape

- ❖ National / subnational law:
 - ❖ Sovereignty in the territorial sea
 - ❖ Sovereign rights over living and non-living resources, including fisheries, renewable energy production
 - ❖ Jurisdiction over marine environment, installations, marine scientific research
 - ❖ Jurisdiction over flagged vessels on the high seas
 - ❖ National laws and policies related to the Paris Agreement (including NDCs)

Existing Legal and Institutional Landscape

- ❖ Soft law declarations, resolutions, decisions, codes of conduct etc.
 - ❖ E.g., OSPAR Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area, UN Declaration on the Use of Scientific and Technological Progress in the Interests of Peace and for the Benefit of Mankind, UNESCO Recommendation on the Status of Science and Scientific Researchers, UNESCO Declaration of Ethical Principles in Relation to Climate Change, Oxford Principles, Asilomar Principles
- ❖ On marine geoengineering relevant to the US: e.g., Res LC-LP.1(2008) on the regulation of ocean fertilisation, Res LC-LP.2(2010) on the assessment framework for scientific research involving ocean fertilisation

Prescriptively, can we do better?

“Responsible research and innovation (RRI) has emerged in recent years as a science-policy framework, which seeks to align technological innovation with broader social values, and to support the institutional decisions concerning the goals of research and innovation in conditions of uncertainty and ambiguity. RRI aims to engage publics and responsible actors in the science and innovation field to produce ethically acceptable, sustainable and socially desirable research and innovation outcomes.”

— RRI-Practice, EU Horizon 2020

Prescriptively, can we do better?

Normative basis for RRI?

“Responsible research and innovation (RRI) has emerged in recent years as a science-policy framework, which seeks to align technological innovation with broader social values, and to support the institutional decisions concerning the goals of research and innovation in conditions of uncertainty and ambiguity. RRI aims to engage publics and responsible actors in the science and innovation field to produce ethically acceptable, sustainable and socially desirable research and innovation outcomes.”

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The Human Right to Science and Its Relationship to International Environmental Law

Anna-Maria Hubert*

Abstract

This article explores the potential contribution of international human rights law – specifically, the oft-neglected ‘right to science’ – to the interpretation, operation and progressive development of international environmental law. Science and its applications play a critical role in environmental protection. At the same time, society faces persistent controversies at this interface. Environmental regimes may lack sufficient norms and tools for regulating upstream science and innovation processes because they tend to focus narrowly on physical harms to the environment and may not address the wider ethical, legal, social and political concerns. The human right to science, which is codified in various international and regional human rights instruments, may serve to augment international environmental law and contribute to more effective, equitable and democratically legitimate and accountable processes and outcomes in relation to the application of science and technology in environmental regimes. The article begins by outlining the scope and contents of, as well as the limitations on, the right to science, focusing on Article 15(1)(b) of the International Covenant on Economic, Social and Cultural Rights (ICESCR) and its overlaps with the norms of international environmental law.¹ It then analyses the ways in which the right to science may influence the development of international environmental law by elucidating mechanisms for the integration of a human rights perspective in science and technology and by outlining its potential substantive contributions to the development of international environmental law.

Draft Code of Conduct for Responsible Geoengineering Research

Subjects of governance

Article 1 – Nature and Scope

1. This Code of Conduct is voluntary. However, certain parts of it are based on relevant legal principles and rules of international law. It also contains provisions that may be binding amongst the States Parties to specific legal instruments.⁷
2. This Code of Conduct is global in scope, and is directed at States and international organisations, as well as sub-State and non-State actors, including research funding bodies and other governmental authorities, scientific academies and institutions, individual scientists, non-governmental organisations, businesses, private foundations and other relevant actors.⁸

Legal form and bindingness of provisions contained therein

Article 1 – Nature and Scope

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Aims and objectives of governance

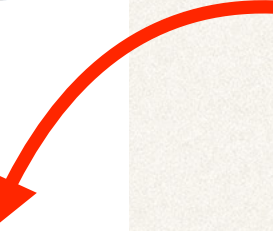
Article 2 – Objective

Recognising the need for safe, effective and progressive responses to the urgent threat of climate change and that more transdisciplinary research and sharing of knowledge is needed to better understand the potential efficacy, benefits, and adverse effects of geoengineering,⁹ this Code of Conduct aims to promote the responsible conduct of geoengineering research for the benefit of present and future generations of humankind. In particular, it seeks to provide principles and procedures for the responsible conduct of outdoor experiments on geoengineering.

(1) Facilitation and promotion of research



(2) Recognition of participatory rights in decision-making about research



(3) The prevention of any adverse effects of research and development, including to the marine environment



Object of governance

- ❖ Matter of significant debate in the literature
- ❖ Preferences for particular terminology depend upon the particular lens through which the topic is being considered, and are shaped by differing objectives, values, and disciplinary understandings
- ❖ Concept of “geoengineering” and related terms remains highly controversial, and is likely to evolve as scientific and societal understandings change over time
- ❖ Given that geoengineering R&D is in the early stages, the Code adopts a broader, more inclusive approach to defining the object of governance, rather than binding the definition of geoengineering narrowly to the assumed technical characteristics of the technologies being proposed

Object of governance

Article 2 – Objective

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Code of Conduct primarily targets ‘unencapsulated’ or ‘open air research’, setting out best scientific practices and procedures for perturbative field experiments

Contents of the Code of Conduct

- ❖ Includes the following:
 - ❖ General Principles, Art 3: To be interpreted and applied in light of general principles and rules of international law, including adopting a precautionary approach
 - ❖ Use of Geoengineering, Art 4: Includes a principle addressing mitigation deterrence
 - ❖ Cooperation on Geoengineering Research, Art 5
 - ❖ Principles and practices for responsible geoengineering research, Art 6

Contents of the Code of Conduct

- ❖ Includes the following:
 - ❖ Assessment of outdoor experiments on geoengineering, Art 7, Appendix I
 - ❖ Access to information, public participation on decision-making, and access to justice, Art 8, 10
 - ❖ Post-project monitoring of outdoor experiments, Art 9: Including for adverse affects; monitoring should inform future research and governance (adaptive management)
 - ❖ Interpretation and application of the Code, Art 11: To be interpreted and applied flexible and adaptive approach in light of new information and by drawing upon the work of and involving, as appropriate, existing institutional bodies, experts, and civil society

Cooperation on Geoengineering Research

Article 5 – Cooperation on Geoengineering Research

1. States and international organisations, as well as sub-State and non-State actors should cooperate in good faith to promote the responsible conduct of geoengineering research in accordance with international law and on the basis of the guidance in this Code of Conduct.
2. To this end, in accordance with respective capabilities, efforts should be made:
 - (a) to cooperate, through appropriate mechanisms, in the establishment and implementation of laws, measures or policies and their harmonisation for the responsible conduct of geoengineering research;
 - (b) to gather new knowledge through the fullest possible cooperation and coordination of geoengineering research in order to understand and assess the potential efficacy, benefits, and adverse effects of geoengineering and to support decision-making;
 - (c) to promote and cooperate in the full, open, and prompt exchange of relevant information on geoengineering;²¹
 - (d) on the basis of equity, to cooperate to assist and strengthen the capabilities and capacities of those in developing countries to participate in geoengineering research and to support decision-making through, *inter alia*, joint programmes to provide education and training of scientific and technical personnel.²²

- ❖ States and other actors should cooperate on geoengineering research
- ❖ This includes cooperation on:
 - ❖ Development of governance measures
 - ❖ Gathering of new knowledge to support decision-making
 - ❖ Exchange of information on geoengineering
 - ❖ Considering equity, capacity-building (and technology transfer) for developing states

Principles and Practices for Responsible Geoengineering Research

Article 6 – Principles and Practices for Responsible Geoengineering Research

1. Geoengineering research should be conducted in a responsible manner, including in accordance with all applicable laws and regulations and on the basis of the guidance in this Code of Conduct.
2. All appropriate and effective measures should be taken to prevent and minimise the risk of harm from outdoor experiments on geoengineering and to maximise the benefits of such experiments.²³ Such measures include, with respect to outdoor experiments on geoengineering and on the basis of the guidance in this Code of Conduct, the establishment of an assessment procedure that permits public participation, the preparation of assessment documentation as described in Appendix I, the establishment of post-project monitoring measures, and the publication and dissemination of information about the geoengineering research.
3. Geoengineering research should be conducted taking a prudent, step-by-step approach.²⁴ As far as practicable, the nature, scale, duration, and intensity of an outdoor experiment on geoengineering should be proportionate to the current state of knowledge about the potential adverse effects taking into account the precautionary approach.
4. Outdoor experiments on geoengineering should be conducted using the best scientific methods and means that are reasonably available.²⁵ Research methods should be designed to match the site-specific characteristics and use minimally-intrusive approaches.²⁶
5. In the conduct of outdoor experiments on geoengineering, care should be taken to avoid activities which could disturb the experiments and observations of other scientists as well as other legitimate activities. This requires that those who plan to conduct outdoor experiments on geoengineering familiarise themselves with the status of current and planned experiments, observations and other activities in the area, and that they duly publicise their own research plans and activities in a timely manner.²⁷

- ← Should be conducted responsibly, including with all relevant laws and based on the guidance in the Code
- ← Aim of minimising the risks of research (through environmental assessment, monitoring etc) and maximising the benefits (information sharing, etc)
- ← “Step-by-step” approach to knowledge gathering for outdoor experiments
- ← Conducted using best scientific methods and means and minimally intrusive approaches
- ← Avoid interference with other legitimate uses of the seas and oceans, including other experiments in the area

Assessment of Outdoor Experiments on Geoengineering

Article 7 – Assessment of Outdoor Experiments on Geoengineering

1. Prior to the authorisation or conduct of a proposed outdoor experiment on geoengineering, the experiment should be assessed, at an early stage, in accordance with international law and domestic laws and requirements and on the basis of the guidance in Appendix I this Code of Conduct.
2. Proposed outdoor experiment on geoengineering should be assessed on a case-by-case basis at the project level.²⁸ To the extent appropriate, policies, plans and programmes on geoengineering research should also be assessed.²⁹
3. The proposed outdoor experiment on geoengineering should be reassessed where there is a change to the proposed experiment, if it is plausible that the change may result in potential adverse effects which were not considered previously.³⁰
4. The proposed outdoor experiment should be assessed based on the best available scientific information and with a degree of detail proportionate to the potential for adverse effects taking into account the precautionary approach.³¹
5. The information provided as part of the assessment of a proposed outdoor experiment on geoengineering should be subject to an arm’s length review prior to a decision to authorise or conduct the proposed experiment.³²

Guidance on the assessment of outdoor experiments involving geoengineering research, and linked to public participation recommendations

6. Before a decision is made to authorise or conduct an outdoor experiment on geoengineering, the interested public should be informed, either by public notice or individually as appropriate, early in an decision-making procedure, and in an adequate, timely and effective manner, on the basis of the guidance in Appendix I.³³
7. A decision as to whether a proposed outdoor experiment on geoengineering should be authorised or conducted should not be taken until an appropriate period has elapsed to consider comments.³⁴
8. If upon completion of an initial environmental assessment there is uncertainty regarding possible effects or any gaps in knowledge and uncertainties, these may be addressed by seeking further information on the specific issues of concern.
9. Any knowledge gaps, uncertainties, and assumptions relating to the proposed outdoor experiment should be identified and assessed.³⁵ Lack of scientific knowledge should not necessarily be interpreted as indicating a particular level of risk, an absence of risk, or an acceptable risk.³⁶ Any knowledge gaps, uncertainties, and assumptions should be used for planning, assessing and monitoring future geoengineering research and for improving legal and institutional frameworks and decision-making.³⁷
10. A decision to authorise or conduct an outdoor experiment should not be taken before all steps of the assessment are completed³⁸ and due account is taken of all relevant information, including, where available, the results of the assessment, consultation, and information from previous assessments and monitoring relevant to the proposed outdoor experiment.³⁹
11. The decision on a proposed outdoor experiment on geoengineering subject to an assessment should be in writing, state the reasons therefore and include the conditions to prevent, reduce or mitigate adverse effects. The written decision should be made available in a timely manner to interested persons or groups in accordance with Article 10 of this Code of Conduct.⁴⁰ It should include a brief, non-technical summary of the information and should be also made publicly available in accordance with Article 10 of this Code of Conduct.

APPENDIX I – GUIDANCE ON THE ASSESSMENT OF OUTDOOR EXPERIMENTS ON GEOENGINEERING

INTRODUCTION

The assessment process outlined in this ‘Code of Conduct for Responsible Geoengineering Research’ provides a mechanism to ensure that the environmental effects as well as ethical, social, and legal consequences of proposed outdoor experiments on geoengineering are evaluated and taken into account before the experiment is authorised or conducted. Assessment and monitoring are elements of due diligence, which is expressed in the principle in this Code of Conduct that all appropriate and effective measures should be taken to prevent and minimise the risk of harm from proposed outdoor experiments on geoengineering and that efforts should be made to maximise the benefits of such experiments.

The requirements for the assessment of projects or plans differ between countries and across different international agreements. The guidance in the Code of Conduct is without prejudice to any laws and regulations that may be applicable to the proposed outdoor experiment on geoengineering, including under international law with regard to activities having or likely to have a risk of transboundary harm or regarding application of domestic laws and requirements. Project proponents must ensure that their research plans comply with local, national and international laws and decision-making processes. However, given that existing laws and regulations at all levels may be inadequate for addressing the particular risks of geoengineering research, this Code of Conduct aims at providing general principles and a common process for assessment of outdoor experiments.

This guidance has been prepared to provide a description of basic principles and methodology for identifying, predicting and communicating the possible environmental and other consequences of a proposed geoengineering experiment. This guidance is general in recognition that individual geoengineering experiments are likely to be unique in terms of their purpose, scale, duration and intensity, and that they may involve large uncertainties due to the novelty of the research activity. Importantly, even where there is a low likelihood of direct, physical impacts from a proposed experiment, the assessment process is linked to public participation and transparency provisions to enable informed decision-making and encourage public deliberation on geoengineering more broadly. This recommendation draws attention to the need to incorporate into the research and innovation process more effective communication amongst stakeholders and the public at large, and as well as information about stakeholder preferences and values. Finally, it is noted that the assessment process is typically based on existing knowledge and analogies from previous experience of similar projects. Outdoor experiments on geoengineering may involve various degrees of uncertainty. Hence, post-project monitoring is recommended as an integral part of the assessment process for the reasons outlined below.

Assessment should be seen as an integral part of the research planning process, by identifying potential impacts at an early stage and throughout the planning processes, and by including public participation as much as possible. A general description of the contents and steps in the preparation of the assessment document are outlined in this guidance.

SCREENING

The first step in the assessment process is to determine whether the proposed experiment constitutes an ‘outdoor experiment on geoengineering’. The screening mechanism employed in this Code of Conduct refers to the purpose and nature of the research (and not its effects). It relies on expert and common-sense judgment to make this determination. The assessment process in this

Code of Conduct is limited to outdoor experiments on geoengineering. The provisions on assessment do not target other kinds of research activities that do not concern geoengineering, nor are they triggered by geoengineering desk studies or laboratory research.

‘Geoengineering’ remains a contested term and one that is likely to evolve as scientific and societal understandings change over time. Given that geoengineering research is at an early stage, this instrument favours a more inclusive approach, rather than binding the definition of geoengineering narrowly to the technical characteristics of the experiments being proposed. The disadvantage of adopting a broad definition of geoengineering in this Code of Conduct is that it provides less certainty to those undertaking geoengineering research. The advantages are however that opening up the conversation about the meaning and scope of the term geoengineering facilitates expert and public debate about the implications of the promise of the technology that is being investigated. This exercise in public deliberation and reasoning is valuable for determining the boundaries of the concept and enhancing the effectiveness, fairness, and legitimacy of governance over time. Moreover, it is argued here that an inclusive approach is not particularly onerous given that the principles and assessment process outlined in this Code of Conduct take a relatively light touch and are subject to the principle of proportionality. Finally, a more inclusive definition that covers ‘unencapsulated’ or ‘open air research’ on greenhouse gas removal or solar radiation management is more likely to capture potentially harmful research activities, and moreover is in keeping with best scientific practices and procedures for other kinds of perturbative field research or disruptive observational studies have been adopted in other contexts. This Code of Conduct follows in the vein of these instruments, which aim to prevent and minimise harms in accordance with a precautionary approach and increase the benefits of research.

Intent is a typical basis in the law for distinguishing scientific research from other activities and as a basis for defining the meaning of geoengineering. As a matter of good practice and to engender public trust in the science, researchers are called upon to be transparent about the purposes of their research plans and to act in good faith on their declared intentions. If the proponents of an outdoor experiment intend to conduct research on geoengineering or conduct research for multiple purposes, including to investigate geoengineering, this Code of Conduct urges them to be forthright in declaring their intentions. If the proponents of an outdoor experiment intend to carry out research that may be reasonably viewed as relating to geoengineering, but is carried out for some other purpose, the greatest encumbrance is that they may be called upon to justify their intentions at some stage, but the consequences of this would be minimal and could be demonstrated post hoc based on their publication record.

A more challenging situation arises at the screening stage where an independent authority is attempting to apply the guidance in the Code of Conduct. For example, given that early research on geoengineering may be dual purpose and may not be distinguishable from other kinds of basic or applied research that does not pertain to geoengineering. In such circumstances, it may be difficult to make an independent determination about whether an experiment pertains to geoengineering research. Again, as a matter of best practice, researchers involved in the conduct of outdoor experiments on geoengineering are encouraged to be transparent about their intentions with third parties.

There is no accepted definition of an ‘outdoor experiment’. The term should be viewed as encompassing all intentional, experimental perturbations of natural processes, ecosystems, habitats, and species. As mentioned above, the use of the term in this Code of Conduct is not intended to cover desk studies (modelling, social science research etc.), nor is it meant to include laboratory experiments. Other principles and processes outlined in this Code of Conduct may nonetheless be

Access to information

Article 10 – Access to Information

1. In order to facilitate the scientific process, to promote cooperation and coordination of geoengineering and its governance, and to support informed decision-making and public deliberation on geoengineering, there should be timely, complete and reliable access to information on geoengineering research. The confidentiality of any information may be protected where such confidentiality is protected by law.⁴³
2. Those involved in the planning and conduct of geoengineering research should notify and make publicly available information about that research through appropriate channels and to the extent practicable, including:
 - (a) research plans, programmes, and their objectives and methodologies;
 - (b) information and data relevant to determining environmental baselines;
 - (c) the results of peer review;
 - (d) the results of assessment;⁴⁴
 - (e) the results of the authorisation or decision to conduct an outdoor experiment on geoengineering;
 - (f) the results of monitoring;⁴⁵
 - (g) the results of research, data and information, including observational data, model results and other analysis tools, and any null and adverse environmental effects;
 - (h) compliance reporting;
 - (i) a brief, non-technical summary in the local language and English of the information provided under the above headings;⁴⁶ and
 - (j) any other relevant information.⁴⁷
3. Efforts should be made to facilitate and promote access to information on geoengineering research, including through the establishment of a centralised clearing-house mechanism that is publicly accessible.



Including a non-exhaustive list of information to be disclosed by those involved in the planning and conduct of geoengineering research

Interpretation and Application of the Code of Conduct

Article 11 – Interpretation and Application

1. This Code of Conduct should be interpreted and applied in conformity with the relevant principles and rules of international law. Nothing in this Code of Conduct shall prejudice the jurisdiction, rights and duties of States under international law.⁴⁸
2. This Code of Conduct should be interpreted and applied in its entirety.
3. This Code of Conduct should be interpreted and applied in a mutually-supportive manner with other relevant international law in accordance with the interrelationship and integration principle which reflects the interdependence of social, economic, financial, environmental and human rights aspects of principles and rules of international law relating to sustainable development as well as of the interdependence of the needs of current and future generations of humankind..⁴⁹
4. This Code of Conduct should be applied taking a flexible and adaptive approach in the light of new information and by drawing upon the work of and involving, as appropriate, existing institutional bodies, experts and civil society.⁵⁰
5. Efforts should be made to facilitate the implementation of and promote compliance with this Code of Conduct.
6. The guidance provided in this Code of Conduct should be reviewed periodically, as necessary, in the light of new knowledge and public participation. This review should take into consideration the work of and involve, as appropriate, institutional bodies, experts and civil society.⁵¹

← Idea that the provisions of the code are “not completely fixed” and “may be sources of change as well as continuity” (Jordan et al., 2018)

Code provide a starting point, and is to be applied adopting a flexible and adaptive approach, in light of new information taking into account efforts of other stakeholders

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Thank you for your interest.

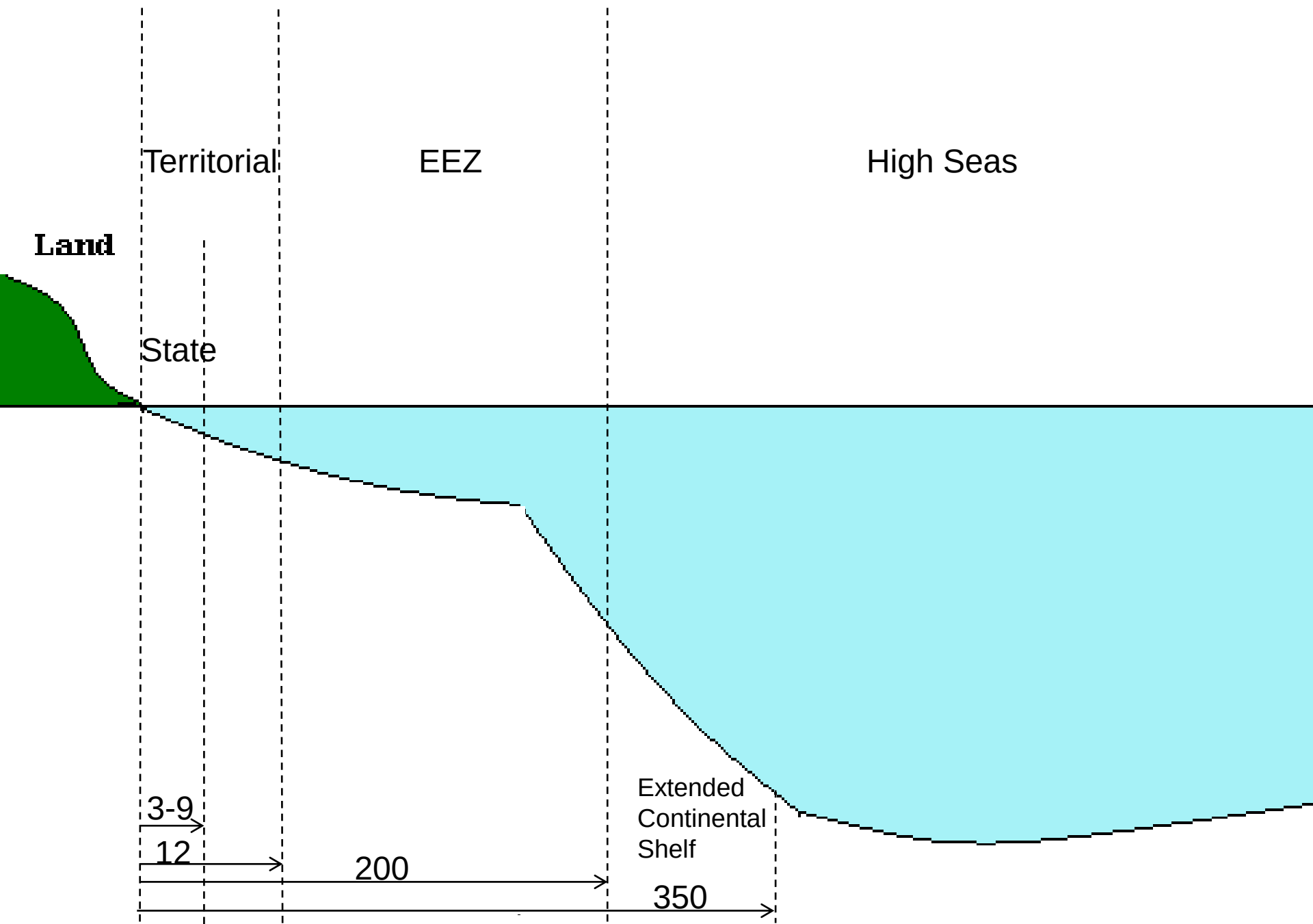


Ocean-Based CDR: Legal and Political Landscapes

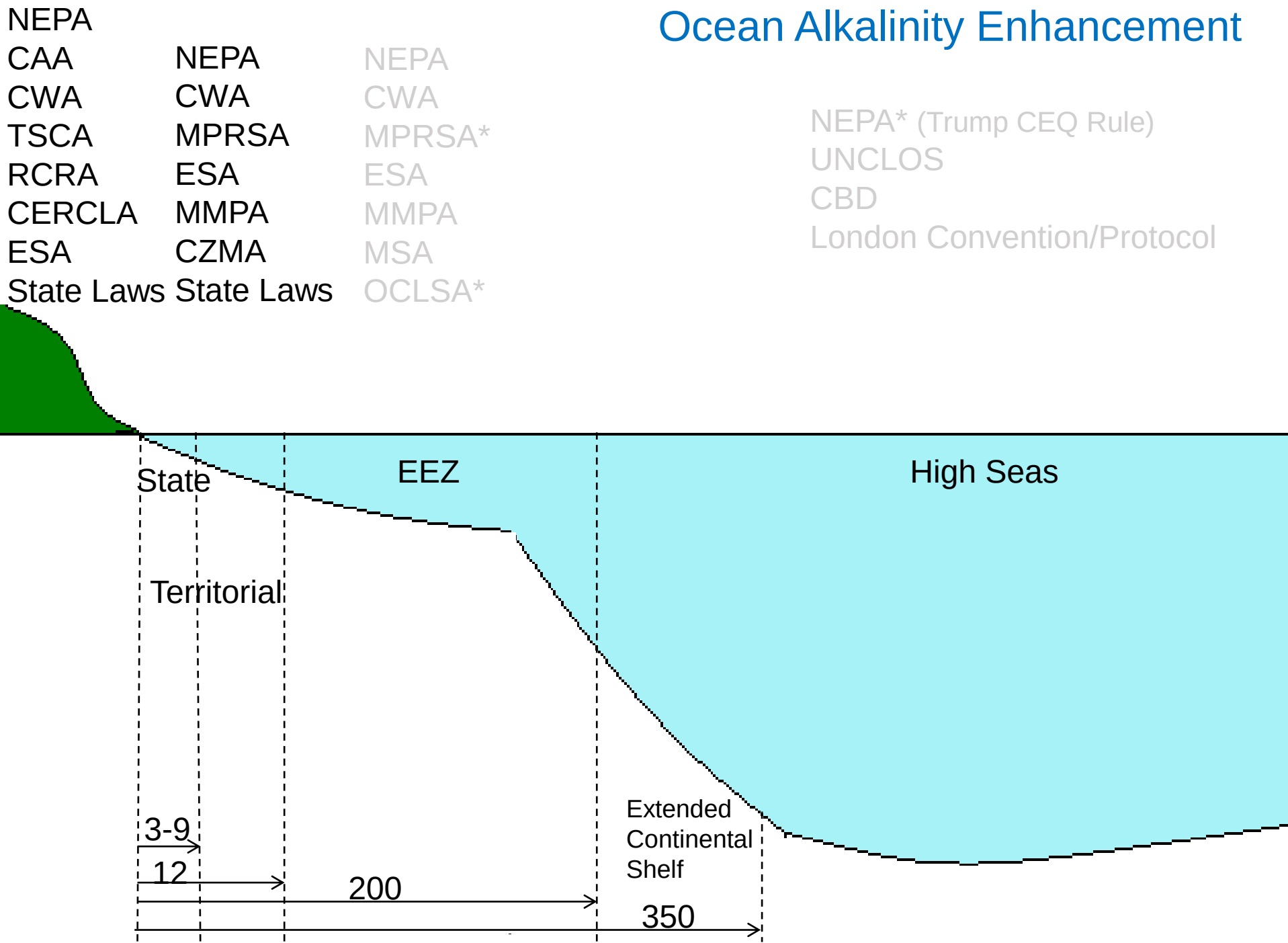


By Lisa Suatoni and Rebecca Loomis

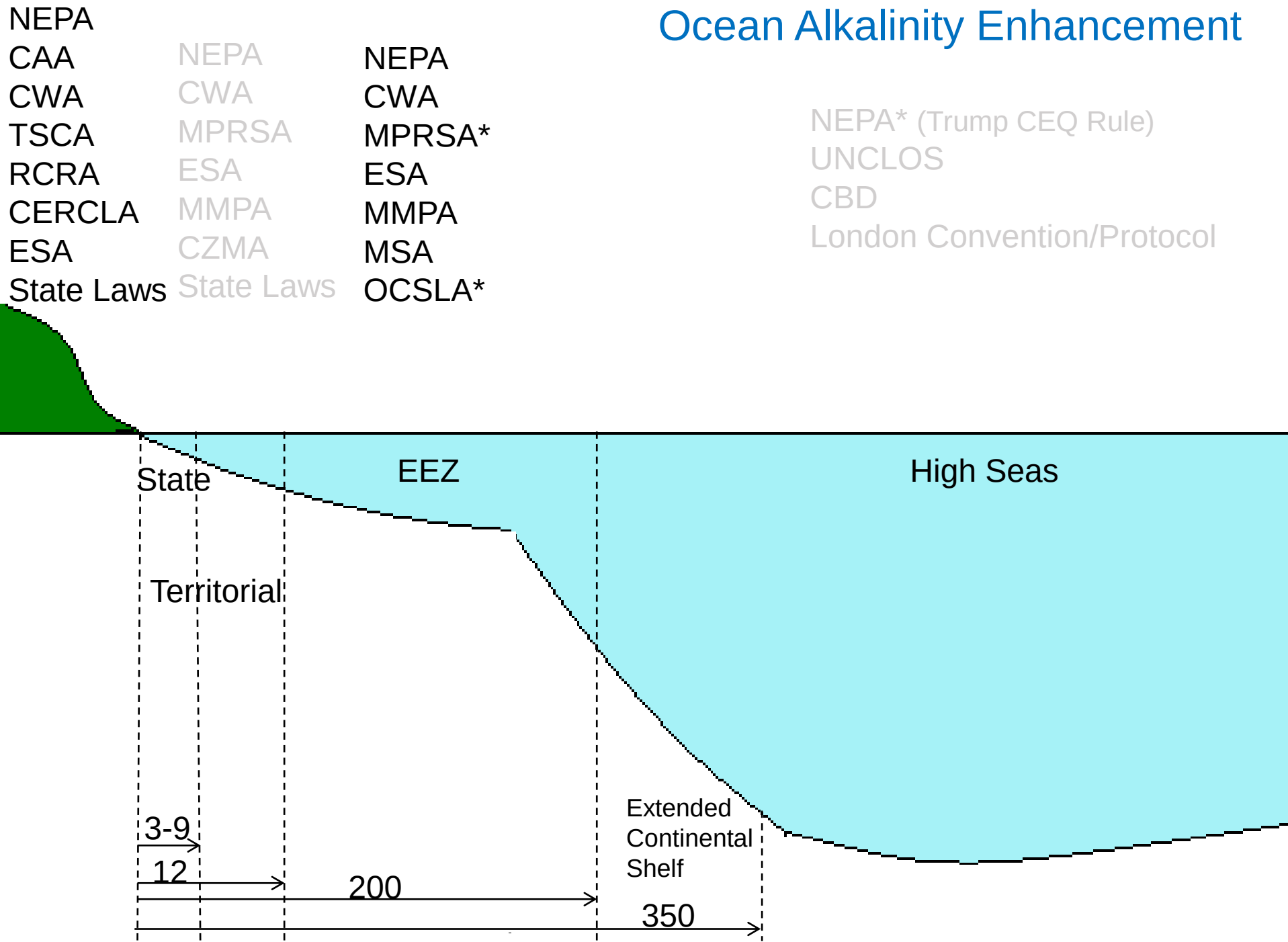




Ocean Alkalinity Enhancement



Ocean Alkalinity Enhancement

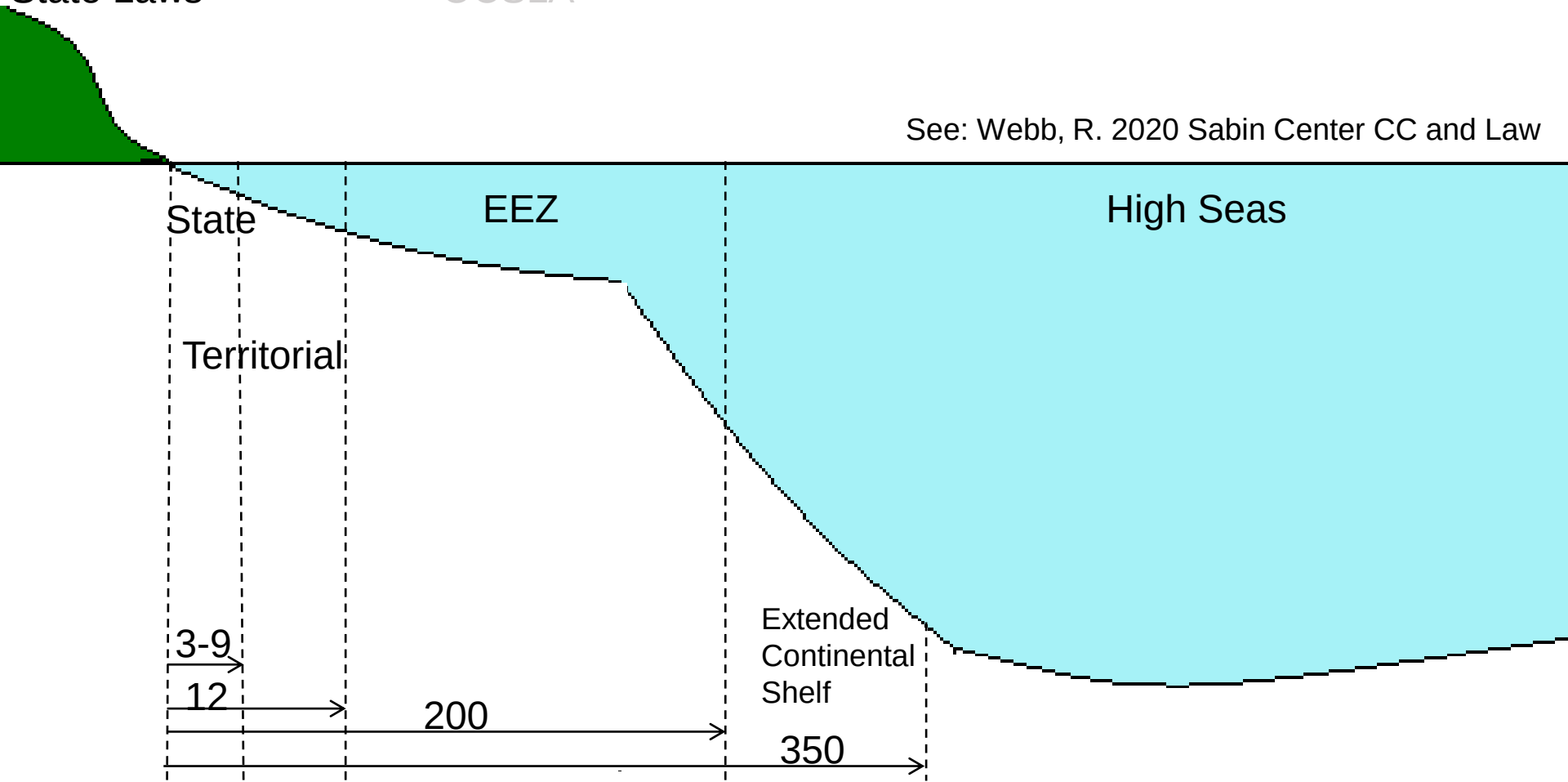


Ocean Alkalinity Enhancement

NEPA	NEPA	NEPA
CAA	CWA	CWA
CWA	MPRSA	MPRSA*
TSCA	ESA	ESA
RCRA	MMPA	MMPA
CERCLA	CZMA	MSA
ESA	State Laws	OCSLA*

NEPA* (Trump CEQ Rule)
UNCLOS* (U.S. not a party)
CBD* (U.S. not a party)
London Convention/Protocol*

See: Webb, R. 2020 Sabin Center CC and Law



Existing Regulatory Landscape in U.S. waters ...

	Ocean alkalinity enhancement	Macroalgae cultivation	Nutrient fertilization	Electrochemical CDR	Artificial up/downwelling
Environmental review	National Environmental Policy Act	National Environmental Policy Act	National Environmental Policy Act	National Environmental Policy Act	National Environmental Policy Act
Wildlife and habitat	Endangered Species Act	Endangered Species Act	Endangered Species Act	Endangered Species Act	Endangered Species Act
	Magnuson-Stevens Act	Magnuson-Stevens Act	Magnuson-Stevens Act	Magnuson-Stevens Act	Magnuson-Stevens Act
	Marine Mammal Protection Act	Marine Mammal Protection Act	Marine Mammal Protection Act	Marine Mammal Protection Act	Marine Mammal Protection Act
Coastal impacts	Coastal Zone Management Act	Coastal Zone Management Act		Coastal Zone Management Act	Coastal Zone Management Act
		Rivers and Harbors Act		Rivers and Harbors Act	
Pollution and dumping	Clean Water Act	Clean Water Act?	Clean Water Act	Clean Water Act?	
	Marine Protection, Research & Sanctuaries Act	Marine Protection, Research & Sanctuaries Act?	Marine Protection, Research & Sanctuaries Act	Marine Protection, Research & Sanctuaries Act?	
Other	Terrestrial Mining	State laws	State laws	Outer Continental Shelf Lands Act (wind energy)	Outer Continental Shelf Lands Act (wind energy)
	Shipping/Transport	Personnel	Terrestrial Mining		
	Personnel		Shipping/Transport	Personnel	Personnel
			Personnel		

Existing Regulatory Landscape in U.S. waters ...

	Ocean alkalinity enhancement	Macroalgae cultivation	Nutrient fertilization	Electrochemical CDR	Artificial up/downwelling	Ecosystem Recovery
Environmental review	National Environmental Policy Act	National Environmental Policy Act	National Environmental Policy Act	National Environmental Policy Act	National Environmental Policy Act	National Environmental Policy Act
Wildlife and habitat	Endangered Species Act	Endangered Species Act	Endangered Species Act	Endangered Species Act	Endangered Species Act	Endangered Species Act
	Magnuson-Stevens Act	Magnuson-Stevens Act	Magnuson-Stevens Act	Magnuson-Stevens Act	Magnuson-Stevens Act	Magnuson-Stevens Act
	Marine Mammal Protection Act	Marine Mammal Protection Act	Marine Mammal Protection Act	Marine Mammal Protection Act	Marine Mammal Protection Act	Marine Mammal Protection Act
Coastal impacts	Coastal Zone Management Act	Coastal Zone Management Act		Coastal Zone Management Act	Coastal Zone Management Act	Coastal Zone Management Act
		Rivers and Harbors Act		Rivers and Harbors Act		
Pollution and dumping	Clean Water Act	Clean Water Act?	Clean Water Act	Clean Water Act?		Clean Water Act
	Marine Protection, Research & Sanctuaries Act	Marine Protection, Research & Sanctuaries Act?	Marine Protection, Research & Sanctuaries Act	Marine Protection, Research & Sanctuaries Act?		Marine Protection Research & Sanctuaries Act
Other	Terrestrial Mining	State laws	State laws	Outer Continental Shelf Lands Act (wind energy)	Outer Continental Shelf Lands Act (wind energy)	State Laws
	Shipping/Transport	Personnel	Terrestrial Mining			
	Personnel		Shipping/Transport	Personnel	Personnel	
			Personnel			

Some further resources:

recent legal analyses ocean-based CDR...

Carnegie Climate Governance Initiative: C2G

Institute of Carbon Removal Policy, American University
(Wil Burns & Simon Nicholson American University)

Sabin Center for Climate Change Law Columbia:
(Michael Gerrard; Romany Webb, Korey Silverman-Roati)

Anna-Marie Hubert University of Calgary

Jeffrey McGee, from University of Tasmania IMAS and the Faculty of Law

Partial list!

The U.S. Political Landscape ...



2015

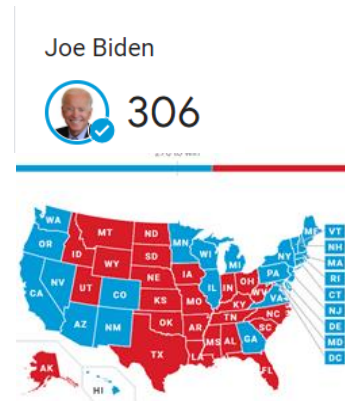
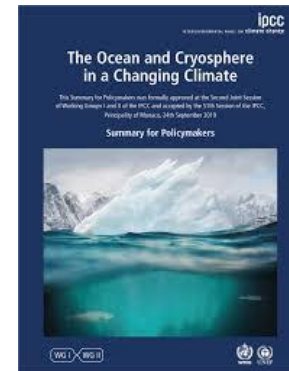
2016

2017

2018

2019

2020



Recent CCS Bills ...

	Bill Name	Short summary	Bipartisan	Cosponsor(s)
HR 3828 / S 1685	LEADING Act	Natural gas CCS RD&D	Y	Cornyn, Cassidy (Senate) / Lucas, Flores, Walberg, Crenshaw (House)
HR 5156	Carbon Capture and Sequestration Extension Act	Extend 45Q for one year	N (D only)	Sewell et al.,
HR 3607	Fossil Fuel Research and Development Act	DOE R&D CCS, Partnerships	Y	Veasey, Schweikert et al.
HR 5883		Amend 45 Q tax credit DAC/CCS	N	Schweikert et al.,
HR 1166/S 383	USE IT Act	amend CAA research CCS; DOE report; CDQ guidance	Y	Barasso, Whitehouse et al., (Senate)/Peters, Mickinley, Schweikert et al., (House)
HR 5523	Energy Sector Innovation Credit Act	Emerging tech tax credits for certain CCS, RE, nuclear	Y	Reed, LaHood, Schweikert
S 407	Carbon Capture Modernization Act	48A tax credit for advanced coal	Y	Hoeven, Cramer, Barasso, Grama, Daines, Capito et al.
S 2263	CO2 Regulatory Certainty Act	'secure geological storage'	N (R only)	Hoeven, Daines, Hyde-Smith, Wicker, Cramer et al.
Senate Amend to HR 133	COVID-19 Economic Relief Bill	R&D; competition; Task Force	Y	many/enacted

Recent CDR Bills ...

	Bill Name	Short summary	Bipartisan	Cosponsor(s)
HR 3282	Carbon Capture Prize Act	Cash prizes for CDR research, \$30M bucket	N	Meng et al.
H.R.	CREATE Act	R&D, Demonstration, Agency CDR directive	Y	Tonko, Kuster et al.
HR 5859	Trillion Trees Act	Tree planting, slashing, biomass	Y	Westerman et al. (37)
HR 8632	Ocean-Based Climate Solutions Act	Study geologic stores of carbon deep sea; wetland restoration	N	Grijalva et al., (39)
H R 5589	Blue Carbon for Our Planet	study blue carbon stores/potential/restoration	Y	Bonamici, Posey (22)
HR 3227 / S 1679	SEA FUELS Act	DoD Program for removing CO2 from seawater	Y	Schweikert (House) / Whitehouse (Senate) et al.
Senate Amend to HR 133	COVID-19 Economic Relief Bill	R&D; competition; Task Force	Y	many/enacted

NGO landscape ...



advocating for ecosystem recovery

NGO landscape ...



advocating for ecosystem recovery



NGO landscape ...



advocating for ecosystem recovery



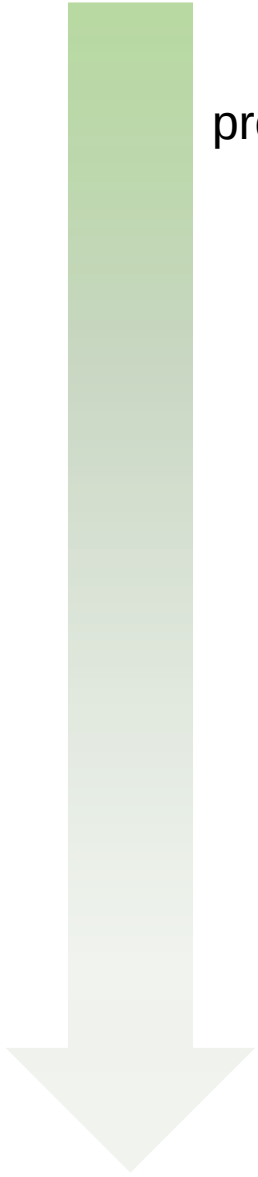
developing positions, identifying policy concerns and priorities

Partial list!

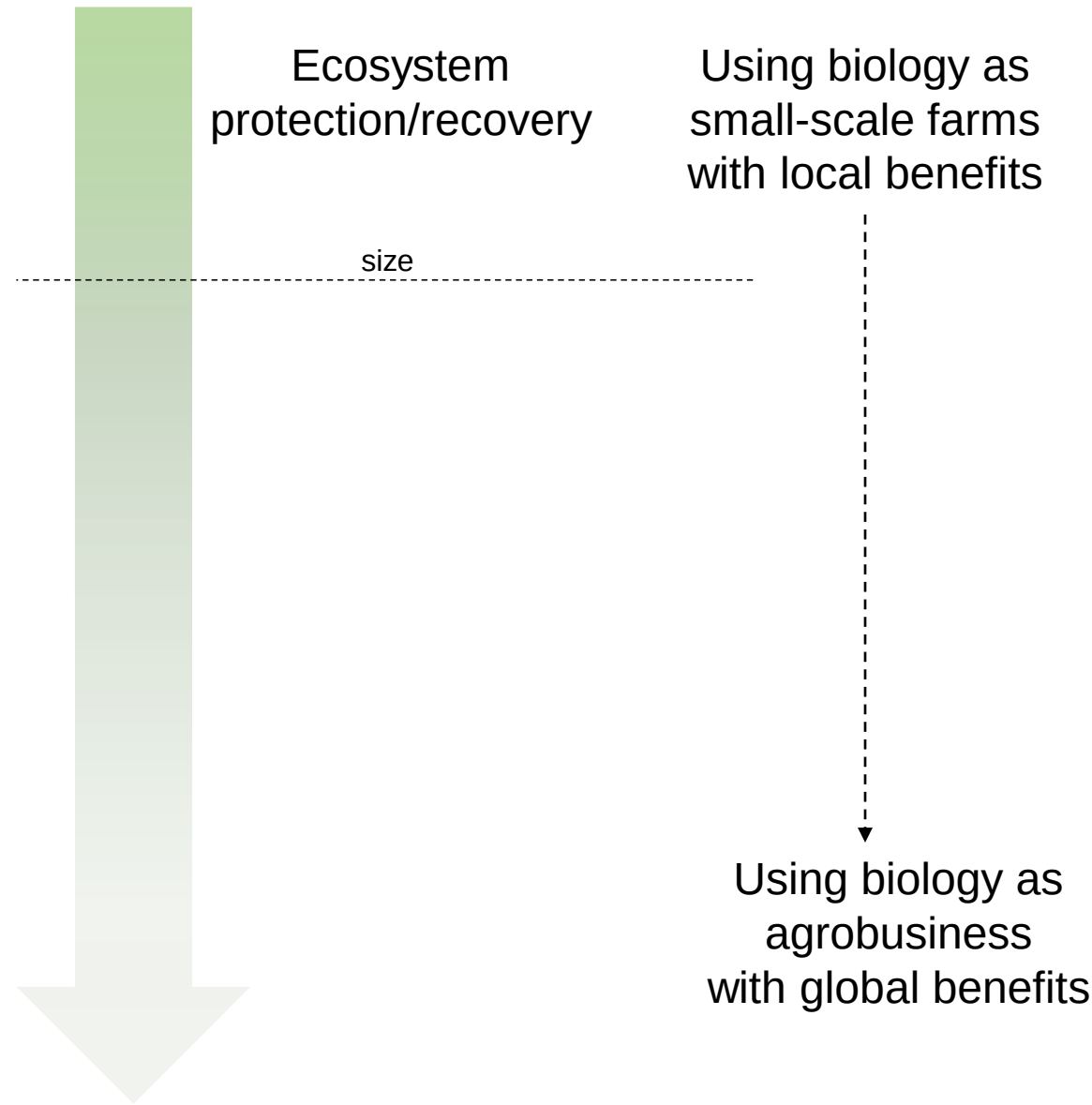
Support from eNGO community

Ecosystem
protection/recovery

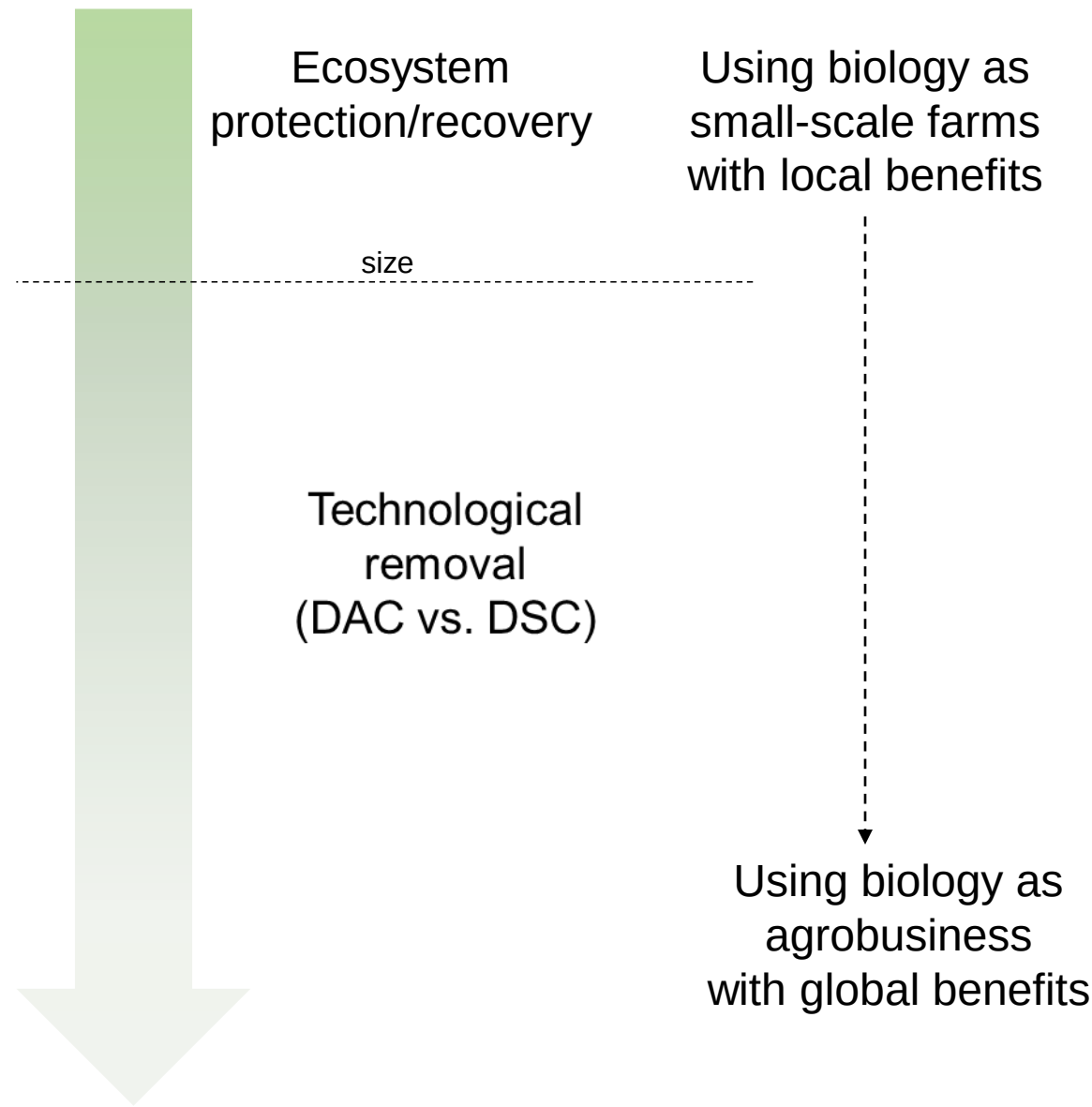
Using biology as
small-scale farms



Support from eNGO community



Support from eNGO community



“Carbon removal must be part of Plan A” EDF

1. How much land/water is used and where?
2. How much matter must be processed (extracted, transported, dumped)?
3. What is its cost and net contribution to CC mitigation?
4. Does the technology help perpetuate fossil fuel facilities?
5. What are the tradeoffs associated with food security and biodiversity?
6. What public process(es) are being followed to ensure input from key stakeholder?

BREAK

We will resume at 1:45pm EST

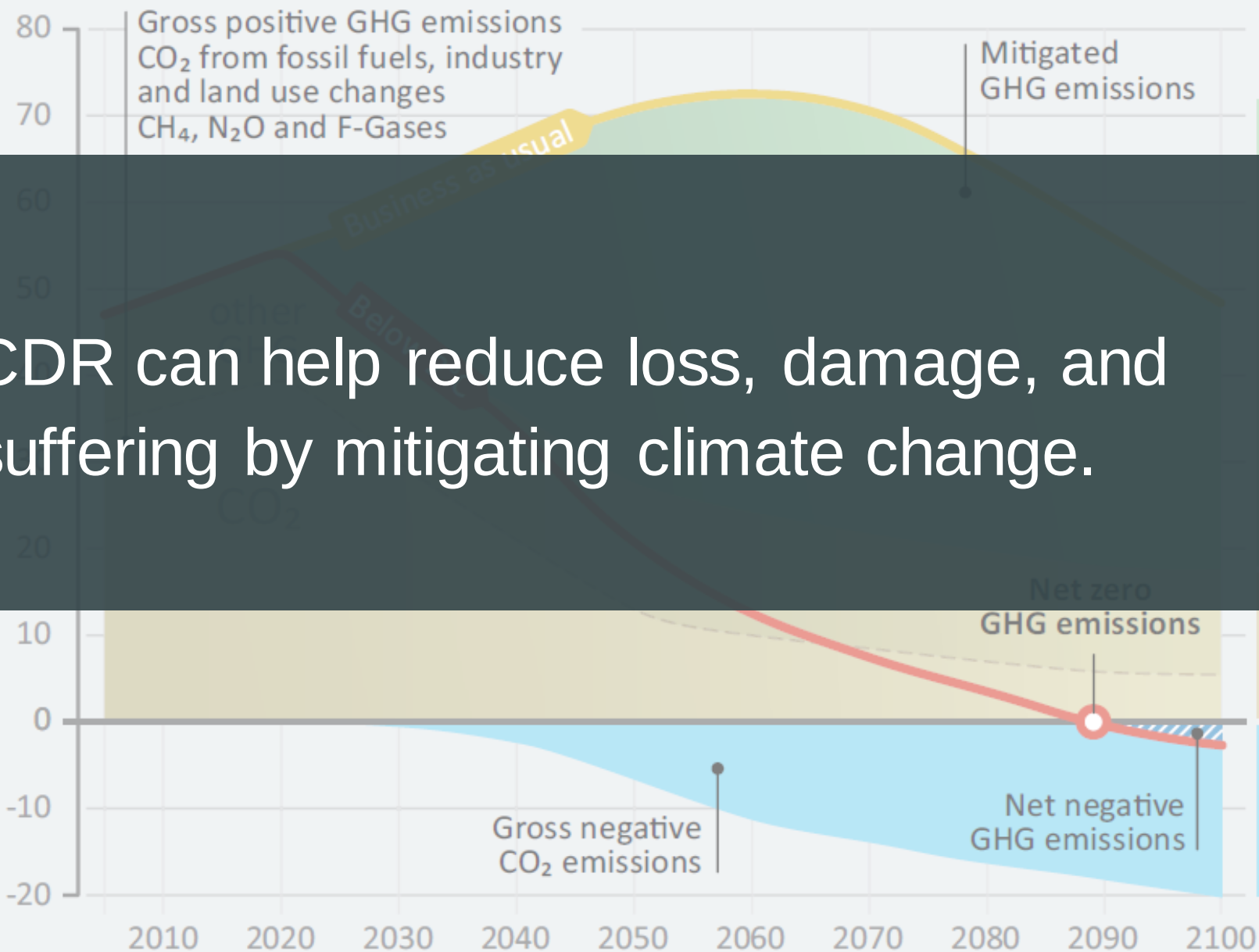
ETHICAL ISSUES IN OCEAN CDR

DAVID MORROW
INSTITUTE FOR CARBON REMOVAL LAW AND POLICY
AMERICAN UNIVERSITY
JANUARY 19, 2021



INSTITUTE *for* CARBON REMOVAL
LAW AND POLICY

GHG emissions (GtCO₂e/year)



Examples of associated technologies



Conventional abatement technologies



Emitting technologies



Carbon removal technologies



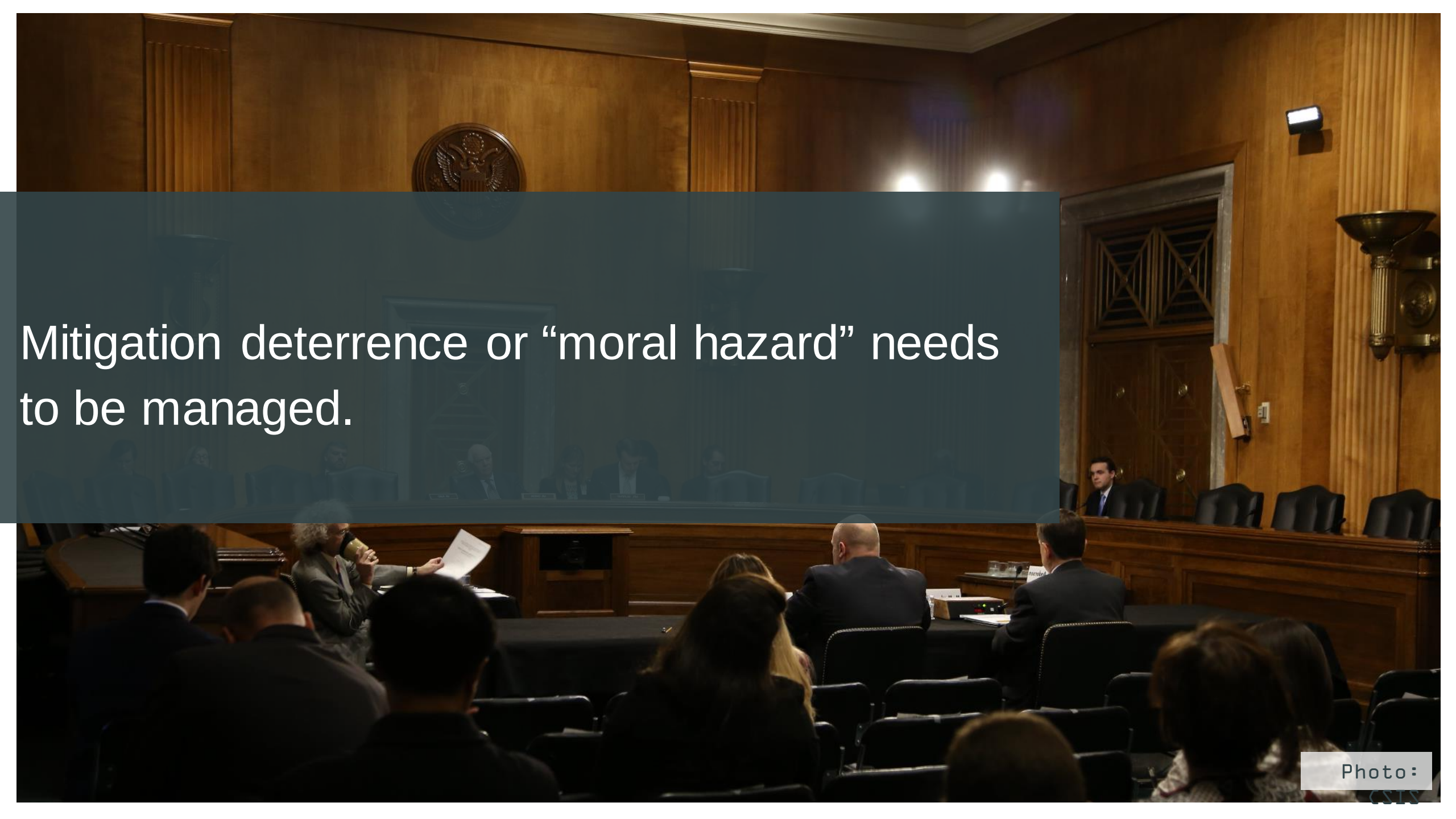
Figure: UN Emissions Gap Report 2018

CDR can help reduce loss, damage, and suffering by mitigating climate change.

An underwater photograph showing a large school of small, silvery fish swimming in clear blue water. In the foreground, there are large, green kelp leaves and dark, brown kelp stalks. The scene is brightly lit, suggesting a shallow depth.

Evaluate ocean CDR technologies, projects,
and policies in light of the magnitude and
distribution of benefits, costs, burdens, and
risks.

Photo: Sharon Suzuki-
Martinez



Mitigation deterrence or “moral hazard” needs to be managed.

Familiar lessons from the ethics of environmental interventions apply.

A photograph of a sunset over a body of water. The sun is low on the horizon, creating a bright orange glow and a reflection on the water. Two children are in the water: one is standing on the left, and the other is crouching on the right, possibly picking something up. The sky is a mix of orange and blue. A dark grey rectangular box is overlaid on the left side of the image, containing white text.

Go beyond technoeconomic assessment to evaluate magnitude and distribution of social and environmental risks, burdens, and benefits.

Photo: Trey
Ratcliff

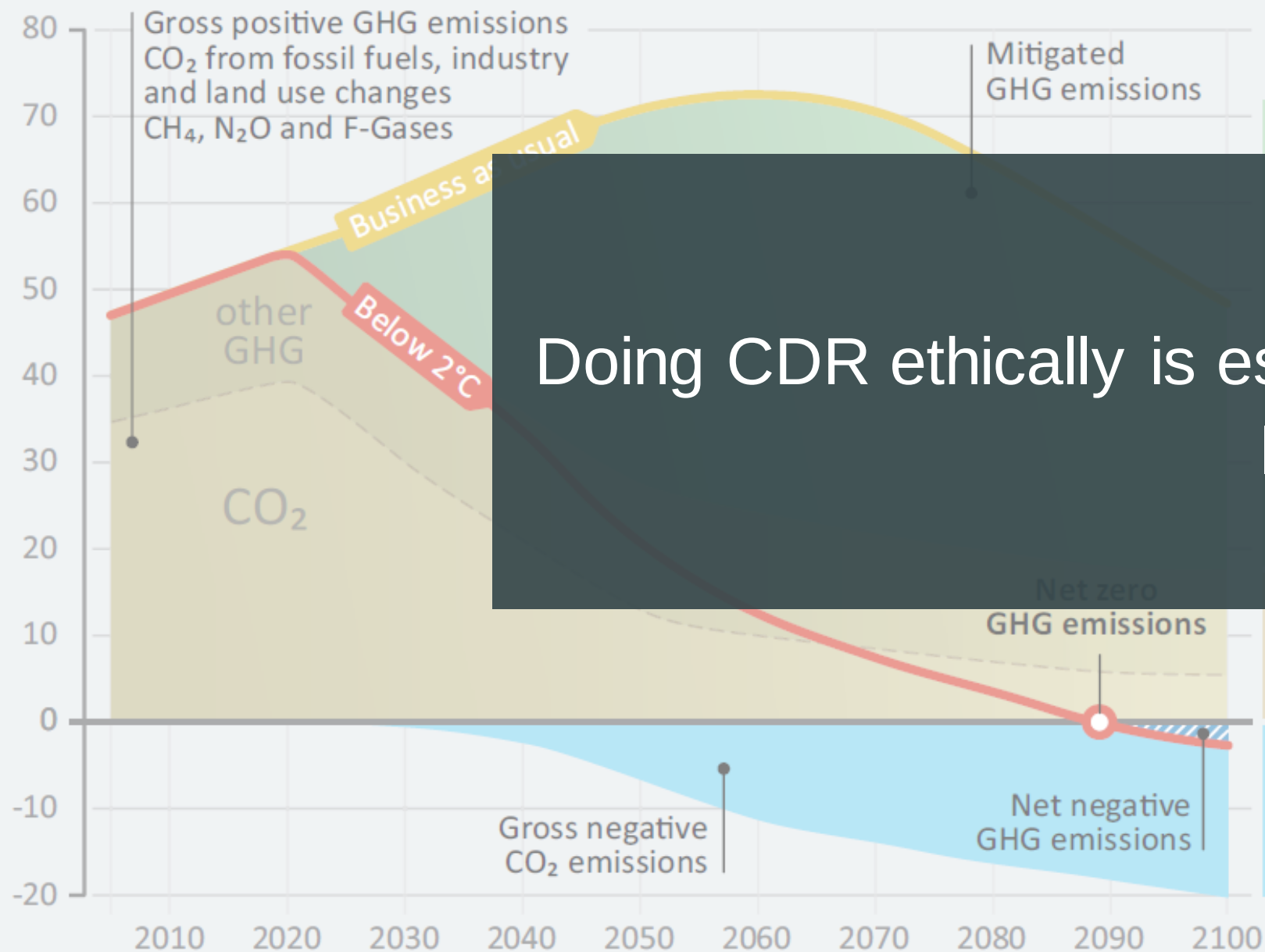


Don't neglect social impacts and opportunities, including opportunities to support adaptation and a just transition.



Stakeholder engagement is crucial.

GHG emissions (GtCO₂e/year)



Doing CDR ethically is essential to sustaining it
long enough to matter.

Examples of associated technologies



Conventional
abatement technologies



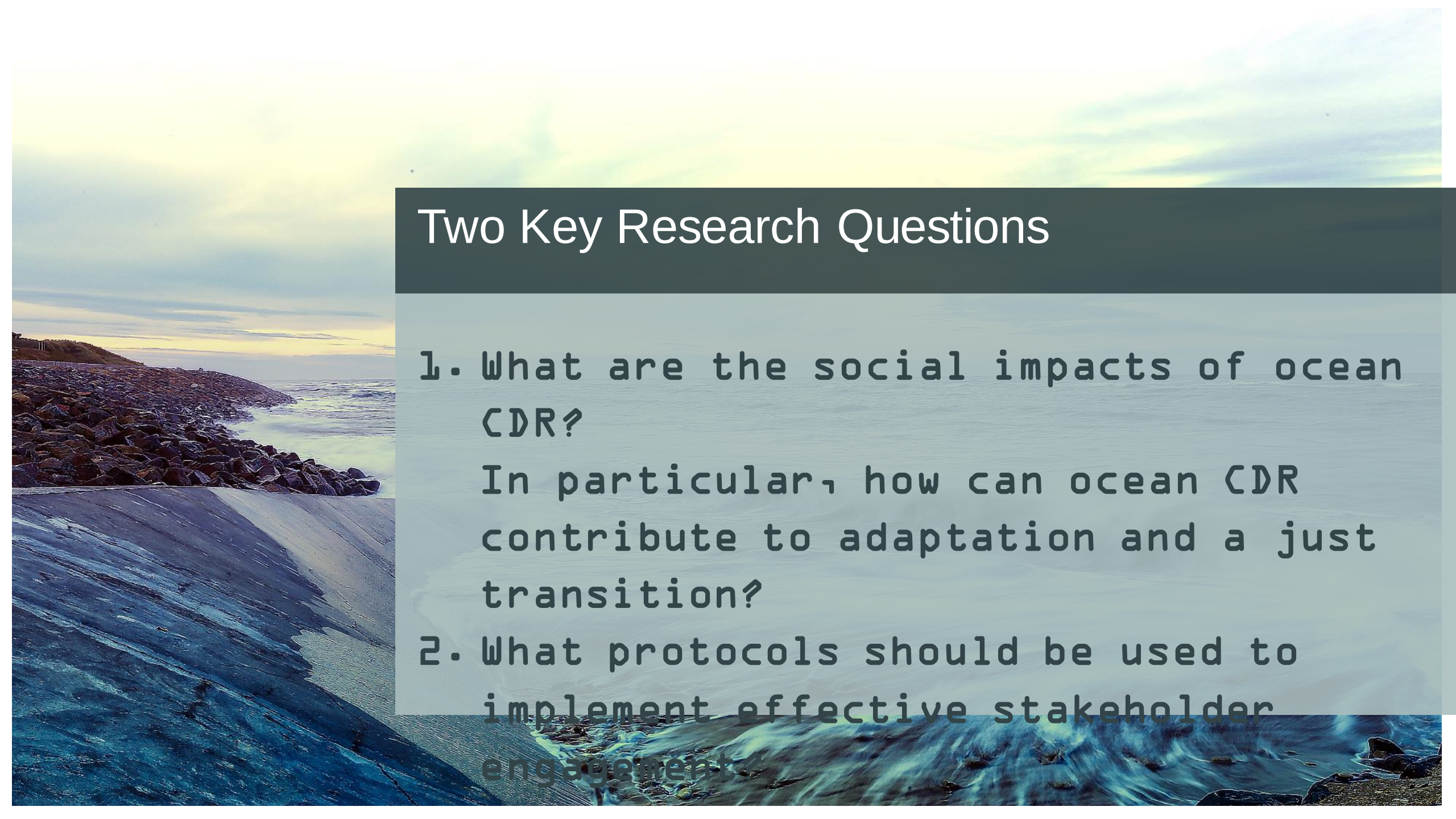
Emitting
technologies



Carbon removal
technologies



Figure: UN Emissions Gap
Report 2018



Two Key Research Questions

1. What are the social impacts of ocean CDR?

In particular, how can ocean CDR contribute to adaptation and a just transition?

2. What protocols should be used to implement effective stakeholder engagement?

Ocean CDR: social considerations

Sarah Cooley
January 19, 2021
scooley@oceanconservancy.org

Ocean Conservancy is working with you to protect the ocean from today's greatest global challenges. Together, we create science-based solutions for a healthy ocean and the wildlife and communities that depend on it.

Opportunities and challenges: social acceptance of ocean CDR

- Language matters
- Case studies: developing marine policy and resource management
- Lessons learned from case studies



LANGUAGE MATTERS

“Social license”

- Ongoing acceptance of a company or industry to operate using standard practices.
- Difficult to define & measure.
- Scale matters.
- Easy to notice when it's gone!



“Social license” vs.

- Ongoing acceptance of a company or industry to operate using standard practices.
- Difficult to define & measure.
- Scale matters.
- Easy to notice when it's gone!

“Social considerations”

- Who are the stakeholders?
- What do stakeholders need?
- What are stakeholders worried about?
- What scales are important to consider?
- Who is included or excluded in decision making?

CASE STUDIES



Gulf of Mexico Red Snapper Management

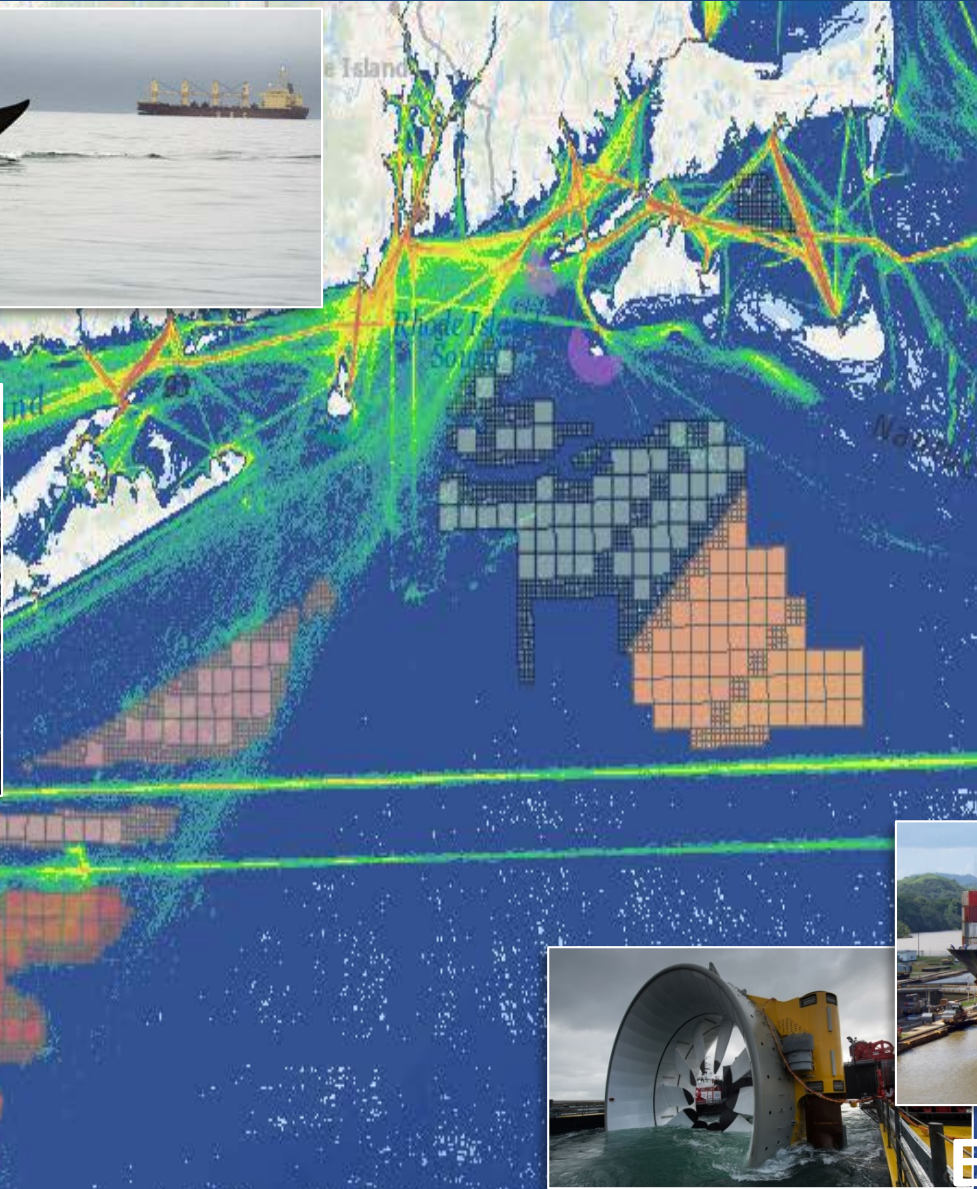


Courtesy of Kyle Bailey



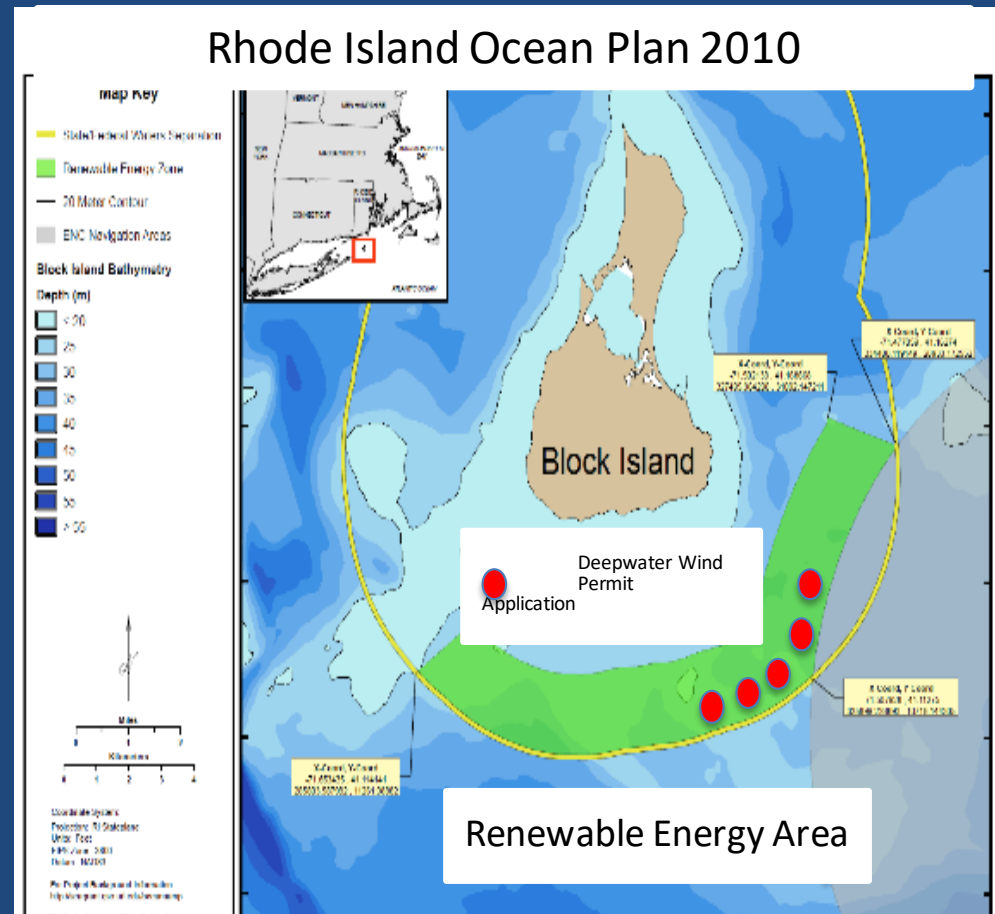
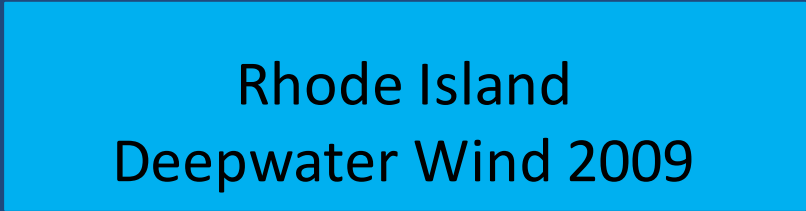
Ocean planning/Offshore wind

Existing uses



Emerging uses

Rhode Island Deepwater Wind 2009



Ocean acidification

Targeted science



Concerned users

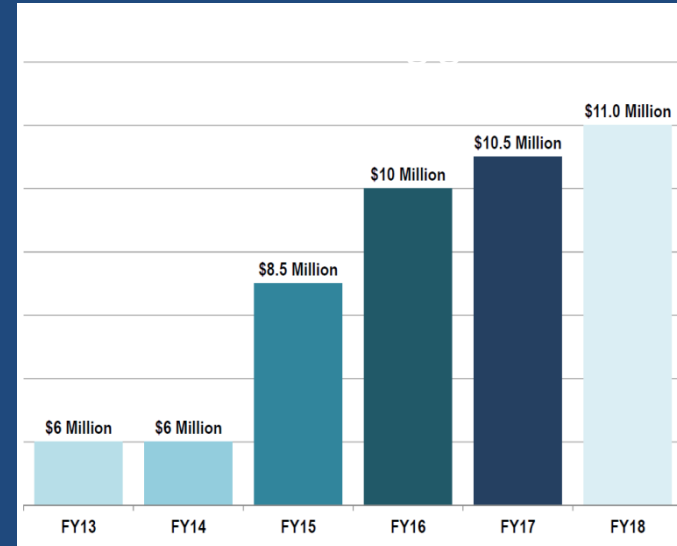


"Coral reefs are our business. That is what we're all about. The health of the ocean. Without that, we don't have a business. It's everything to us, so the importance of the health of the reefs and the fishing itself is everything to us. Without it we're nothing."

Only fishermen in the general maritime and coastal area of the Captain's house, the Captain's house, a family-owned business for generations, has been in Miami, Fla. The number and importance of the house are everything to us. Without it we're nothing."



Connecting personally



Policymaker concern

Compare/Contrast with CDR

Similar

- Determine risk tolerance of community to new activity
- Common values among ocean users?
- Scientific motivation to proceed
- Opportunities to narrow problem via scenario planning
- Someone will always oppose
- Interdisciplinary research needs
- Risks/benefits accrue to different groups?

Different

- Unclear scope of CDR (spatial, temporal, jurisdictional)
- Engage stakeholders to define CDR science?
- Need to be socio-culturally precautionary (not just environmentally)?
- Unclear governance/decider(s)
- Unknown potential for unintended consequences



TAKEAWAYS

Lessons learned

1. Meaningful, early, iterative public engagement is critical.
2. Inclusive, equitable consideration of many perspectives.
3. Develop trust by sharing/co-producing data and responding to concerns.
4. If the majority believes that benefits outweigh risks & negative consequences not unfairly distributed: social license.
5. Maintain social license via continued public engagement.

Thank you

For the opportunity:
NASEM Committee on
A Research Strategy for Ocean-
based Carbon Dioxide Removal
(CDR) and Sequestration

For the input:
Ocean Conservancy colleagues
Elizabeth Cerny-Chipman
Jeff Barger
J.P. Brooker
Anna-Marie Laura
Michael Levine
George Leonard
Olivia Lopez
Reginald Paros
Amy Trice
Sandra Whitehouse
Anna Zivian

On the social acceptability of Solid Carbon

Terre Satterfield
Guillaume Peterson-St. Laurent
University of British Columbia

January 19th, 2021
NAS CDR Opportunities and Challenges

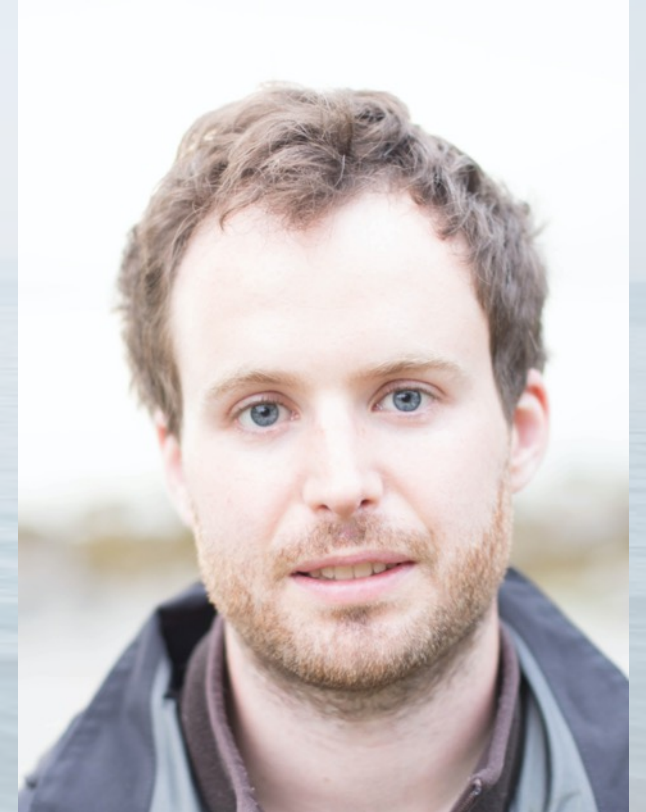
Terre Satterfield

- Professor of Culture, Risk and Environment (IRES, UBC)
- Methodologist: Upstream Risk *Perceptions, Decision Making and Analysis*
- Long-standing work on perception of new technologies including energy systems, nanotechnologies, gene editing and synthetic biology
- Other research: meaning and measurement, cultural ecosystem services and environmental and biodiversity assessment
- PI Funding: *SSHRC, NSF, CIHR,*
- Academic audiences: *Nature, PNAS, PLOS One, Bioscience, Global Environmental Change, Environmental Science and Technology, Ecological Economics ...*

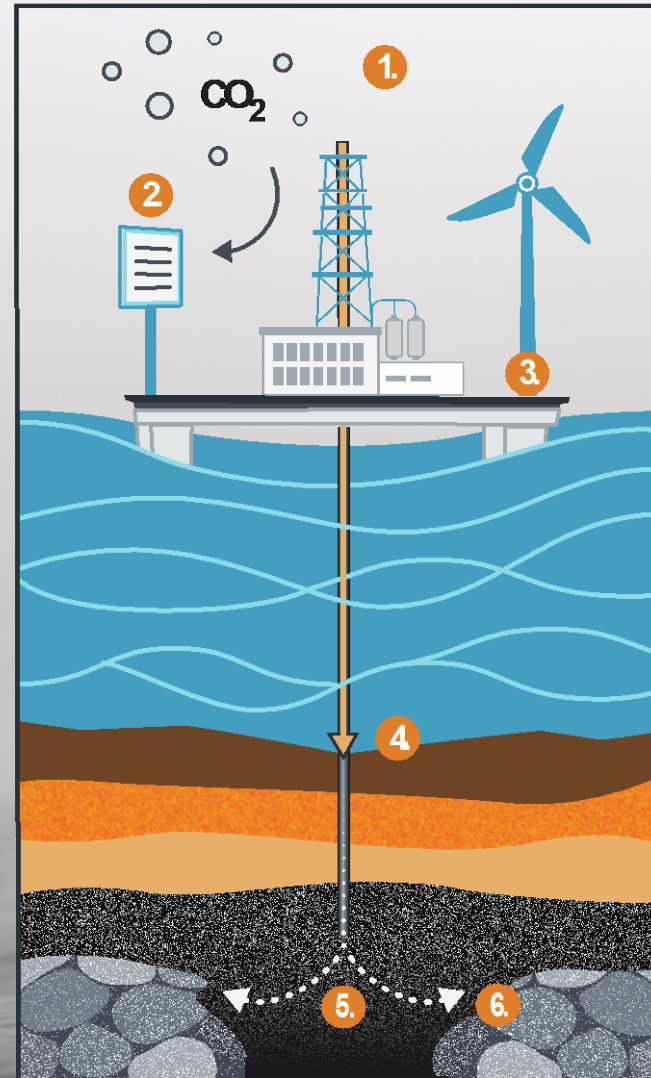
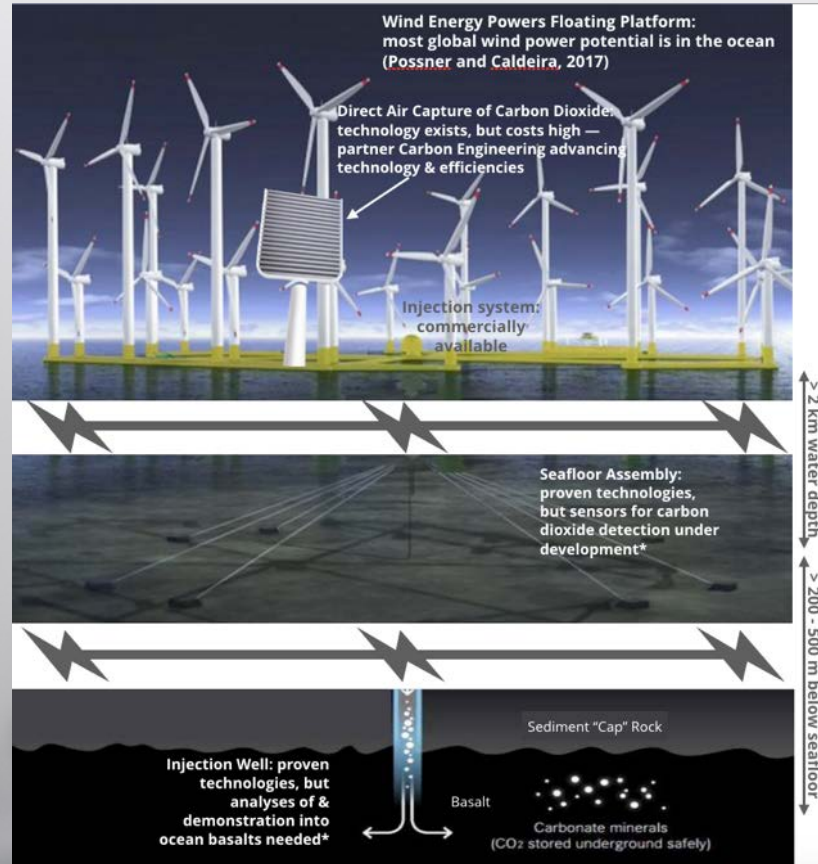


Guillaume Peterson St-Laurent

- Multidisciplinary & transdisciplinary:
 - BSc & MSc in environmental sciences & biology
 - Grad dip. & PhD in natural resources management
- Expertise & research interests:
 - Climate change adaptation & mitigation
 - Natural resources management and policy
 - Human and natural dimensions of transformative changes
 - Participatory engagement and analytic-deliberative processes
 - Mixed method
 - Applied and policy relevant research



Solid Carbon (SC): A Tutorial for Empirical Work



1. The Solid Carbon system is located on an ocean-floating platform approximately 200km from the shore.
2. Direct air capture pulls CO₂ from the atmosphere and converts it to a pure form of liquid CO₂.
3. The system is powered by wind turbines located on the same floating platform.
4. Drilling into the seafloor rock creates sub-seafloor sites for storage.
5. The compressed liquid CO₂ is injected at high pressure into porous rock below the seafloor.
6. The liquid CO₂ spreads throughout the porous rock and becomes solid rock through a process known as mineralization.

What we should assume about perceived risk and acceptance in a nutshell



When knowledge of a new technology is low, the power of particular signals or heuristic-style filters will prevail

- Platform and stability?
- “Pure” versus industrial or ‘dirty’ CO₂?
- Pipelines or drilling?
- Wind v another energy source?
- Mineralization confidence?

In sum: is the whole (and so overall NET purpose) greater than the sum of its parts or vice versa?



Legacy controversies may permeate perception in general and in reference to siting

- Pipeline battles on west coast, fishing on the east coast.
- First Nations jurisdictional battles or support on west coast.
- As a group, geoengineering, genetic engineering, stem cell research and nuclear energy almost always group as their own very particular class of perceived risks.
 - **Where will SC fall?**

Perceptions of alternatives will matter/be key determinant...

- Strong relative acceptability of ‘natural’ carbon removal/storage options versus ‘technological’ ones (Corner et al., 2013, 2015; Thomas et al., 2018).
- This is an uphill battle (e.g., people approve afforestation at almost any scale; Peterson St-Laurent et al., 2017) but most likely have hard time thinking about scale.
- Understanding the spatial area needed across solutions will be key and may well have a positive effect on this perceptual difference.

Perceptions on climate urgency are changing... for the better

- Tolerance of mitigating interventions indicate greater acceptance in last few years of research (Cox et al., 2020).
- This appears evident [even] in large scale climate interventions (Corner et al., 2013).



Trust in monitoring, regulation and science always improves acceptability, and yet ...

- Trust in regulation, etc., is a finding strongly linked to political worldview (e.g., Seigrist, Cvetkovich, Roth 2000).
- Policy options that address the fullest possible political spectrum matter (e.g., it's not the climate science that people reject, it's the policies that tend to be aligned with these).
- The difference may be as simple as strongly free market v strongly regulatory interventions.



Cost is a huge consideration for the team and will matter tremendously, but ...

- Most “willingness to pay” studies on equivalent topics (e.g., higher utility bills for different energy mix) do not indicate rejection of expenditures (Klain et al., 2020)
- Likely better to use gas or flight cost comparisons?
- Employment for oil and gas sector might be much more important an economic argument.



Knowledge is mediated by political controversy and initial classification of risk

- When the technology being evaluated is new and understanding is nascent -- openness to knowledge and perceived benefit can prevail (Allum et al., 2008; Satterfield et al. 2009; 2013)
- When the technology is immediately controversial (e.g., such as fracking), the reverse is often true

Research questions – data collection underway

- Is it judgements about the whole or the specific design features (the parts) that most determine public perceptions of a solid carbon system?
- How does perception of this solid carbon system compare to other large-scale climate interventions when equivalent ‘scale comparisons’ (e.g., 1 platform v area of afforestation needed)?
- Are logics of benefit more powerful than logics of risk, when each is disaggregated into arguments of cost, moral hazard, solution need, etc?
- Is there evidence for power of ‘climate urgency’ instead of ‘climate belief’?

Next surveys ...

- Development of different scenarios/choice scenarios to achieve greater calibration of the problem of scale of natural v technological CR solutions.
- Pathway survey to investigation progressive (from simply to more complex) explanations and reflections on SC.
- Expert survey on how different expert communities evaluate the risks and benefits of scaling up SC.

Thank you



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A Research Strategy for Ocean Carbon Dioxide Removal and Sequestration

Financial and Economic considerations to Ocean-based CDR

Juan Moreno-Cruz

Associate Professor School of Environment, Enterprise and Development

Canada Research Chair in Energy Transitions

University of Waterloo

What is required to incorporate CDR into climate management?

- A clear definition of “a ton of CDR.”
- A clear understanding of the magnitude of the effort.
- A clear strategy to support that effort.

Clear definition of
“a ton of CDR.”

- Technical properties:
 - Scalability
 - Costs
- Effects:
 - Transiency (Latency and Persistence)
 - Regionality
- Impacts:
 - Efficacy
 - Side-effects and co-benefits

Clear definition of “a ton of CDR.”

	Technology		Transience		Regionality		
Method	Scalability	Cost	Latency	Persistence	Implement	Effect	Side effects & co-benefits
Mitigation and carbon reduction							
Bioenergy with carbon capture and storage (BECCS)	high	mod	mod	high	high	low	Provides decarbonized energy, land use competes with natural ecosystems
Carbon reduction							
Afforestation (AF)	low	low	high	high	high	low	Positive or negative land use and ecosystem impacts
Direct air capture (DAC)	high	high	high	high	low	low	Competing for materials in a global economy. Driving up prices of scarce resources.
Ocean alkalinity enhancement (OAE)	mod	mod	high	high	mod	mod	Could positively or negatively impact ecosystems
Ocean Iron fertilization (OIF)	mod	high	high	mod	mod	mod	Could upset natural balance of marine ecosystems

Katharine Ricke, Juan Moreno-Cruz, “Geo-Wedges: A Portfolio Approach to Geoengineering the Climate,” Reference Module in Earth Systems and Environmental Sciences, Elsevier (2020)

Clear definition of
“a ton of CDR.”

- Commoditization.
- Standardization.

A clear understanding of
the magnitude of the effort

- Energy is cheap because we invested over many decades in all the infrastructure required to make it so.
- If we want to make CDR cheap, there is no reason to believe the process will be easier or less expensive.

A clear strategy to support that effort.

- Curve shifting vs movement along the curve.
 - Coordinated effort in public and private investment in R&D.
 - Think of the NIH.
 - “Turning discovery into effective climate change management.”
 - Increased demand for the *outputs* of the CDR techniques.
 - Government procurement
 - Public-Private Partnerships (pilots)
 - Private sector.

A clear strategy to support
that effort.

- Economic Policy
 - Incentives
 - Technology Subsidies
 - “Carbon” Markets
 - “Carbon” Taxes
 - Standards
 - Requirements
 - Quotas

stripe

How it started

The origins of our carbon removal work

Stripe's negative emissions commitment

Blog

Share this post on Twitter 



Decrement carbon: Stripe's negative emissions commitment

Christian Anderson on August 15, 2019

As part of Stripe's [environmental program](#), we fully offset our greenhouse gas emissions by purchasing verified carbon offsets. Starting this year, we're going a step further. In addition to our offset program, we are committing to pay, at any available price, for the direct removal of carbon dioxide from the atmosphere and its sequestration in secure, long-term storage. We're announcing this commitment to solicit technology partners and to urge other companies to follow suit.

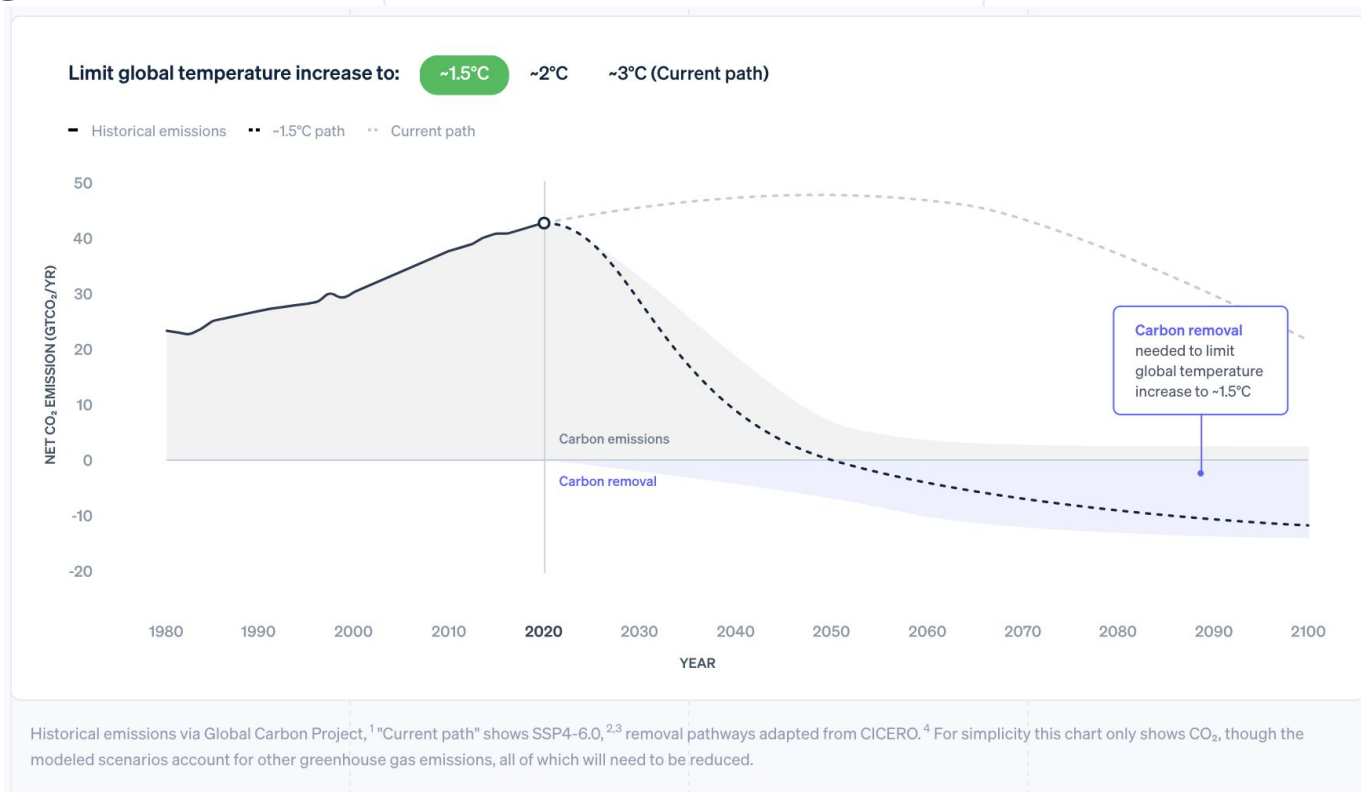
The need to remove CO₂

Urgent global action is needed to halt greenhouse gas emissions, and it looks increasingly likely that in addition to emissions reduction, humanity will need to remove large amounts of carbon dioxide from the atmosphere. In its [most recent summary report](#), the IPCC notes that most scenarios that stay below 2°C of temperature increase involve "substantial net negative emissions by 2100, on average around 2 gigatons of CO₂ per year."

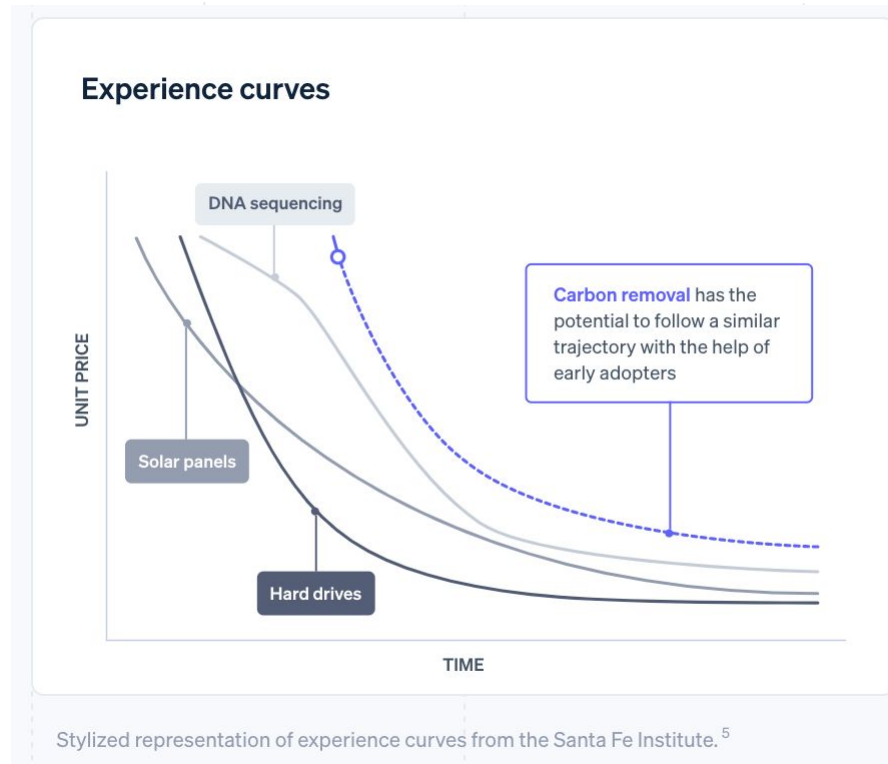
Early adopters and technology learning curves

Carbon capture and sequestration technologies are present today. While a

Carbon removal is critical to counteract climate change



But carbon removal is behind; early adopters can accelerate progress



Maximizing the impact of our own \$1M

Stripe negative emissions target criteria

CRITERIA	TODAY	TARGET BY 2040
Sequestration beyond the biosphere Takes advantage of carbon sinks less constrained by arable land, e.g. carbon mineralization	Yes	Yes
Volume Has a path to being a meaningful part of the negative emissions solution portfolio	–	> 0.5 gigatons per year
Cost Has a path to being affordable at scale	–	< \$100 per ton
Permanence Stores carbon permanently	> 1,000 years	> 1,000 years
Verifiability Uses scientifically rigorous and transparent methods for verification	Modeled or measured directly	Modeled and measured directly
Quality and safety Is globally responsible, considering possible risks and negative externalities	Path to high	High
Net-negative lifecycle Reduces net atmospheric CO ₂ , expressed as a ratio subject to appropriate boundary conditions: [Emissions produced] : [CO ₂ removed from the atmosphere]	Negativity ratio ≤ 1	Negativity ratio < 1

Note that we are very open to supporting projects that focus on either capture or storage, so long as they have a path to a holistic negative emissions solution that meets the above criteria.

Our advisors



Dr. Jennifer Wilcox
Professor, University of Pennsylvania
Direct Air Capture



Dr. Steven Hamburg
Chief Scientist, Environmental Defense Fund
Ecosystem Ecology



Dr. Phil Renforth
Associate Professor, Heriot-Watt University
Carbon Mineralization



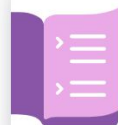
Dr. Jane Zelikova
Chief Scientist, Carbon180
Soil Carbon



Dr. Bill Anderegg
Assistant Professor, University of Utah
Forestry



Dr. Zara L'Heureux
Ph.D. Columbia University
Direct Air Capture



SOURCE MATERIALS →

Project applications, project database, original purchase criteria, expert review forms and more.

We purchased from four projects in May



Climeworks uses renewable geothermal energy and waste heat to capture CO₂ directly from the air, concentrate it, and permanently sequester it underground in basaltic rock formations with Carbfix. While it's early in scaling, it's permanent, easy to measure, and the capacity of this approach is theoretically nearly limitless.



CarbonCure injects CO₂ into fresh concrete, where it mineralizes and is permanently stored while improving the concrete's compressive strength. Today they source waste CO₂, but represent a promising platform technology for permanent CO₂ storage, a key component of future carbon removal systems.



Project Vesta captures CO₂ by using an abundant, naturally occurring mineral called olivine. Ocean waves grind down the olivine, increasing its surface area. As the olivine breaks down, it captures atmospheric CO₂ from within the ocean and stabilizes it as limestone on the seafloor.



Charm Industrial has created a novel process for preparing and injecting bio-oil into geologic storage. Bio-oil is produced from biomass and maintains much of the carbon that was captured naturally by the plants. By injecting it into secure geologic storage, they're making the carbon storage permanent.

Two themes emerged from user conversations

- 1 Many businesses *want* to do something to help fight climate change but haven't because **figuring out what to do is overly complicated or time intensive**.

"I'd give more than X%. But I'd like to spend approximately zero time on this." - Chris F

"We've thought about doing something, but this isn't that high of a priority. Every hour and dollar is so limited and climate is just further down the priority stack. If activation energy was sufficiently low, we would do something." - Alex M

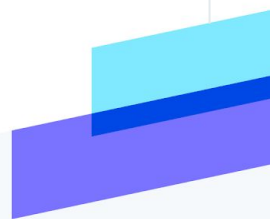
- 2 Businesses want to be able to **easily share what they're doing** with customers and employees in a way that's simple and compelling.

"We'd want to share this with our customers. This would help our customers feel good about our brand." - Aaron T

"Our employees should feel proud to work here." - Josh F

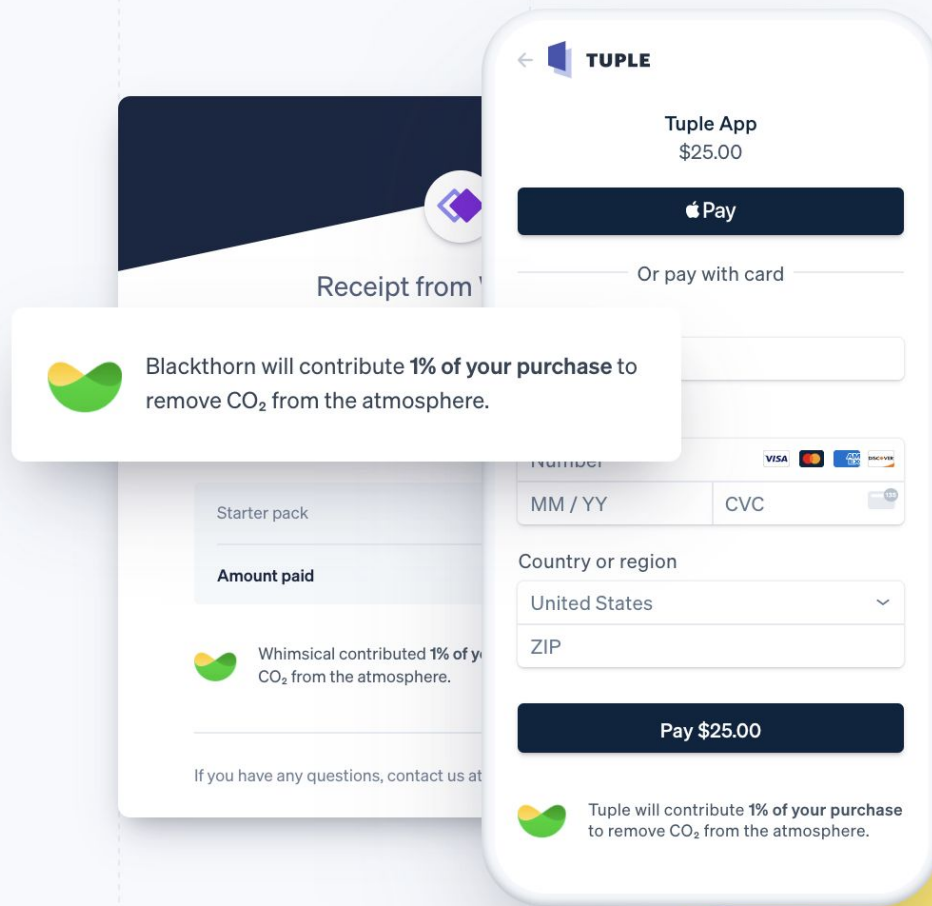
Introducing

Stripe Climate



Remove carbon as you grow your business

With Stripe Climate, you can direct a fraction of your revenue to help scale emerging carbon removal technologies in just a few clicks. Join a growing group of ambitious businesses changing the course of carbon removal.

[Start now >](#)[Contact us >](#)

Settings > [Climate](#)

Remove carbon with every payment

STEP 1 OF 2

Set your contribution

Direct a fraction of your revenue to help scale emerging carbon removal technologies, and let your customers know with a new badge automatically added to Stripe Checkout, Receipts, and Invoices. You can edit your contribution at any time.

STARTING

0.5% of revenue

\$230

est. per month

MOST POPULAR

1% of revenue

\$460

est. per month

HIGH IMPACT

1.5% of revenue

\$690

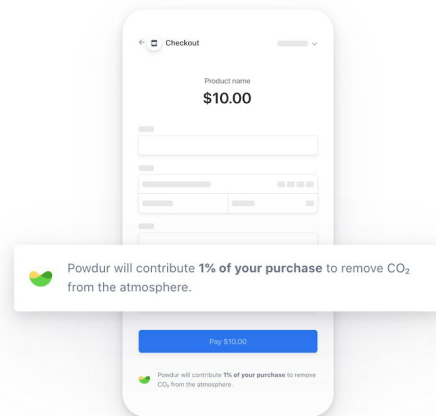
est. per month

 Custom

YOUR IMPACT



This contribution is the equivalent of removing the previous emissions of 9.7 cars. 

[FAQs](#) Contact us at support-climate@stripe.com[Continue →](#)

A new, larger round of carbon removal purchases

- We believe ocean CDR has tremendous potential for scale and permanence, but have seen few projects
- We hope to speak with ocean CDR researchers and founders to see how we can best accelerate your progress
- We're open to anything with the potential to meet our target criteria (right): from direct or indirect ocean capture to electrochemical methods or macroalgae sequestration.

- Please reach out to our purchasing team at cdr-spring21@stripe.com.

Stripe negative emissions target criteria

CRITERIA	TODAY	TARGET BY 2040
Sequestration beyond the biosphere Takes advantage of carbon sinks less constrained by arable land, e.g. carbon mineralization	Yes	Yes
Volume Has a path to being a meaningful part of the negative emissions solution portfolio	–	> 0.5 gigatons per year
Cost Has a path to being affordable at scale	–	< \$100 per ton
Permanence Stores carbon permanently	> 1,000 years	> 1,000 years
Verifiability Uses scientifically rigorous and transparent methods for verification	Modeled or measured directly	Modeled and measured directly
Quality and safety Is globally responsible, considering possible risks and negative externalities	Path to high	High
Net-negative lifecycle Reduces net atmospheric CO ₂ expressed as a ratio subject to appropriate boundary conditions: [Emissions produced] : [CO ₂ removed from the atmosphere]	Negativity ratio ≤ 1	Negativity ratio < 1

Note that we are very open to supporting projects that focus on either capture or storage, so long as they have a path to a holistic negative emissions solution that meets the above criteria.

Experience with Carbon Offsets:

Lessons and research ideas for ocean CDR

Barbara Haya, PhD

Research Fellow

Center for Environmental Public Policy

University of California, Berkeley

bhaya@berkeley.edu

January 19, 2021

Presentation to NASEM Committee on A Research Strategy for Ocean-based Carbon Dioxide Removal (CDR) and Sequestration

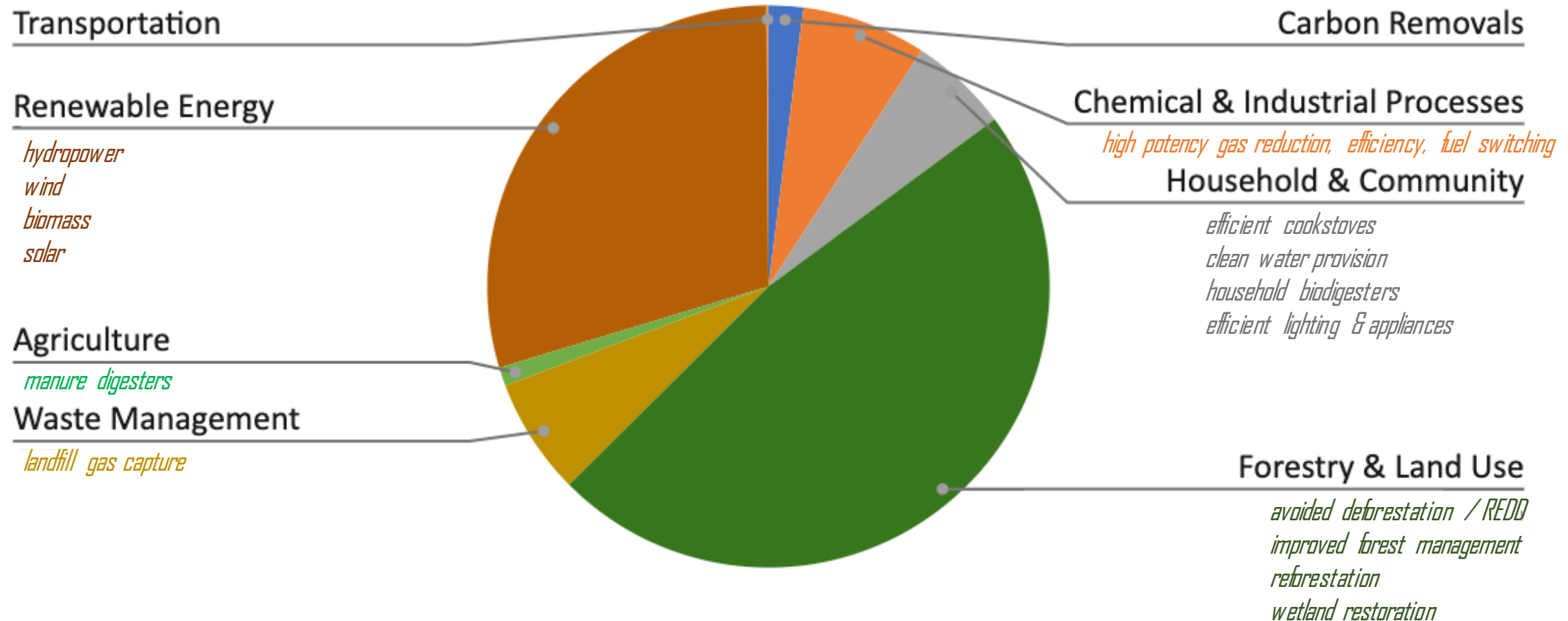
For the next 10 minutes:

- Quick primer on carbon offsets
- Quality of offset on the market today is poor
- Why is this happening?
- Lessons learned and research ideas for ocean CDR

Quick primer on offsets

1.1 billion credits were issued through the end of 2020 from **the four largest voluntary offset registries**
Standard (also includes California's offset program)

– CAR, ACR, Verra, and Gold



Quality of offsets on the market today is poor

High quality offsets manage uncertainty in:

- Additionality
- Baselines
- Leakage
- Perverse incentives
- Durability
- Do no harm

Quality of offsets on the market today is poor

High quality offsets manage uncertainty in:

- **Additionality**
- Baselines
- Leakage
- Perverse incentives
- Durability
- Do no harm

How additional is the Clean Development Mechanism?

Analysis of the application of current tools and proposed alternatives

Berlin,
March 2016

Study prepared for DG CLIMA
Reference: CLIMA.B.3/SERI2013/0026r

Authors

Dr. Martin Cames (Öko-Institut)
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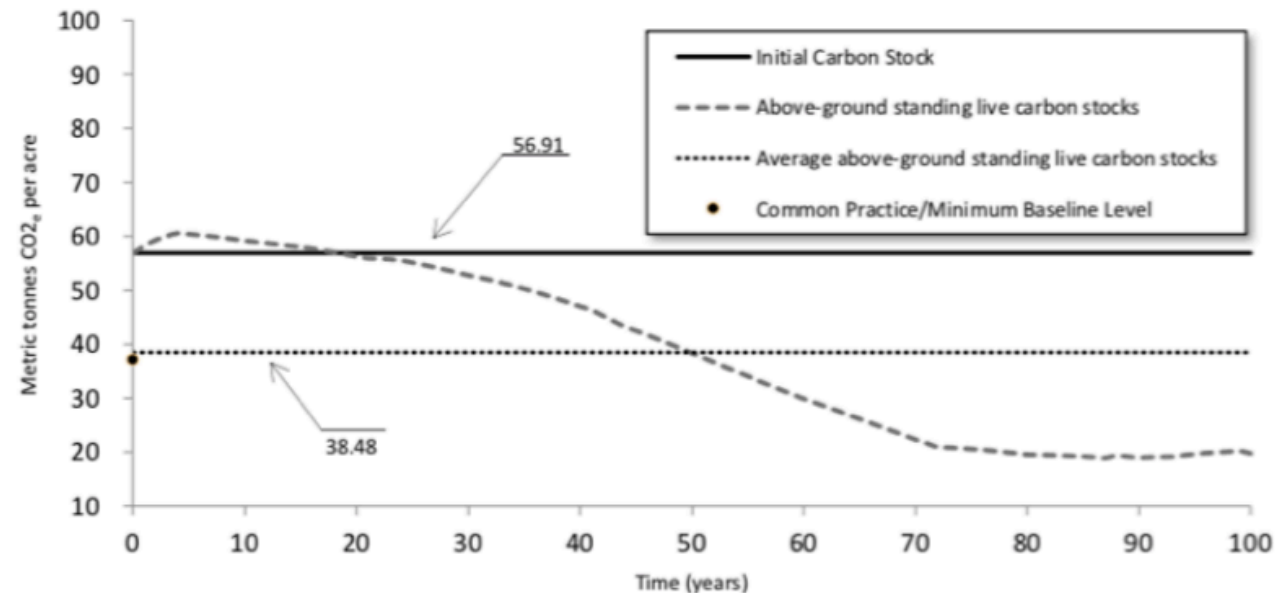
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64295 Darmstadt
Tel. +49 6151 8191-0

Quality of offsets on the market today is poor

High quality offsets manage uncertainty in:

- Additionality
- **Baselines**
- Leakage
- Perverse incentives
- Durability
- Do no harm

Baseline carbon stocks for Finite Carbon – Ahtna Native Improved Forest Management offset project



From: ACR360 “Finite Carbon – Ahtna Native Alaskan IFM” Version 1.3, Attachments G and H: Baseline Carbon Stocks, Submittal Date: 1/19/2018

Quality of offsets on the market today is poor

High quality offsets manage uncertainty in:

- Additionality
- Baselines
- Leakage
- Perverse incentives
- Durability
- Do no harm

POLICY BRIEF: The California Air Resources Board's U.S. Forest offset protocol underestimates leakage

May 7, 2019

Barbara Haya, PhD, Research Fellow, Center for Environmental Public Policy, University of California, Berkeley, bhaya@berkeley.edu

SUMMARY

Analysis of projects generating 80% of total offset credits issued by the California Air Resources Board's (ARB) U.S. Forest offset protocol finds that 82% of these credits likely do not represent true emissions reductions due to the protocol's use of lenient leakage accounting methods. The U.S. Forest protocol has generated 80% of the offset credits in California's cap-and-trade program. The total quantity of emissions allowed because of this over-crediting equals approximately 80 million tons of CO₂, which is one third of the total expected effect of California's cap-and-trade program during 2021 to 2030 (ARB 2017).

Leakage, in the context of the protocol, occurs when a reduction in timber harvesting at a project site causes an increase in timber harvesting elsewhere to meet timber demand. The way ARB's protocol accounts for leakage when calculating the number of credits awarded has three serious problems.

First, the protocol uses a 20% leakage rate when a rate of 80% or higher is supported by published studies of leakage rates from reduced timber harvesting in the United States (Gan & McCarl 2007, Wear & Murray 2004). Using an unsupported low rate results in over-crediting.

Second and more importantly, there is an inconsistency between the timing of when increases in on-site carbon storage and releases due to leakage are accounted for in the protocol's methods. Most improved forest management projects assume and credit a large reduction in timber harvesting in the first year of the offset project, but deduct the associated leakage over 100 years. This outcome is physically inconsistent, as it assumes the forest would be harvested in the first year for the purpose of giving credit but assumes harvesting would be spread out over 100 years for the purpose of reducing credits to account for leakage. As a result, most forest offset projects begin in greenhouse gas debt; project landowners generate offset credits that allow emitters in California to emit more than the state's emissions cap today, in exchange for promises that their lands will continue to increase their storage of carbon over 100 years.

Third, it is unclear whether the protocol requires forestland owners to increase carbon stocks to cover leakage for 25 years or for 100 years. The ambiguity relates to whether forestland owners are required to continue to maintain on-site growth to cover the impacts of leakage after the end of the project's 25-year crediting period. If forestland owners are only required to account for leakage for 25 years, participating projects could result in no net increase in carbon storage over 100 years compared to the baseline scenario.

The below table presents the actual emissions reductions achieved by projects under the protocol under different assumptions, reported as proportions of the emissions reductions achieved by projects under the protocol.

Quality of offsets on the market today is poor

High quality offsets manage uncertainty in:

- Additionality
- Baselines
- Leakage
- Perverse incentives
- Durability
- Do no harm



Quality of offsets on the market today is poor

High quality offsets manage uncertainty in:

- Additionality
- Baselines
- Leakage
- Perverse incentives
- **Durability**
- Do no harm

Quality of offsets on the market today is poor

High quality offsets manage uncertainty in:

- Additionality
- Baselines
- Leakage
- Perverse incentives
- Durability
- **Do no harm**

Perfect storm for poor quality offsets

- Uncertainty -> quality judgements are subjective
- Subjective quality judgements
 - > vulnerability to politics & financial interest
 - > influence by values
 - > few academic studies
- It is easy to forget that offsets trade rather than increase mitigation

What does this mean for ocean CDR? / Research needs

- It's hard to get offsets right; the structure of the market is stacked against quality
- Four possible ways forward:
 - Focus on project types with low uncertainty in climate impact, like many CDR activities
 - Convince the registries to use conservative methods for estimating emissions reductions and additionality when there is uncertainty
 - Reconceptualize offsets as a way to provide financing for climate mitigation rather than as quantified verified tons of carbon removal
 - Don't use offsets and focus on other public and private funding approaches
- Research needs:
 - quality of offsets on the market
 - as long as offset quality is poor, prices will be too low to drive needed mitigation
 - institution creation – how to create a high-quality offset market given the challenges

Thank you! Barbara Haya, bhaya@berkeley.edu

BREAK

We will resume at 4pm EST



Parallel EU/German Efforts in the Advancement of Ocean-based CDR Strategies

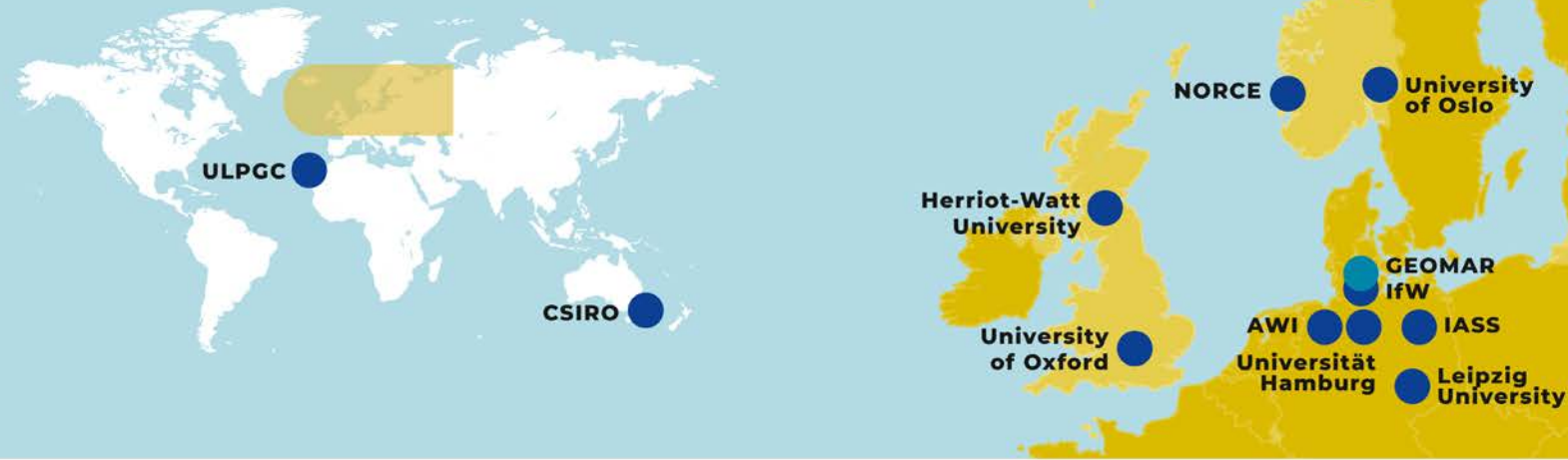
David P. Keller
GEOMAR Helmholtz Centre for Ocean Research Kiel

The OceanNETs project



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 869357.

14 Participating Institutions

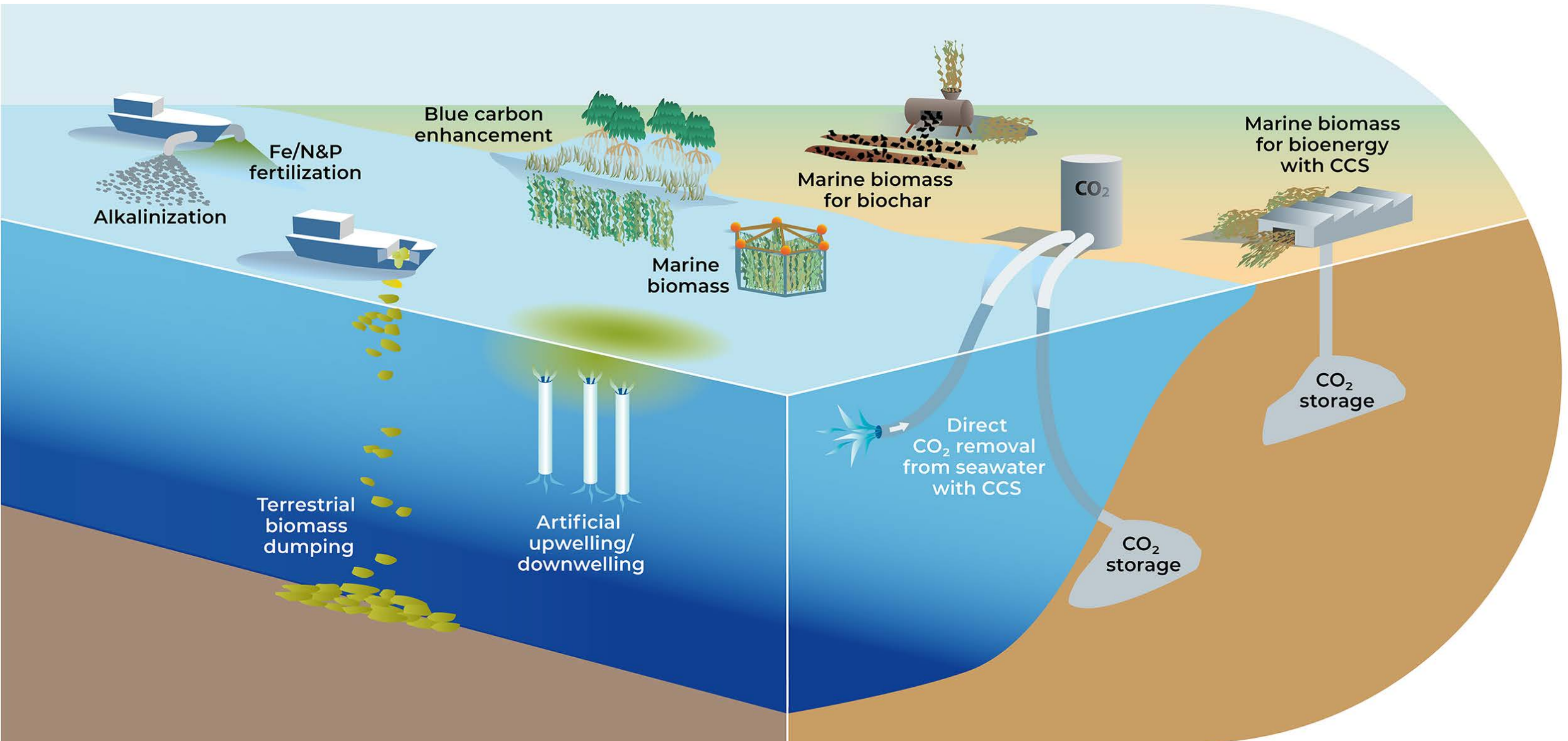


Funding: 7.2M €

4 year project (started July 2020)



Ocean-based Negative Emission Technologies



OceanNETs Objectives

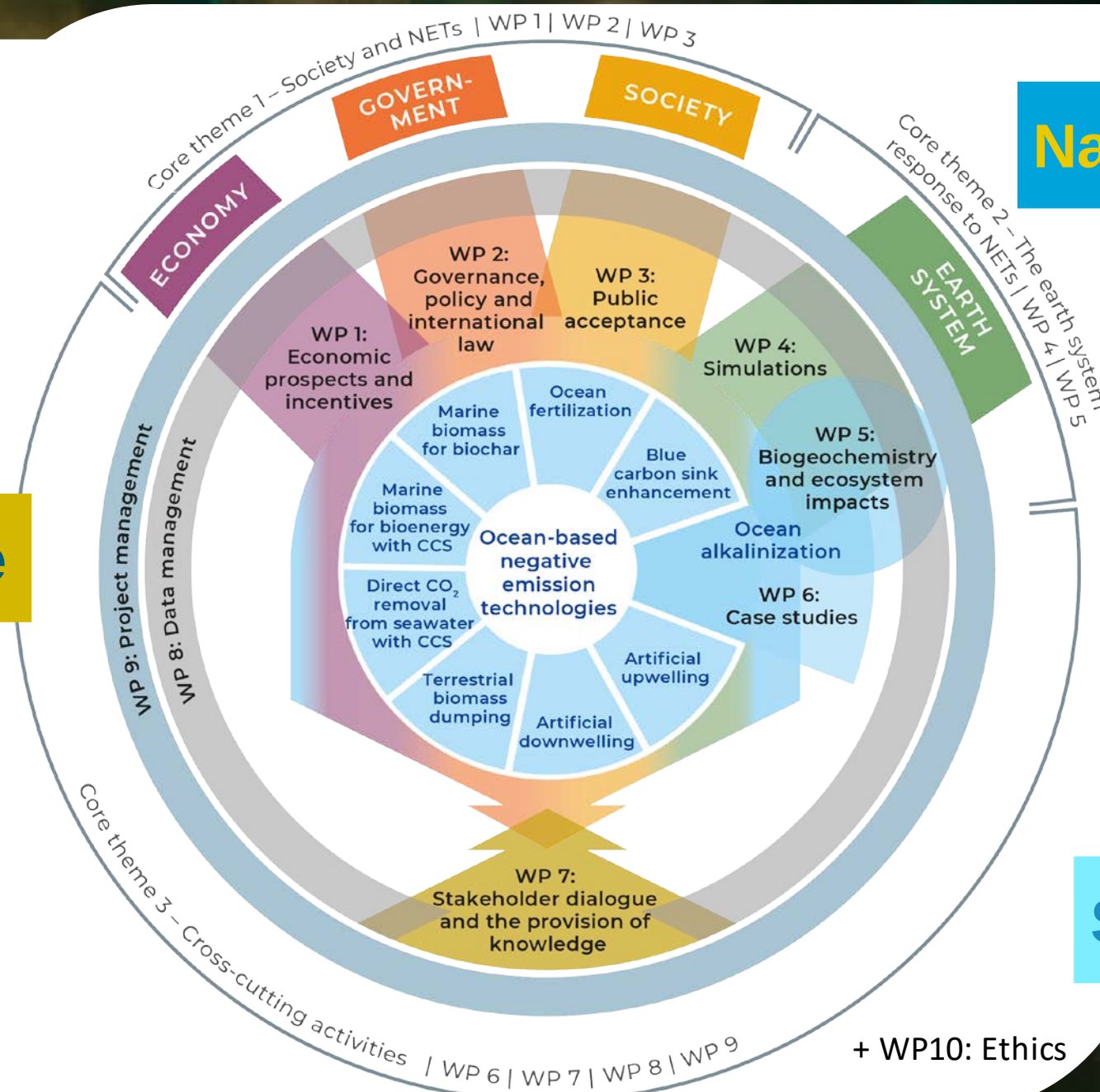
- ▶ Determine the most effective ocean-based NETs with low environmental and ecological risks (e.g., to biodiversity, ecosystem services) and high co-benefits.
- ▶ Identify for different ocean-based NETs the degree of (and factors affecting) social and political acceptance, affordability, and societal impacts and risks (e.g., to food security).



OceanNETs Structure

Natural Science

Social Science



Stakeholders

WP 1: Economic Prospects & Incentives

Objectives:

- ▶ Determine how many carbon credits various ocean NETs provide
- ▶ Quantify the (operational) cost of various ocean NETs
- ▶ Determine what the future role of ocean NETs is in climate policy



WP 2: Governance Policy & International Law

Objectives:

- ▶ To analyze the governance, policy and international legal dimensions of Ocean NETs.
- ▶ To identify key barriers and synergies for Ocean NETs with current and future ocean governance regimes, to promote their successful and cost-effective implementation.
- ▶ To offer recommendations for overcoming governance challenges and exploiting opportunities.



WP 3: Public Acceptance

Objectives:

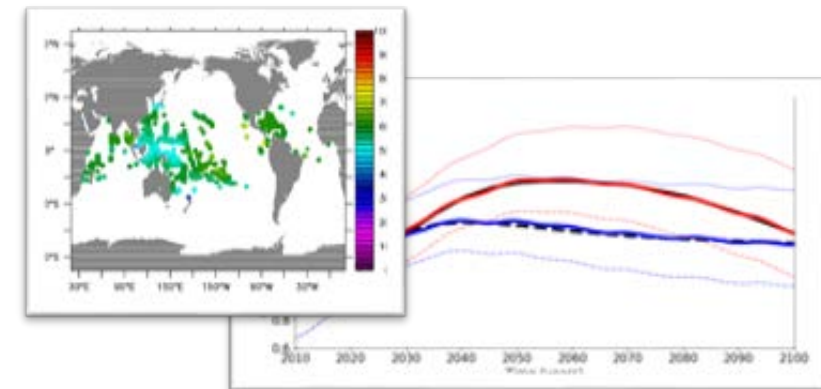
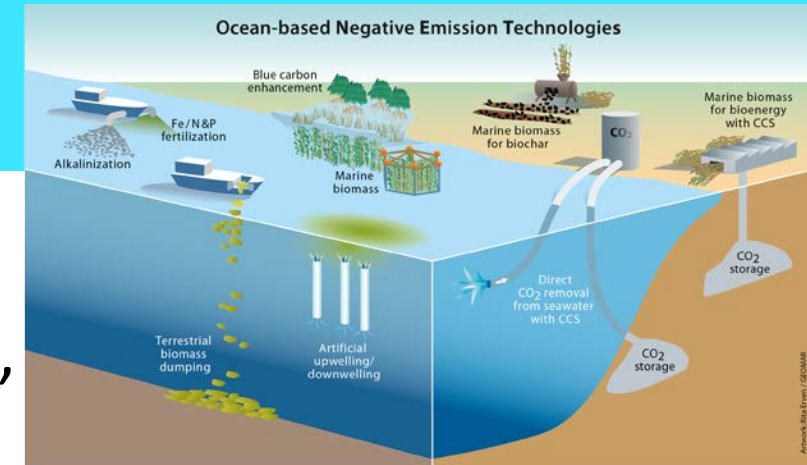
- ▶ Explore laypersons' perceptions of ocean-based NET research and deployment.
- ▶ Explaining the variations in acceptance based on values, political outlook, framings, and demographics.
- ▶ Link laypersons' perceptions with experts' economic assessment and stakeholders' views on governance to contribute to the development of scenarios constrained by socio-economic factors.



WP 4: Simulations

Objectives:

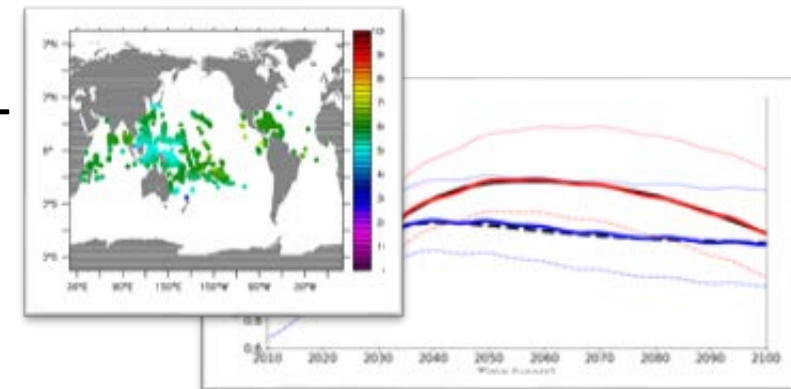
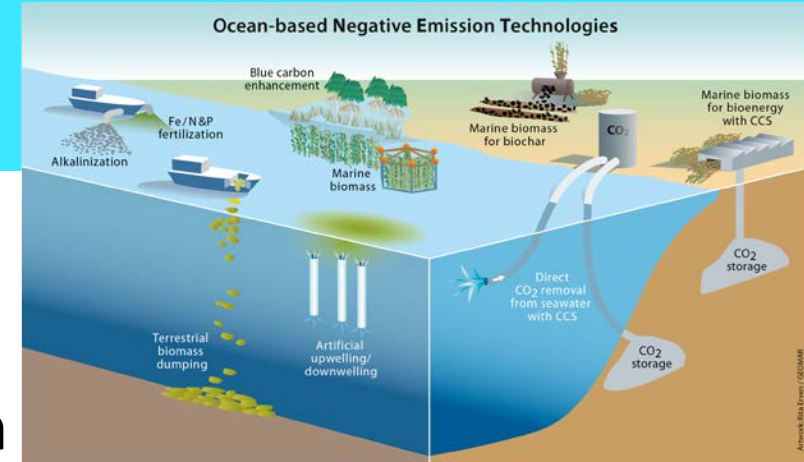
- ▶ To understand and quantify the potential, effectiveness, and impacts of ocean NETs through model simulations from regional to global scales on decadal to multi-centennial timescales.
- ▶ To identify maximum (physically and chemically possible) deployment rates, as well as constrained deployment rates, which allow staying within “safe operating spaces” (e.g. local ecological thresholds, planetary boundaries), and which ensure compatibility of ocean NETs with the UN sustainability goals and public acceptance.



WP 4: Simulations

Objectives:

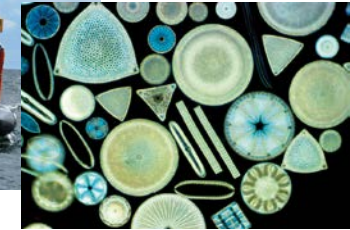
- ▶ To provide an assessment of impacts (co-benefits and risks) of different ocean NETs associated with changes in ocean physics and biogeochemistry, with “termination effects”, and potential impacts on ecology; taking into account model uncertainties.
- ▶ To understand and quantify impacts of ocean NETs on the land and atmosphere.
- ▶ To assess interactions of ocean NETs with land-based NET methods, particularly through changes in carbon and nutrient cycling.



WP 5: Ocean Alkalinization Biogeochemistry and Ecosystem Impacts

Objectives:

- ▶ To provide an assessment on the suitability of various minerals for ocean alkalinization purposes
- ▶ To examine ecological and biogeochemical responses to different approaches of ocean alkalinization in representative pelagic systems



**laboratory
experiments**

modelling

**mesocosm
experiments**

WP 6: Ocean Alkalinization Case Studies

Objectives:

- ▶ Scope and define realistic deployment scenarios for two ocean alkalinization approaches
- ▶ Ocean liming by using spare capacity in cement industry
- ▶ Electrochemical weathering integration into the desalination industry



CO₂



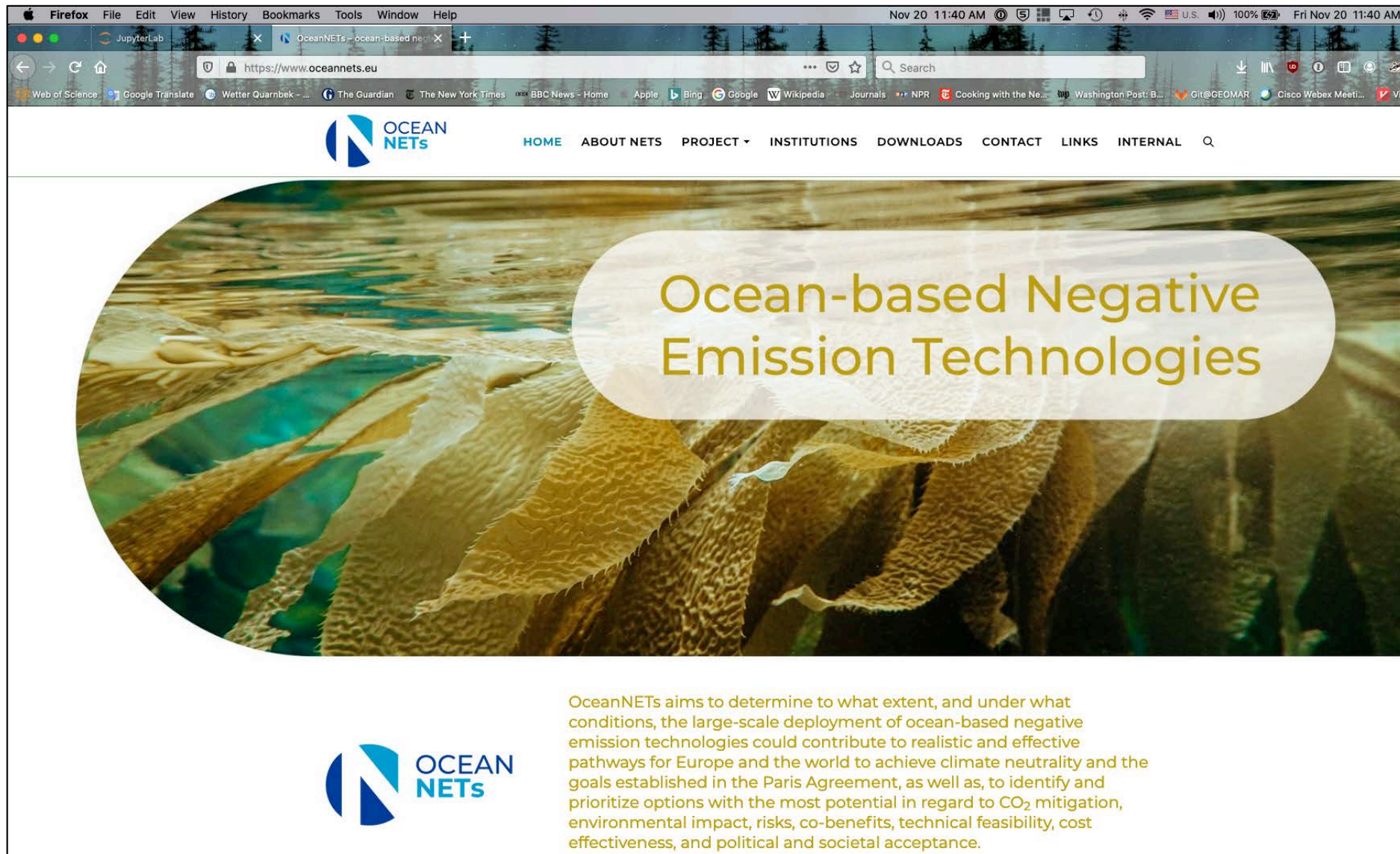
WP 7: Stakeholder Dialogue and the Provision of Knowledge

Objectives:

- ▶ Establish a project-wide stakeholder dialogue to inform the project's research, shape its final outcomes (e.g., ensure the results are relevant for different audiences), and facilitate the communication and uptake of the results.
- ▶ Synthesize knowledge on OceanNETs results for dissemination, communication, and exploitation, as well as use within the project.
- ▶ Enable cross-cutting activities, including the **development of a sustainable development goals evaluation framework** and **protocols for responsible innovation** within the consortium.



Learn more at our website: <https://www.oceannets.eu/>



The screenshot shows the OceanNETs website homepage. The browser is Firefox, and the address bar shows <https://www.oceannets.eu/>. The website features a large, circular, abstract image of ocean waves in shades of blue and green. Overlaid on this image is a white, rounded rectangle containing the text "Ocean-based Negative Emission Technologies" in a bold, dark blue font. Below the image, the OceanNETs logo is displayed on the left, and a paragraph of text is on the right. The text describes the organization's mission to determine the extent and conditions for large-scale deployment of ocean-based negative emission technologies, aiming to contribute to realistic and effective pathways for Europe and the world to achieve climate neutrality and the goals established in the Paris Agreement. It also mentions identifying and prioritizing options with the most potential in regard to CO₂ mitigation, environmental impact, risks, co-benefits, technical feasibility, cost effectiveness, and political and societal acceptance.

OCEAN NETS

HOME ABOUT NETS PROJECT INSTITUTIONS DOWNLOADS CONTACT LINKS INTERNAL

Ocean-based Negative Emission Technologies

OceanNETs aims to determine to what extent, and under what conditions, the large-scale deployment of ocean-based negative emission technologies could contribute to realistic and effective pathways for Europe and the world to achieve climate neutrality and the goals established in the Paris Agreement, as well as, to identify and prioritize options with the most potential in regard to CO₂ mitigation, environmental impact, risks, co-benefits, technical feasibility, cost effectiveness, and political and societal acceptance.

**Or contact
us directly!**

German Alliance for Marine Research (DAM) research mission on Carbon Removal



► ~27M € of research funding for (2021 – 2024); will continue after 2024



Topics include:

- 1) Geological methods for enhancing marine CO₂ uptake and storage
 - 2) Alkalinity enhancement
 - 3) Blue carbon approaches
 - 4) Emerging proposals for enhancing marine CO₂ uptake and storage
- Proposals have passed an initial round of evaluation and are currently being revised
- Projects will start in summer of 2021

OceanNETs Objectives

Overall goal: OceanNETs aims to determine to what extent, and under what conditions, the large-scale deployment of ocean-based negative emission technologies could contribute to realistic and effective pathways for Europe and the world to achieve climate neutrality and the goals established in the Paris Agreement, as well as, to identify and prioritize options with the most potential in regard to CO₂ mitigation, environmental impact, risks, co-benefits, technical feasibility, cost effectiveness, and political and societal acceptance.



WP 1: Economic Prospects & Incentives

Approach:

- ▶ Integrated assessment modelling to determine carbon credits and climate policies
- ▶ Cost estimate studies
- ▶ Stylized, regional, strategic forward-looking ecological-economic integrated assessments
- ▶ Create a database on existing and proposed ocean NETs



WP 2: Governance Policy & International Law

Approach:

- ▶ National case studies of selected NETs
 - ▶ Canada, Germany, & Australia
- ▶ Identification of regional and global governance challenges and opportunities
 - ▶ Stakeholder surveys
 - ▶ Expert interviews
 - ▶ Participatory workshops
- ▶ Analysis of the international law of the sea
 - ▶ Analysis of international agreements and other instruments
 - ▶ Contextual legal research to determine how to best establish new regulations



WP 3: Public Acceptance

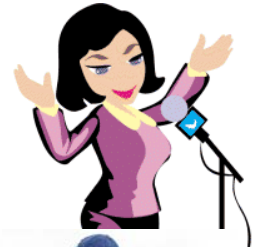
Approach:

Focus groups

Germany and Norway

China, Taiwan, and Norway

Canada, China, Germany, and Norway



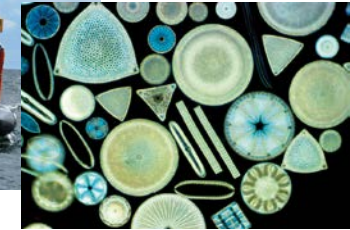
WP4 Models

Model Name	Description	Spatial coverage	Ocean Resolution	Developed or used by partner
<i>Earth System Models</i>				
NorESM2-LM	State-of-the-art CMIP6 era ESM	Global	$1.0^{\circ} \times 1.0^{\circ}$ (nominal)	NORCE, NTNU
AWI-CM-REcoM ⁴⁶⁻⁴⁹	State-of-the-art CMIP6 era ESM	Global	Multi-resolution mesh, approx. 1° , with higher resolution in the North Atlantic, Southern Ocean and around the Equator	AWI
FOCI	Novel ESM with high-resolution nesting capabilities	Global	$0.5^{\circ} \times 0.5^{\circ}$ with $0.1^{\circ} \times 0.1^{\circ}$ regional nests	GEOMAR
ACCESS-ESM ⁵⁰	State-of-the-art CMIP6 era ESM	Global	$1.0^{\circ} \times 1.0^{\circ}$ with enhanced tropical resolution	CSIRO
EC-Earth v3	State-of-the-art CMIP6 era ESM	Global	$1^{\circ} \times 1^{\circ}$	FMI
UVic v2.10 ^{51,52}	Earth system model of intermediate complexity	Global	$1.8^{\circ} \times 3.6^{\circ}$	GEOMAR, FMI

WP 5: Ocean Alkalinization Biogeochemistry and Ecosystem Impacts

Approach:

- ▶ Characterization of dissolution kinetics and stability of minerals with high potential for ocean alkalinization approaches
 - ▶ Laboratory experiments
 - ▶ Modelling to extend dissolution experimental results to ocean conditions



**laboratory
experiments**

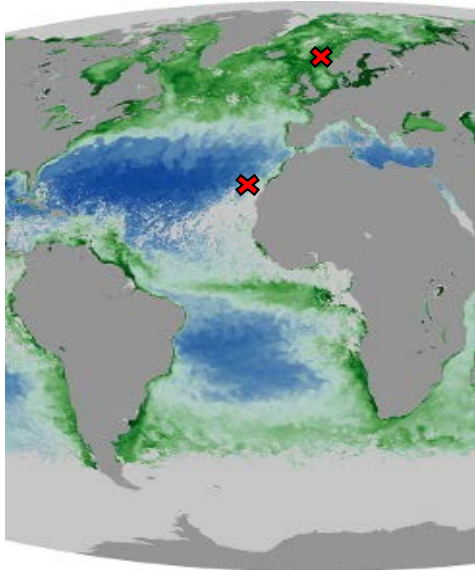
modelling

**mesocosm
experiments**

WP 5: Ocean Alkalinization Biogeochemistry and Ecosystem Impacts

Raunefjord, Bergen, Mar 2021 ~~TBD~~

Mesocosm
experiments

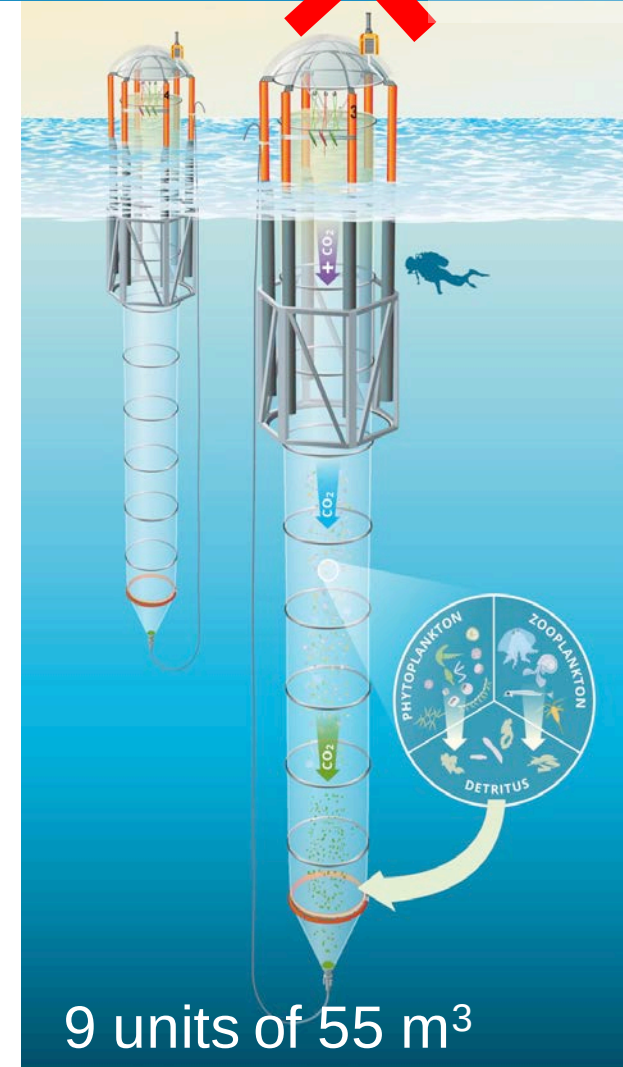


Gran Canaria, Jan Feb 2021 ~~TBD~~



9 units of 10 m³

- Model-supported mesocosm data analysis and synthesis



9 units of 55 m³

WP 5: Ocean Alkalinization Biogeochemistry and Ecosystem Impacts

Raunefjord, Bergen, May – July, 2021

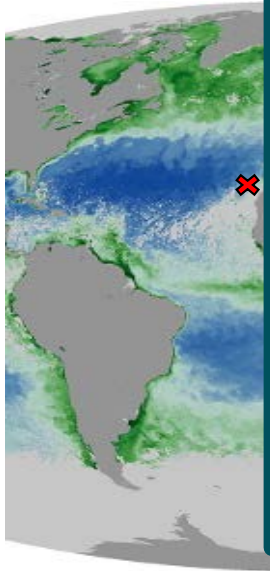
Mesocosm
experi

Deliberative workshops with local stakeholders will take place in parallel

***Purpose:* elicit the preferences, priorities and existing knowledge of relevant stakeholders; engage in a dialogue**

- Model-supported mesocosm data analysis and synthesis

9 units of 55 m³



WP 6: Ocean Alkalinization Case Studies

Approach:

- ▶ Scoping research into cement and desalination industries
 - ▶ Including interviews & workshops
 - ▶ Scoping of deployment scenarios
- ▶ Life cycle assessments based on international standards
- ▶ Stakeholder engagement for co-development
- ▶ Synthesis and policy engagement



WPs 8, 9, and 10

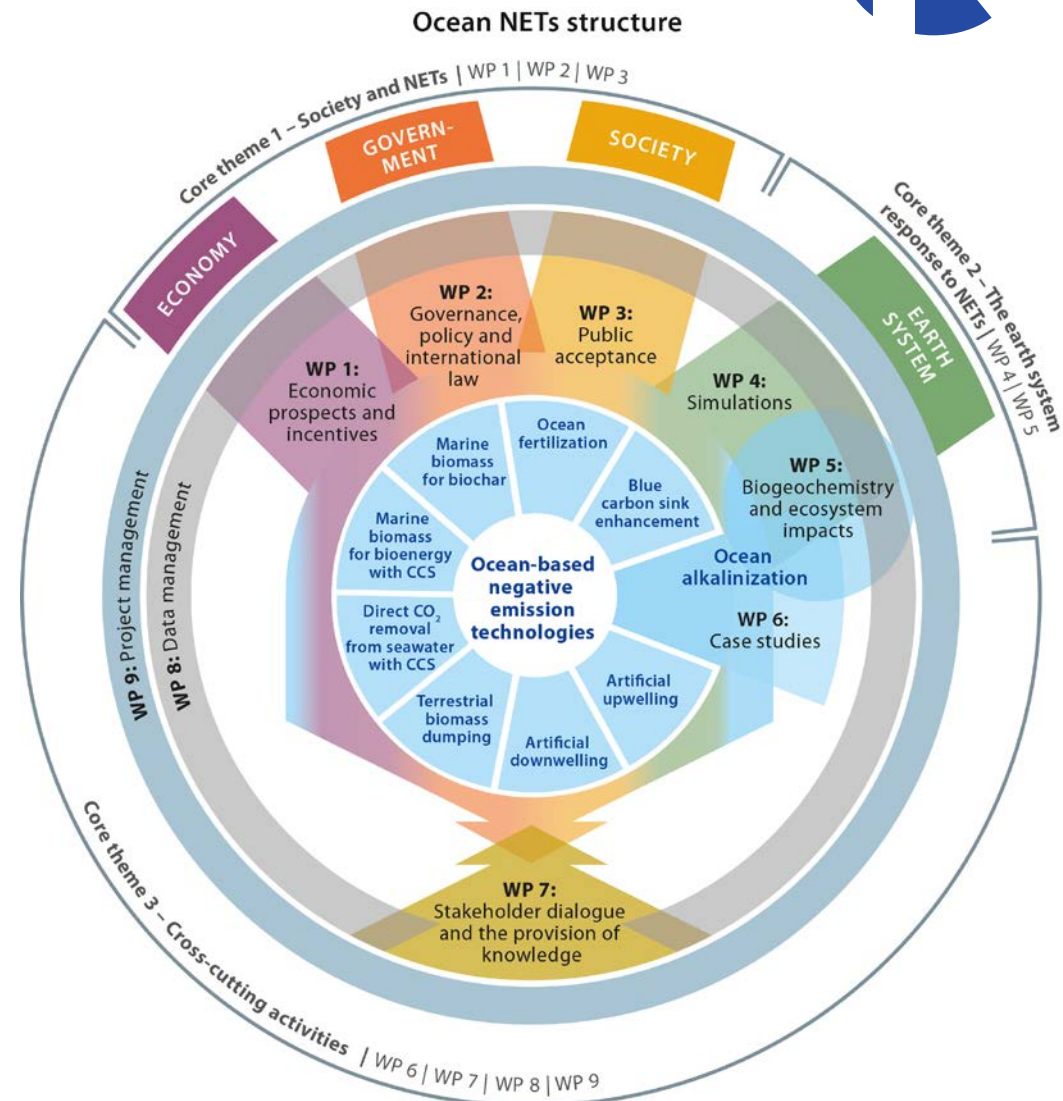
#8 – Data management

#9 – Project management

#10 – Ethics

OceanNETs also aims to have a small CO₂ footprint!

- We will monitor our CO₂ footprint and take steps to minimize it





Parallel Advancements - NEGEM & EU CDR Policy

January 19th 2021

National Academies of Science Engineering & Medicine

Virtual Workshop on Ocean CDR

Prepared by: Mark Preston Aragonès



This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 869192.



NEGEM - Quantifying and Deploying Responsible Negative Emissions in Climate Resilient Pathways

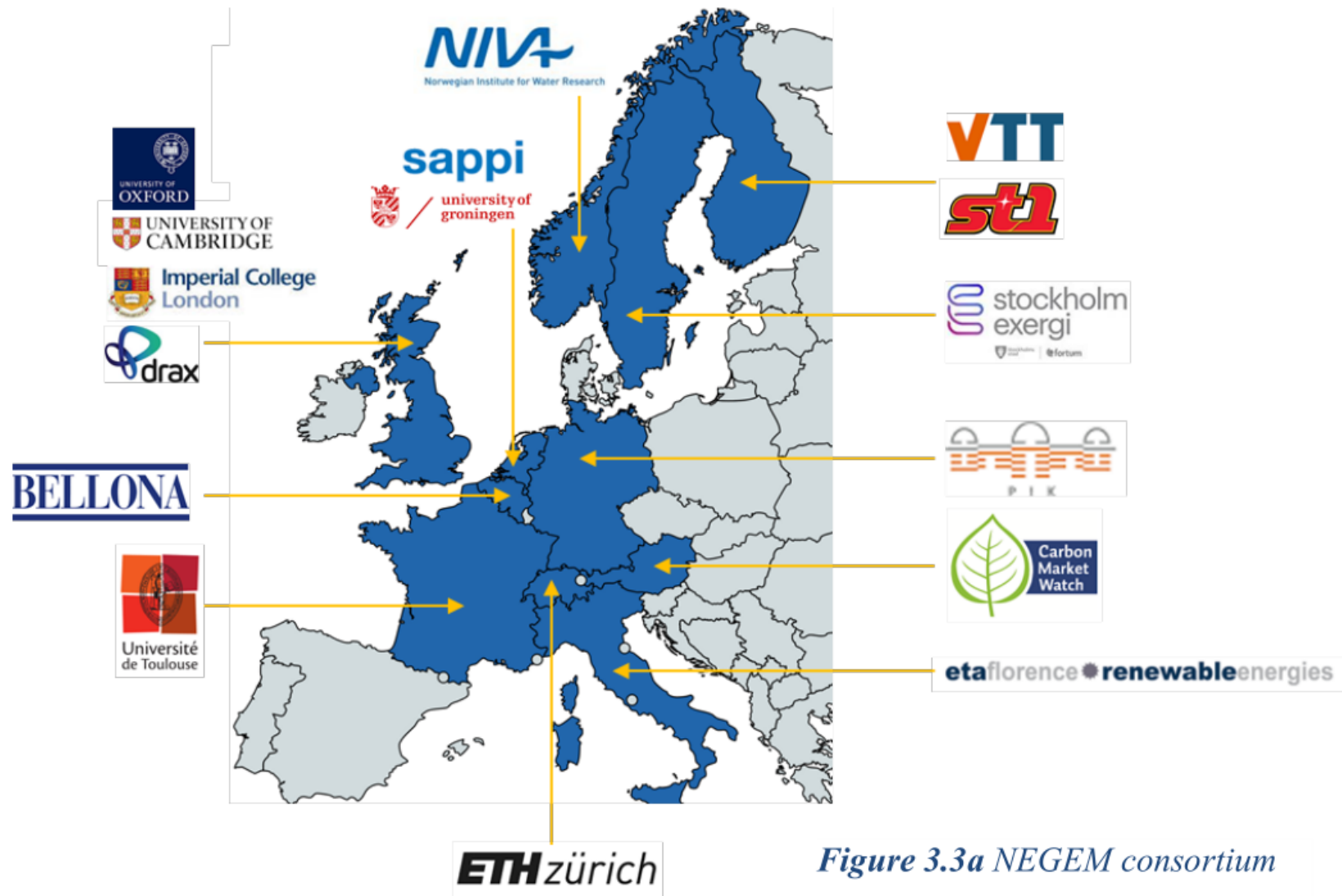


Figure 3.3a NEGEM consortium

- 16 partners
- 11 countries
- 6 universities
- 3 RTOs
- 2 NGOs
- 5 industrial



NEGEM's main research questions



- What role can NETPs play in the EU's goal for climate neutrality by 2050 (and beyond)?
- At what scale might it be feasible to implement them, given their technical, economic and socio-political aspects?
- How to formulate policies and governance frameworks to optimise the deployment of NETPs within the overall climate architecture?

NETPs = Negative Emission Technologies and Practices

The objective of NEGEM is to analyse the “realistic” potential of NETPs

What is the realistic potential NETPs?



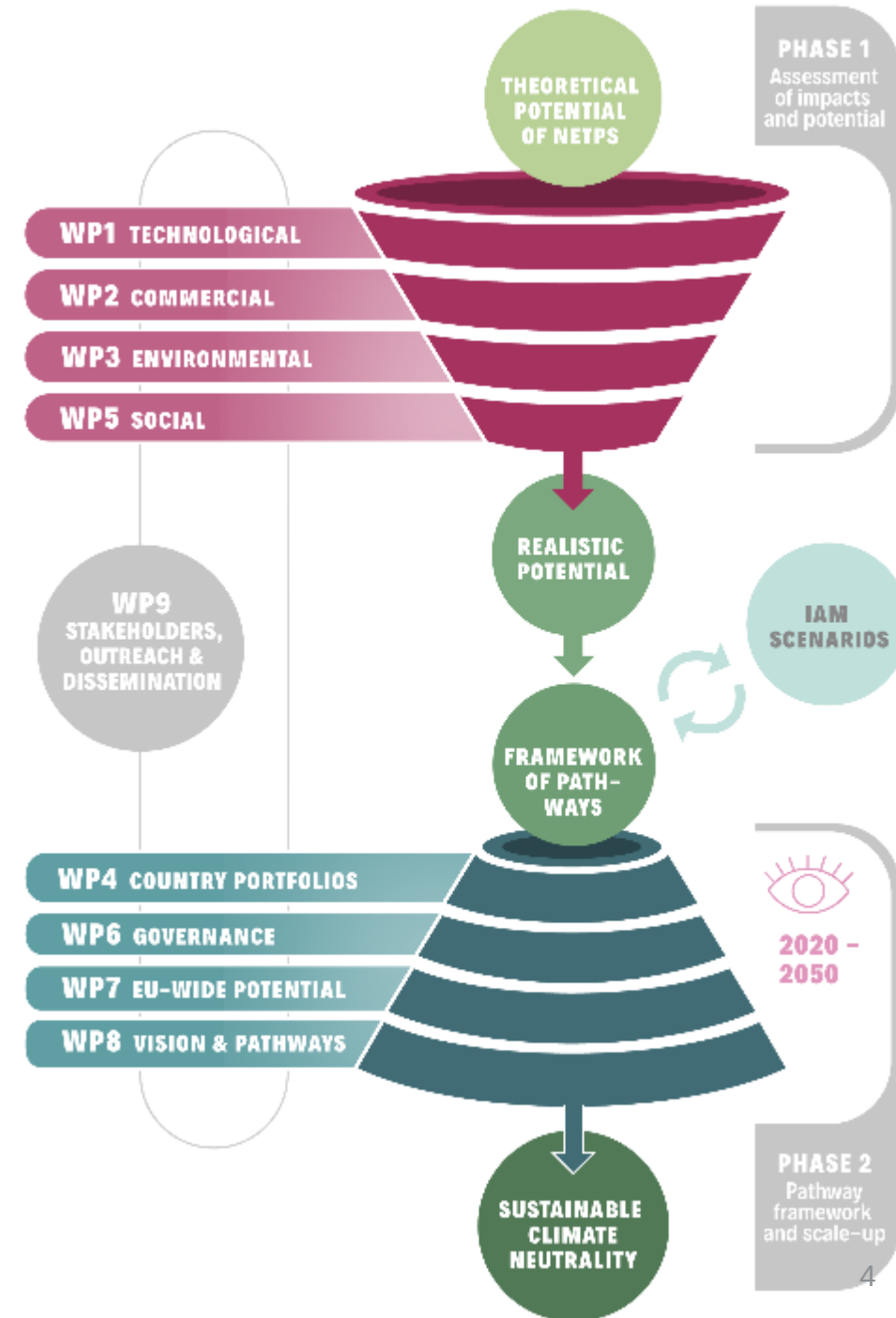
- Technological potential
- Commercial potential
- Planetary Boundaries
- Social License to Operate

Sustainable NETP deployment



- Country portfolios, EU-wide potentials
- Enabling governance frameworks

How do we meet the realistic potential for NETPs?



What are EU up to?



European Green Deal – 2019

Set of policy initiatives by the European Commission with the aim of making Europe climate neutral in 2050

EU Climate Law – Climate Neutrality 2050

Net reductions of 'at least 55%' by 2030

Piecemeal approach to CDR:

- Carbon Removal Certification Mechanism (by 2023)
- Carbon Farming Initiative
- Review of the EU Emission Trading System
- Circular Economy Action Plan
- Land-Use, Land-Use Change and Forestry (LULUCF) Directive



No work planned on specifically on Ocean-based CDR

Shifting CDR from research to policy



The concept Carbon Dioxide Removal is relatively simple

Rationale and role of CDR is well understood in research circles

- An additional and necessary tool in reaching climate goals

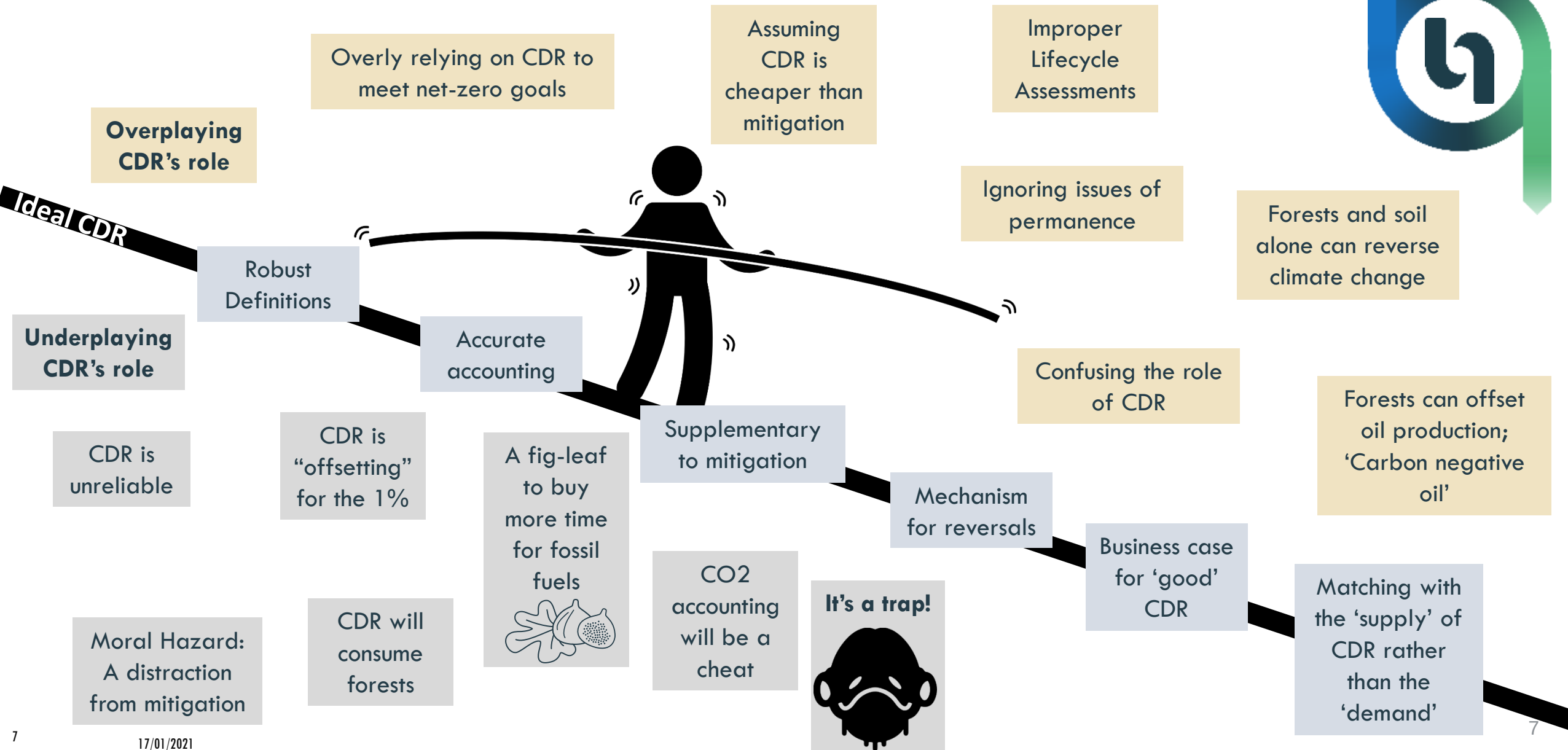
CDR is now becoming 'real'

Translating the research into policy will be a huge challenge

- Rampant confusion among policymakers
- Wide range of interests
 - Many stakeholders benefit from improper assessments
- Large uncertainties and unknowns
 - How do we deal with **permanence** and **reversibility**?
 - How to account for CDR?



Carbon Dioxide Removal can go wrong in many ways



First step – A Robust Definition of CDR



4 Principles that collectively define CDR:

1. Carbon dioxide is **physically removed** from the atmosphere;
2. The **removed carbon dioxide is stored** out of the atmosphere in a manner **intended to be permanent**;
3. **Upstream and downstream greenhouse gas emissions**, associated with the removal and storage process, are comprehensively estimated and **included in the emission balance**;
4. The total quantity of atmospheric carbon dioxide removed and permanently stored is greater than the quantity of carbon dioxide equivalent emitted to the atmosphere.

(adapted from Tanzer and Ramirez, 2019)

Many open research questions for CDR



How to limit the 'hype' around CDR without dismissing its role?

How do we match the 'demand' with the 'supply'?

How to price a future scarcity of CDR into present market mechanisms?

How to assess the 'quality' of removals?

How to shift the conversation from 'demand-driven' CDR to 'supply-driven' CDR?



Thank you!

Project Partners



@NEGEMProject
info@negemproject.eu
www.negemproject.eu



UK perspective on marine CDR

Phil Williamson
University of East Anglia



(personal)

UK perspective on marine CDR

not Gideon Henderson

- Chief Science Adviser, Defra
- Oxford academic/CDR researcher
- Chair, 2018 RS/RAE report on GGR



Geoengineering the climate

Science, governance and uncertainty
September 2009



Royal Society: 2009

Convention on Biological Diversity:
2012 and 2016

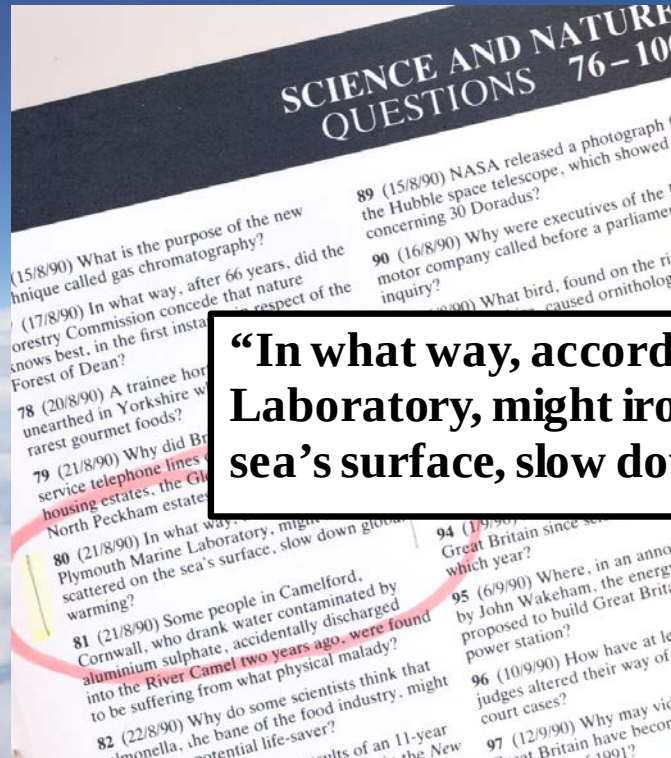
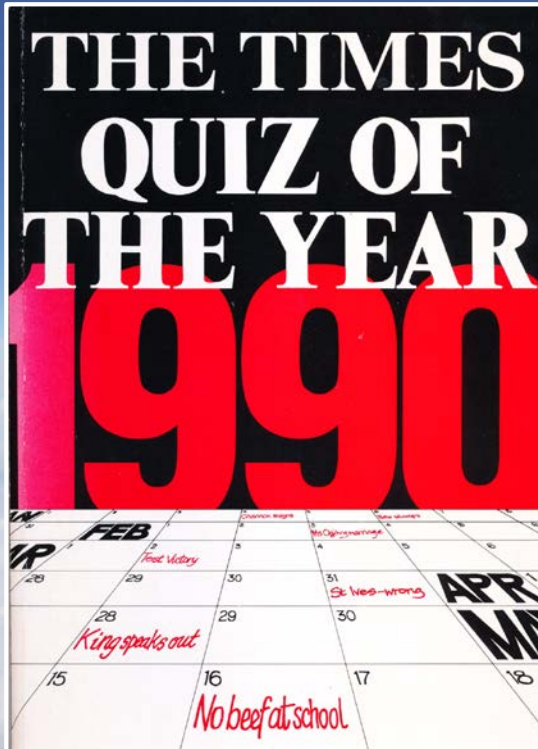
Background #1: The UK has led several reviews on marine CDR (in wider context)



Royal Society & Royal Academy of Engineering: 2018

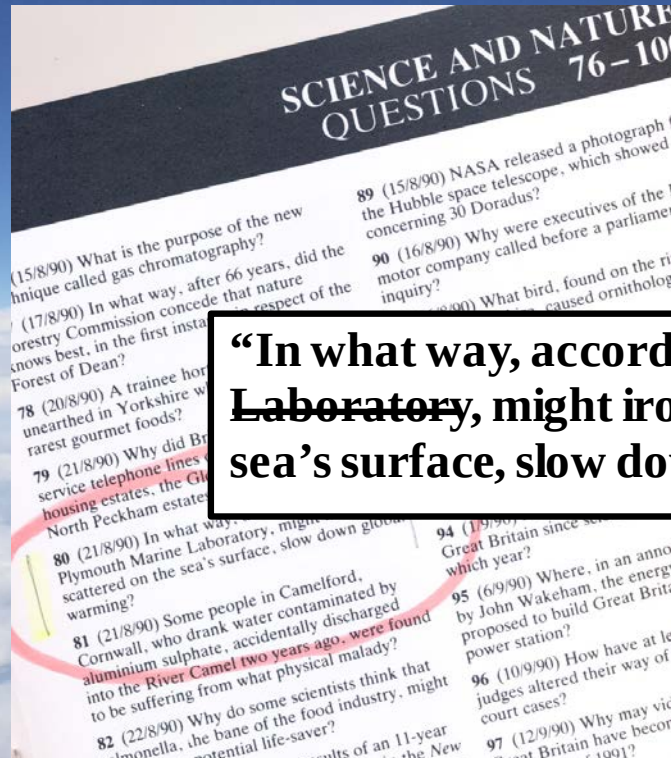
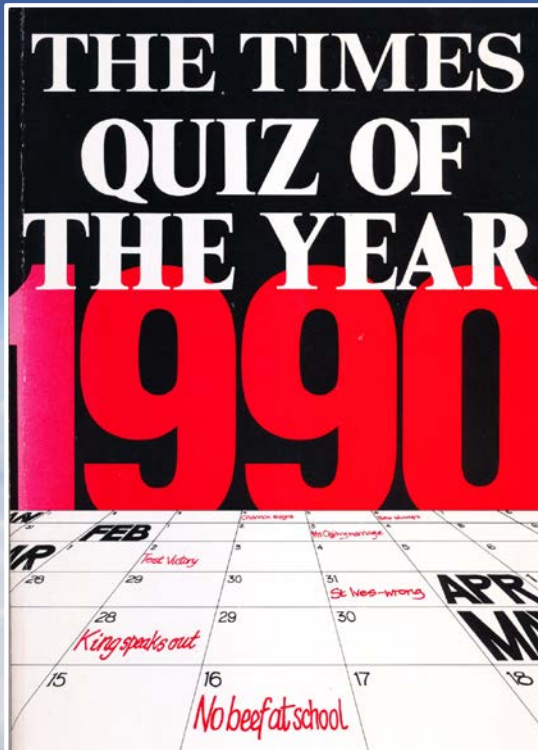


Background #2: The UK has supported research relevant to CDR for rather a long time (*more recently through the Greenhouse Gas Removal programme*)



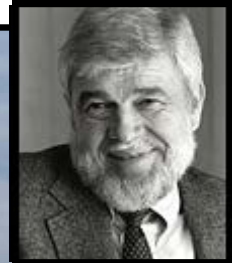
“In what way, according to Plymouth Marine Laboratory, might iron, if scattered on the sea’s surface, slow down global warming?”

Background #2: The UK has supported research relevant to CDR for rather a long time (*more recently through the Greenhouse Gas Removal programme*)



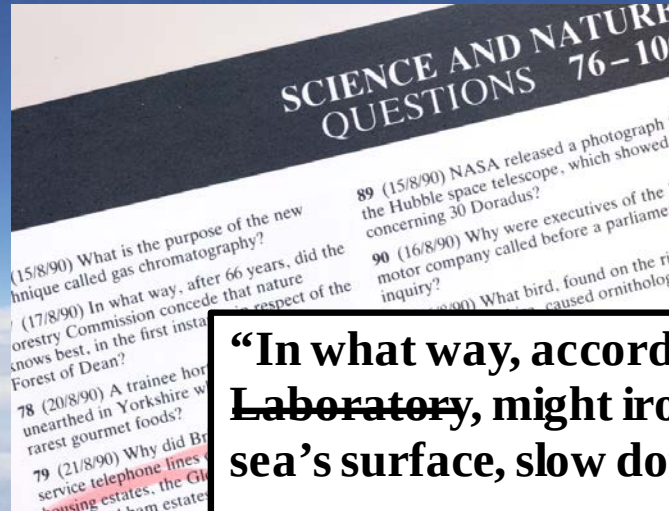
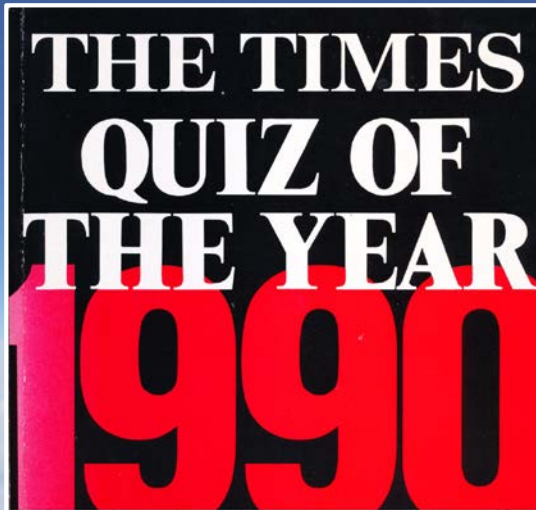
John Martin

“In what way, according to ~~Plymouth Marine Laboratory~~, might iron, if scattered on the sea's surface, slow down global warming?”



1935-1993

Background #2: The UK has supported research relevant to CDR for rather a long time (recently through the Greenhouse Gas Removal programme)

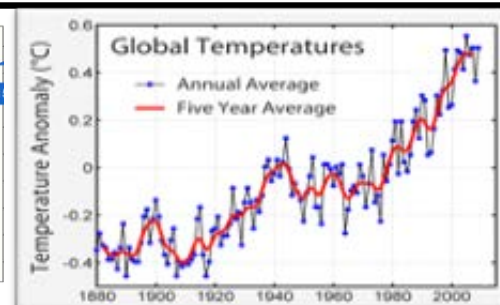
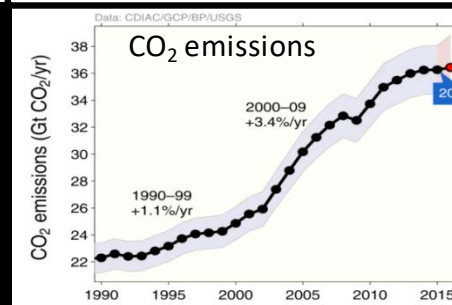


John Martin

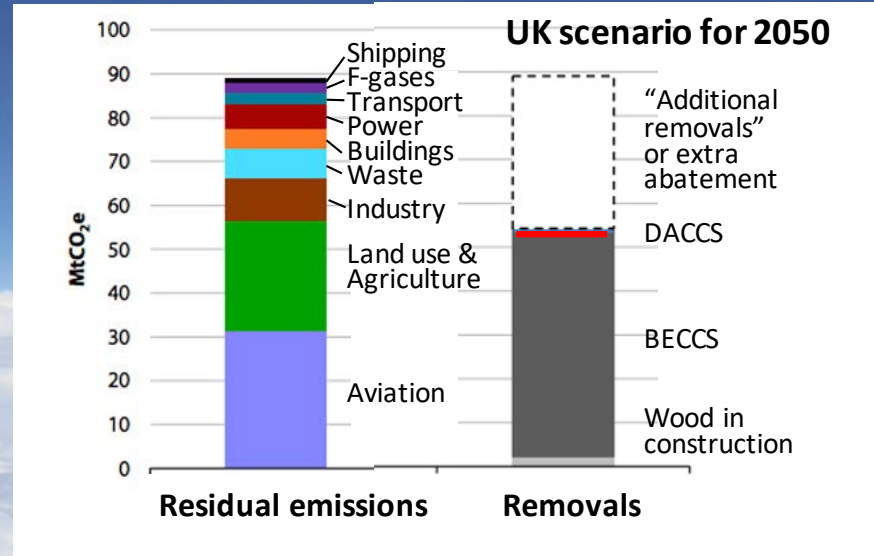
“In what way, according to Plymouth Marine Laboratory, might iron, if scattered on the sea’s surface, slow down global warming?”

What has happened in the past 31 years?

- Lots of science; some policy commitments
- Global CO₂ emissions increased by ~60%
- Global surface temperature increase of ~0.5°C



Background #3: The UK government has recognised that CDR ('removals') will be necessary to achieve 2050 net zero climate commitment



Climate Change Committee report on Net Zero (2019)

BUT marine CDR not included in recent scenario



Focus on specific options for marine CDR:

1. Nutrient fertilization
2. Ecosystem recovery
3. Seaweed cultivation
4. Ocean alkalinity enhancement
5. Seawater CO₂ stripping
6. Artificial upwelling and downwelling

Focus on specific options for marine CDR:

UK effort directed at
DEPLOYMENT

Past

Recent

Future

DEMONSTRATION

RESEARCH

1990-2015

2015-2020

2021-2025

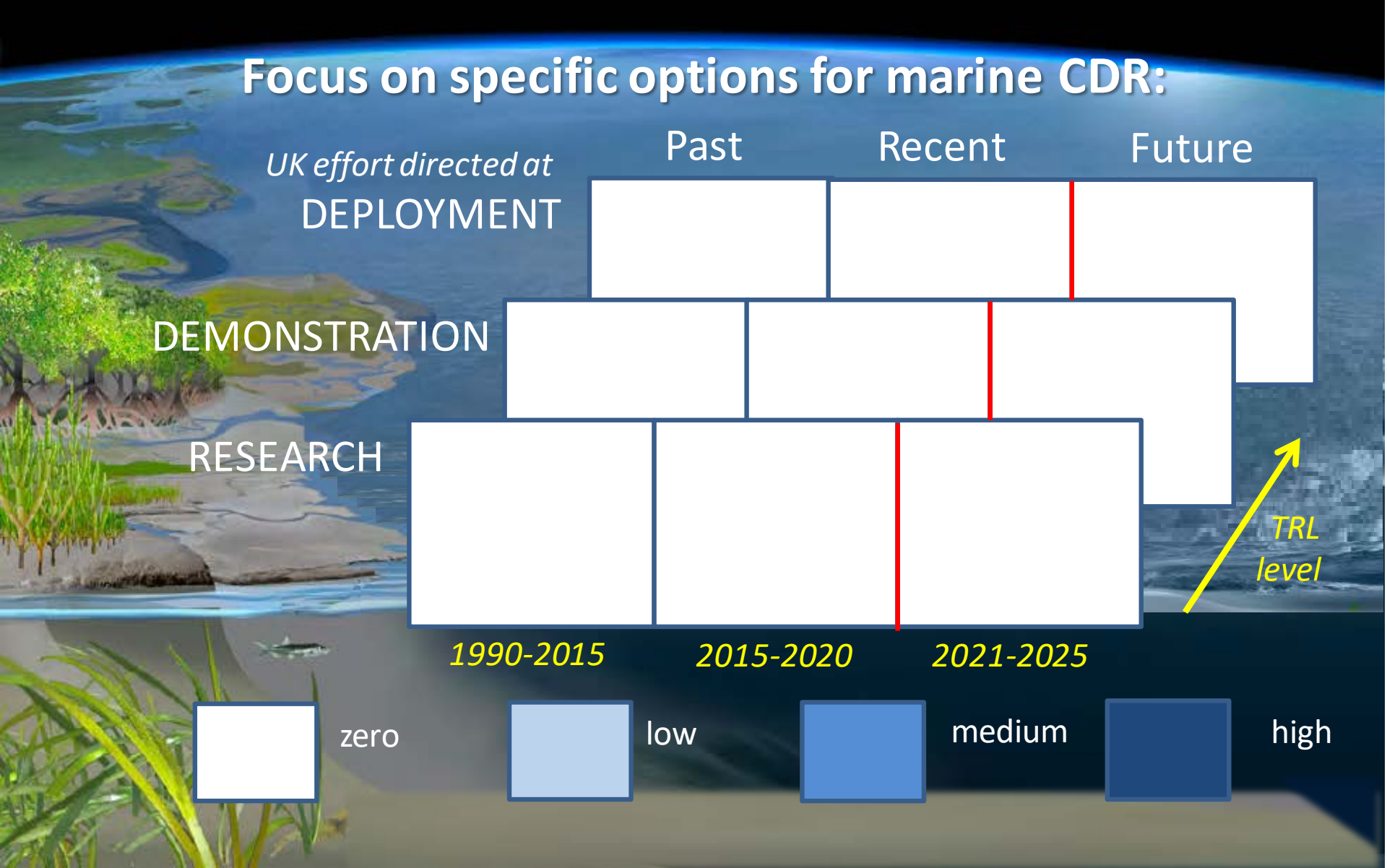
*TRL
level*

zero

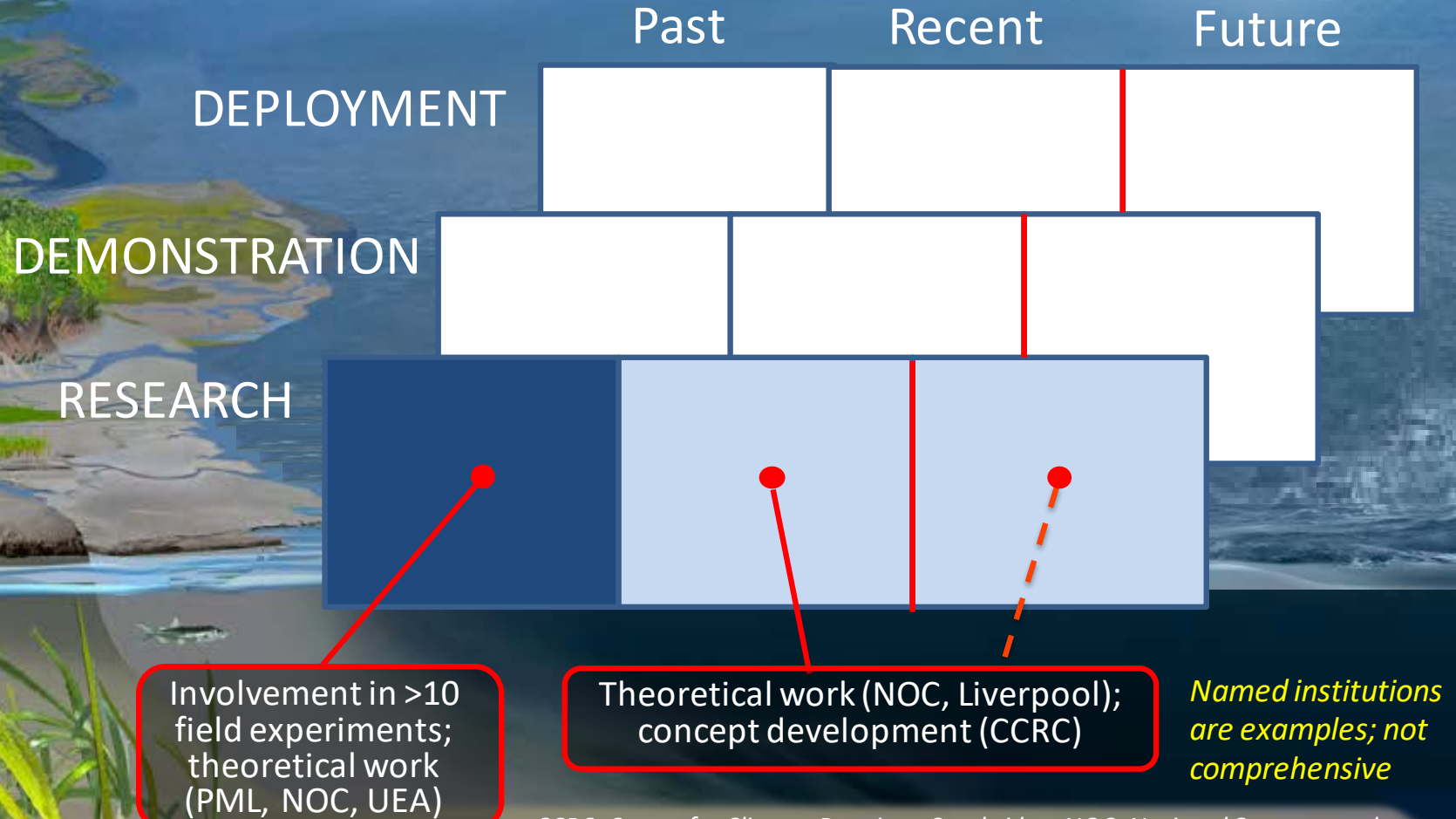
low

medium

high

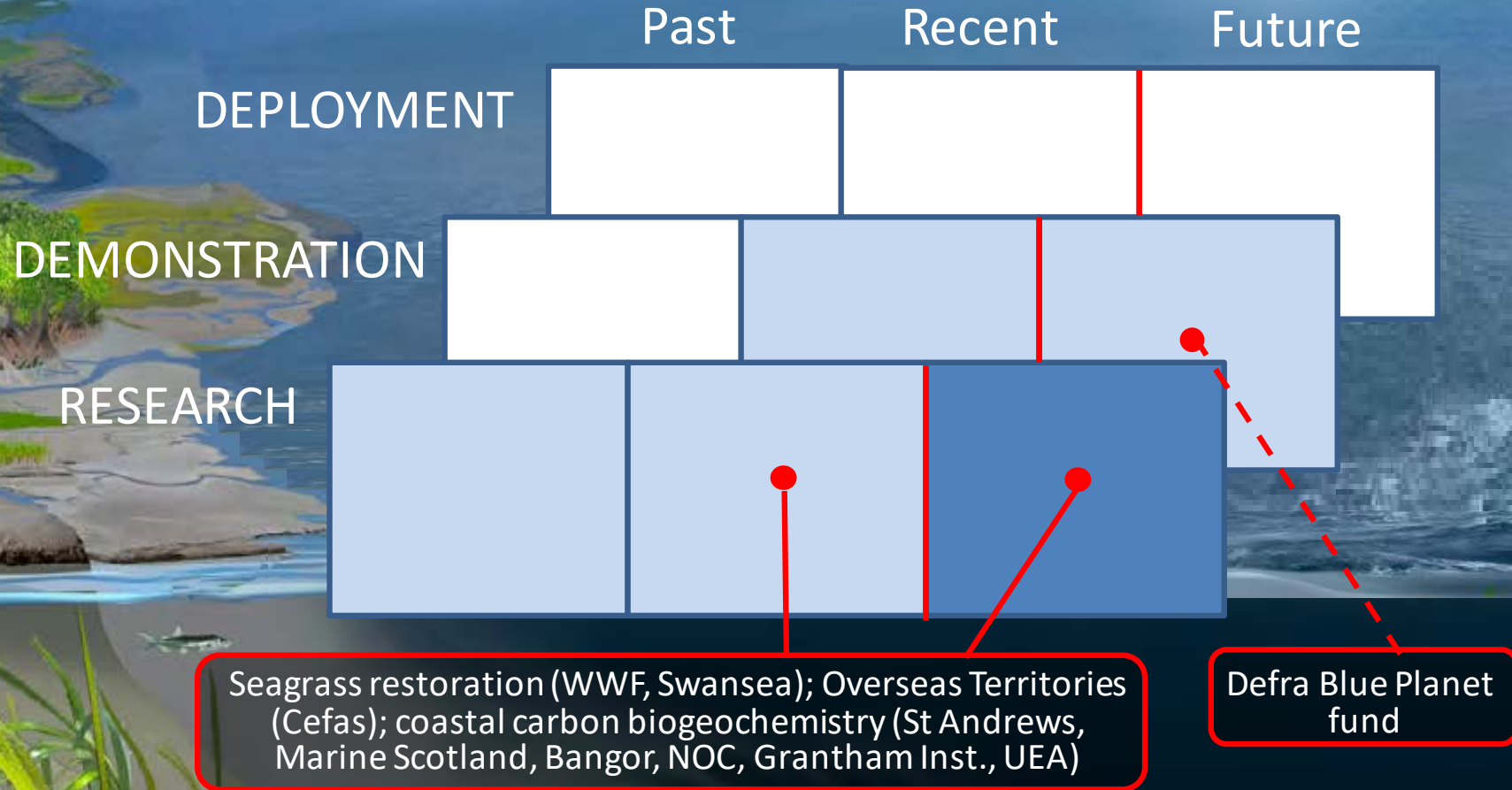


1. Nutrient fertilization *adding Fe or macronutrients*



CCRC, Centre for Climate Repair at Cambridge; NOC, National Oceanography Centre,; PML, Plymouth Marine Laboratory; UEA, University of East Anglia

2. Ecosystem recovery *'Blue carbon' (on global basis)*



Cefas, Centre for Environment, Fisheries & Aquaculture Science; Defra, Department for Environment Food & Rural Affairs; NOC, National Oceanography Centre; UEA, University of East Anglia

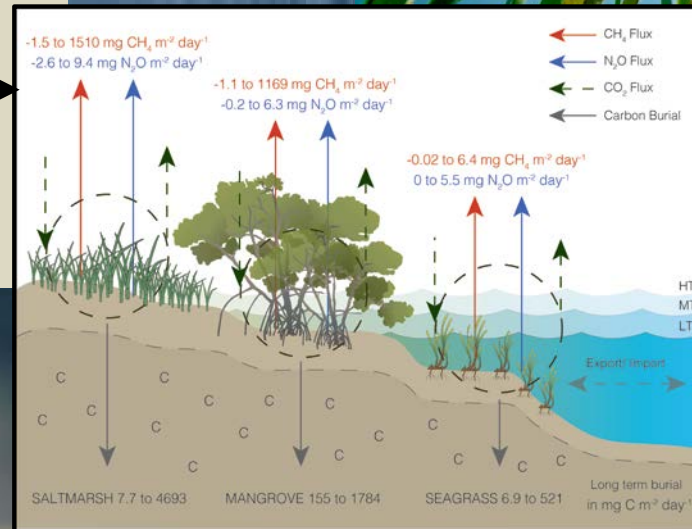
2. Ecosystem recovery ‘Blue carbon’ (on global basis)

Critical appraisal and field testing

Factors affecting reliability of carbon sequestration in coastal ecosystems:

- Local variability in C burial rates
- Errors in measuring C burial rates
- Lateral C transport
- Fluxes of CH_4 and N_2O
- GWP timescale for CH_4 and N_2O
- Carbonate formation & dissolution
- Vulnerability to future climate

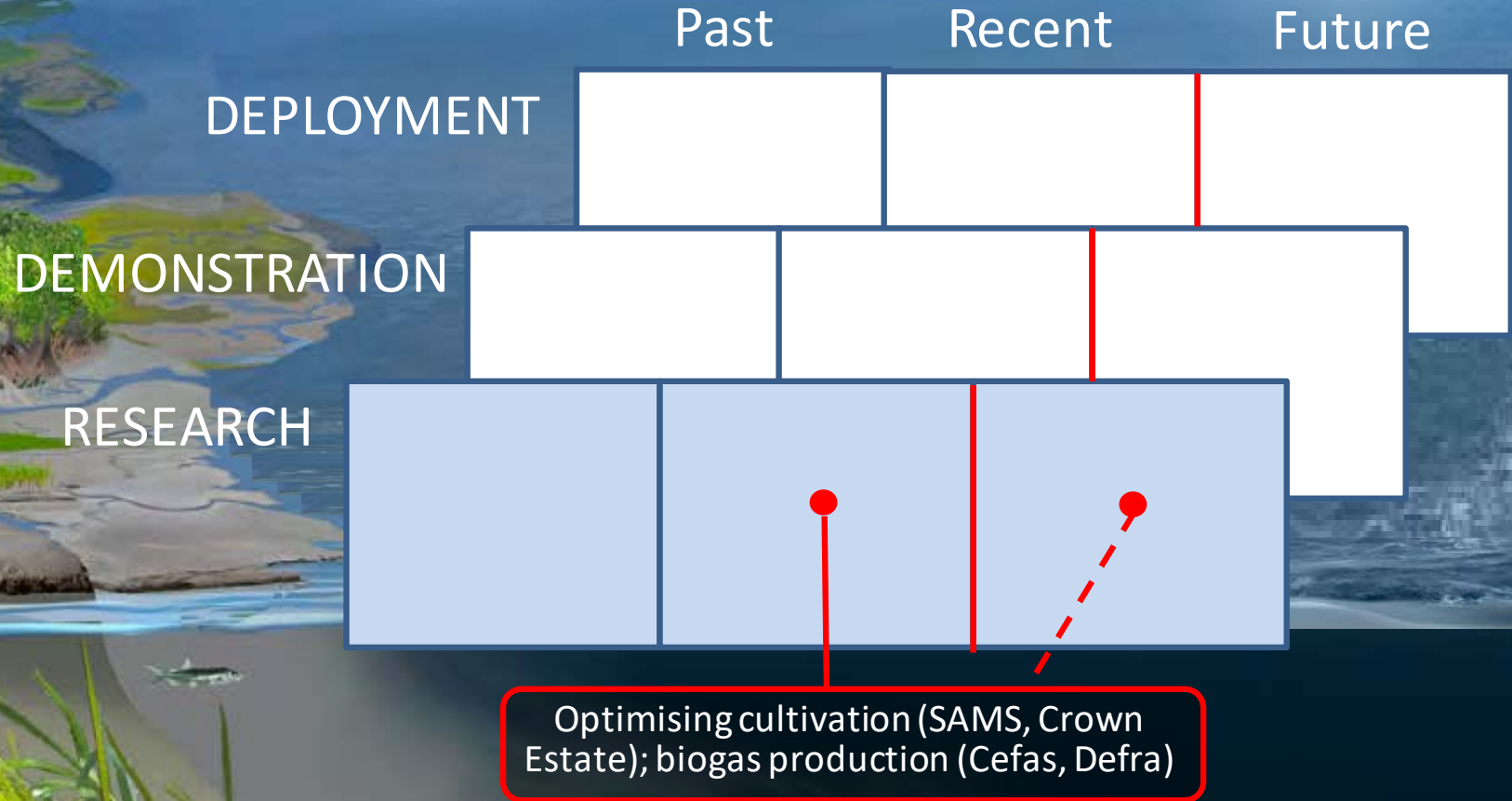
Analysis by Williamson et al in RSC book Negative Emission Technologies (2021)



Rosentreter, Al-Haj, Fulweiler & Williamson
Submitted to *Global Biogeochemical Cycles*

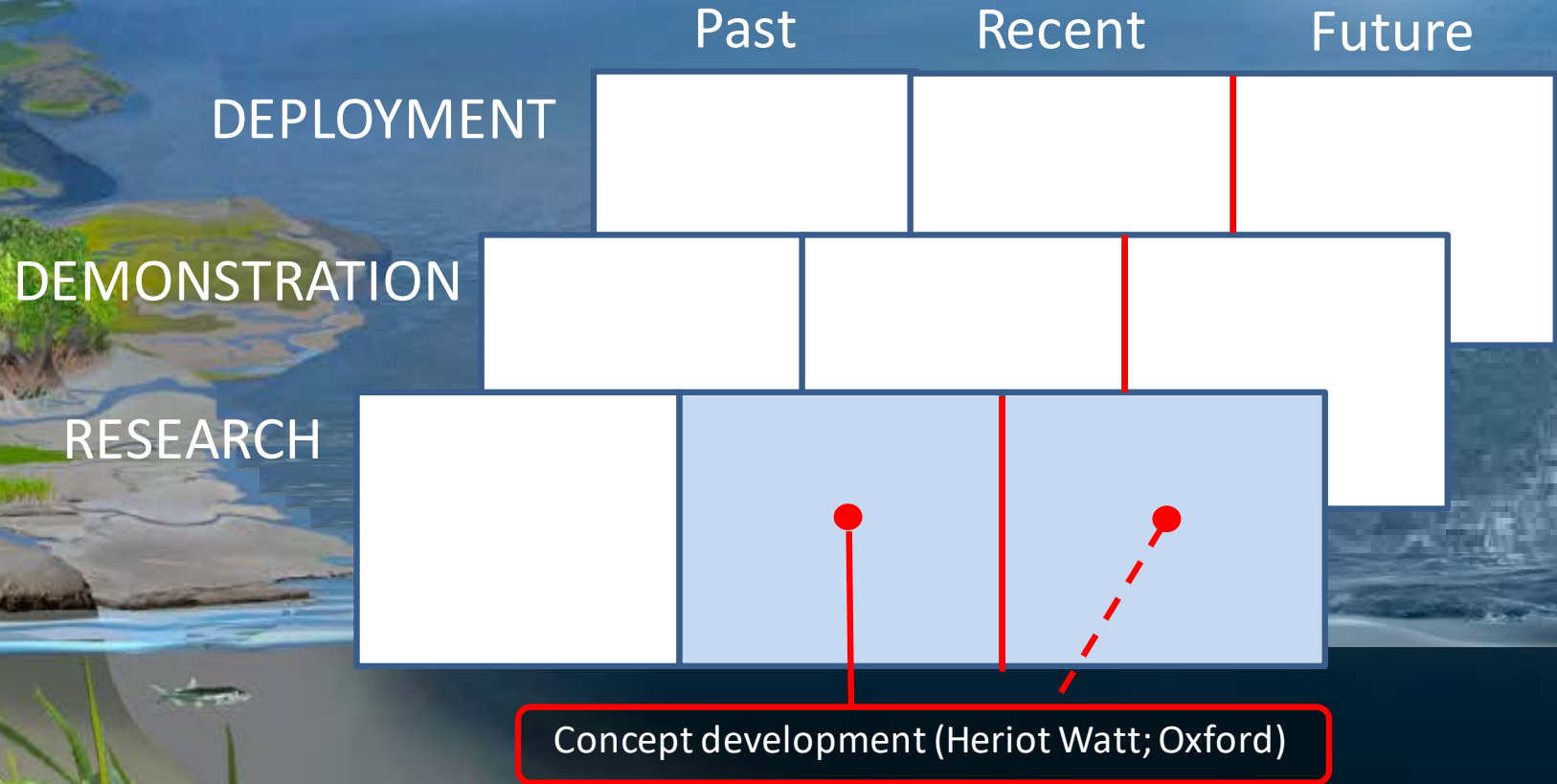
“Seagrass Ocean Rescue”
project; Sky Ocean Rescue,
WWF, Swansea University

3. Seaweed cultivation *for bioenergy*



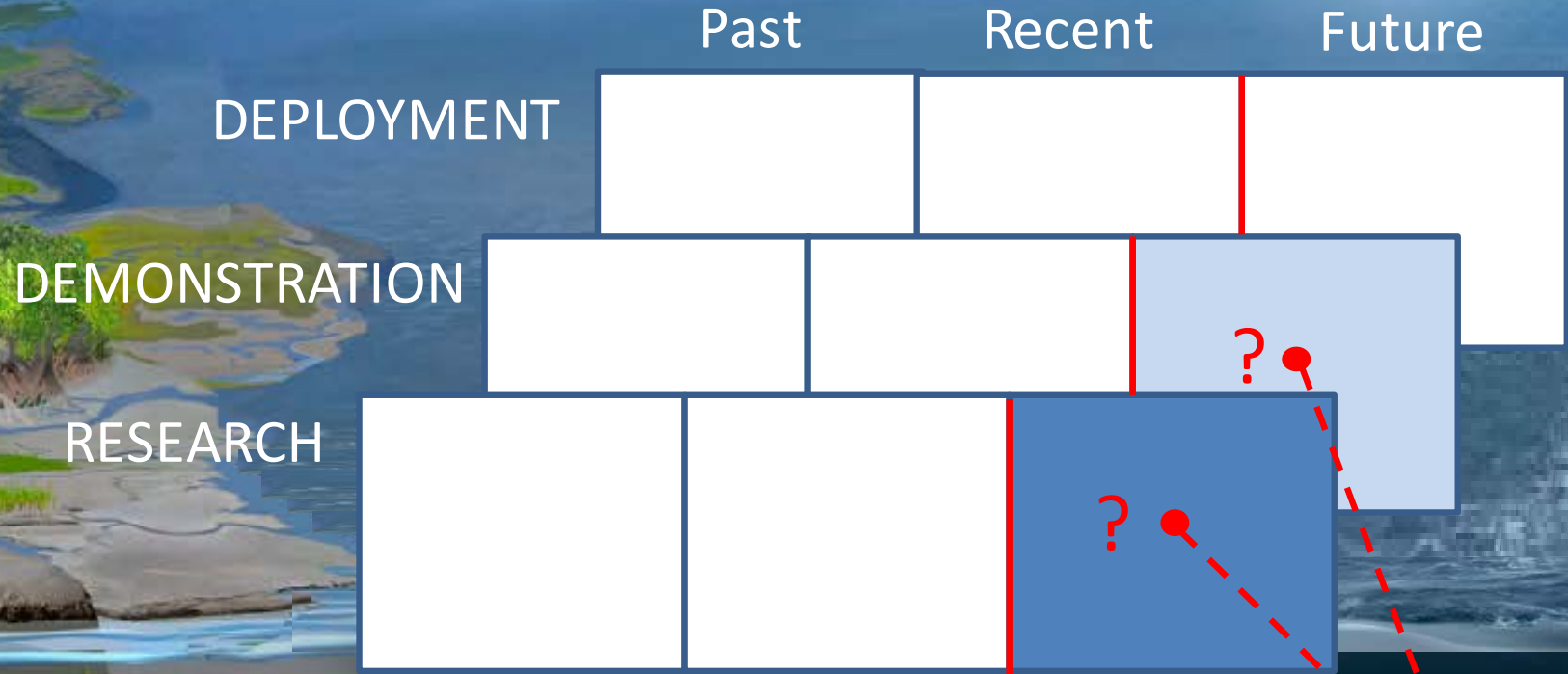
Cefas, Centre for Environment, Fisheries & Aquaculture Science; Defra, Department for Environment Food & Rural Affairs; SAMS, Scottish Association for Marine Sciences

4. Ocean alkalinity enhancement



Support under NERC-led Greenhouse Gas Removal project

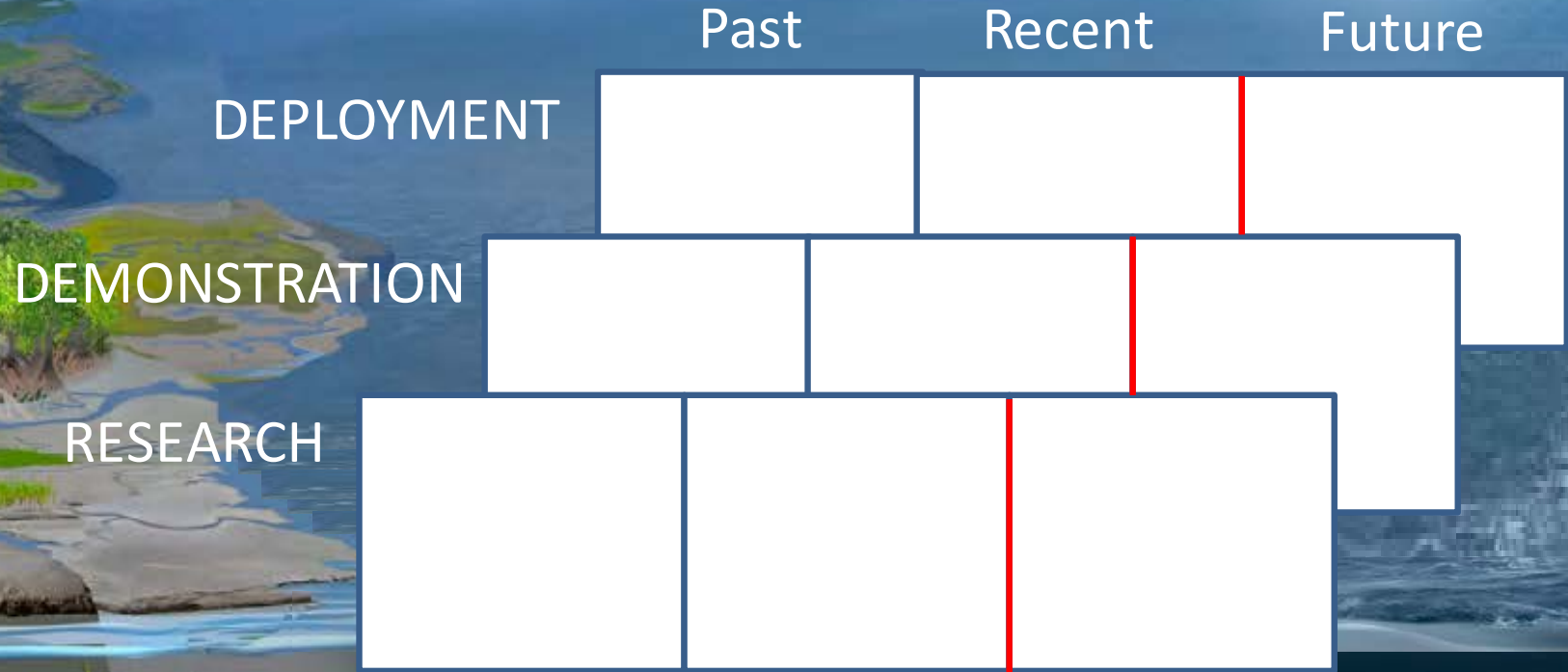
5. Seawater CO₂ stripping



“The competition will take a portfolio approach, aiming to fund a range of different solutions which could include use of biochar, direct air capture, bioenergy carbon capture and storage solutions, **removal of CO₂ from seawater**, and others.” Up to £100m support.

BEIS initiative
on DAC

6. Artificial upwelling and downwelling



No known UK interests or involvement



**Thank you for the
opportunity to participate!**

p.williamson@uea.ac.uk



Coastal enhanced silicate weathering



Universiteit
Antwerpen



Prof. Filip Meysman

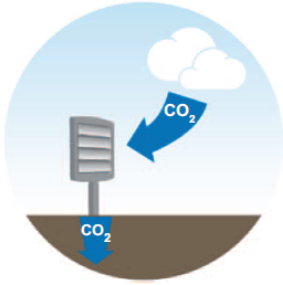
Department biology, University of Antwerp (Belgium)

Department Biotechnology, Delft University of Technology (The Netherlands)

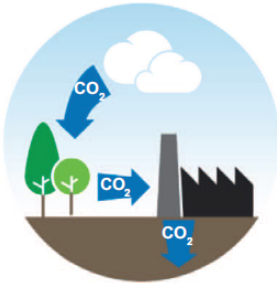
filip.meysman@uantwerpen.be

Proposals for negative emission technologies

Direct Air Capture



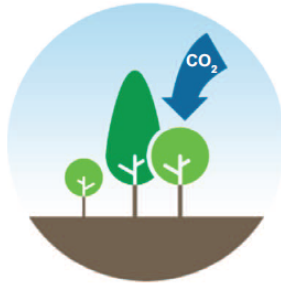
Bio-energy with CCS



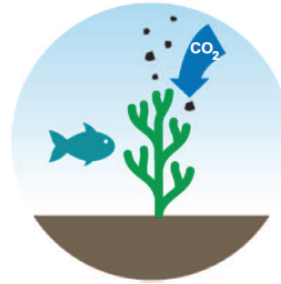
Soil carbon



Afforestation & reforestation



Ocean fertilisation



Enhanced weathering



Where to store the CO₂:

geological

geological

land sink

land sink

ocean sink

ocean sink

How to capture of CO₂:

chemistry

photosynthesis

photosynthesis

photosynthesis

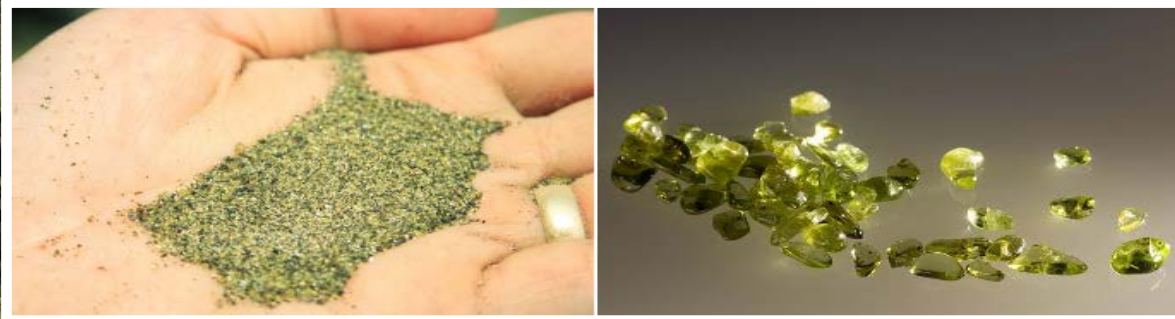
photosynthesis

chemistry

Silicate weathering: natural process inducing oceanic CO₂ sequestration

Green beach (Big Island, Hawaii)

- (1) selectively mine rapidly weathering rocks
- (2) increase reactive surface area by crushing and grinding
- (3) distribute in locations with high weathering rates
- (4) export alkalinity to the ocean
- (5) increased CO₂ storage + alleviation of ocean acidification



Application areas of enhanced weathering

Open ocean



Terrestrial soils



Coastal ocean



Potential

Low efficiency, high milling and transport costs

Agro-soil management with co-benefits

New realm, no competition with land NETS

Cost

> 100 € per tCO₂

> 100 € per tCO₂

~ 40 € per tCO₂

Meysman & Montserrat (Biol. Lett., 2017)

Coastal ESW is highly cost-competitive

1. Mining



2. Distribution



3. CO₂ monitoring

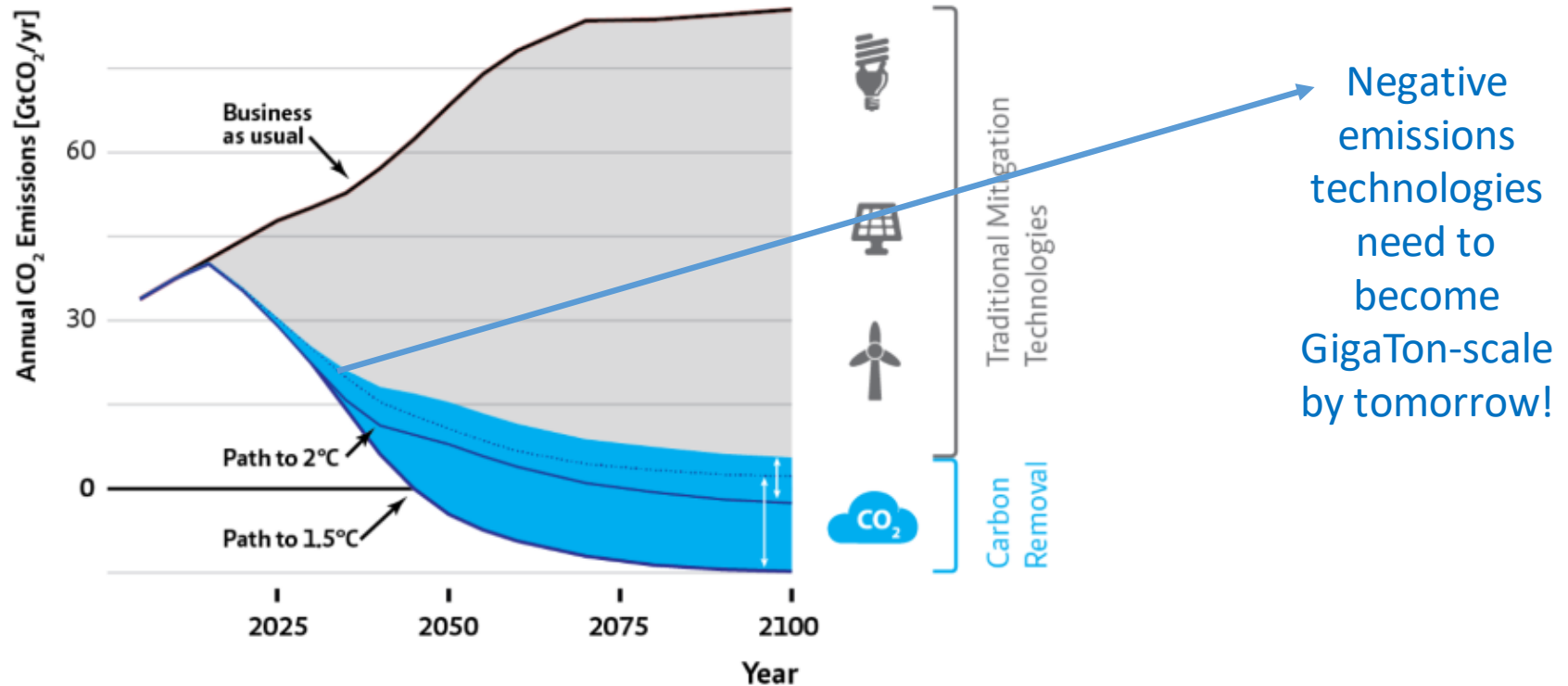


4. CO₂ trading



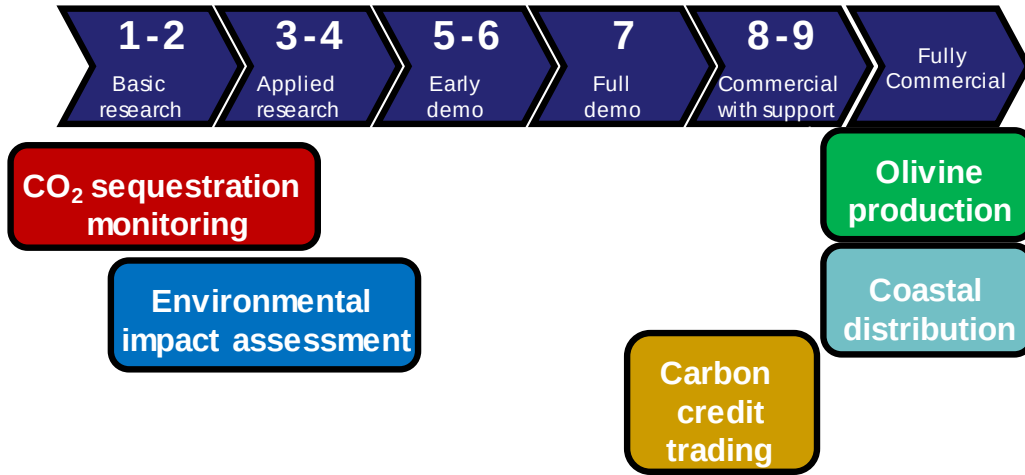
- Estimated cost of large volume application: ~30-50 Euro per ton CO₂
- Highly cost competitive!
- Advantage. We don't need any subsidies: it can be “business as usual” -> strong economic incentive for fast deployment and scaling
- Disadvantage. Potential for “cowboy entrepreneurs”

Roadmap for climate stabilization requires rapid scalability!



Coastal ESW has a high Technology Readiness Level

Technology Readiness Level



Technology question: Can we do it?

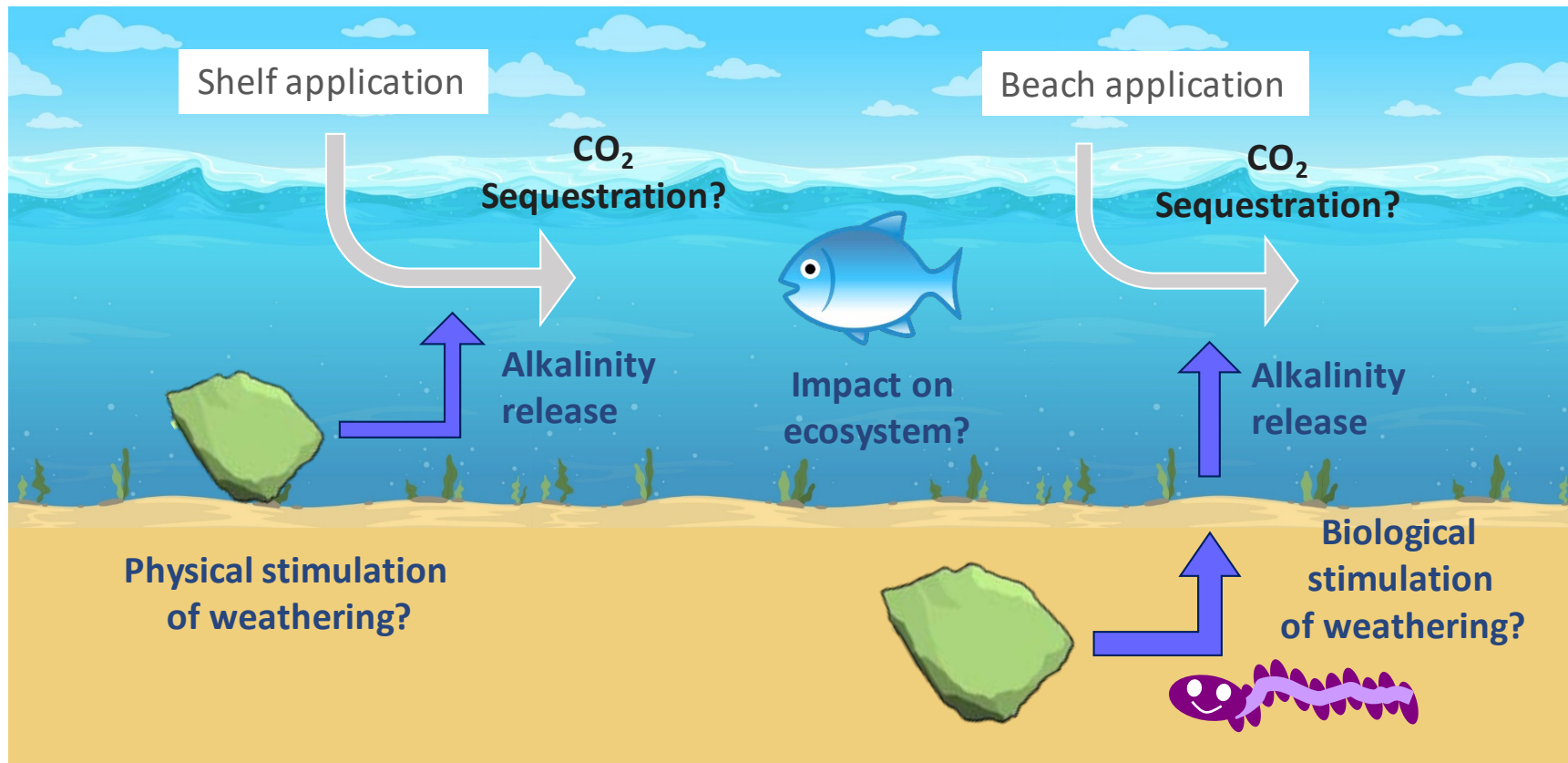
Yes. Industry (mining companies and marine engineering companies) are ready to roll

Societal question: Should we do it?

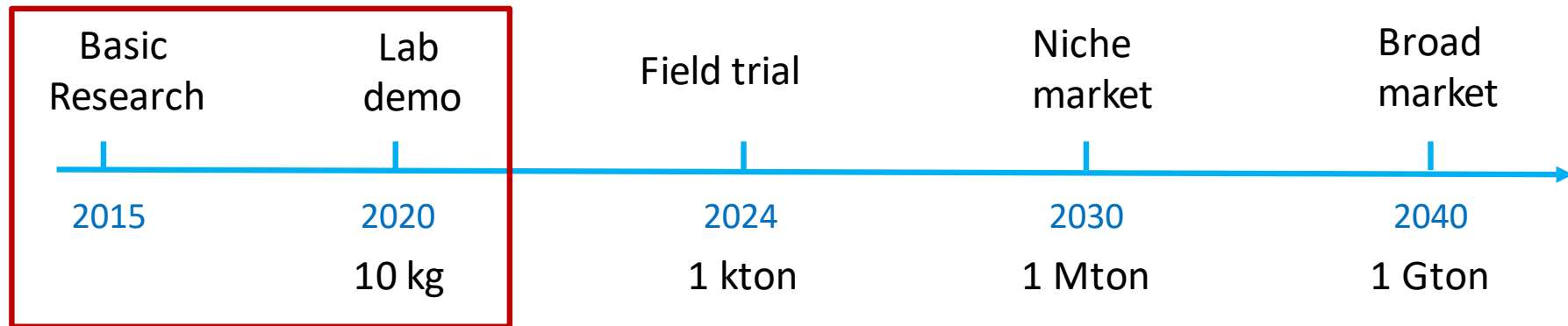
Critical research questions

- Does it work? What is the CO₂ sequestration efficiency?
- Is it safe? What are the environmental consequences?

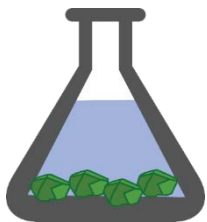
Our research questions



Coastal ESW: Research and development map



Kinetic studies



Flume experiments



Mesocosms



Natural sites



International mesocosm test-facility for coastal ESW

Project website: <https://coastalesw.com>

[Home](#) [The Challenge](#) [The Idea](#) [The Project](#) [The Infrastructure](#) [News](#) [Publications](#)

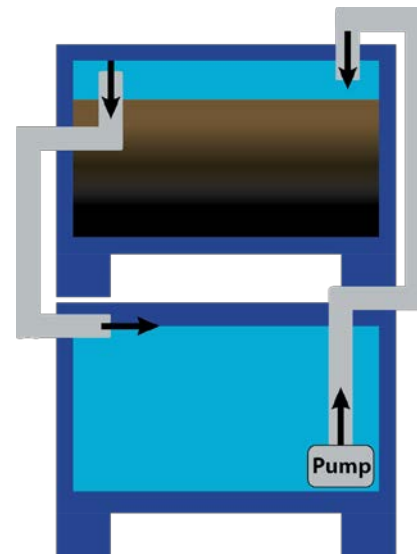
The Infrastructure

A unique mesocosm research facility to study enhanced silicate weathering processes by closely simulating natural conditions

This **unique mesocosm research facility** enables scientists to study the potential of enhanced silicate weathering processes for coastal environments in a controlled aquatic environment closely **simulating natural conditions**.

Each mesocosm can be modified to accommodate **different treatments** such as defaunated and faunated sediments, the addition of olivine versus control treatments, and endless other treatments. Each mesocosm can **replicate approximately 1 m² of seafloor** which can be monitored continuously and/or sampled intermittently as needed both for water as well as sediment biogeochemistry and biology.

Mesocosm set-up



International mesocosm test-facility for coastal ESW

Project website: <https://coastalesw.com>

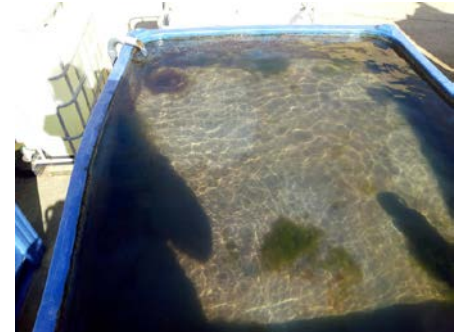


- 22 mesocosms
- Simulation of 1 m² natural seabed
- Automated chemistry (T, S, O₂, pH,...)

With fauna

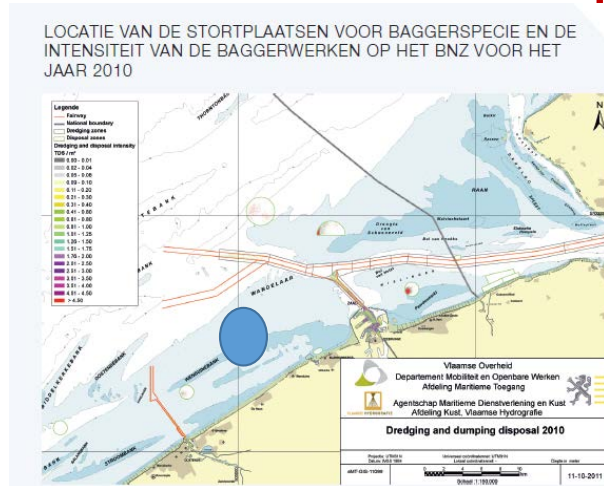
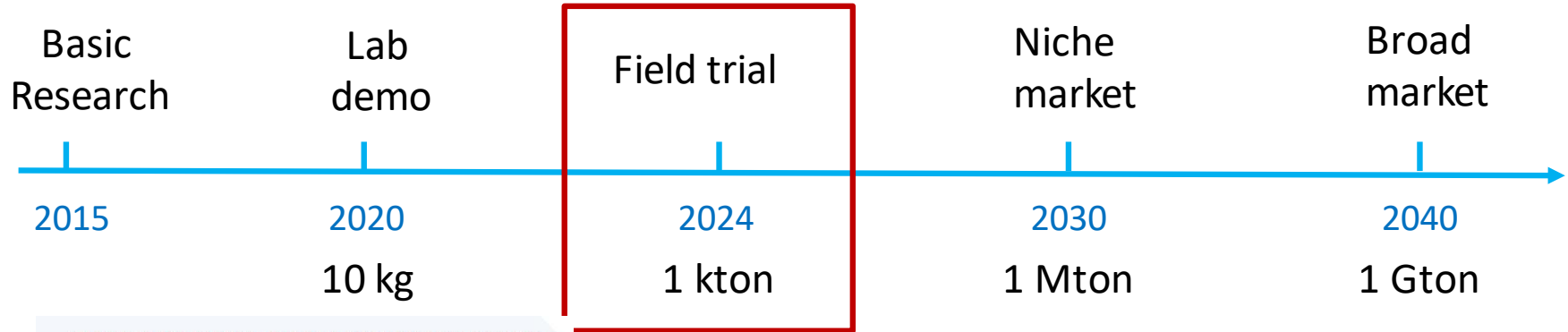


Without fauna



- Silicate types (natural, artificial)
- Different grain sizes, application loads
- Geochemistry, toxicology, ecology, grain scale dissolution

Research and development map



Research climate

- Research has been ongoing over last 8 years
- Early research: a hobby (financed by “crumbles from other projects”)
- Current research financed by applied technology schemes (e.g. FET-OPEN)
- There are no dedicated programs at the national level (though first call at EU level)
- Strong interest from private companies (mining & marine engineering)
- Strong interest from journalists and the broader public

More information

Project website: <https://coastalesw.com>

[Home](#) [The Challenge](#) [The Idea](#) [The Project](#) [The Infrastructure](#) [News](#) [Publications](#)



Coastal enhanced silicate weathering

Investigating the potential for CO₂ drawdown in coastal environments