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Advancing a Solutions Agenda

for Ocean-Climate *Repair and Restoration*

Brad Ack – CEO, Ocean Visions

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Ocean Visions is a collaborative network. We work to co-design, develop and test ocean-based climate solutions, and build an enabling environment for their deployment.

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We need a more comprehensive agenda to address the interlocking ocean and climate crises

4 R's

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Commissioned by

HIGH LEVEL PANEL for A SUSTAINABLE OCEAN ECONOMY

The Ocean as a Solution to Climate Change

Updated Opportunities for Action

COORDINATING LEAD AUTHORS

Ove Hoegh-Guldberg and Eliza Northrop

SECTOR EXPERTS

Oliver S. Ashford, Thierry Chopin, Jessica Cross, Carlos Duarte, Steve Gaines, Tess Geers, Stefan Gössling, Peter Haugan, Mark Hemer, Jennifer Howard, Claire Huang, Andreas Humpe, Gabriella Kitch, David Koweek, Dorte Krause-Jensen, Catherine E. Lovelock, Kathryn Matthews, Patrick Mustain, Finn Gunnar Nielsen, Robert Parker, Joyashree Roy, Tristan Smith, Shreya Some, Ya-Yen Sun, Torsten Thiele and Peter Tyedmers

oceanpanel.org

REDUCE

Maximize the Role of the Ocean in Global Decarbonization

"Ocean-based climate solutions could assist in reducing the 'emissions gap' in 2050 by up to 35 percent on a 1.5°C pathway and up to 47 percent on a 2.0°C pathway."

REDUCE

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Figure ES.2. Sustainable Ocean-based Interventions Have Very High Benefit-cost Ratios and Could Yield Trillions of Dollars of Benefits

Source: Konar, M., and H. Ding. 2020. "A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs." Washington, DC: World Resources Institute.

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Other More "Early Stage" Opportunities Exist

- But a Great Deal More Investment of Attention is Needed

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Cleaning Up Carbon Pollution

AKA: Carbon Dioxide Removal.

Not Optional

All pathways that limit global warming **to 1.5°C** with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of **100–1000 $GtCO_2$** over the 21st century.

REMOVE

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"The next decade is crucial for novel CDR. Failure to create momentum in this formative phase will contribute to a widening gap by 2050 and beyond. **Closing the CDR gap requires rapid growth of novel CDR".**

HOW ARE WE DOING ON CDR TO DATE?

World currently removing ~2 billion tons of CO_2 each year, almost entirely through conventional strategies like as afforestation.

Only a tiny fraction (0.002 $GtCO_2$ per year) comes from "novel" CDR methods.

Virtually all scenarios that limit warming to 1.5°C or 2°C require "novel" CDR, such as BECCS, biochar, DACCS, and enhanced rock weathering.

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WHY LOOK AT THE OCEAN?

OCEAN-BASED CARBON DIOXIDE REMOVAL
ELECTROCHEMICAL OCEAN CARBON DIOXIDE REMOVAL
DEEP SEA STORAGE
OCEAN ALKALINITY ENHANCEMENT
RESTORING LIVING BLUE CARBON
MICROALGAE CULTIVATION
MACROALGAE CULTIVATION AND CARBON SEQUESTRATION
ARTIFICIAL UPWELLING AND DOWNWELLING
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MACROALGAE CULTIVATION AND CARBON SEQUESTRATION
Carbon dioxide
Sunlight
Macroalgae cultivated in diverse offshore systems
Seaweed farm
Harvest by ship or remotely operated vehicle
Process at sea or onshore
Use for long-lived low carbon products
Use for algal bioenergy with carbon capture and storage
Photosynthesis produces organic carbon
Natural biomass sinking
Intentional biomass sinking
CARBON SEQUESTERED IN DEEP OCEAN
CARBON SEQUESTERED IN SEDIMENT
CARBON SEQUESTERED UNDERGROUND
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MICROALGAE CULTIVATION
Carbon dioxide
Nutrients
• Nitrogen
• Phosphorus
• Iron
USE FOR LONG-LIVED LOW CARBON PRODUCTS
Cultivate microalgae in shore-based facilities
Microalgae
Some carbon recycled as nutrients and carbon dioxide
Additional nutrients in nutrient-limited areas cause growth of microalgae, which increases ocean uptake of carbon dioxide from the atmosphere.
Photosynthesis produces organic carbon
SEQUESTER MICROALGAE IN THE DEEP OCEAN
BURY MICROALGAE IN UNDERGROUND RESERVOIR
Some carbon sinks to ocean floor as biomass
Artificial upwelling brings nutrients from the deep ocean to the sunlit region to support photosynthesis. It also brings trapped carbon from the deep ocean to the surface ocean.
CARBON SEQUESTERED IN DEEP OCEAN
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OCEAN ALKALINITY ENHANCEMENT
CARBON DIOXIDE IN SEAWATER + ALKALINITY = CARBON STORED IN THE OCEAN AS BICARBONATE
CO_2
H_2O
Alkaline materials
Bicarbonate storage
Carbon dioxide
Alkaline solution returned to sea through outfall pipes
Coastal infrastructure can be co-purposed for alkalinity production and delivery
Alkalinity produced electrochemically from seawater
Seawater intake
Mining alkaline minerals
Silicates
Carbonates
Lime
Lime kiln
Beach spreading of silicate minerals
Ocean spreading of alkaline materials
CO_2 FROM LIME PRODUCTION SEQUESTERED UNDERGROUND
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ELECTROCHEMICAL OCEAN CARBON DIOXIDE REMOVAL
Processing
Storage
Input
Electricity
Seawater
Strip CO_2 from seawater
Produce acid
Neutralize with alkaline materials
Offtake for industrial use
Produce base
Use carbonates as building materials
Carbon dioxide
Discharge seawater with elevated alkalinity to drawdown atmospheric CO_2
Add alkalinity to replace alkalinity lost during carbonate formation
Sequester CO_2 in geologic reservoir
Discharge CO_2 -depleted seawater to drawdown atmospheric CO_2
Discharge re-balanced seawater
Precipitate carbonates
Add alkalinity to replace alkalinity neutralized by the acid
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ARTIFICIAL UPWELLING AND DOWNWELLING
UPWELLING
DOWNWELLING
Infrastructure must withstand ocean environment
Carbon dioxide
Monitoring systems and sensors collect data and upkeep infrastructure
Artificial upwelling brings nutrients from the deep ocean to the sunlit region to support photosynthesis.
Natural sinking of biomass
Trapped carbon from the deep ocean is also transported to the surface ocean.
Artificial downwelling by pump accelerates biomass sinking to the deep ocean.
Deep ocean (cold nutrient-rich water)
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BLUE CARBON RESTORATION AND CARBON SEQUESTRATION
Respiration releases CO_2 and other greenhouse gases, such as methane (CH_4), and nitrous oxide (N_2O)
Photosynthesis transforms carbon dioxide into plant biomass
Habitat destruction releases carbon dioxide back to the atmosphere
Restoration permits carbon dioxide uptake into new biomass
ADAPTIVE BENEFITS
Ecosystems protect from erosion and reduce flooding from sea level rise
ECOLOGICAL BENEFITS
Improved water quality and fish nurseries
Salt marsh
Mangrove forest
Seagrass medow
Kelp
Degraded habitat
Habitat restoration
Carbon storage in large marine organisms
CARBON SEQUESTERED UNDERGROUND
Newer
Older
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Ocean-Based Carbon Dioxide Removal: Road Maps

Pathways to accelerate the development and testing of ocean-based carbon dioxide removal approaches.

About Road Maps | How to use Road Maps

TECHNOLOGY ROAD MAP

CROSS-CUTTING ROAD MAP

Read the core principles guiding our work on carbon dioxide removal and the ocean.

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Ocean Alkalinity Enhancement

Adding alkalinity to seawater to capture CO_2

State of Technology

Development Gaps and Needs

First-Order Priorities

- Develop New Modeling Tools to Support Design and Evaluation
- Accelerate Design and Permitting of Controlled Field Trials
- Develop New In-Water Tools for Autonomous CDR Operations
- Develop CDR Monitoring and Verification Protocols
- Accelerate RD&D Through New Partnerships
- Growing and Maintaining Public Support for Research and Development

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Science and Engineering Support to Innovators – Cohort 1

CAPTURA

RUNNING TIDE

ebb carbon

Seafields

Phykos

TROFX

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Science and Engineering Support to Innovators – Cohort 2

BANYU CARBON

Brilliant Planet

CAPTURE6

CarbonBlue

Carboniferous

SeaO2

Subtidal

VYCARB

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The leading knowledge hub on ocean-based Carbon Dioxide Removal (CDR)

Join the Community

Exploring ocean-based solutions for the climate crisis

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RESEARCH ARTICLE | CLIMATE CHANGE

Exceeding 1.5°C global warming could trigger multiple climate tipping points

DAVID I. ARMSTRONG MCKAY, ARIE STAAL, JESSE F. ABRAMS, RICARDA WINKELMANN, BORIS SAKSCHEWSKI, SINA LORIANI, INGO FETZER, SARAH E. CORNELL, JOHAN ROCKSTRÖM, AND TIMOTHY M. LENTON Authors Info & Affiliations

REPAIR AND REGENERATE

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CAN WE DO ANYTHING ABOUT IT?

WE HAVE A MORAL RESPONSIBILITY TO ASK AND ANSWER THIS QUESTION

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Focus: the Arctic

REPAIR AND REGENERATE

Box 1: Over 50% of climate tipping points with global repercussions are located in the Arctic

McKay *et al.* 2022 identify 16 major Global Climate Tipping Points. Nine of these are in the Arctic and northern regions (in order of the estimated global warming needed to pass their tipping point):

- Collapse of the Greenland ice sheet
- Abrupt thaw of northern permafrost
- Loss of Barents Sea ice
- Collapse of Labrador Sea current
- Collapse of northern permafrost
- Southern dieback of boreal forests
- Northern expansion of boreal forests
- Collapse of North Atlantic deep-water formation
- Collapse of the Arctic winter sea ice

Global consequences of these tipping points include:

- Amplified global warming
- Rapidly increasing sea level
- Changes in weather patterns and weather extremes
- Changes in ocean currents
- Ocean acidification, de-oxygenation
- Impact on ecosystems (fisheries, wildlife, plants)
- Impact on food production
- Impact on freshwater supply

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OV's Arctic Sea Ice Repair Map: *Can we prolong the life of sea ice?*

Follows mCDR mapping approach:

1. **What do we know?**
2. **What do we need to know?**
3. **How do we get that knowledge?**

Steps

- Assess all potential technologies
- State of development
- Potential impacts, risks and benefits
- Knowledge gaps and research priorities
- What RD&D is needed?

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Prolonging the life of Arctic Sea Ice

- Solar Radiation Management
- Surface Albedo Modification
- Structural Ice Management
- Protection
- Pollution Management

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