



OCEAN  
NETs



CDR  
mare

# The big picture behind ocean-based Carbon Dioxide Removal (CDR) & Negative Emission Technologies (NETs)

David P. Keller

GEOMAR Helmholtz Center for Ocean Research Kiel



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



Federal Ministry  
of Education  
and Research

# Climate Goals and Carbon Dioxide Removal

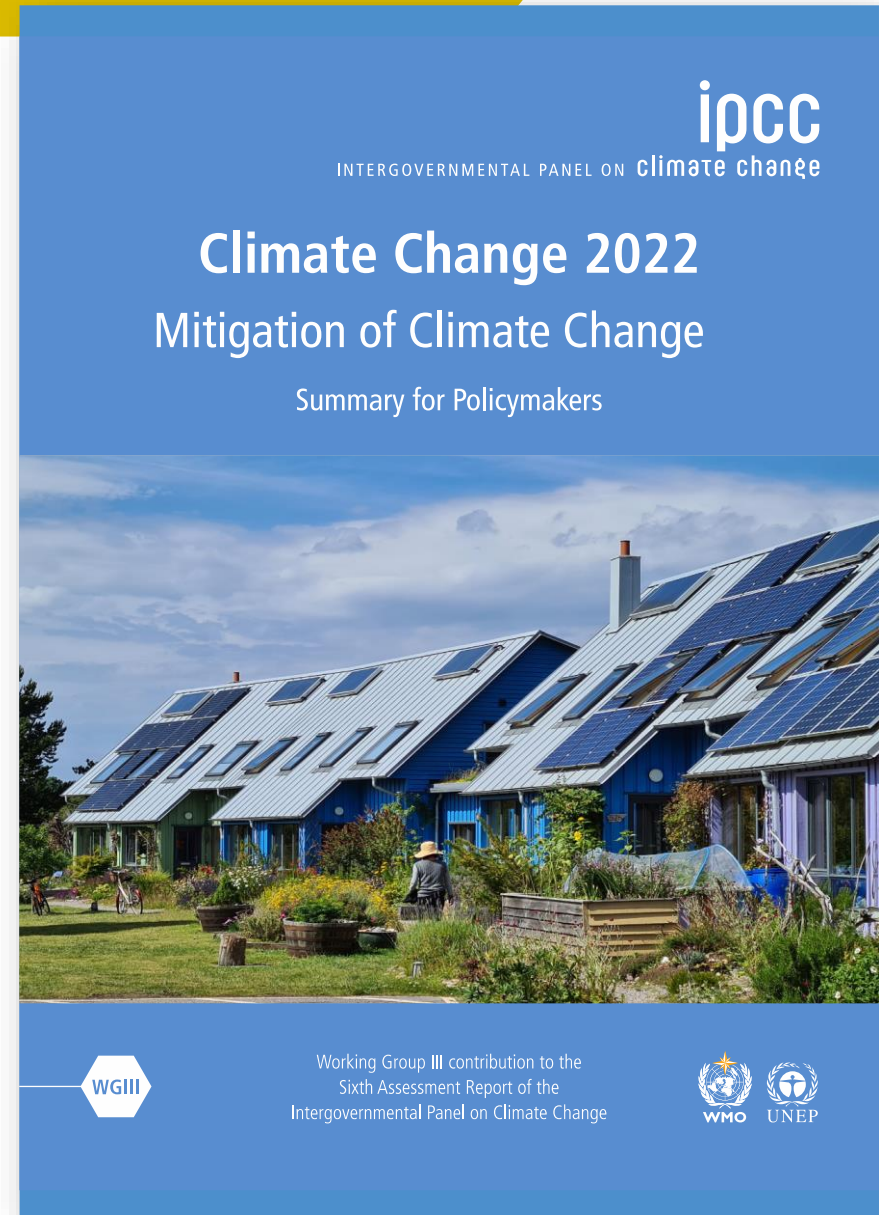
**Paris Climate Agreement** – goal to keep the global mean temperature to “**well below 2°C**” and promised to “pursue efforts” to cap warming at **1.5°C**

- ▶ Primary mitigation effort must focus on reducing CO<sub>2</sub> emissions, but...

**UNEP Emissions Gap Report (2017)** – “To achieve the goals of the Paris Agreement, to keep the global mean temperature increase well below 2°C (or even below 1.5°C), carbon dioxide removal is likely a necessary step.”

**IPCC 1.5° C Special Report** - “All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of CDR on the order of 100–1000 Gt CO<sub>2</sub> over the 21<sup>st</sup> century.”

**IPCC AR6 Mitigation of Climate Change Report** – “CDR is a necessary element of mitigation portfolios to achieve net zero CO<sub>2</sub> emission”





# Carbon Dioxide Removal (CDR) – what & where?

So far, mainly **land-based** approaches for CO<sub>2</sub> removal have been discussed and developed

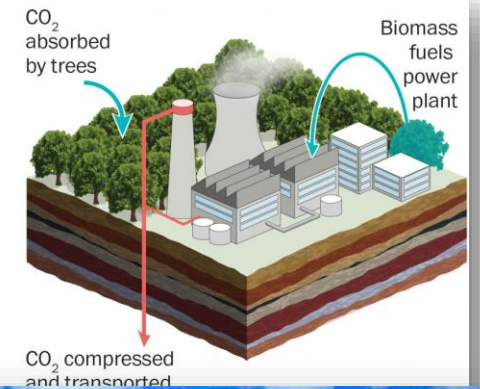
Can land-based approaches achieve the amount of CDR that is likely needed?

## Limitations on land-based CDR:

- ▶ Regional suitability and resources
  - ▶ Availability of land – e.g., use for food or CDR?
    - ▶ Island state / coastal country
  - ▶ Water availability
  - ▶ Carbon storage (CCS) availability
  - ▶ Other resources...

### Bioenergy combined with carbon capture and storage (BECCS)

Trees or other forms of biomass are burned in power plants and replanted. Power plants capture, compress and send carbon dioxide to sequestration sites, where it is buried or used for enhanced oil recovery.



⊕ Both technologies already exist

⊖ Carbon sequestration technology has not been adopted yet.

⊖ Requires a very large area of land to have a significant impact on CO<sub>2</sub> levels.



# Carbon Dioxide Removal (CDR) – what & where?

A few good reasons to consider **ocean-based** CO<sub>2</sub> removal:

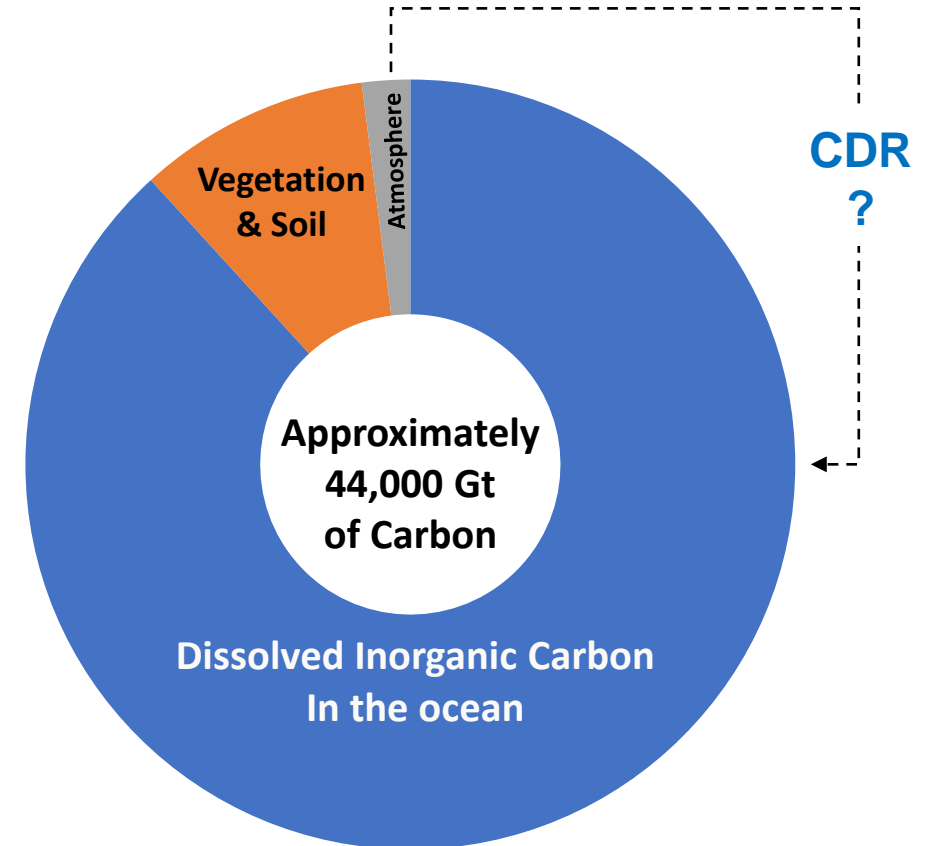
- ▶ The ocean covers most of the Earth's surface
- ▶ Generally less competition for space when compared to land



# Carbon Dioxide Removal (CDR) – what & where?

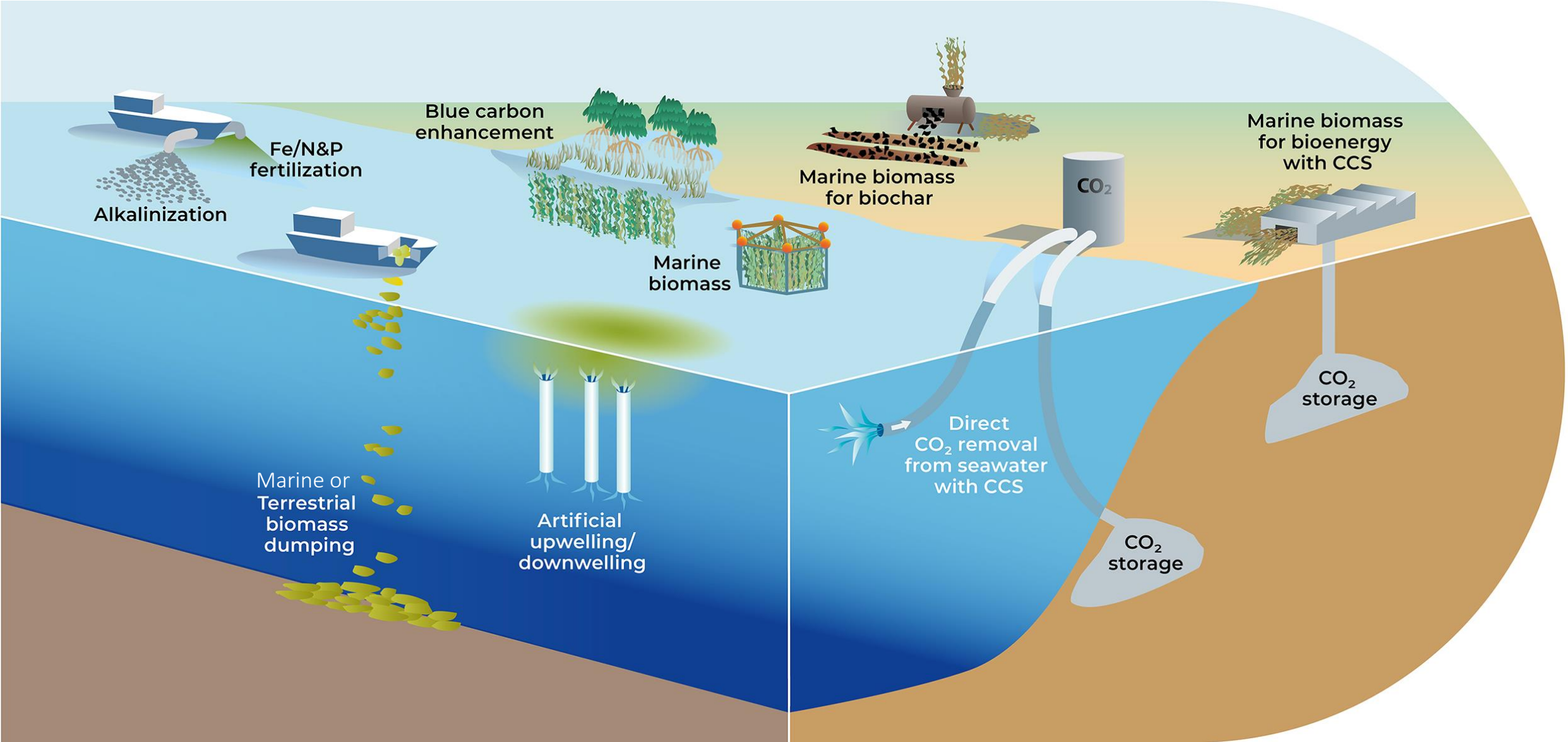
A few good reasons to consider **ocean-based** CO<sub>2</sub> removal:

- ▶ The ocean holds most of the carbon in the active carbon cycle
  - ▶ Massive carbon storage capacity
  - ▶ Where most anthropogenic carbon will ultimately end up



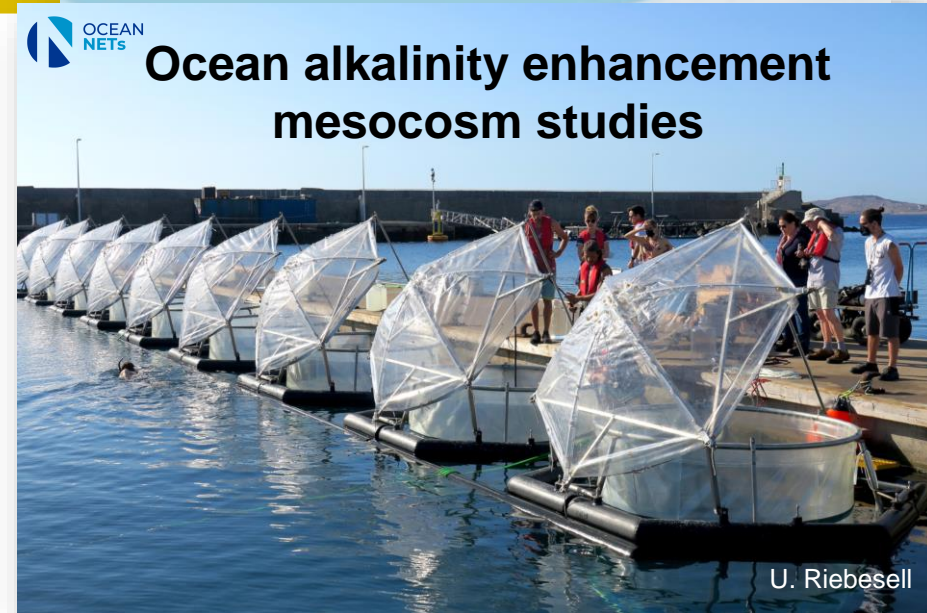


# Proposed ocean-based CDR / NET approaches

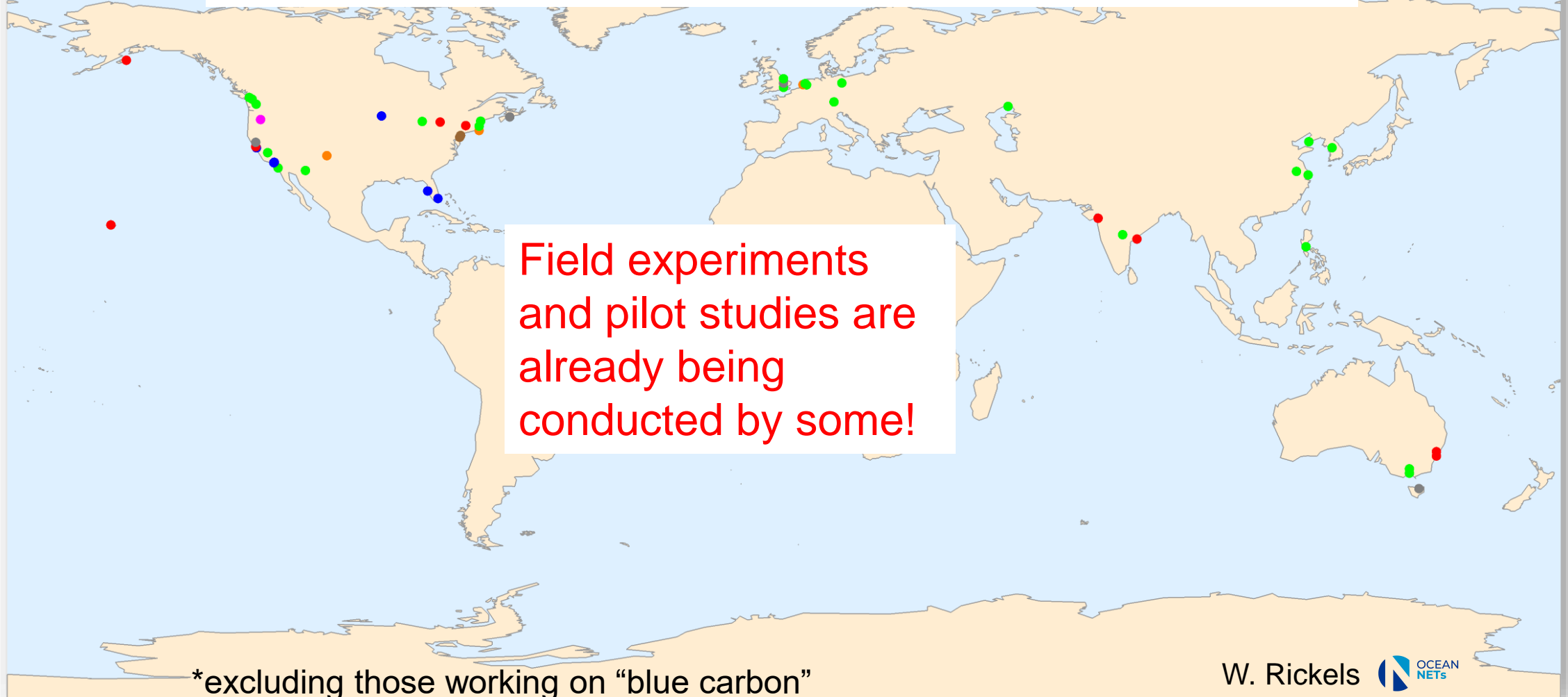


# State of ocean-based CDR research

- ▶ Early work focused on theoretical CDR potential and techno-economic feasibility
  - ▶ Idealized research via modeling, desk-based studies, and a very few laboratory studies
- ▶ Ongoing research takes the next steps with new experiments, more realistic simulations, and better techno-economic analyzes
- ▶ More social science research to determine not only what is feasible, but also desirable
  - ▶ Stakeholder dialogues



# 58 companies working on ocean-based CDR\*



- Artificial Upwelling • Ocean Fertilization • Electrochemical Weathering
- Alkalinity Enhancement • Marine Biomass Farming • Marine Biomass Sinking
- Coral Reef Restoration



# Can ocean-based CO<sub>2</sub> removal contribute to realistic and effective pathways to achieve the Paris Agreement goals?

Feasibility of some approaches ✓

Desirability of these approaches ?