BLUE ECONOMY
COOPERATIVE RESEARCH CENTRE

OCEAN CARBON MARKETS
IN AUSTRALIA AND NEW ZEALAND

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Australian Government
Department of Industry, Science, Energy and Resources

AusIndustry
Cooperative Research Centres Program

Contents

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Message from the CEO

The opportunity to better understand ocean carbon markets aligns with the objectives of the Blue Economy CRC.

This study provides an industry-investor-project developer lens to sizing ocean-carbon markets with a focus on opportunities in Australia and New Zealand. The insights gained through engagement with and feedback from many stakeholders provide important insights and into how this critical opportunity can evolve in the future.

Taking urgent action to combat climate change through limiting the amount of carbon in our atmosphere is at the heart of UN Sustainable Development goal 13. To understand the opportunities to achieve this, we need to be clear about what pools and fluxes exist naturally, both terrestrial and oceanic, and where carbon sinks can most effectively be enhanced through intervention. Oceanic opportunities are huge, but the methodologies and regulations are far less developed than for terrestrial systems. This report provides necessary background to understand and utilise blue carbon opportunities.

This report provides context, scope and scale for potential ocean carbon markets, and identifies the potential role for blue economy industries in this emerging field.

I'd like to thank the efforts of the team for compiling and consolidating the information in this report and sharing their insights into the future of ocean carbon markets in Australia and New Zealand.

John Whittington
CEO
Blue Economy CRC

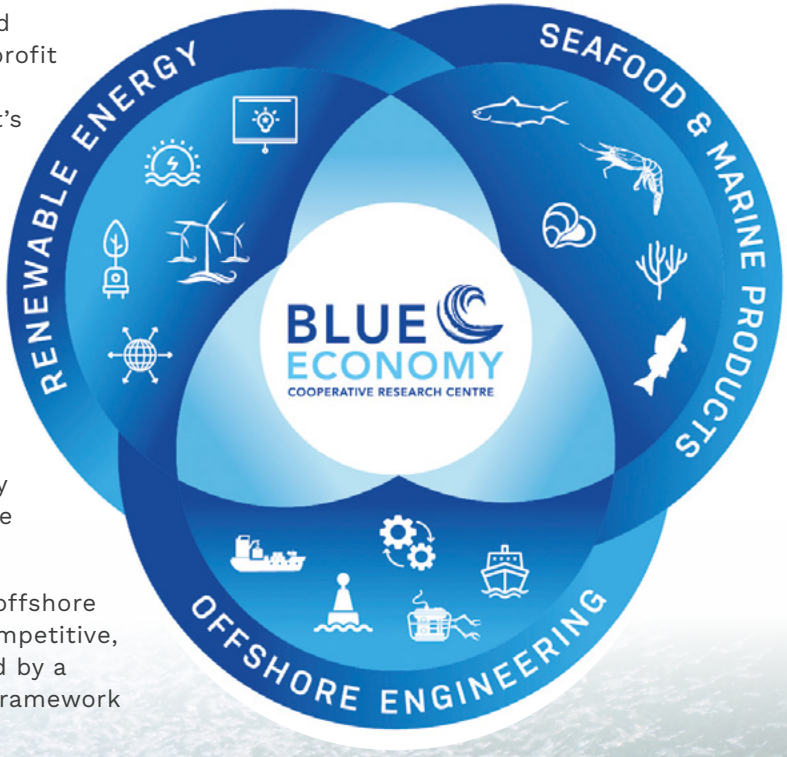
About the Blue Economy CRC

Established in 2019, the Blue Economy CRC-Co Ltd (ABN 64 634 684 549) is an independent not-for-profit company limited by guarantee and a Cooperative Research Centre under the Australian Government's CRC Program.

With a 10-year life and a budget above $329 million, the Blue Economy CRC brings together 43 industry, government, and research partners from ten countries with expertise in aquaculture, marine renewable energy, maritime engineering, environmental assessments and policy and regulation.

Through targeted industry-focussed research and training, the Blue Economy CRC paves the way for innovative, commercially viable and sustainable offshore developments and new capabilities.

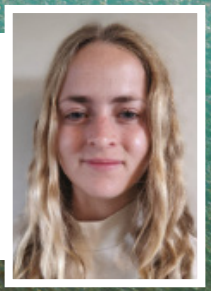
Our vision is that our blue economy industries in offshore aquaculture and renewable energy are globally competitive, at the forefront of innovation and are underpinned by a robust environmental planning and management framework which consumers trust and value.



STUDY SUPERVISOR
Associate Professor Dr Sebastian Leuzinger
Department of Environmental Science, School of Science, Auckland University of Technology

PROJECT/THEME LEADER, KEY RESEARCHER AND MANAGER
Marni Oaten
Carbon markets advisor and net zero industry collaborator, OCT Emissions Solutions Pty Ltd

STUDY RESEARCHER AND ANALYST
Vere Michiels
Ocean Carbon Analyst and Marine Scientist, OCT Emissions Solutions Pty Ltd



TEAM MENTOR AND ETHICS LEAD
Professor Marcus Haward
Institute of Marine and Antarctic Studies, University of Tasmania
RP5 Program Leader

Executive Summary / Key Insights

Australia's and New Zealand's blue economy and adjacent industry participants are well-placed to take advantage of their access to the natural capital of the ocean in the immature but emerging global ocean-based carbon markets.

The range of ocean-based and ocean-derived negative emissions technologies (Figure 1) and associated projects that are ready for development could benefit coastal communities with jobs and skills.

They will help address the direct physical impacts of climate change, while claiming a large share of the $1trillion+ (as suggested by our survey participants) of investment opportunities now available, reducing barriers to trade in a lower emissions economy.

There are a few key barriers that need addressing to enable this market to thrive. The first is the implementation of ready-now project development opportunities that do not need to wait for further regulatory processes. The second is the lack of investable assurance processes that apply specifically to the projects that could drive investor confidence in large scale adoption of ocean-based carbon market activity. A third barrier is access to information between investors, researchers, project developers, and other key stakeholders that prevent them from playing a significant role in the market. All of these can be addressed with funding and focus of stakeholders in a position to respond to the opportunity.

Other remaining barriers to the development of blue and ocean carbon removal offsets have been explored in this report, setting the scene for governments to better realise the blue and ocean carbon wealth of their nations.

Image Courtesy of Kelp Blue.

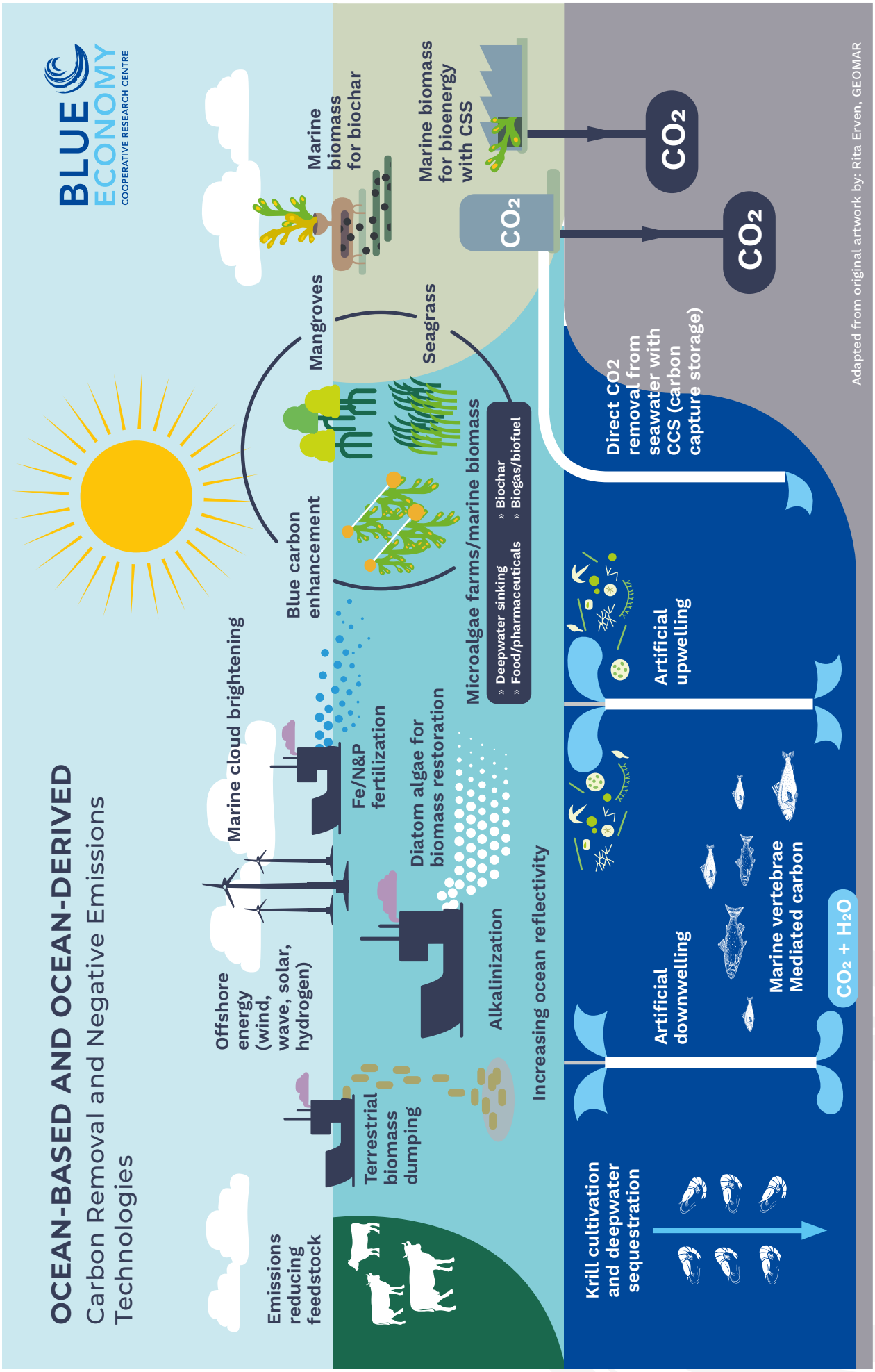


Figure 1: Ocean-based and Ocean-derived Carbon Removal and Negative Emissions Technologies.

This study provides an industry lens to sizing ocean carbon markets and opportunities for the Blue Economy and its industry via desktop studies and key stakeholder interviews and surveys. It references recent and planned research and carbon methodologies work being progressed by others.

Our survey set out to better understand the voluntary carbon market and the role of ocean-based and ocean-derived carbon. We have explored what is ready now and what are the gaps and challenges.

This is a first phase of a strategic assessment of ocean carbon markets in Australia and New Zealand, that will help those participating broadly in the Blue Economy define their roles in addressing barriers and enabling their members, partners and investors to participate in ocean carbon project development opportunities.

The reports produced for this study are intended for a broad audience, and to help describe an evolving opportunity with a variety of opinions and levels of complexity. Its goal is the identification of active and potential participants/ stakeholders and their involvement in the space of blue and ocean carbon. The reports are intended to support stakeholders to navigate their near and longer-term decision making and participation opportunities. The scope of this study did not include the development of blue and ocean carbon methodologies.

The report produced from this study provides synthesised information not currently available in the public domain. Stakeholders shared their views on what should be included in fundamental definitions such as 'Ocean carbon markets', and 'Ocean-based and Ocean-derived carbon removal and negative emissions technologies'. Stakeholders also defined risks, gaps and development opportunities that are hindering progress of ocean-based carbon markets. Industry representatives shared their approach and scale to address emissions reduction efforts to achieve declared targets, and investors shared investment criteria for high demand projects (with perceptions of shortage of supply). Our survey participants confirmed their preference for internationally trading carbon markets, brokering ocean-based carbon offsets that include co-benefits.

Opportunities driven by the potential 'size of the prize'. Currently, carbon markets are largely land focussed, ocean-based carbon markets are immature. Over 50% of stakeholders surveyed described the potential scale of ocean-based carbon markets as having the potential to be larger or significantly larger than land-based markets. The potential scale of ocean-based carbon markets could be >$1trillion (according to our survey) in value and recent reports (Bertram et al. 2021) have estimated Australia as "the largest contributor to global blue carbon wealth", estimated at US$25 billion annually, leaving a net contribution of US$22 billion annually to the rest of the world.

What ocean-carbon projects are Investable now? *Figure 2* shows blue and ocean carbon project opportunities available for development and investment. Stakeholder engagement in our study shows that research and industry is on track to ensure projects with quantifiable co-benefits can be implemented now or the near future. Ocean carbon removal accelerates natural sequestration processes, some with numerous co-benefits (such as increased biodiversity and improving ocean acidification).

Investor ready | On the way to be investor ready | Significant further work required to be investor ready

	Sea grass, tidal marsh, and mangrove protection and restoration	Offshore energy production (wind, solar, wave hydrogen)	Terrestrial biomass sinking	Macroalgae cultivation	Offshore C capture and storage	Krill (and marine vertebrate? cultivation and sinking	Geo-engineering (ocean fertilisation, alkalisation, & increasing ocean reflectivity)
Key Projects							
Research	✓ Available	○ Further research needed	✓ Available	✓ Available	○ Medium	○ Further research needed	○ Further research needed
Prototyping, Implementation, Testing	✓ Complete	○ Partly lacking	○ Partly lacking	✓ Complete	○ Medium	✗ Lacking	○ Partly lacking
Risks	✓ Low	○ Medium	✓ Low	✓ Low	○ Medium	○ Medium	✗ High
Funding Availability	○ Medium	✓ High	○ Medium	○ Medium	✓ Available	✗ Low	✗ Low
Carbon Accounting Tools	✓ Available	✓ Available	✓ Available	○ Medium	✓ Available	✗ Lacking	✗ Lacking
Co-benefits	✓ High	○ Medium	✗ Low	○ Medium	✗ Low	○ Medium	✗ Low

Figure 2: Ocean Carbon Readiness Matrix for Investable Ocean-based Carbon removal and Ocean-Derived Negative Emissions Project Development opportunities.

Globally there is rising investor and project development activity addressing ocean carbon removal, In Australia and New Zealand, project activity is currently focused on:

- Macroalgae (seaweed) cultivation (feedstock/food/pharmaceuticals)
- Macroalgae (seaweed) cultivation (sinking), deep water sequestration of biomass
- Macroalgae (seaweed) cultivation (biochar)
- Seagrass protection and restoration
- Mangrove protection and restoration
- Tidal marsh protection and restoration
- Macroalgae (seaweed) cultivation (biogas/biofuel products)
- Carbon capture and storage
- Offshore energy production (e.g. wind, wave, solar, hydrogen)

Recommendations:

We asked our stakeholders *'why are there not more approved ocean-based carbon projects in development?'*, the responses have been collated as recommendations that are addressing the challenges or barriers shared:

1. Prioritisation for the full suite of blue and ocean based carbon markets opportunities to be aligned to land based carbon markets, enabling the opportunity for a strategic national plan for international and domestic supply of project development to participate in emerging international voluntary carbon markets.
    a. Enable or upgrade regulatory mechanisms to also support ocean carbon opportunities alongside land;
    b. Prioritise funding to mobilise more activity targeting the barriers limiting confidence in validating ocean carbon projects today;
    c. Reduce the high costs and accessibility of rigorous and bespoke carbon accounting requirements to satisfy regulatory requirements designed for land-based carbon projects;
    d. Clarify processes for easy access to permits enabling strategic project development access to ocean and blue carbon resources, including access to commonwealth and international waters for ocean harvesting;
2. Engage across research/investor/developer/community stakeholders to align opportunities -
    a. Educate and guide alignment across regulators, carbon markets experts and scientists on readiness of research and methodologies in the ocean carbon sector;
    b. Align and collaborate across blue and ocean carbon industry groups, on mission, priorities and awareness of progress.
3. Greater transparency of financial investment criteria and associated assurance requirements targeting ocean carbon investments:
    a. Knowledge sharing across potential project developers to confirm what funds are accessible for projects so there is greater supply through alignment with performance criteria;
    b. Prompt standardised methods to quantify and value co-benefits (social, economic and environmental benefits) that align to investible metrics for ocean carbon projects;

Potential roles for the Blue Economy CRC

Our survey participants confirmed an average of 85% support for the statement:

> ***The Blue Economy CRC should play a proactive role in supporting the development of Ocean-based Carbon Markets in Australia, New Zealand and participate in international decarbonisation projects and carbon market mechanisms/products.***

The Blue Economy CRC already plays a role in collaborative engagement across government and industry, with a focus on 5 key programs. This study is linked to Program 5 "Sustainable Offshore Developments" and explores the opportunity to align the Blue Economy CRC engagement and research program with emerging research and opportunities connected to Ocean Carbon Markets.

Blue Economy CRC's Blue Economy Zones

The launch of **Blue Economy Zones (BEZ)** championed by the Blue Economy CRC will be helpful in supporting ocean carbon technologies seeking testbed sites for trialling all aspects of developing sustainable economic activities offshore.

This will include developing policy, regulatory and monitoring/reporting procedures as well as a future at-sea testing of technology. In the initial phase of a multi-year endeavour to establish a BEZ in the Bass Strait, the Blue Economy CRC has worked closely with the Governments to propose a regulatory environment for offshore marine farming in Commonwealth waters.

Fieldwork commenced in December 2020 in Bass Strait with placing of moorings and commencement of physical data collection (such as waves, currents, temperature, etc.), and a seabed and mobile fauna survey. The collection of baseline data at the site is providing an early indication of the suitability of the area for aquaculture and renewable energy production platforms and systems and will support marine spatial planning and site selection for future developments offshore.

Image Courtesy of Saitec Offshore.

Recommendations for the Blue Economy CRC and its industry partners

The Blue Economy CRC and its industry partners could consider playing a role to enable broader participation in Ocean-based Carbon Markets, suggestions include:

1. Provide project development initiation support, including natural capital (or carbon) accounting and other project assurance activities for project developers i.e. share industry capability and resources to enable project development activity;
2. Sponsor research necessary to underpin robust and defensible ocean carbon accounting methodologies, and to demonstrate the potential of offshore activities undertaken by existing and future participants of carbon markets;
3. Prompt cross industry/sector engagement on specific project development opportunities that have large scale impact and create a register of active investment and project development opportunities, with key project metrics, to be accessible by industry partners and investors;
4. Expand the role of **Blue Economy Zones**, championed by the Blue Economy CRC, to support ocean carbon technologies seeking testbed sites for trialling all aspects of developing sustainable economic activities offshore;
5. Further explore the Environmental Management Accounting (EMA) & Integrated Reporting (blueeconomycrc.com.au) that will pave the way for next generation ocean carbon methodologies and accounting assurance programs.
6. Represent ocean carbon project developers and associated stakeholder groups in direct engagement with government bodies - prompting international ocean carbon market opportunities with specific local project opportunities (and address regulatory challenges that delay and prevent development);
7. Facilitate introductions and networking opportunities for industry sponsors, project developers, investors, technology providers.
8. Directly engage and collaborate with leading ocean carbon research and industry groups globally and in Australia and New Zealand, refer below for examples:
    - Australia's **Carbon Market Institute** and its Blue Carbon Working Group, on sharing news of projects Project Registry | Australia's Carbon Marketplace (carbonmarketinstitute.org) and prioritising research and project development efforts.
    - **Climate Active.** Homepage | Climate Active. Climate Active is an ongoing partnership between the Australian Government and Australian businesses to drive voluntary climate action. The brand represents Australia's collective effort to measure, reduce, and offset carbon emissions to lessen our negative impact on the environment.
    - **Oceans Negative Emissions Technologies** (OceanNETs) OceanNETs – ocean-based negative emissions technologies.
    - **Oceans 2050.** Oceans 2050. With a focus is on five ocean recovery programs for the regeneration of oceans including a ground-breaking global study that advances climate restoration through seaweed aquaculture.
    - **Greenwave.** https://www.greenwave.org. Representing a global network of regenerative ocean farmers, and a goal of 10,000 ocean farmers in the next 10 years.

This research was conducted under approval by the University of Tasmania Human Research Ethics Committee as a project "Ocean Based Carbon Markets" (Project ID: 26600).

This research complied with the National Statement on Ethical Conduct in Human Research 2007 (updated 2018).

1. Introduction

Climate change is a globally recognised phenomenon that requires urgent attention. The International Panel on Climate Change (IPCC) estimates the need for approximately 10 gigatons of net CO^2 removal per year by the year 2050 in order to keep global temperature rise under 1.5 or 2 degrees Celsius above pre-industrial levels.

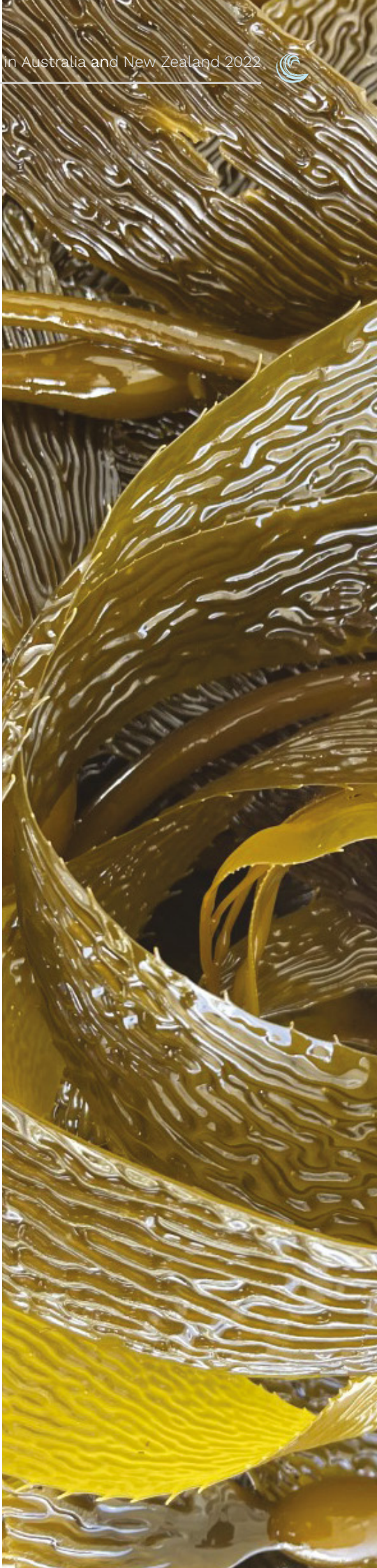
At the UN Climate Change Conference (COP26) at the end of 2021, there was substantial global engagement and alignment on many aspects of Climate change mitigation. This follows a growing movement that commenced in 2015 with 196 parties (Australia and New Zealand included) adopting the Paris Agreement. It is becoming increasingly clear that simply reducing emissions will not achieve this in time, and that further action is required. Most importantly, the potential for removing greenhouse gases from the atmosphere needs to be considered.

The oceans play a vital role in moderating the earth's climate, absorbing over 80% of the world's anthropogenic heat (IPCC 2021). Ocean-based Carbon Dioxide Removal has the potential to play a major role in the battle against climate change, with the capability of providing 1/5th of the carbon mitigation required to meet the Paris Agreement goals by 2050 (Stuchtey et al. 2020). This translates to a reduction of global greenhouse gas emissions of up to 11 billion tonnes by 2050 (Hoegh-Guldberg et al. 2019). Bach et al. (2021) state that "Acceleration in (Ocean) Carbon Dioxide Removal research and development is urgently needed as global negative emissions must be upscaled to gigatons within this decade".

The rationale for ocean-based carbon removal can be explained by the slow cycling of carbon through soil, biomass, air, and water. Accelerating the rate by which the ocean can take up and store carbon dioxide will help achieve climate goals, if at the same time emissions are reduced.

Use of the ocean for carbon dioxide removal has several advantages:
(1) the ocean has a virtually unlimited potential for carbon dioxide storage,
(2) ocean carbon removal does not compete for space with other land uses such as food production,
(3) ocean carbon removal targets and accelerates natural sequestration processes, some with numerous co-benefits (such as increased biodiversity and improving ocean acidification) that enhance the investability of blue carbon projects.

The blue carbon wealth of nations report by Nature Climate Change (Bertram et al. 2021) estimates Australia's coastal carbon sequestration potential to be 10.6 million ton of carbon per year. These estimates include carbon sequestration in mangroves, salt marshes and seagrass meadows only, therefore this potential increases significantly when we include offshore carbon sequestration potentials, and particularly active carbon capture processes.



During the period of our study, a number of key reports on related topics were released that align with the ambitions of the present report and demonstrate a rising awareness and call-to-action to address a market opportunity for the blue economy and adjacent industry stakeholders. Below is a summary of the key messages in reports released provide supporting analysis and define the opportunity for Ocean Carbon Markets, as explored in this study:

- **A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration | The National Academies Press** (December 2021). As of 2021, atmospheric carbon dioxide levels have reached historically unprecedented levels, higher than at any time in the past 800,000 years. Worldwide efforts to reduce emissions by creating a more efficient, emission-free energy system may not be enough to stabilize the climate and avoid the worst impacts of climate change. Carbon dioxide removal (CDR) strategies, which remove and sequester carbon from the atmosphere, likely will be needed to meet global climate goals. The ocean, covering 70% of the Earth's surface, holds much of the global potential for natural carbon sequestration and active CO2 removal.
- **The (blue) wealth of nations (assets.kpmg)** (October 2021) "Net Zero ambitions require blue carbon solutions'' (October 2021). The report describes how blue carbon removal solutions can address the potential constraints of 'onshore' offsets. The report breaks down the demand-side, where escalating prices will make projects more commercially feasible, and supply-side dynamics for blue carbon removal solutions can address the contrast of onshore offsets. The report provides a summary of barriers of blue carbon removal offsets is also provided.
- **The blue carbon wealth of nations | Nature Climate Change** (July 2021), Coastal ecosystems such as mangroves, salt marshes and seagrass meadows are important global carbon sinks, sequestering carbon at significantly higher rates than forests per unit surface area. Carbon sequestration and storage is an essential coastal 'blue carbon' ecosystem service for climate change mitigation. The study offers a global and spatially explicit economic assessment of carbon sequestration and storage in three coastal ecosystem types.
- **Exploring the future of the voluntary carbon market | Shell Global** (2021) An outlook on the voluntary carbon market report (2021), commissioned by Shell & BCG. It explains how voluntary carbon markets might develop. It presents practical insights across industries, outlining potential future market characteristics and scenarios for growth. The report concludes that for sustained success, the voluntary carbon market needs to mature both in terms of structure and credibility and choices made today will play a key role in this.
- **Ocean Sequestration (climateworks.org) (2021)** The ClimateWorks Ocean Carbon Dioxide Removal (CDR) Program develops an ocean CDR portfolio by supporting the scientific rigor that is required to vet each promising approach; build a community of actors to accelerate the solution-oriented discourse across scientists, entrepreneurs, and policymakers; and steer the attention of decision makers to the ocean as a potential contributor to carbon dioxide removal.
- **COP26-Glasgow-Key-Takeaways.pdf** (carbonmarketinstitute.org) (December 2021). This report outlines key takeaways from the formal decisions agreed at COP26, as well as an Article 6 Rulebook Explainer, providing a high-level outline of the key elements of the rules for global carbon markets.

Organisations contributing to the development of Blue and Ocean Carbon Markets, globally and locally:

- **Oceans Negative Emissions Technologies**
  OceanNETs – ocean-based negative emissions 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.

- **Oceans 2050**
  Oceans 2050 Our focus is on five ocean recovery programs for the regeneration of oceans including a ground-breaking global study that advances climate restoration through seaweed aquaculture. These efforts will set the robust scientific foundation to support the development of a new voluntary carbon protocol for seaweed aquaculture, which will be a public good and allow seaweed farmers to monetize the carbon impact of their activities.

- **Greenwave**
  www.greenwave.org Representing a global network of regenerative ocean farmers, and a goal of 10,000 ocean farmers in the next 10 years. GreenWave replicates and scales regenerative ocean farms to create jobs and protect the planet, by training and supporting ocean farmers in the era of climate change, working with coastal communities around the world to create a blue economy - built and led by farmers.

- **International Partnership for Blue Carbon**
  Blue Carbon Partnership The International Partnership for Blue Carbon (IPBC) connects government agencies with non-governmental organisations, intergovernmental organisations and research institutions from around the world, with a joint vision to protect, sustainably manage and restore global coastal blue carbon ecosystems contributing to climate change mitigation, adaptation, biodiversity, ocean economies and livelihoods of coastal communities. The Partnership was launched at the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP21) in Paris in 2015.

- **(Australia's) Carbon Market Institute (CMI)**
  Carbon Market Institute is an independent industry association. CMI stewards Australia's carbon market building integrity and related effective policies, while supporting their continued evolution and integration with regional and global markets; and champions the UNFCCC Paris Agreement and the emerging framework of climate and net-zero emission goals and mechanisms for increasing ambition, international cooperation and investment. They have a working group on Blue Carbon.

- **The Australian Seaweed Institute (ASI)**
  Australian Seaweed Institute is a driving force behind a sustainable and climate-positive seaweed industry in Australia, and leads the development of **Seaweed Biofilters** to help protect the Great Barrier Reef from water pollution and build resilience to climate change.

- **FutureFeed**
  FutureFeed (future-feed.com) is supporting the growth of the value chain by working with our partners to drive adoption of the use of Asparagopsis as a feed ingredient for livestock to reduce methane emissions. More than licenses, FutureFeed is working to build this new, global industry in four ways -- through research and development; certification and standards, providing regulatory pathways and marketing. In practice, it is paving the way for sustainable ocean harvesting for other emissions reduction solutions. The inroads made to establish fit-for-purpose policy and processes in Australia, New Zealand and other countries will secure development licenses, will lead to other offshore developments and ocean solutions with emissions reduction benefits.

Plus, many others reached out for their insights on research & development activities as part of this study.

2. Our approach and stakeholders in this study

2.1 How we collected and collated inputs: Desktop research, interviews and surveys

Figure 3 shows the analysis and reporting process followed for our study, with inputs, interfaces and outcomes.

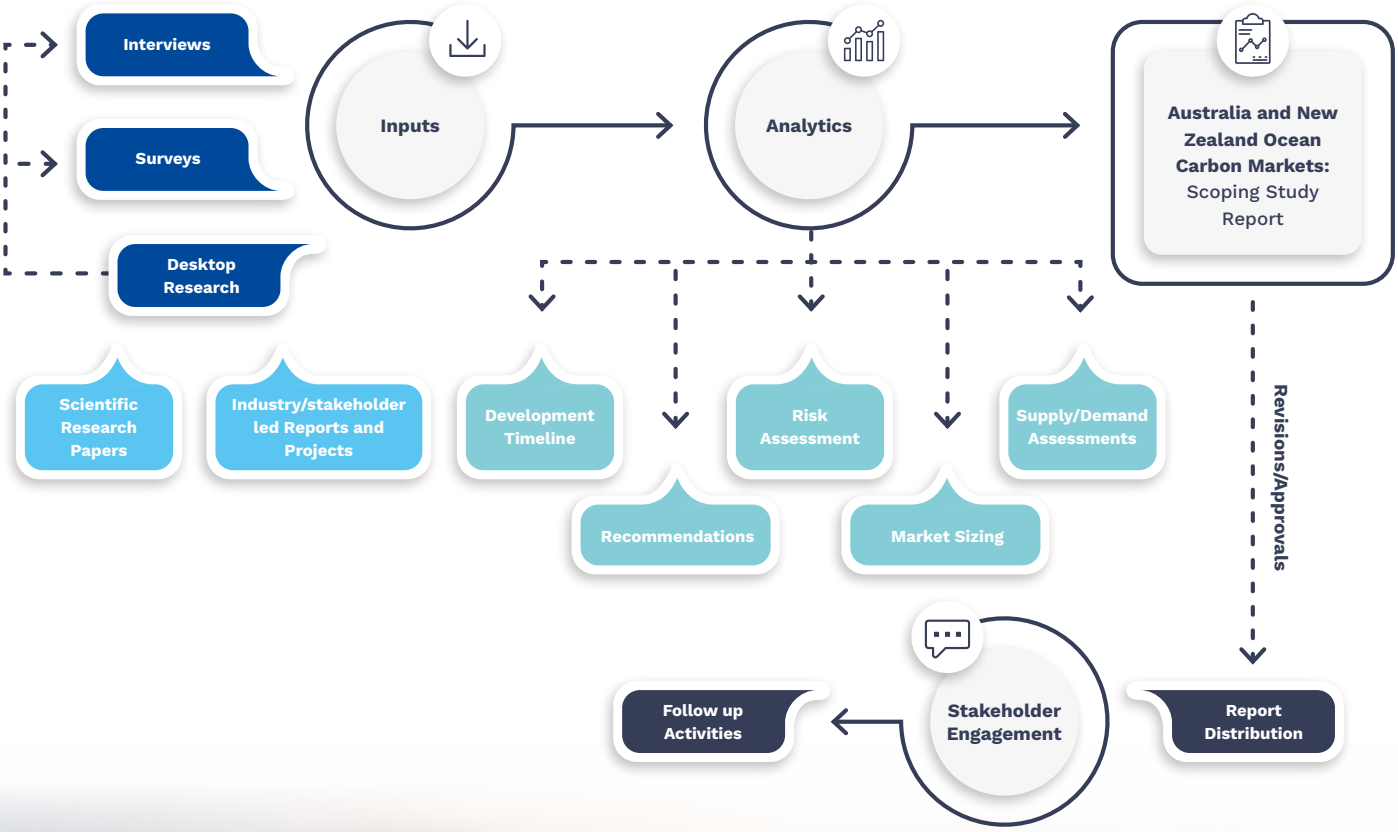


Figure 3: Analysis and Reporting Process for this Scoping Study.

Stakeholders with a role to play in Ocean Carbon Markets

Through the engagement with carbon market stakeholders, we developed a map of the stakeholders by category as per *Figure 4*.

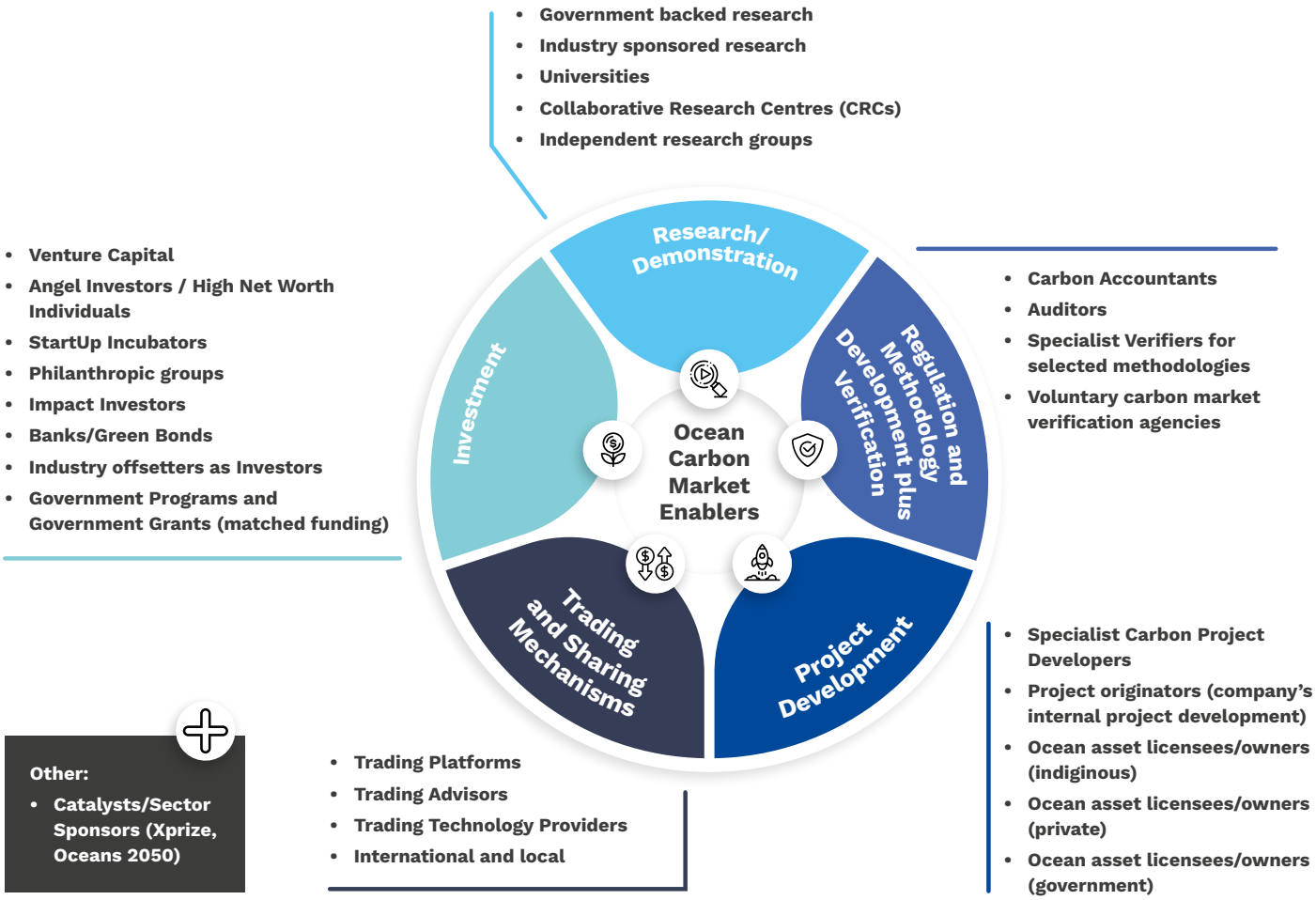


Figure 4: Stakeholder map by categories.

We invited over 150 participants via direct email to contribute to the Survey we conducted. A further 3,500++ made impressions on LinkedIn social media invitations in posts referencing the Ocean Carbon Markets Survey. Informal contributions were made in ~50 interviews and over 40 individuals contributed to the online survey, by stakeholder group, are as follows. The largest 3 groups were industry participants not connected to the Blue Economy CRC, Project Developers and Researchers (*Figure 5*).

ANSWER CHOICES	RESPONSES	
I am a subject matter expert in Carbon Markets	13.33%	4
I represent a Blue Economy CRC Industry Partner organisation	6.67%	2
I am an Industry Participant and not connected to the Blue Economy CRC	36.67%	11
I am an Investor or represent an investment organisation	13.33%	4
I am a Research Scientist or represent an academic/research organisation	30.00%	9
I am a Government Regulator or other Government representative	3.33%	1
I am a Project Developer or represent a Project Development organisation	36.67%	11
I am interested in the Blue Economy and co-benefits (tourism, biodiversity, carbon markets etc)	36.67%	11
Total Respondents: 30		

#	OTHER (PLEASE SPECIFY)	DATE
1	I am a Partner Investigator in RE academic research	2/7/2022 11:13 AM
2	A BE CRC Company Director	1/20/2022 12:28 PM
3	I am a member of the board of the Blue Economy CRC.	1/18/2022 3:41 PM

Figure 5: Participant groups (from survey results).

3. Results

3.1 Definitions

Stakeholders engaged in this study had a range of views on what they considered to be included in ocean-based and ocean-derived negative emissions technologies and hence defining **Blue and Ocean Carbon Removal.** We asked and received feedback along with examples. We evolved our definitions throughout the period of this study. Some of the (not always aligned) feedback around the definitions included the placement of offshore energy production and clarifying coastal wetlands are part of the Blue and Ocean Carbon definition.

Stakeholders we engaged were asked to rank and add types of ocean-based and ocean-derived carbon reduction or removal techniques. Project types that included macroalgae, seagrass and tidal marsh were more strongly supported to be developed as part of Ocean Carbon Markets. Less supported were marine cloud brightening and ocean reflectivity amongst others. The full list is included in our list of Ocean-based and Ocean-derived Carbon Removal and Negative Emissions Technologies below and in *Figure 4*. A full list of definitions explored within this study are found in **Appendix C.**

Blue and Ocean Carbon definitions

After the feedback collated from engaged stakeholders, we revised the definitions of blue carbon, ocean carbon, and ocean carbon markets:

- **Blue Carbon** is the total inorganic and organic carbon pool found in the oceans, coastal and shallow water ecosystems.
- **Ocean Carbon** (Ocean-based and Ocean-derived Carbon) is the total inorganic and organic carbon pool found in oceans derived from ocean and atmospheric carbon transfer (a subset of Blue Carbon)
- **Carbon Markets** or Emissions Trading Systems (ETS) enable the trading of carbon credits, also referred to as carbon offsets. One carbon credit is equivalent to one metric ton of greenhouse gas (GHG) emissions. Compliance carbon markets are determined by the regulating authority, while voluntary carbon markets tend to address a broader range of environmental and social issues (such as climate adaptation, biodiversity or poverty). In Australia, the Clean Energy Regulator administers national carbon markets. Participation in the Emissions Reduction Fund is voluntary. Internationally, the number of ETS around the world is increasing. Besides the EU emissions trading system, national or subnational systems are already operating or under development in Canada, China, Japan, New Zealand, South Korea, Switzerland and the United States.
- **Ocean Carbon Markets** are carbon markets where carbon offsets units are traded as verified ocean-based (nature-based solutions) and ocean-derived carbon removal projects.

Figure 6 shows the relationships between carbon markets, blue and ocean carbon markets. and examples of what may be included in future project supply of carbon units into these markets are in *Figure 6*. As shown , ocean carbon markets are a subset of Carbon and Blue Carbon markets.

Figure 6: Blue and Ocean Carbon Markets definition chart.

Blue and ocean-based and ocean-derived Carbon Negative Emissions Technologies

After the collated feedback from engaged stakeholders, we have expanded commonly applied definitions for Blue Carbon removal technologies to include deep water biological and geological sequestration and storage. In recent years, there have been numerous research and project development efforts to better understand ocean-based carbon removal opportunities. The XPRIZE Carbon Removal Challenge (launched in 2021 and continuing) is an example of such a global initiative. Ocean-derived negative emissions projects including offshore renewable energy (wind, solar, wave) provide the opportunity for negative emissions projects as displacement of fossil fuel energy production.

Ocean-based and Ocean-derived Carbon Removal and Negative Emissions Technologies: is the sequestration of carbon dioxide from the earth's atmosphere. Solutions focus on oceanic, coastal and shallow water ecosystems, and include deep water biological and geological sequestration and storage as well as offshore energy production. *Refer Figure 1.*

Engaged stakeholders ranked and provided additional examples to support their understanding of this definition. While at various levels of maturity and eligibility as carbon-offset units, Voluntary Carbon methodologies have been successfully kick-started, a number of barriers (Section 4.3.) remain in place that are preventing emerging Ocean Carbon markets from reaching their full potential.

Ocean-based Carbon Removal and Emissions Reduction Technologies/Solutions

Ranked (high to low) by stakeholder support for inclusion in carbon markets:

- Macroalgae (seaweed) cultivation (food/pharmaceuticals)
- Macroalgae (seaweed) cultivation (sinking), deep water sequestration of biomass
- Macroalgae (seaweed) cultivation (biochar)
- Seagrass protection and restoration
- Mangrove protection and restoration
- Tidal marsh protection and restoration
- Macroalgae (seaweed) cultivation (biogas/biofuel products)
- Marine vertebrae mediated carbon
- Ocean alkalinisation
- Krill cultivation and deepwater sequestration
- Diatom algae for biomass restoration
- Artificial ocean carbon upwelling
- Ocean fertilisation
- Marine cloud brightening
- Increasing ocean reflectivity
- Artificial ocean carbon downwelling
- Ocean acidification: electrochemical approaches to mitigate ocean acidification
- Terrestrial biomass sinking
- Fertilising the ocean with iron

Ranked high to low support by survey stakeholders in support for inclusion in carbon markets:

- Offshore wind energy generation
- Offshore wave energy generation
- Offshore carbon capture and storage (CCS),
- Deepwater storage of CO2
- Offshore Direct Air Capture (DAC) or Direct Ocean Capture
- Offshore solar energy generation
- Offshore hydrogen energy storage/generation

Image Credit: Ole Jørgen Bratland © Dudgeon Offshore

Blue and ocean carbon market activities, methodologies, and project development timelines

Reviewing the status of research and approved methodologies for carbon removal and negative emissions, we can see there is a sweet-spot of opportunities for project developers and industry to participate in blue and ocean carbon projects. By engaging with active market participants, we reviewed Australian, New Zealand and international developments in the blue carbon methodologies for carbon markets.

We started with a desktop review, then continued with interviews and a survey that asked a number of market defining questions that covered challenges and opportunities for investors, regulatory representatives, researchers and developers progressing this agenda. This will profile the development of the industry and will underpin further analysis outcomes. Our preliminary assurance plan with methodology for ocean-based carbon offset projects can assist stakeholders in participating in voluntary carbon offset markets in the near term, with a timeline of key milestone developments (*Figure 7*).

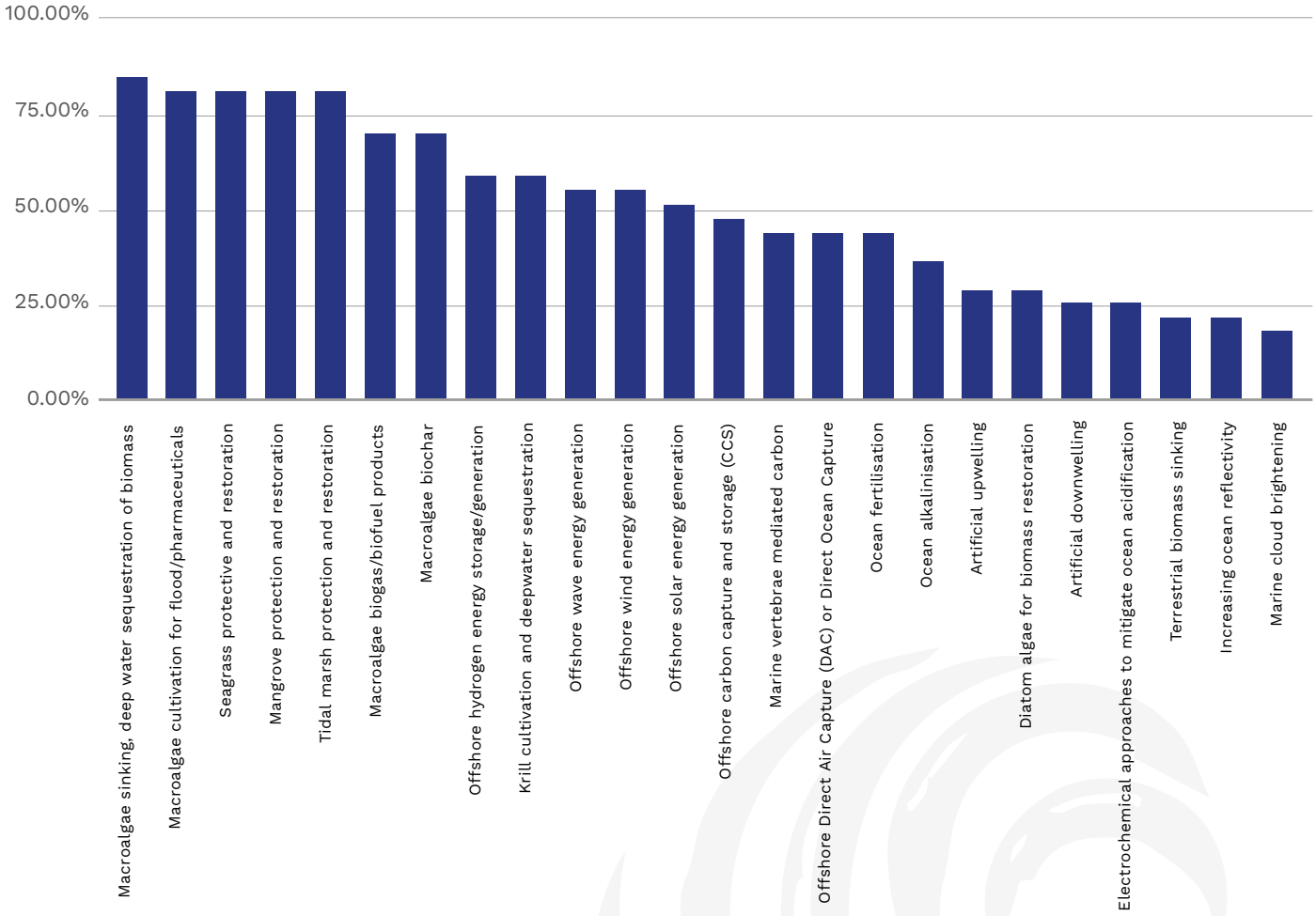


Figure 7: Ocean-based and Ocean-derived carbon removal and negative emissions solutions: ranked by desire to be included for potential development and inclusion in carbon markets (from survey results).

3.1.1. Carbon offset methodology and compliance

There is no globally consistent standard for determining the criteria of a carbon offset. Offsetting methodologies generally require projects to provide an authentic and 3rd party verifiable removal, reduction, or avoidance of emissions beyond what would have occurred if the offsetting project had not taken place. Common requirements for carbon offset methodologies include addressing issues of permanence, leakage, additionality and double-counting.

This creates many practical challenges and concerns that are slowing down the rate of potential development of in-demand carbon offset projects that are ocean-based and ocean-derived.

There is no ocean equivalent definitions by the United Nations Climate Change Secretariat definitions for Land use, Land-use change, and Forestry (LULUCF), also referred to as Forestry and other land use (FOLU), “greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use such as settlements and commercial uses, land-use change, and forestry activities.” This creates barriers for adaptation of the various mechanisms available for land-based offsets.

3.1.2. Carbon market mechanisms and methodologies

In Australia, there are government defined FullCAM and BlueCAM models which allow calculations on how much carbon has been sequestered from carbon offsetting projects. In terrestrial projects, the participants’ input figures are entered into the model (i.e., where, how many trees and in what configuration), which uses a formula to calculate how much carbon will be removed from the atmosphere over a 25-year period. This is currently not fully developed to include ocean-based projects. Refer the Blue Carbon Accounting Model (BlueCAM) Guidelines: **Blue carbon accounting model (BlueCAM) guidelines (cleanenergyregulator.gov.au)**

The internationally active voluntary carbon market is undergoing significant growth as companies seek ways to reduce their carbon footprints. However, voluntary markets address a small proportion of today’s emissions - less than 1% - vs. 16% that are offset by compliance markets and carbon taxes (BCG/Shell report 2021). Aligned with the above, we are seeing a preference for voluntary emissions reduction offsets, with over 50% of respondents to our survey confirming “International voluntary carbon standards (VCS) are cheaper and easier for project developers to adopt than waiting for domestic regulatory standards development.”

3.1.3. Buyers’ preferences (Industry emitters)

We engaged with stakeholders across the Blue Economy and adjacent industries and asked them about their company’s efforts and interest areas to reduce emissions. Some themes are emerging:

- The survey respondents seek advice and support from consultants/advisors as well as in-house subject matter experts / researchers to learn about investment/project opportunities for ocean-based blue carbon. One respondent suggested Investable Oceans as a recommended source of valuable information on project investment opportunities.
- As industry participants set commitments to reduce global greenhouse gas emissions , there is rapid growth in demand for voluntary carbon credits to supplement their broader decarbonisation efforts.
- Buyers focusing on quality are likely to increasingly look to nature-based solutions as a source of credits. Carbon removal credits would play a key role in the linked scenario, although would be unable to scale to meet all demand. High-quality avoidance credits generated from projects which protect natural carbon sinks under threat, will be critical in meeting corporate emissions reduction pathways on the journey to net-zero.
- Instead of buying through emissions trading schemes, many industry participants are exploring options to develop their negative emissions projects through project origination (when a company develops a negative emission project within their operational footprint).

How industry chooses to reduce carbon equivalent emissions

When it comes to buying carbon reduction offset units, the Australian and New Zealand based industry participants surveyed confirmed they would accept carbon units validated by:

- Clean Energy Regulator (Australia);
- Australian Carbon Credit Units (ACCUs);
- Verified Emissions Reductions (VERs) issued by the Gold Standard;
- Verified Carbon Units (VCUs) issued by the Verified Carbon Standard;
- Certified Emissions Reductions (CERs) issued under the Clean Development Mechanism of the United Nations Framework Convention on Climate Change;
- Natural Capital Accounting 3rd party independent verification (following the UN SEEA standards Customised inhouse company processes with 3rd party verification).

Natural Capital Accounting:
An increasingly accepted option for project verification

Over half the surveyed stakeholders agreed that natural capital accounting standards (following globally agreed standards, UN SEEA) allow robust, verifiable and acceptable assurance for evaluating social, environmental and human capital value of ocean-based carbon projects, and are available now. This process is widely accepted to inform government, corporate and consumer decision making as each relates to the use or consumption of natural resources and land, and sustainable behaviour.

Natural capital accounting is helping Australia's red meat and livestock industry measure and monitor its carbon and natural capital outcomes. This will support the industry's progress towards its carbon neutrality targets, and facilitate access to emerging carbon and biodiversity markets.

- The QLD LRF requires natural capital accounting to be done to report and verify environmental benefits are being delivered including biodiversity, water quality, native vegetation and great barrier reef.
- The Global Ocean Accounting Partnership is working on project level environmental accounting guidelines. https://www.oceanaccounts.org/goap-in-brief/

28% of our survey respondents included Natural Capital Accounting as a credible option for international voluntary carbon/accounting market standard to apply to ocean-based carbon projects.

Image Courtesy of Tassal.

Case Study

Western Australia's Geographe Bay (2020)
Ocean accounting pilot for Geographe Marine Park

[Ocean accounting pilot for Geographe Marine Park | EEA (environment.gov.au)]

What is Natural Capital Accounting? Assesses an ecosystem or region, by quantifying co-benefits alongside carbon removal. Why choose it? With a holistic ecosystem approach, it NCA can be used to quantify carbon removal and co-benefits being supplied from ecosystems, so it is ideal for the multi-technology "portfolio" approach to ocean carbon project development and it is widely (and increasingly) accepted as an investable accounting standard (UN approved to SEEA standards).

Example project: Ocean accounting pilot for Geographe Marine Park was developed for the Department of Agriculture, Water and the Environment by IDEEA Group: Reiss McLeod, Mark Eigenraam, Carl Obst. The project reported on the extent of seagrass, sandy bottom, rocky reef and kelp ecosystems in Geographe Marine Park, assessed the ecosystem services and benefits provided, and identified the links between potential human induced pressures and ecosystems in the marine park.

It is the first Australian Government led ocean environmental-economic account developed under the National Strategy and Action Plan for Environmental-Economic Accounting. The pilot accounting project applied internationally accepted accounting frameworks and technical guidance in an Australian marine context, building Australian and international experience in ocean accounting.

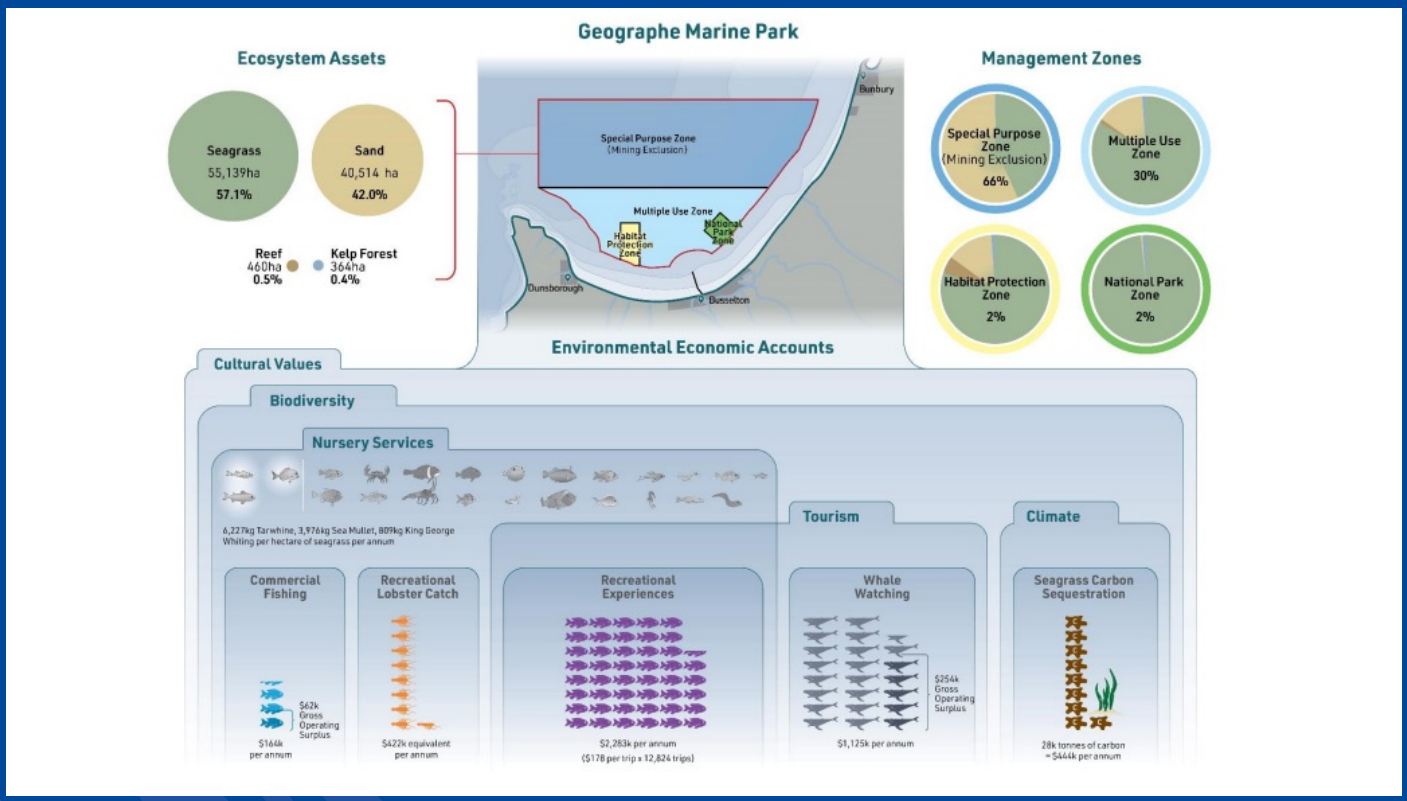


Figure 8a: Ocean Accounting Pilot Geographe Bay DEEA Group: Reiss McLeod, Mark Eigenraam, Carl Obst. (2020) Ocean accounting pilot for Geographe Marine Park | EEA (environment.gov.au).

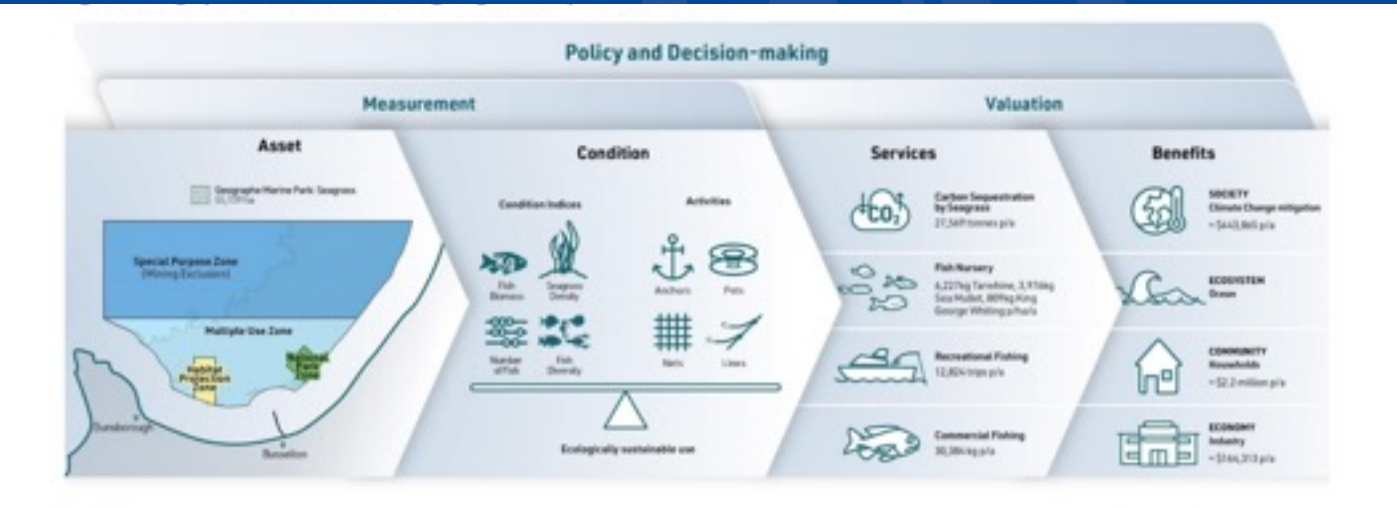


Figure 8b: Geographe Marine Park - Framing seagrass ecosystems as an asset.

Carbon credits and pricing impacts

The engaged industry participants shared what their emissions reduction and offset programs are prioritising, and 80% of the participants indicated that their company is planning to reduce their full range of emissions (Scope 1,2&3, including supply chain) and will consider origination of negative emissions projects while also purchasing carbon reduction offsets via emission trading schemes.

We also asked (in the context of prioritising project development, project origination or buying carbon offsets units) what project co-benefits are 'attractive' and are taken into consideration for the business case for the above selected emissions reduction projects.

The ranked survey responses on attractive co-benefits are:

1. Ecological benefits
2. Additional revenue opportunities from sales of by-products
3. Coastal protection Indigenous participation/community benefits
4. Regional social and economic benefits
5. Fisheries enhancement
6. Counteracting ocean acidification
7. Creation of regional jobs
8. Exportable skills/services and technology
9. Reduced methane from farming activities
10. Water filtration Tourism / recreational activities
11. Skills development
12. Water quality improvements - nutrient removal
13. Reduced methane from seaweed farming for cattle feed

Co-benefits impact pricing

There is a price premium associated with carbon offset units that carry valued co-benefits. The high demand and price for the Fire Management projects in northern Australia are not only large scale eligible for Australian Carbon Credit Units (ACCUs), co-benefits include local employment, community development, biodiversity protection and ancient culture site protection.

Other Factors Impacting Pricing

There are a range of other factors that impact attractiveness and hence willingness-to-pay for these industry participants who are active as project developers and buyers of negative emissions carbon units.

The Shell-BCG report An outlook on the voluntary carbon market carbonmarketreports.

Pricing Factors

Several factors have an impact on the price of a credit. Among those are:

Methodology:

Some methodologies, have a higher premuim because the method of credit generation is more desireable, driven by the co-benefits.

Verification standard:

The different standards by which a project is developed, certified and tracked, imact price and value of credits depending on the external perception of the standard.

Additionality:

Emissions reductions from carbon projects should not have occured without the offset in financing activity.

Leakage:

Emission reductions from carbon credits will not be counter-balanced elsewhere.

Co-benefits:

Positive impacts, in addition to direct greenhouse gas emissions mitigation, resulting from the project. These might include co-benefits linked to: restoring degraded ecosystems and preserving biodiversity, improving resilience of ecosystems and the impact on local communities through liveable or social-economic improvements, often linked to the UN's Sustainable Development Goals. (SDGs)

Permanence:

Proper assurances have to be made to cover the reveral risk.

Figure 9: Pricing Factors: (source: The Shell-BCG report An outlook on the voluntary carbon market.

COP26 and Maturing Local and International Carbon Markets

The Carbon Market Institute's report on COP26 outlines six key messages from the formal decisions agreed at COP26, as well as an Article 6 Rulebook Explainer, providing a high-level outline of the key elements of the rules for global carbon markets.

1. COP26 boosted climate ambition but recognising more action and ambition is critical within this decade. Countries with a large blue carbon potential like Australia and New Zealand will be under greater scrutiny at COP27 and COP28's global stocktake.
2. New rules for international cooperation and carbon markets provide a platform for high integrity, transparency and comparability but will require corporate and national vigilance on integrity and emission reduction.
3. Global capital costs and risks are rising for carbon-intensive countries, companies and projects amidst deepening investor activity, corporate disclosure requirements and carbon trade instrument development
4. There is greater emphasis on the importance of protecting, conserving and restoring nature and ecosystems, including forests and other terrestrial and marine ecosystems in achieving net-zero emissions. Australia is well positioned to become a global leader in nature-based solutions development, knowledge brokering, finance and capacity building but needs to nurture its crediting mechanism integrity frameworks and have a more credible emissions reduction trajectory.
5. Whether it is a 'phase down' or 'phase out' approach, global focus shifts to managing the transition from fossil fuels and the need to do this in an inclusive way.
6. Failure to deliver on public and private climate finance pledges remains a stumbling block with commitments to double adaptation funding, and a "dialogue" on Loss and Damage barely keeping developing countries at the table; this issue to be central to COP27 and future progress.

International blue/ocean carbon methodologies
(Available now and in development)

There are a number of blue and ocean carbon methodologies for carbon assurance/accreditation already secured with national and international programs, with more planned for release in 2022 and 2023 (*Figure 10*).

Our engaged survey contributors shared frustrations with the costs, complexity, lack of transparency and information available on available carbon methodology to align with the assessment of commercially viable ocean carbon projects for development. Via our survey, participants shared comments about political and association bias towards terrestrial carbon projects and methodologies under development coincides with perceptions and assumptions on lack of availability and lower confidence of carbon removal in the ocean environment, and a lack of governmental recognition and inclusion. This leads to a reduced impetus for governmental prioritisation of ocean carbon removal and removal/conservation projects, and hence market development.

Some themes across the feedback are:

- Improving carbon literacy amongst carbon practitioners will lead to improved opportunities and regulator/investor confidence.
- Government grants and funding opportunities are not in the right places to match commercial opportunities and demand from industry's demand for ocean-based carbon units, limiting ocean carbon market activity.
- There is a perception that creating methodologies and verification in ocean environments is far more expensive than in terrestrial environments. i.e., the sequestration rates of ocean biomass is not mature.
- There is not enough action to close the gap to apply the methodology development to practical implementation.
- In Australia and New Zealand, the lack of intergovernmental recognition of the ocean carbon market.
- Global, the lack of recognition in in UNFCCC annual emissions reporting and the still voluntary nature of and lack of inclusion of the offshore in the mandatory LULUC methodology of sink and source alteration.

Verified Carbon Standard (VCS) with Verra have a number of recent and upcoming methodologies, the most recent: Revision to VM0041 Methodology for the Reduction of Enteric Methane Emissions from Ruminants through the Use of 100% Natural Feed Supplement, v1.0 - Verra

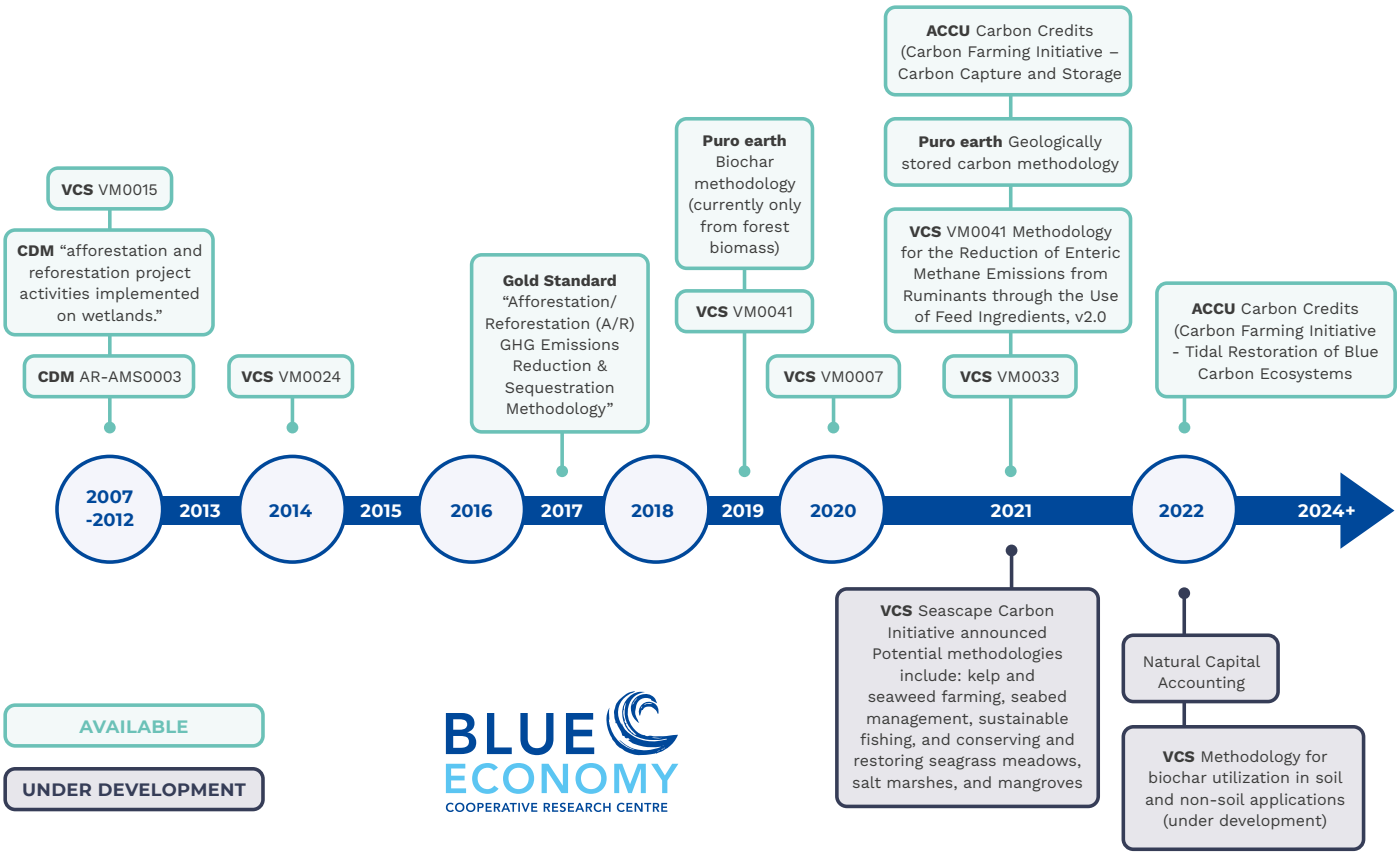


Figure 10: Timeline of key developments in ocean-carbon crediting methodologies, both available methodologies (green boxes) and methodologies under development (blue boxes).

Outside of the limited available options from the Australian and New Zealand regulatory framework for carbon credits, over the past 12 months, there has been an increase in globally accessible international standards for blue and ocean carbon.

The most credible, as selected by our survey stakeholders (*Figure 11*) were: Gold Standard, Verra and Natural Capital Accounting.

Note: Puro Earth was not included in our survey but seems to be growing its support for Blue Carbon methodologies.

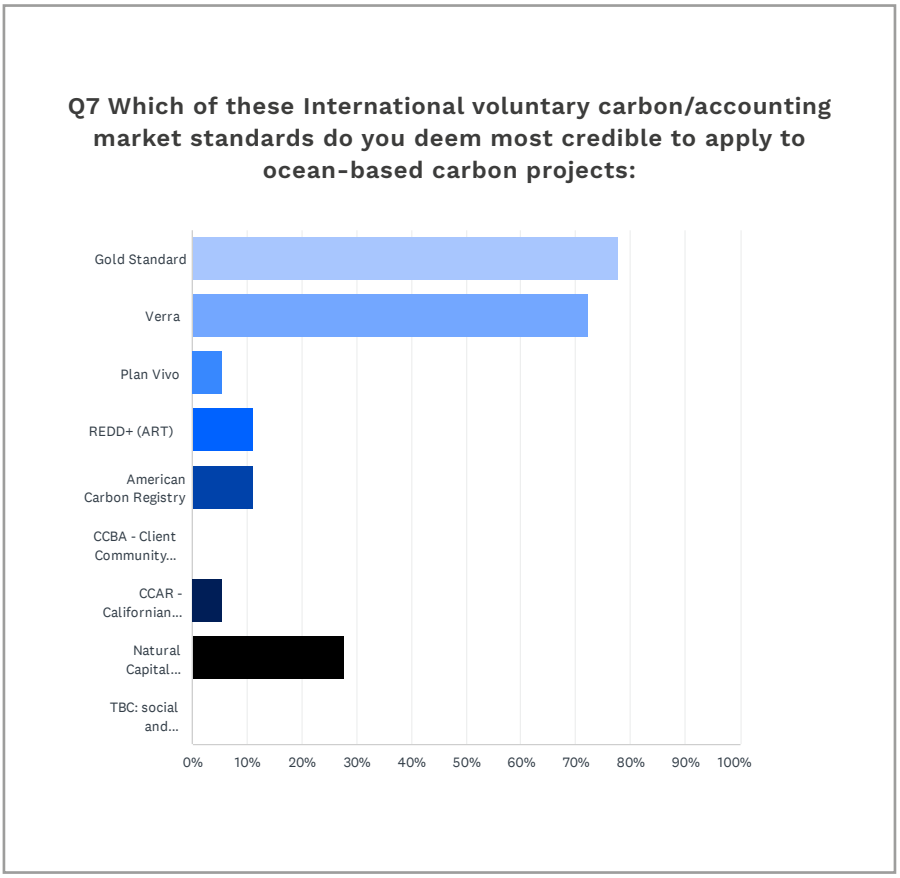


Figure 11: Survey responses identifying the international voluntary carbon/ accounting market standards deemed most credible to apply to ocean-based carbon projects.

Case Study

Ocean Harvesting of Seaweed
FutureFeed and Regulatory Challenges for Developing Export-ready Negative Emissions Products and Technologies

FutureFeed is the global IP holder for the technology behind the methane-reducing (and potentially ocean harvested) Asparagopsis. They are working to enable the commercialisation of this new global industry. However, the need for localised trials and regulatory pathways to be opened up has hindered their progress. They are hoping for cooperation between business and government, with an aim to receive funding to help data collection and reporting transparency to meet the requirements for the approval of Asparagopsis as a stock feed ingredient. This will help the product meet certifiable standards and regulatory requirements, allowing for its commercialisation.

Methodology development: This Verra methodology provides procedures to estimate enteric methane (CH4) emission reductions generated from the inhibition of methanogenesis through the introduction of a feed additive into ruminants' diet. The methodology considers emission reductions from enteric fermentation and is globally applicable for all livestock operations which manage ruminants' diet. Revision to VM0041 Methodology for the Reduction of Enteric Methane Emissions from Ruminants through the Use of 100% Natural Feed Supplement, v1.0 - Verra

Research: FutureFeed is investigating biodiversity risks in cultivating Asparagopsis within the EU. Asparagopsis grows in several locations in Europe and Asparagopsis is not part of the official "List of Invasive Alien Species of Union Concern".

Partners (Licensees) developing ocean harvesting projects include:

Australia and New Zealand

CH4 GLOBAL Zero Methane Agriculture

SEA FOREST

United States of America

Blue Ocean Barns Solving agriculture's biggest climate challenge.

Symbrosia

Europe

V0LTA GREENTECH

3.1.4. Australian Government activity linked to blue and ocean carbon

In January 2022, Australia's Clean Energy Regulator announced the Blue Carbon methodology with clarifications (*Table 1*). A number Australian Government supporting initiatives within-country and in the region have been announced, including:

- The Australian Government's Department of Agriculture Water and the Environment is funding practical action to support restoration, conservation and accounting for blue carbon ecosystems in Australia and overseas, $30.6 million, 2020-2025.
- Australia leads the International Partnership for Blue Carbon with fifty partners from government agencies, non-governmental organisations, intergovernmental organisations and research institutions sharing a vision to protect, restore and sustainably manage global blue carbon ecosystems.
- Australia is one of only a few countries to progressively include coastal wetlands in international carbon accounting using the Intergovernmental Panel on Climate Change 2013 Wetlands Supplement, and capacity building activities for developing countries on measurement, reporting and verification.
- Australia is planning the first national ocean ecosystem account, with a focus on coastal blue carbon ecosystems. This work will provide information on ecosystem extent and condition, and ecosystem services such as coastal protection and carbon sequestration.
- Australia led the development of resolutions adopted by Parties to the Ramsar Convention on Wetlands to encourage global action for the protection and restoration of blue carbon wetland ecosystems.
- The Australian Government's National Environmental Science Program (NESP) funds environmental and climate research, with the NESP Marine and Coastal Hub supporting science for Australia's marine and coastal environments, including blue carbon ecosystems, coast, reefs, shelf and deep-water.
- As part of the Emission Reduction Fund, Australia is developing a method for securing carbon credits for restoring blue carbon ecosystems from the reintroduction of tidal flows.
- Australia is supporting national climate action and livelihoods in Papua New Guinea and Fiji through enhanced mapping, measurement and accounting for blue carbon, demonstrating the viability of generating blue carbon offsets, and biodiversity and livelihood benefits to attract investments and exchanging knowledge and expertise between Australian Indigenous communities across the Pacific (Pacific Blue Carbon Program $6.3 million, 2018-2024).
- Australia is working with Indonesia to improve understanding and management of coastal blue carbon ecosystems for climate action and sustainable livelihoods (Indonesia Blue Carbon Program $2 million, 2019-2023)
- Australia is providing training to Sri Lankan scientists and collecting essential underpinning data to inform evidence-based policy to support the use of blue carbon ecosystems as a nature-based climate mitigation tool (Blue carbon for climate change mitigation and sustainable livelihoods in Sri Lanka $430,000, 2019-2022).
- Australia supports the IORA Indian Ocean Blue Carbon Hub which aims to build knowledge about and capacity in protecting and restoring blue carbon ecosystems throughout the Indian Ocean, in a way that enhances livelihoods, reduces risks from natural disasters, and helps mitigate climate change.
- Australia has launched the Blue Carbon Accelerator Fund to support the development of blue carbon restoration and conservation projects in countries outside Australia and help pave the way for private sector finance.

Table 1: Blue Carbon Methodologies Update. *Table courtesy of Australia's Clean Energy Regulator*, Jan 2022 Issues Register (Blue carbon (cleanenergyregulator.gov.au))

Issue	Response
Permitting seeding and planting for blue carbon projects.	The blue carbon method allows environmental coastal wetland plantings where the plants or propagules used are native to the local area and a mix of species is used that reflects the typical structure and composition of local native vegetation communities.
Whether existing regulatory and approval regimes are sufficient to manage potential adverse impacts from the reintroduction of tidal flows.	The agency undertook an assessment of Commonwealth, State and Territory regulatory frameworks that manage potential adverse impacts from the reintroduction of tidal flows. The method contains provisions to manage outstanding risks such as the requirements to provide an acid sulfate soils management plan and mosquito management plan.
Investigating what low-cost options are available to evidence the modelled abatement figures and that regeneration of vegetated coastal ecosystems is occurring.	The agency has worked with blue carbon experts to develop the Blue Carbon Accounting Model (BlueCAM) to model net abatement from blue carbon projects.
Specifying the mapping and hydrological modelling requirements for blue carbon projects.	The agency has prepared a Supplement to the blue carbon method that outlines the mapping and hydrological mapping requirements for blue carbon projects.

3.1.5. New Zealand government activity linked to blue and ocean carbon

The New Zealand government announced it will provide up to NZD 200 million for climate-related support over the next four years, the majority of which will benefit Pacific nations. This builds on the NZD 65 million New Zealand has already spent over the last three years to help Pacific Nations secure reliable and clean energy (List of Recent Climate Funding Announcements | UNFCCC)

There are examples of research and development activities in NZ linked to international programs supporting globalising Blue/Ocean Carbon Markets. For example, the work of CH4 Global is a partner with Australian based FutureFeed in adopting the use of Asparagopsis as a feed ingredient for livestock to reduce methane emissions.

Blue carbon research and project development activity in New Zealand is in its infancy. The low-emission economy report by the New Zealand Productivity Commission (August 2018) does not mention any ocean-based carbon sequestration technologies. The inclusion of indigenous views and knowledge seems more advanced in New Zealand, which, while desirable, seems to slow down processes overall.

A few New Zealand based companies are developing live-laboratory investigations. For example, Blue Carbon Services bluecarbonservices.com.au are investigating carbon sequestration and mussel productivity in integrated multi-trophic aquaculture (2019-2023) and quantifying blue carbon from kelp contribution to carbon sequestration in marine sediments (2021-2024).

According to the National Institute of Water and Atmospheric Research in New Zealand (NIWA) (2017), New Zealand's mangrove swamps and coastal marshes may be particularly adept at absorbing and storing carbon. They initiate research aligned to their mission to conduct leading environmental science to enable the sustainable management of natural resources for New Zealand and the planet.

'Core and restore' is an initiative run by the Tasman Environmental Trust, and supported by local council and iwi to measure, protect, and restore carbon in coastal soils. https://www.tet.org.nz/projects/blue-carbon-core-and-restore/

Other New Zealand market players who contributed to the survey shared challenges to align industry with government to match with research areas identified, *"while we have received strong New Zealand government support for our macroalgae carbon sequestration research we have struggled to raise co-funding from the private sector."*

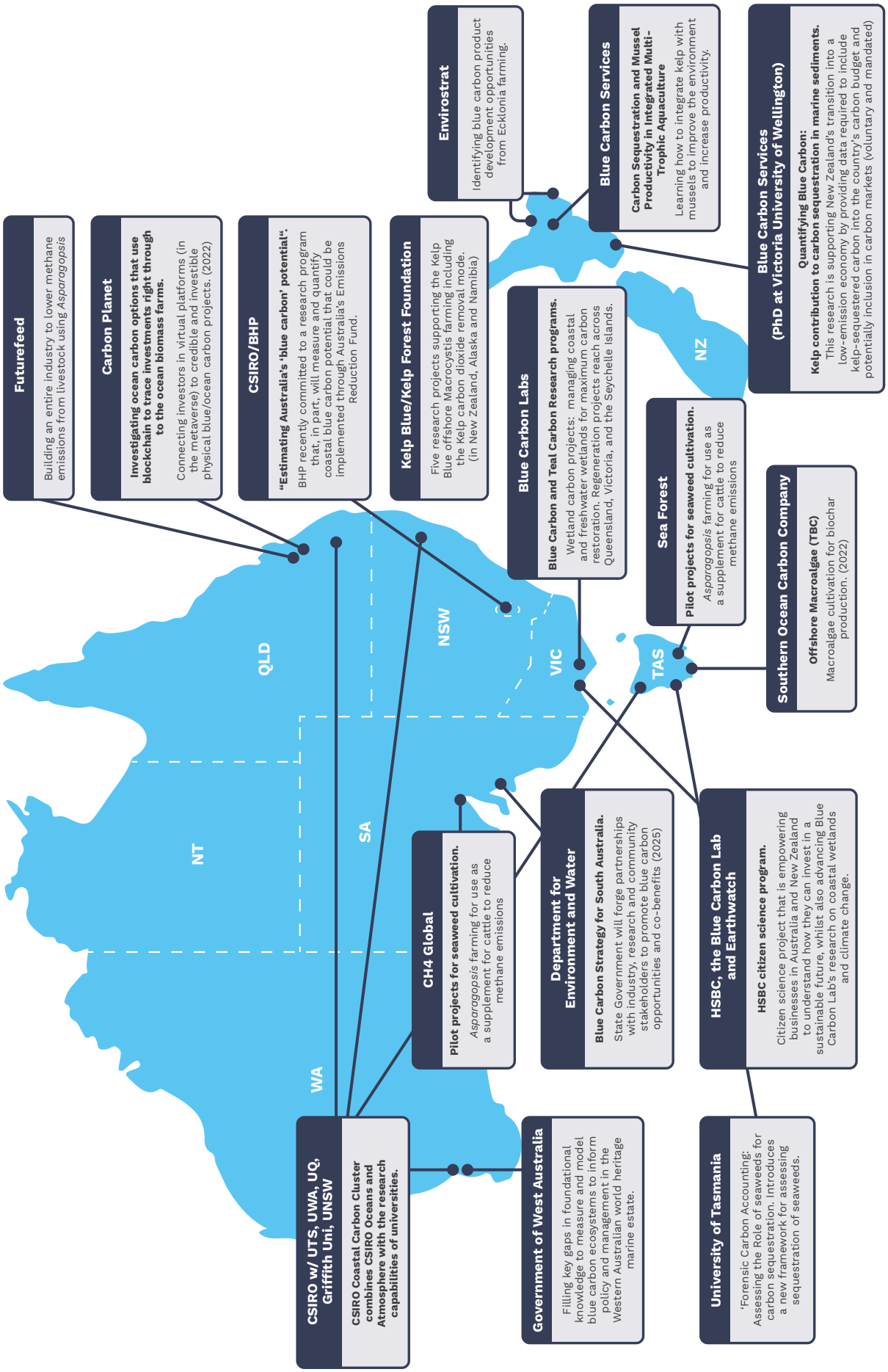


Figure 12: Map of ocean-carbon related research and/or projects being conducted in Australia and New Zealand.

Current Research Collaborations and Topics

The highest ranked areas of ocean carbon research our survey participants are involved in are listed below:

1. Macroalgae (seaweed) cultivation (sinking), deep water sequestration of biomass
2. Macroalgae (seaweed) cultivation (food/pharmaceuticals)
3. Macroalgae (seaweed) cultivation (biochar)
4. Marine vertebrae mediated carbon
5. Mangrove protection and restoration
6. Krill cultivation and deepwater sequestration
7. Artificial ocean carbon upwelling
8. Offshore carbon capture and storage (CCS), Deepwater storage of CO2

Over 70% of the researchers participating in our survey responded that they “usually” or “often” collaborate with industry and project developers within their research.

Challenges for Researchers

We asked our stakeholder to share some of the challenges facing researchers to progress ocean-based carbon related research projects. They confirmed challenges include:

- Long timeframes for research findings to become available
- Funding restrictions
- Uncertainty around commercialisation of research outcomes
- Access to ocean / equipment / labour
- Lack of awareness of opportunities

One respondent expanded on this and added “Ocean technology is lagging behind terrestrial - sensors are expensive and need constant recalibration, they are not user friendly. Creating effective, value for money sensor kits for seaweed farmers would be an idea - that way the data would be collected the same way and easy to compare between one site and another.”

Research gaps identified to enable carbon markets

Our survey participants shared research areas they would recommend to address knowledge gaps and barriers for commercialisation of ocean-based carbon markets.

“Ocean carbon sequestration/abatement rates” was the most selected research gap that would support carbon markets, followed by financial mechanisms and addressing permanency/durable sequestration of projects (*Figure 11*).

Suggested research gaps supported by survey participants:

1. Ocean carbon sequestration/abatement rates;
2. Ocean carbon sequestration periods addressing “permanency” in sediments;
3. Financial mechanisms for ocean carbon projects co-benefits (social, economic, environmental) from proposed development projects;
4. Application of consistent measurement and performance reporting standards (natural capital accounting) to ocean-based carbon technologies and projects;
5. Commercialisation models that encourage smaller projects and smaller scale developers to participate in ocean-based carbon markets Impact assessments from proposed development projects (with scale up);
6. Public perception of the risks and opportunities (social license to operate);
7. Market sizing studies for ocean-based carbon technologies and projects;
8. High level policy barriers or blue carbon inclusion;
9. Carbon sequestration periods occurring in abyssal ocean waters and the associated physical oceanography that determines the median time scale to outcropping;
10. Physical oceanographic expertise to validate the larger pools that will occur in the abyssal oceans rather than the sediments;
11. Market pricing studies to determine willingness to pay (how much), expectations regarding co-benefits (willingness to pay for additionality);
12. Financial instruments by which ocean carbon dioxide removal projects could borrow against accumulated carbon units. This would help capitalise further development and provide an option to sell units.

Ocean Carbon Removal Technologies at Commercialisation Readiness, and Scale Up Potential

The comprehensive summary of ocean carbon removal project development opportunities in the 2021 Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration, developed by the National Academies of Sciences, Engineering, and Medicine, describes the research gaps, costs to fill those gaps and the scale up potential of each key technology as per sample extracts in Table 2a and 2b. By rating each technology by its knowledge base, durability, efficacy, social considerations, cost, environmental risk and scale up potential.

A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration | The National Academies Press (nap.edu)

The Table 2a is an extract from A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration. Washington, DC: The National Academies Press. https://doi.org/10.17226/26278. Download: A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration | The National Academies Press (nap.edu)

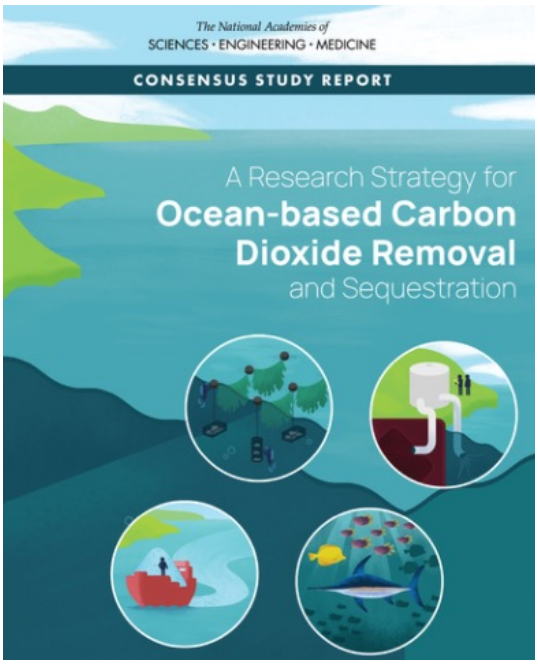


Table 2a: Summary Ocean CDR Scale-Up Potential. A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration | The National Academies Press (nap.edu)

	Ocean Nutrient Fertilization	Artificial Upwelling/ Downwelling	Seaweed Cultivation	Ecosystem Recovery	Ocean Alkalinity Enhancement	Electro-chemical Processes
Knowledge base What is known about the system (low, mostly the oretical, few in situ experiments; medium, lab and some fieldwork, few CDR publications; high, multiple in situ studies, growing body of literature)	**Medium–High** Considerable experience relative to any other ocean carbon dioxide removal (CDR) approach with strong science on phytoplankton growth in response to iron, less experience on fate of carbon and unintended consequences. Natural Fe-rich analogs provide valuable insight on larger temporal and spatial scales.	**Low–Medium** Various technologies have been demonstrated for artificial upwelling (AU), although primarily in coastal regimes for short duration. Uncertainty is high and confidence is low for CDR efficacy due to upwelling of CO2, which may counteract any stimulation of the biological carbon pump (BCP).	**Medium–High** Science of macrophyte biology and ecology is mature; many mariculture facilities are in place globally. Less is known about the fate of macrophyte organic carbon and methods for transport to deep ocean or sediments.	**Low–Medium** There is abundant evidence that marine ecosystems can uptake large amounts of carbon and that anthropogenic impacts are widespread, but quantifying the collective impact of these changes and the CDR benefits of reversing them is complex and difficult.	**Low–Medium** Seawater CO2 system and alkalinity thermodynamics are well understood. Need for empirical data on alkalinity enhancement; currently, knowledge is based on modeling work. Uncertainty is high for CDR efficacy and possible impacts.	**Low–Medium** Processes are based on well-understood chemistry with a long history of commercial deployment, but is yet to be adapted for CO2 removal by ocean alkalinity enhancement (OAE) beyond benchtop scale.

	Ocean Nutrient Fertilization	Artificial Upwelling/ Downwelling	Seaweed Cultivation	Ecosystem Recovery	Ocean Alkalinity Enhancement	Electro-chemical Processes
Efficacy What is the confidence level that this approach will remove atmospheric CO2 and lead to net increase in ocean carbon storage (low, medium, high)	**Medium–High** Confidence BCP known to work and productivity enhancement evident. Natural systems have higher rates of carbon sequestration in response to iron but low efficiencies seen thus far would limit effectiveness for CDR.	**Low Confidence** Upwelling of deep water also brings a source of CO2 that can be exchanged with the atmosphere. Modeling studies generally predict that large-scale AU would not be effective for CDR.	**Medium Confidence** The growth and sequestration of seaweed crops should lead to net CDR. Uncertainties about how much existing net primary production (NPP) and carbon export downstream would be reduced due to large-scale farming.	**Low–Medium** Confidence Given the diversity of approaches and ecosystems, CDR efficacy is likely to vary considerably. Kelp forest restoration, marine protected areas, fisheries management, and restoring marine vertebrate carbon are promising tools.	**High Confidence** Need to conduct field deployments to assess CDR, alterations of ocean chemistry (carbon but also metals), how organic matter can impact aggregation, etc.	**High Confidence** Monitoring within an enclosed engineered system, CO2 stored either as increased alkalinity, solid carbonate, or aqueous CO2 species. Additionality possible with the utilization of by-products to reduce carbon intensity.
Durability Will it remove CO2 durably away from surface ocean and atmosphere (low, <10 years; medium, >10 years and <100 years; high, >100 years) and what is the confidence (low, medium, high)	**Medium** 10–100 years Depends highly on location and BCP efficiencies, with some fraction of carbon flux recycled faster or at shallower ocean depths; however, some carbon will reach the deep ocean with >100-year horizons for return of excess CO2 to surface ocean.	**Low–Medium** <10–100 years As with ocean iron fertilization (OIF), dependent on the efficiency of the BCP to transport carbon to deep ocean.	**Medium–High** >10–100 years Dependent on whether the sequestered biomass is conveyed to appropriate sites (e.g., deep ocean with slow return time of waters to surface ocean).	**Medium** 10–100 years The durability of ecosystem recovery ranges from biomass in macroalgae to deep-sea whale falls expected to last >100 years.	**Medium–High** >100 years Processes for removing added alkalinity from seawater generally quite slow; durability not dependent simply on return time of waters with excess CO2 to ocean surface.	**Medium–High** >100 years Dynamics similar to OAE.

Table 2b: Proposed research gaps and funding needed to fully develop Ocean Carbon Removal technologies.
A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration | The National Academies Press (nap.edu)

Synthesis and Research Strategy

	Estimated Budget	Duration (years)	Total Budget
Ocean Fertilization			
Carbon sequestration delivery and bioavailability	$5M/yr	5	~$25M
Tracking carbon sequestration	$3M/yr	5	~$15M
In field experiments- >100 t Fe and >1,000 km2 initial patch size followed over annual cycles	$25M/yr	10	~$250M
Monitoring carbon and ecological shifts	$10M/yr	10	~$100M
Experimental planning and extrapolation to global scales	$5M/yr	10	~$50M
Total Estimated Research Budget	$48M/yr	5 - 10	$440M
Estimated Budget of Research Priorities	$33M/yr	5 - 10	$290M
Artificial Upwelling and Downwelling			
Technological readiness: Limited and controlled open-ocean trials to determine durability and operability of artificial upwelling technologies (~100 pumps tested in various conditions)	$5M/yr	5	$25M
Feasibility Studies	$1M/yr	1	$1M
Tracking carbon sequestration	$3M/yr	5	$15M
Modeling of carbon sequestration based upon achievable upwelling velocities and known stoichiometry of deep-water sources. Parallel mesocosm and laboratory experiments to \ assess potential biological responses to deep water of varying sources	$5M/yr	5	$25M
Planning and implementation of demonstration-scale in situ experimentation (>1 year, >1,000 km) in region sited-based input from modeling and preliminary experiments	$25M/yr	10	$250M
Monitoring carbon and ecological shifts	$10M/yr	10	$100M
Experimental planning and extrapolation to global scales (early for planning and later for impact assessments)	$5M/yr	10	$50M
Total Estimated Research Budget	~$54/yr	5 - 10	$466M
Estimated Budget of Research Priorities	$5M/yr	5 - 10	$25M
Seaweed Cultivation			
Technologies for efficient large-scale farming and harvesting of seaweed biomass	$15M/yr	10	$150M
Engineering studies focused on the conveying of harvested biomass to durable oceanic reservoir with minimal losses of carbon	$2M/yr	10	$20M
Assessment of long-term fates of seaweed biomass and by-products	$5M/yr	5	$25M
Implementation and deployment of a demonstration-scale seaweed cultivation and sequestration system	$10M/yr	10	$100M
Validation and monitoring the CDR performance of a demonstration-scale seaweed cultivation and sequestration system	$5M/yr	10	$50M
Evaluation of the environmental impacts of large-scale seaweed farming and sequestration	$4M/yr	10	$40M
Total Estimated Research Budget	$41M/yr	5 - 10	$385M
Estimated Budget of Research Priorities	$26M/yr	5	$235M

Our team integrated the suggestions from A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration with feedback from our own stakeholders, from the survey and interviews collected in this study. We have attempted to simplify the “sweet-spot” technologies more likely to attract investors for nearer term project developments - adding context of local Australian and New Zealand research, investability and regulatory approvals. The simplified summary is represented - where macroalgae and blue coast carbon projects are more ready for investible developments.

Investor ready | On the way to be investor ready | Significant further work required to be investor ready

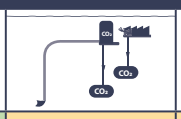
	Sea grass, tidal marsh, and mangrove protection and restoration	Offshore energy production (wind, solar, wave hydrogen)	Terrestrial biomass sinking	Macroalgae cultivation	Offshore C capture and storage	Krill (and marine vertebrate? cultivation and sinking	Geo-engineering (ocean fertilisation, alkalisation, & increasing ocean reflectivity)
Key Projects							
Research	✓ Available	○ Further research needed	✓ Available	✓ Available	○ Medium	○ Further research needed	○ Further research needed
Prototyping, Implementation, Testing	✓ Complete	○ Partly lacking	○ Partly lacking	✓ Complete	○ Medium	✗ Lacking	○ Partly lacking
Risks	✓ Low	○ Medium	✓ Low	✓ Low	○ Medium	○ Medium	✗ High
Funding Availability	○ Medium	✓ High	○ Medium	○ Medium	✓ Available	✗ Low	✗ Low
Carbon Accounting Tools	✓ Available	✓ Available	✓ Available	○ Medium	✓ Available	✗ Lacking	✗ Lacking
Co-benefits	✓ High	○ Medium	✗ Low	○ Medium	✗ Low	○ Medium	✗ Low

Figure 13: Ocean Carbon Readiness Matrix for Investible Ocean-based Carbon removal and Ocean-Derived Negative Emissions Project Development opportunities.

Key Ocean Carbon Research and Project Developments Progressing

If we look globally, there are a number of highly strategic research developments underway that will influence Australia and New Zealand's carbon markets. These are listed below. The most substantial research commissioned are from OceanNETs and Oceans2050. OceanNETs has commissioned research that will address scalable ocean negative emissions technologies, enabling research for ocean carbon markets, with research being conducted in Europe and at CSIRO in Australia. Oceans 2050 is focused on seaweed, leading a global effort to quantify seaweed carbon sequestration. Through the study, they are delivering evidence and the methodologies to validate and monetize the carbon sequestration impact of ocean farming.

The UNFCCC publishes a list of funding announcement on this site List of Recent Climate Funding Announcements | UNFCCC, many are linked to Blue or Ocean Carbon research and project developments.

Table 3: Example ocean carbon research linked and enabling large scale project developments.

Company/project	Funding source	Description	Due
OceanNETs	European Union's Horizon 2020 Research and Innovation Programme	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.	2025
XPrize Carbon Removal	Elon Musk and the Musk Foundation	USD$100 million prize purse, XPRIZE Carbon Removal is aimed at tackling the biggest threat facing humanity - fighting climate change and rebalancing Earth's carbon cycle. It is the largest incentive prize in history, an extraordinary milestone. This four-year global competition invites innovators and teams from anywhere on the planet to create and demonstrate solutions that can pull carbon dioxide directly from the atmosphere or oceans, and sequester it durably and sustainably. To win the grand prize, teams must demonstrate a working solution at a scale of at least 1000 tonnes removed per year; model their costs at a scale of 1 million tonnes per year; and show a pathway to achieving a scale of gigatonnes per year in future. There are 52 teams from Australia and 12 from New Zealand, with approximately half registered under the 'Oceans Track' ; driving some innovative solutions.	2025
Oceans 2050	Philanthropy	The study will quantify carbon sequestration by seaweed in sediment below seaweed farms, advancing the scientific basis for seaweed aquaculture as a solution to helping sequester carbon as well as contributing to ocean restoration. The findings will also contribute to the creation of market incentives for carbon sequestration through seaweed aquaculture.	2022
CSIRO 'Estimating Australia's blue carbon potential'	CSIRO + BHP	This program will measure and quantify the net emissions reduction potential of Australia's mangroves, seagrasses and tidal marshes. The program will also quantify the value of other benefits these ecosystems provide for coastal protection, fisheries and biodiversity. BHP recently committed US$2.4 million to a research program that, in part, will measure and quantify coastal blue carbon potential that could be implemented through Australia's Emissions Reduction Fund.	2024
Oceans 2050	Philanthropy	The study will quantify carbon sequestration by seaweed in sediment below seaweed farms, advancing the scientific basis for seaweed aquaculture as a solution to helping sequester carbon as well as contributing to ocean restoration. The findings will also contribute to the creation of market incentives for carbon sequestration through seaweed aquaculture.	2022
CSIRO 'Estimating Australia's blue carbon potential'	CSIRO + BHP	This program will measure and quantify the net emissions reduction potential of Australia's mangroves, seagrasses and tidal marshes. The program will also quantify the value of other benefits these ecosystems provide for coastal protection, fisheries and biodiversity. BHP recently committed US$2.4 million to a research program that, in part, will measure and quantify coastal blue carbon potential that could be implemented through Australia's Emissions Reduction Fund.	2024
Blue Carbon strategy for South Australia	State Government	The State Government will forge partnerships with industry, research and community stakeholders to promote blue carbon opportunities and co-benefits.	2025
Climate foundation - Marine Permaculture	Philanthropy	The creation and piloting of "wave-energy powered floating platforms that restore nutrient upwelling to pre- global warming levels. While the nutrients encourage plankton and kelp growth, the platform provides a structure onto which kelp will attach. In essence, this forms a mini-ecosystem... What was once an aquatic desert will thrive with life."	Various

The kelp-mussel co-culture project	Ministry of Business, Innovation and Employment; NZ Endeavour Fund; Nature Conservancy	Blue Carbon Services is proposing to develop a large-scale kelp aquaculture for deep-ocean carbon sequestration. They aim to have 2,000 ha of open-ocean kelp by 2030 sequestering ~74,000t CO2/yr. and producing 14,000t Greenshell Mussels.	2022+
Quantifying Blue Carbon: kelp contribution to carbon sequestration in marine sediments	Endeavour Fund	The project outcomes will provide data required to include kelp-sequestered carbon into New Zealand's carbon budget and potentially inclusion in carbon markets (voluntary and mandated). This will incentivise the protection of existing natural kelp beds and the development of new kelp aquaculture.	2025
Kelp Blue https://kelp.blue/ and the Kelp Forest Foundation https://kelpforestfoundation.org/	Kelp Blue; Kelp Forest Foundation	Five research projects supporting the Kelp Blue offshore Macrocystis farm in Lüderitz, Namibia: 1) Kelp carbon dioxide removal model; 2) Impact of biodiversity- baseline for fauna and flora; 3) Impact on geochemistry- baseline; 4) Kelp carbon in sediments – baseline. Similar projects planned for Aotearoa New Zealand and Alaska.	2021-2024
FutureFeed (future-feed.com)	FutureFeed (future-feed.com)	Investigating biodiversity risks in cultivating Asparagopsis within the EU. Asparagopsis grows in several locations in Europe and Asparagopsis is not part of the official "List of Invasive Alien Species of Union Concern". https://ec.europa.eu/environment/nature/invasivealien/list/index_en.htm The impact of Asparagopsis affecting biodiversity negatively is being investigated. This addresses concens of the EU commission regulating cultivation of Asparagopsis in the EU, that will support better understanding of this risk.	2022+

3.2. Ocean Carbon Market Size (Supply/Demand)

We assessed the market opportunity for Australian and New Zealand developed ocean carbon offset projects (supply/demand). Using the definitions we asked developers about types and scale of ocean carbon projects in Australia and regional waters, utilising inputs available publicly.

Responses to our survey question on the potential market size of ocean carbon markets offsets globally, in billions of Tonnes CO^2-e emissions ranged:

- **by 2030: globally 2-6 billion tons a year**
- **by 2050: globally 10-20 billion tons a year**

If we ran a sensitivity assessment of the $USD value of the potential size of ocean carbon markets, using a carbon market price per ton range of $50-$200. At the lower end of that scale at a carbon price of $50/ton CO^2-e, based on the perceptions of market size from our survey participants, there is a market range of 100-300million, and at the higher end of $200/ton CO^2-e, market size is more like $1.2trillion, as shown in *Figure 13*. This is supported by the indicative investment budget available to the survey participants for eligible ocean carbon project investments.

In the past 12 months, there has been a huge uptake across most top 100 listed companies, as well as private and public sector organisations, making commitments to reduce emissions. Those surveyed confirmed their company's commitments. Figure 11 shows the popularity across our survey participants for the Climate Active program (Australian), Science Based Targets, Net Zero (100% emissions reduction) by 2050 and Net Zero (100% emission reduction) by 2030.

When the surveyed Industry participants were asked which decarbonisation approaches are priorities in their company's emissions reduction strategies? 80% were choosing Project Origination of negative emissions projects while also Reducing their Scope 1 & 2 & 3 emissions via decarbonisation and transitioning business products and services to low emissions alternatives.

This growing trend to self-develop rather than rely on market trading for accessing carbon credits is contributing to the demand for nature based solutions such as ocean carbon projects.

1. Reduce Scope 1 & 2 & 3 emissions via decarbonisation and transitioning business products and services to low emissions alternatives
2. Offsets (develop own projects): Collaborative partnerships with solutions providers and carbon offset project developers (on company owned/ leased assets) i.e project origination
3. Reduce Scope 1 & 2 emissions via operational improvement: energy efficiency and technology upgrade programs
4. Offsets (partial develop and invest in developments): Contribute assets/operational support for a partial ownership of the carbon offsets generated. i.e project development alongside a specialist carbon project development team/organisation.
5. Offsets (invest in developments): Collaborative partnerships with solutions providers and carbon offset project developers (not on company owned/ leased assets)
6. Offsets (purchase only) - International (via carbon traders)
7. Offsets (purchase only) - Australia/NZ (via carbon traders)

Half the project developers we engaged with are focused on building over 1M ton/year CO2 removal.

All these elements lead to the defining of a large scale demand-side of the market for ocean carbon removal projects.

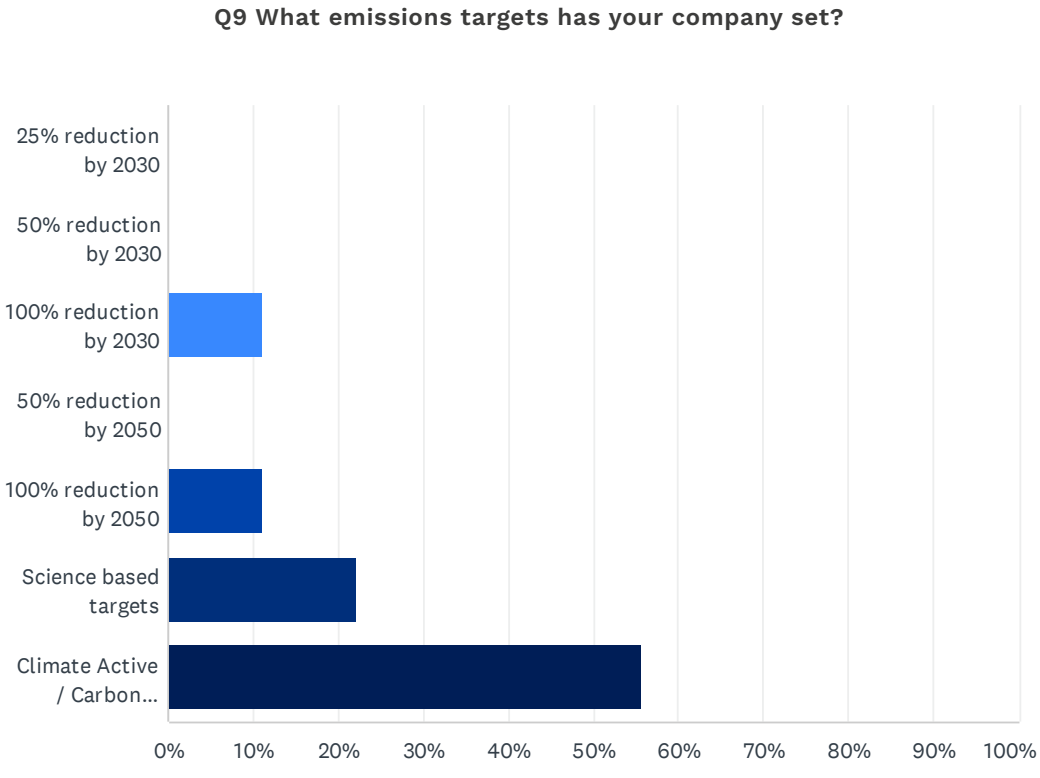


Figure 14: Typical Emissions Targets (Survey responses).

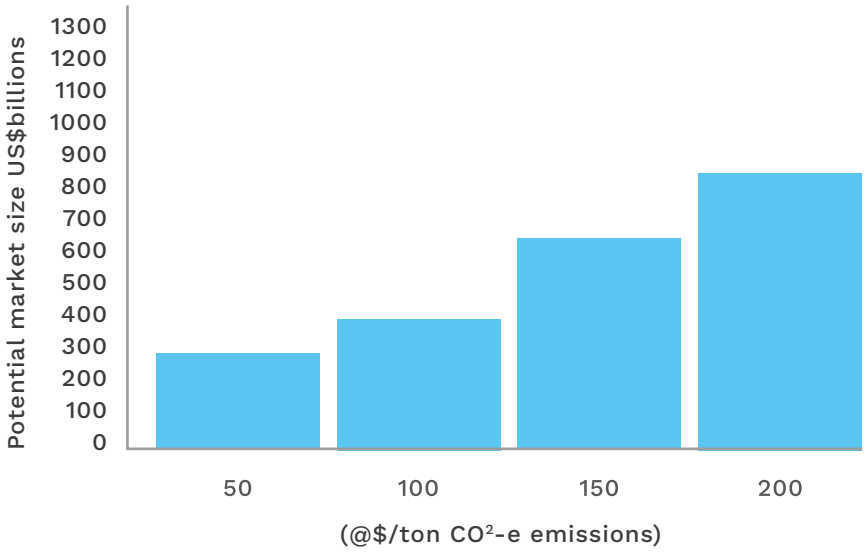


Figure 15: Potential Market Size for Ocean Carbon Market Activity by 2050 as provided by survey respondents ($USD billions).

Supply: Market supply of Ocean Carbon

At 10 million square kilometres, Australia has one of the world's largest Exclusive Economic Zones (an area of coastal water and seabed within a certain distance of a country's coastline, to which the country claims exclusive rights for fishing, drilling, and other economic activity). In combination with New Zealand's 4 million square kilometres, this leaves a lot of (mostly unused) room for the potential supply of ocean-based carbon projects. There is currently a gap between the potential and actual supply of ocean-based carbon projects.

For the full scale of the ocean carbon market opportunity to be realised, we need to move beyond coastal ecosystems to support carbon offset markets with units of carbon credits, via the development of ocean carbon projects. One survey respondent commented:

> ***There is a limited ocean-based potential in Australia and NZ coastal zones, with the opportunity to export knowledge and expand development of carbon removal in the mid-ocean zones are key for going multi-billion market scale for ocean carbon markets.***

We are already seeing significant private enterprises such as Kelp Blue (www.kelp.blue) entering into seaweed cultivation, harvesting and processing, which will grow the potential supply of large-scale carbon dioxide drawdown through its offshore cultivated kelp forests. The assessment of carbon dioxide drawdown removal of the operations (already underway in Namibia), is estimated to be between 1500-3000 tons of carbon dioxide per km².

Quantification of the carbon removal and biodiversity co-benefits of seaweed cultivation will complement the current business case for the production of sustainable agri-foods, fertiliser, pharmaceuticals and textiles. Kelp Blue is partnering with the Kelp Forest Foundation to fund research in Aotearoa New Zealand, Alaska, and Namibia, supporting offshore *Macrocystis pyrifera* cultivation.

Case Study

Kelp Blue: Building the World's first singular large-scale giant kelp farm in exposed waters, Namibia

www.kelp.blue

Kelp Blue grows giant kelp forests (Macrocystis pyrifera) at commercial scale to restore ocean health through carbon sequestration, de-acidification, and increased biodiversity.

Kelp Blue is removing barriers to scale seaweed farming by cultivating offshore and choosing a species not requiring annual re-planting. By only harvesting the canopy, leaving roughly 80% of the biomass in the water, it allows them to take more advantage of the environmental benefits of kelp forests. The harvested material will be used as sustainable input material to many historically environmentally damaging industries like chemical fertilisers, animal feed industry and the textile and single-use plastic industry.

In 2021 the pilot operations commenced in Lüderitz, Namibia. Lüderitz has the ideal conditions (clear, clean, cold waters) for cultivating giant kelp (Macrocystis pyrifera). The kelp will benefit from the constant upwelling of the Benguela Current, as well as strong and consistent hours of sunlight. The cultivated kelp forest is expected to draw down over 1-million-ton CO2/year and aid in boosting regional fish stocks and increase in marine biodiversity in the surrounding area. Kelp Blue is currently exploring potential opportunities in Australia and Aotearoa New Zealand.

These projects will be building on the learnings from Kelp Blue's operations in Namibia, where all initial engineering and environmental baseline assumptions will be validated.

Kelp Blue is partnering with the Kelp Forest Foundation (https://kelpforestfoundation.org/), a Dutch non-profit entity set up with the purpose of unlocking the power of kelp afforestation to mitigate the effects of climate change. The Kelp Forest Foundation (KFF) is doing so by funding research that will help fill the gaps in the science and knowledge of the many ecosystem benefits of giant kelp cultivation and making these findings publicly available for the benefit of the entire industry. Cultivated kelp forests will likely provide similar benefits resulting in an increase in biodiversity, enhanced production of local fisheries and an improvement in ecosystem resilience but this needs to be measured and quantified. KFF will also be researching and measuring the extent cultivated kelp forests will impact the surrounding flora and fauna.

KFF sponsors MSc and PhD students around the world to undertake fauna and flora baseline studies beginning in January 2022, as well as supporting further independent research.

The Kelp Blue project in Namibia offers a unique opportunity to research giant kelp cultivation in the Benguela Current and use it as a "before and after" comparison test site. This will help fill some of the deep knowledge gaps around the true impacts of kelp cultivation at scale.

Supply: Ocean-carbon projects are being developed (globally) and scale

It became apparent during our interviews with stakeholders, that many were not aware of the current level of recent global project developments of blue and ocean carbon projects.

The list in Table 4 provides summary level insight into a sample of globally active projects that are funded and hence meet investable criteria. Collectively they make up a supply of over 6.5 million tons of CO2-e emissions sequestered annually.

Table 4: List of global ocean-carbon projects, outlining which methodologies and standards were used as the foundation of these projects.

Project name	Country	Status	Description of activities	Methodology	Standard	Estimate of tCO2e sequestered annually
Blue Carbon Project Gulf of Morrosquillo	Colombia	Active	Mangrove protection - avoided emissions	VM0007	Verra	31,310
Carbon sequestration in mangroves of the South-Central coastal zone of the state of Sinaloa, Mexico	Mexico	Under development	Reforestation and conservation of mangrove swamp	VM0007	Verra	3,123,836
Delta Blue Carbon -1	Pakistan	Under validation	Afforestation, Reforestation and Revegetation of tidal wetlands	VM0003	Verra	2,000,000
India Sunderbans mangrove restoration	India	Active	Mangrove restoration through reforestation	AR-AM0014	Verra	51,249
Livelihoods' mangrove restoration grouped project in Senegal	Senegal	Active	Afforestation, Reforestation and Revegetation of degraded wetlands	AR-AM0014	Verra	30,000
Mangrove restoration and coastal greenbelt protection in the east coast of Aceh and North Sumatra province	Indonesia	Active	Increasing the environmental carrying capacity of mangrove ecosystems, restoration of degraded mangroves	AR-AM0014	Verra	124,706
Mangrove restoration and sustainable development in Myanmar	Myanmar	Under development	Afforestation, Reforestation and Revegetation of mangroves	AR-AM0014	Verra	460,954
Mikoko Pamoja	Kenya	Active	Mangrove protection and forestation		Plan Vivo	2,500

Image Courtesy of Tassal.

Reforestation and restoration of degraded mangrove lands, sustainable livelihood and community development in Myanmar	Myanmar	Active	Afforestation, Reforestation and Revegetation of mangroves	AR-AM0014	Verra	184,006
Restoring Wetlands on California Department of Water Resources-Owned Areas of Twitchell and Sherman Islands	US	Active	Wetland restoration	Criteria for 'The Restoration of California Deltaic and Coastal Wetlands' methodology	American Carbon Registry	40,425 (average)
Small-scale and low-income community-based mangrove afforestation project on tidal flats of three small islands around Batam City, Riau Islands Province, Republic of Indonesia	Indonesia	Active	Mangrove afforestation	AR-AMS0003	CDM	3,821
SWAMP	Senegal and West Africa	Under development	Afforestation, Reforestation and Revegetation of mangroves	VM0007	Verra	2,547
Tahiry Honko	Madagascar	Active	Conservation, reforestation and sustainable use of magroves	CDM AR-AM0014 and VCS VT0001	Plan Vivo	1,443
The Haidar El Ali Mangrove Initiative (HEAMI)	Senegal	Under development	Restoration of degraded wetlands by reforestation of mangrove patches	AR-AMS0003	Verra	30,170
Vanga	Kenya	Active	Mangrove conservation and restoration	VCS VM0033 and CDM AR-Tool 14	Plan Vivo	5,019
Zhanjiang mangrove afforestation project	China	Active	Mangrove afforestation	VM0007	Verra	4,020

Demand: Assessment of Project Demand of Ocean

While global ocean-based carbon markets were identified as being immature/maturing at a slow rate at the present time it was commonly estimated that the potential ocean-based carbon market size will be larger than the land-based carbon market by 2050.

Companies identified that developing their own carbon offset projects is regarded as a priority. Additionally, reducing emissions via operational improvement and via decarbonisation and low emission alternatives was regarded highly by participants. There is a large amount of interest in seaweed-related projects, however, additional research is required before these types of projects can become commercialised.

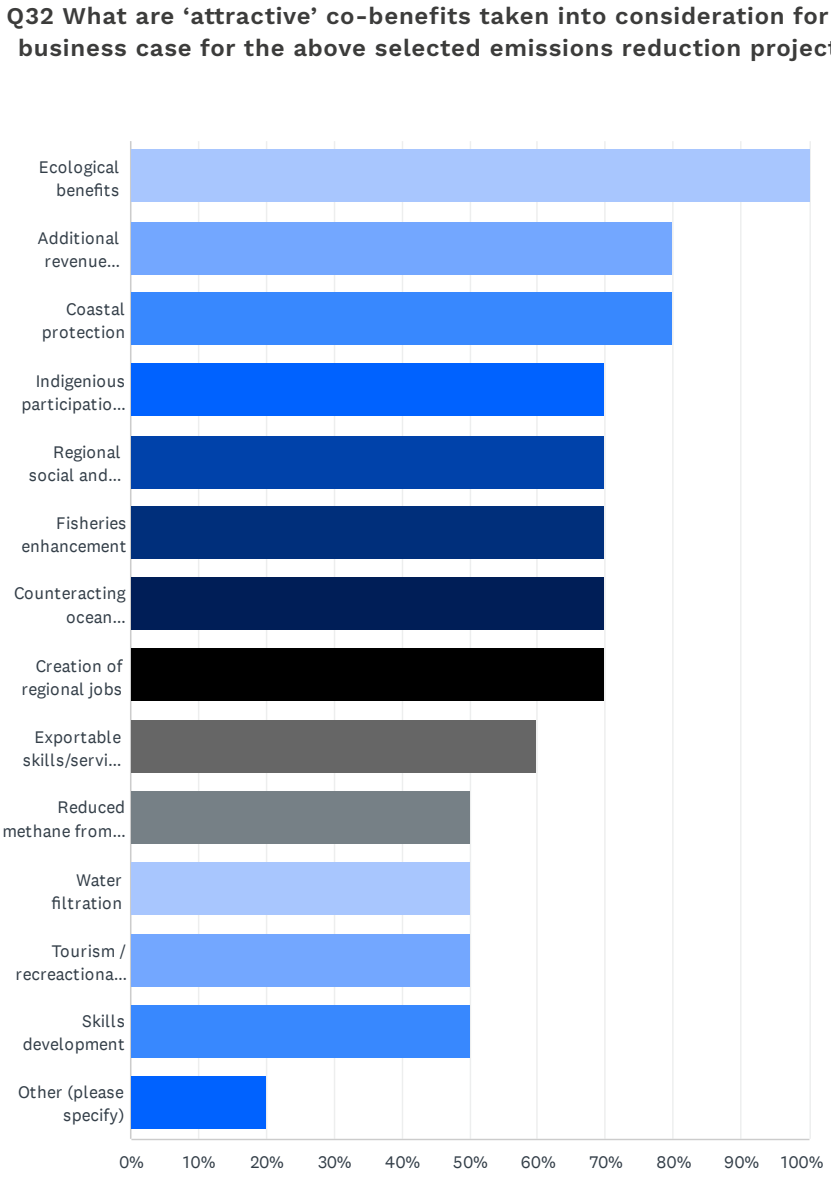


Figure 16: Co-benefits ranked by attractiveness (from survey responses).

Carbon offsets go far beyond solely emissions reduction, they provide many other co-benefits. These include but are not limited to: environmental, socio-economic, indigenous, and educational co-benefits. Our survey participants indicated that investments with multiple co-benefits are valued highly. The following co-benefits were identified as being most highly regarded:

Additional revenue opportunities from sales of by-products, regional social and economic benefits, ecological benefits. Figure 12 indicates the list of 'attractive' co-benefits as identified by survey respondents.

The survey identified that ocean-based carbon projects could generate an accumulated potential of 5300 to 6900+ FTE jobs by 2030 in Australia and New Zealand. While co-benefits can be difficult to quantify, projects such as "Natural Capital Accounting and Valuation of Ecosystem Services" (NCAVES) and the "Land Restoration Fund (LRF) Co-Benefits Standard'' are providing ways to improve the measurement of ecosystem services and their co-benefits.

Potential for 5,300 to 6,900 jobs to be created from ocean carbon markets.

Our survey participants ranked challenges with project delivery of ocean-based carbon projects facing industry and project developers, these are (starting with the most challenging):

1. Lack of standardised methods to quantify and value co-benefits (social, economic and environmental benefits) that align with investable metrics.
2. The high costs connected to rigorous and bespoke carbon accounting requirements to satisfy regulatory requirements are prohibitive.
3. There are diverse opinions across regulators, carbon markets experts and scientists on readiness of research and methodologies in the ocean carbon sector.
4. There are diverse opinions on the future availability/quality/validity of some voluntary carbon markets that is limiting confidence in valuing ocean-based carbon projects today.
5. The community perception of social license issues of projects is not clear and presents a project execution risk.

One respondent commented:

> ***It is not easy to navigate options available now to apply carbon accounting or natural capital accounting standards to satisfy investment requirements for my projects.***

Demand: What is the Investment Ecosystem for Ocean Carbon projects?

There is a complex web of investment opportunities matching a range of potentially eligible ocean carbon projects. Groups like Investable Oceans have been helping make the process to invest more accessible and transparent.

When analysing the United Nations Climate Change and Climate Funding Announcement List of Recent Climate Funding Announcements | UNFCCC, we can confirm there is substantial funding available, which is on top of the funding available from the private sector and philanthropic sources that contribute to the ecosystem.

Image Courtesy of Tassal.

Case Studies

HSBC funds a project to establish a blueprint for a mangrove bond

HSBC Australia and London-based Earth Security have launched a new project that will develop a framework for a mangrove bond that can be used to protect and restore vital natural habitats. The project will develop a blueprint for a mangrove bond that could be used by issuers in Australia and other global markets.

The Australia-first project is part of HSBC Australia's broader commitment to developing new financial tools, including nature-based climate solutions, which can support the transition to a low carbon economy and also protect livelihoods in local communities.

The two-year project builds on previous work conducted by Earth Security in collaboration with HSBC's Centre for Sustainable Finance and other global partners. This previous work identified the opportunity for municipal districts and cities to issue bonds to support mangrove ecosystems and also 40 specific locations, including Brisbane and Darwin, with the potential to do so.

Mangroves are a cost-effective climate solution which act as a natural barrier to storm damage, providing an estimated USD65 billion in storm and flood protection to coastal properties around the world every year. Mangroves capture and store, or sequester, carbon up to 400% faster than tropical rainforests.

Mangroves have economic benefits too. Fish found in mangroves and similar ecosystems contribute 75% of Australia's commercial fishery catch and 90% of our recreational fisheries.

The new project will aim to design a practical bond model for the Australian market in consultation with stakeholders across the scientific, conservation, governance and financial sectors.

Municipal bonds are already a proven method of financing climate resilient infrastructure. More than half of the largest US cities have issued municipal bonds to fund resilience projects, including projects related to mangroves and seawall construction.

Green Climate Fund

www.greenclimate.fund

Developed countries announced pledges totalling USD 10.1 billion during the initial resource mobilization of the Green Climate Fund. The Green Climate Fund operates through a network of over 200 accredited entities and delivery partners who work directly with developing countries for project design and implementation. Partners include international and national commercial banks, multilateral, regional and national development finance institutions, equity funds institutions, United Nations agencies, and civil society organizations. This open partnership enables the Fund to foster unprecedented coalitions between private investors, development agencies and civil society organizations to achieve transformative change and support harmonization of standards and practices. GCF can structure its financial support through a flexible combination of grant, concessional debt, guarantees or equity instruments to leverage blended finance and crowd-in private investment for climate action in developing countries. This flexibility enables the Fund to pilot new financial structures to support green market creation.

Open funding opportunities for Ocean Carbon projects

From our direct engagement with investors, it has been established that there is an excess of funds of more than a trillion dollars, available for suitable projects that meet funding criteria for nature based solutions driving negative emissions, that include ocean carbon projects. The criteria (timelines for ROI, assurance requirements, verification standards, quantified co-benefits) all vary as per *Table 6*.

Industry participants are gaining more complex requirements and larger budgets for projects which consider the future development (scope 3 emissions) global supply chain and seek to decarbonise with second-order and third-order effects.

Investors surveyed announced their investment will be outside of Australia. Most likely to start with mangrove restoration before moving to more offshore solutions. One survey participant confirmed they have up to AUD $1trillion available for ocean carbon projects if they met their investable criteria developed for Blue Impact Bonds.

There seems to be a hunt for scale, with one participant confirming “scale needs to be at hundreds of millions of dollars this decade” and others confirmed they have unallocated funds available for “Domestic (NZ) seaweed focus $10-15m. International (Pacific / Asia) seaweed, seagrass, mangroves - $50-100m”.

Table 5: Ocean Carbon Markets - Examples of Financing Mechanism and Stakeholders supporting Blue and Ocean carbon Programs. (source: various, including Envirostat)

1. Blue Impact Bonds	HSBC said it will speed up the issuance of blue impact bonds and other green assets that can be used to fight climate change and improve livelihoods in coastal regions. (HSBC to fund Australia project with US$800,000 | RFI Global (rfigroup.com)). HSBC has teamed up with The Nature Conservancy Australia to announce a new project called Blue Impact Bonds for Nature, to be funded by a US$800,000 grant from the global lender. The Nature Conservancy Australia will use the grant to identify nature-based restoration activities which will improve livelihoods, biodiversity, and climate change mitigation outcomes on the mid-north New South Wales coast. The project will also establish a framework for capital market assets that can be used to raise conservation finance, in a further step toward establishing natural capital as an investment asset class. Blue bonds are debt securities that are issued to raise capital specifically to restore the ocean’s ecosystems. Blue Impact Bonds for Nature is part of HSBC’s new global Climate Solutions Partnership, which will provide US$100 million in funding over five years to help climate-related companies and projects reach commercial viability.
2. Equity funds - various	Examples of equity funds targeting the blue economy sectors, ocean health and sustainability are DWS Concept ESG Blue Economy, BNP Paribas Easy ECPI Global ESG Blue, Credit Suisse Ocean Engagement Fund and Eurazeo Sustainable Maritime Infrastructure thematic fund.
3. PES Queensland, Australia	**Reef Credits Scheme** HSBC and the Queensland government have become the first purchasers of “reef credits”, a novel financial instrument that pays farmers to improve water quality by reducing the pollution load that runs off into the Great Barrier Reef. The scheme is part of a larger strategy from the bank to become net-zero, which includes a goal of providing USD750 billion to USD1 trillion of sustainable financing and investment until 2030. Issued by GreenCollar, reef credits are based on a similar structure of payment for carbon credits. Metrics for credits attribution involve reducing the amount of nitrogen and sediment that runs into the ocean by adopting improvements in farming practices. The investment required to meet water quality targets for the reef is estimated to be at least AUD4 billion. HSBC and the Queensland government have together purchased about AUD1 million in Reef Credits. The money has been earmarked to help farms implement better fertiliser management to prevent more than 3,000 kilograms of nitrogen from entering the Great Barrier Reef area.
4. INSURANCE Mexico, Honduras, Belize, Guatemala	**Blue Natural Capital Finance Facility Marine Protected Area** Innovative nature-based tourism solutions and blue carbon credits from the conservation of mangroves are business models adopted by the partnership between the government of Belize, Mirova (through the Althelia Sustainable Ocean Fund) and IUCN (International Union for Conservation of Nature) through its Blue Natural Capital Finance Facility. The group also counts with Blue Finance, a specialised impact investment project developer for MPAs. An amount of US$1.2 million allows the Marine Protected Area co-manager, Turneffe Atoll Sustainability Association (TASA), to implement the sustainable revenue-generating initiatives. This agreement redistributes the financial burden and attracts long-term economic and technical support needed for effective management.

6. **BLUE CARBON** Gulf of Morrosquillo, Colombia	**Blue Carbon Project Gulf of Morrosquillo** The Blue Carbon Project Gulf of Morrosquillo was developed by Conservation International in partnership with several local institutions and organisations. Funding was provided by Apple and the technical support of South Pole. The project used a Verra methodology (VM0007) that was revised in September 2020 to include tidal wetland conservation and restoration activities. The Project began on May 15, 2015 and will have an expected duration of 30 years; during this period, the reduction of 1,221,717 tCO2e. The project was recently accredited (May, 2021) with 9664 VCS and the revenue obtained with the credits generated will contribute to a centralised fund.
7. **LOANS** Chile	**Rabobank's Sustainability-linked loans for salmon production** RaboFinance Chile - a subsidiary of Rabobank Salmon selected producers Blumar and Ventisqueros to receive green loans, which come with a series of sustainability commitments the companies must meet. Rabobank and the World Wildlife Fund have partnered with Chile's farmed salmon leaders to find a path to the retail shelf for sustainable, certified and traceable fish. With technical support and advice from WWF, to finance part of its recent acquisitions in the Chilean salmon industry. The loan is a seven-year agreement with several green conditions such as a commitment to reduce antibiotic use in salmon farming, increase the number of certifications and implement an aquaculture improvement program for production centres.
8. **BLUE BOND** Baltic Sea	**Nordic Investment Bank (NIB) Nordic-Baltic Blue Bonds** The Nordic Investment Bank launched a "Nordic-Baltic Blue Bond" in January of 2019, raising SEK2 billion (around US$ 228M at current exchange rates) for projects such as wastewater treatment, prevention of water pollution and water-related climate change adaptation (NIB, 2019).
9. **BLUE CARBON** Mikoko Pamoja - Gazi-Kwale County, Kenya	**Mikoko Pamoja Blue Carbon Project** Mikoko Pamoja is a community-based organisation established in 2014 to ensure conservation of 117 ha of mangroves in the Gazi bay, Kenya. The project is considered the first blue carbon project accredited by Plan Vivo and has earned a total of 9880 Plan Vivo Certificates (PVC) so far. It involves prevention of deforestation of the local mangrove forest, as well community-based reforestation. The group, through the technical support from Kenya Marine and Fisheries Research Institute (KMFRI) and WWF-Kenya, has established new mangrove and, in return, the community has received a total of Ksh. 2.6 million shillings (around US$24,000 at current exchange rates) over the past two years. Gazi is a subsistence fishing and agricultural community, and extraction of mangrove trees for construction and wood fuel was common practice in absence of alternative affordable energy sources and construction materials.
10. **PES** Casamance and Siné Saloum, Senegal	**Livelihoods Carbon Fund - mangrove restoration and carbon credits** HSBC and the Queensland government have become the first purchasers of "reef credits", a novel financial instrument that pays farmers to improve water quality by reducing the pollution load that runs off into the Great Barrier Reef. The scheme is part of a larger strategy from the bank to become net-zero, which includes a goal of providing USD750 billion to USD1 trillion of sustainable financing and investment until 2030. Issued by GreenCollar, reef credits are based on a similar structure of payment for carbon credits. Metrics for credits attribution involve reducing the amount of nitrogen and sediment that runs into the ocean by adopting improvements in farming practices. The investment required to meet water quality targets for the reef is estimated to be at least AUD4 billion. HSBC and the Queensland government have together purchased about AUD1 million in Reef Credits. The money has been earmarked to help farms implement better fertiliser management to prevent more than 3,000 kilograms of nitrogen from entering the Great Barrier Reef area.
11. **BLUE BOND** Seychelles	The sovereign blue bond was issued in February 2016 and originates from a debt buy-back of USD22 million with Paris Club creditors. The size of bond issuance was a nominal amount of USD 15 million with a maturity of 10 years. Multilateral organizations provided support in the form of a finance package including credit, loans, grants and guarantee. By restructuring part of its national debt, the country was able to generate up to USD 430,000 per year that was used towards the protection of 86 million acres of the ocean, which corresponds to more than 30% of Seychelles' EEZ.
12. **BLENDED FINANCE** Global	**The Global Fund for Coral Reefs (GFCR)** The GFCR is designed as a 10-year $625 million blended finance vehicle with a first grant window and a second investment window. The grant window seek to incubate a pipeline of investible projects, grant capital is sequenced to build local capacity and de-risk the private sector role in the burgeoning blue economy sector. The investment window provides investment capital to scale initiatives and maximise the impact of projects incubated by the grant window. Guarantees and concessional loans from the GCF, multilateral development banks and other sources are being mobilised to further de-risk investments in the unfamiliar markets of the blue economy and attract private investor capital.

13. **EQUITY FUND** Global	**Althelia Sustainable Ocean Fund** Mirova's Althelia Sustainable Ocean Fund focuses on emerging markets and small island states to channel private investment into the ocean economy and help reverse this decline. As of August 2020, the fund had raised US$132million to provide growth capital to companies in developing countries in Asia, Africa and Latin America that harness the ocean's natural capital, focusing on sustainable fisheries and aquaculture. A sovereign downside guarantee from USAID aims to reduce the investment risk and significant institutional co-investment commitments have also been made. Mirova requires that funds: Δ meet the IFC Social and Environmental Performance Standards; secure certification under "credible schemes"; drive conservation of locally and internationally important natural habitats, wild species and IUCN Red List-threatened species; involve no net loss of biodiversity; and Δ are not involved in the trade of wild animals and plants listed by Convention on International Trade in Endangered Species.
14. **BLUE BOND** Global	**Blue Bonds for Conservation Programme** TNC announced in 2019 the launch of the Blue Bonds for Conservation Programme with plans to implement 20 other similar projects in coastal and island countries. The program seeks to mobilise USD 1.6 billion of funding for marine resources protection through debt-swap mechanisms, replicating the successful experience TNC has had in Seychelles and debt-conversion projects to protect tropical forests in Latin America and Southeast Asia since 2001. The program counts on NatureVest, the investment arm of TNC, to restructure a portion of the country's national debt in a way that reduces its debt burden. This will secure funds for marine conservation activities, including new financial flows that support governments to reach their protection targets for their ocean areas, including for coral reefs, mangroves and other important habitats, and engage in ongoing conservation work such as improving fisheries management and addressing climate change adaptation. TNC counts on raising USD 40.5 million in philanthropic money to initiate projects over the next five years. Another USD 200 million is then secured through a blend of grant funding and private investment to purchase the country's debt. In turn, debt is refinanced in exchange for the country's commitment to direct the funding to ocean conservation, sustainable use of the marine space and to repay commercial lenders

The future outlook on carbon markets

According to Australia's Carbon Market Institute, new rules for international cooperation and carbon markets provide a platform for high integrity, transparency and comparability but will require corporate and national vigilance on integrity and emissions reduction. Under Article 6 of the carbon market rules, COP26 has delivered a platform for greater cooperation and established a governance framework for international emissions trading with the capacity for high integrity. Providing access to authorised 'international mitigation' units will also help to prevent private sector issues around 'double claiming' emissions reductions that are being 'counted' towards nationally determined credits commitments and ensure that such net-zero or carbon neutral claims made by businesses have integrity, are trustworthy and credible.

Here is some of the feedback from COP26, as interpreted and explained by Australia's Carbon Market Institute (see this practical quick lookup guide COP26-Glasgow-Article-6-Explainer.pdf (carbonmarketinstitute.org):

1. Booming global and Australian voluntary carbon markets will now need to appropriately align with these rules to ensure verified emission reductions are eligible for international trading. Indeed our existing and planned emissions trading and crediting verification frameworks, the Safeguard Mechanism backed by Australian Carbon Credit Unit registration and the Indo-Pacific Carbon Offsetting Scheme in development, could help establish international standards and norms of best practice. Agreement was reached on all the major critical issues of double counting, corresponding adjustments, the transition of the Kyoto Protocol's Clean Development Mechanism (CDM) and levying a 'share of proceeds' from global market transactions to help fund global adaptation efforts.
2. The full suite of Article 6 outcomes reached at COP26 (including much-needed definitions) have been outlined in CMI's Article 6 Rulebook Explainer. A Supervisory Body is to be established in 2022 and will be required to approve methodologies and verification frameworks. For market participants, there have been two previously unresolved issues that might have impacted ongoing access to, and engagement in, global voluntary carbon markets.
3. No Double Counting Allowed with requirement for Corresponding Adjustments: There have been ongoing questions about whether units that are generated in sectors not covered by a country's NDC can be freely traded in carbon markets, or whether the need for corresponding adjustments of units between registries would restrict market access to such units. The rules now in place require host countries to 'authorise' new Paris-era units for use either towards (inside) an NDC, or for a non (outside) NDC-related international mitigation purpose.
4. Under Article 6 rules, businesses will be able to invest in emissions reductions abroad, and communicate that they are either contributing towards our domestic national emissions reductions targets, or independently claiming these 'international mitigation' units for their own corporate purposes. All such trades will now require corresponding adjustments to ensure accurate accounting, transparency and integrity (avoiding double counting by countries, or double claiming by other market participants). The exact interaction between Article 6.4 mechanism registries, international COP26 Glasgow registries, and domestic registries under 6.2 bilateral/ multilateral arrangements are for discussion in 2022 and decision at COP27.

Our survey responses identified carbon market mechanisms they would like to see developed to address their expectations, these included:

1. Ocean-based carbon offsets available on trading platforms, which have included co-benefits into their value;
2. Ocean-carbon offsets that have enhanced credibility of assurances by leveraging blockchain for tracking carbon Internationally trading carbon markets;
3. Collectives of smaller ocean-carbon projects bundled into large scale tradable units, with a centralised carbon accounting assurance process across the portfolio of projects;
4. Financial mechanisms for ocean carbon farmers to borrow against;
5. Crypto currency carbon trading platforms;
6. Further ACCU (Australia) certification.

3.3 Risk Assessment

We conducted a Risk assessment from the contributions collected from stakeholders engaged, that identifies mitigating outcomes that address both perceived and real potential negative impacts of ocean carbon projects, as well as opportunities.

A Risk Matrix below (table 6) collates the key risks and suggests mitigations as identified in the various areas of our study (Regulatory/Carbon Markets/Research/Investment/Project Development) where we have asked about risks, barriers, challenges that may prevent full market potential to be released for ocean carbon markets in Australia and New Zealand.

In addition, a number of research areas are already being addressed that will support some of the risks and barriers that are blocking full scale commercialisation of ocean-based carbon markets (Appendix D). The most commonly identified areas were: sequestration/abatement rates, permanency of sequestration, commercialisation models that encourage smaller projects, financial mechanisms for ocean carbon projects, and co-benefits.

Table 6: Risk Matrix: Risks/barriers/challenges to ocean carbon market enablers, with potential mitigation measures and opportunities to enable development. Green text represents a direct response from survey participants.

Ocean Carbon Market enablers	Risks/barriers/challenges as identities in the survey and interviews	Mitigation/Opportunities
Regulatory: Processing and approving new methodologies	The lack of scientific support for applications for ocean-based methodologies + the lack of consistency of project methodologies. The lack of stacking and valuing co-benefits alongside carbon. International voluntary carbon standards are cheaper and easier for project developers to adopt than waiting for domestic regulatory standards development.	More independent research to determine the science needed for scientifically robust and verifiable ocean carbon accounting and subsequent methodologies. Engaging industry experts for the methodology development process. Bootstrap the industry to develop the projects and develop the methodologies in parallel to support these projects. This needs to be supported by rigorous science. Increased collaboration and pioneers in quantifying and supporting/proving the carbon that is sequestered through ocean-based carbon projects. Research to analyse the value of co-benefits and how to incorporate stacking into methodologies. The advancing Natural Capital Accounting following the UN SEEA standards is likely to supersede the need for domestic regulatory standards.
Carbon Markets	Limited approved methodologies under the regulators that do not apply to ocean-based carbon projects. Lack of volume/supply of projects generating ocean-based carbon offsets. Lack of project/investment credentials to meet long term third party verification requirements (leakage, additionality, permanence, prevention of double-counting) NZ - government has not included blue carbon within nationally determined contribution.	Global debate, improved ocean literacy amongst carbon practitioners. Investment in science methodologies and increased understanding of the technologies/more acceptance. “More focus on ocean carbon, better data and education for investors, evidence of cost effectiveness of ocean-based carbon offsets. Viewed as more expensive so therefore easier to stay with tried and true land-based projects. Also perceived as lacking social benefits which needs to be debunked.” Technological solutions approaching commercial TRLs will spur investment, standards and regulatory interest. Other barriers are political and influence based but can be overcome by RE entrepreneurs. developers and investors working collaboratively. Stakeholders working collaboratively Encourage the NZ government to include blue carbon in its NDC programs.

Research	Funding restrictions. Uncertainty around commercialisation of research outcomes. Long timeframes for research findings. Access to ocean/equipment/labour.	Identify funding opportunities and stakeholders for the following research: Δ Carbon sequestration/abatement rates Δ Ocean carbon sequestration periods addressing permanency Δ Financial mechanisms for ocean carbon projects Δ Co-benefits (social, economic, environmental) from proposed development projects Δ Application of consistent measurement and performance reporting standards (natural capital accounting) to ocean-based carbon technologies and projects) Δ Commercialisation models that encourage smaller projects and smaller scale developers to participate in ocean-based carbon markets Δ Impact assessments from proposed development projects (with scale up) Δ Public perception of the risks and opportunities (social license to operate) Δ Market sizing studies for ocean-based carbon technologies and projects Δ Financial mechanisms for ocean-based carbon projects
Project Development	The high costs connected to rigorous and bespoke carbon accounting requirements to satisfy regulatory requirements are prohibitive. It is not easy to navigate options available now to apply carbon accounting or natural capital accounting standards to satisfy investment requirements for my projects. Lack of standardised methods to quantify and value co-benefits (social, economic and environmental benefits) that align to investible metrics. There are diverse opinions across regulators, carbon markets experts and scientists on readiness of research and methodologies in the ocean carbon sector. The community perception of social licence issues of projects is not clear and presents a project execution risk. There are diverse opinions on the future availability, quality and/or validity of some voluntary carbon markets that is limiting confidence in valuing ocean-based carbon projects today.	Unlock private finance. Improved ocean literacy amongst carbon practitioners. Research to analyse the value of co-benefits and how to incorporate stacking into methodologies. Bootstrap the industry to develop the projects and develop the methodologies in parallel to support these projects. This needs to be supported by rigorous science. Increase community engagement in the industry.

4. Conclusions & Recommendations

We asked our stakeholders 'why are there not more approved ocean-based carbon projects in development?', the responses have been collated as recommendations that are addressing the challenges or barriers shared:

1. Prioritisation for the full suite of blue and ocean based carbon markets opportunities to be aligned to land based carbon markets, enabling the opportunity for a strategic national plan for international and domestic supply of project development to participate in emerging international voluntary carbon markets.
    a. Enable or upgrade regulatory mechanisms to also support ocean carbon opportunities alongside land;
    b. Prioritise funding to mobilise more activity targeting the barriers limiting confidence in validating ocean carbon projects today;
    c. Reduce the high costs and accessibility of rigorous and bespoke carbon accounting requirements to satisfy regulatory requirements designed for land-based carbon projects;
    d. Clarify processes for easy access to permits enabling strategic project development access to ocean and blue carbon resources, including access to commonwealth and international waters for ocean harvesting;
2. Engage across research/investor/developer/community stakeholders to align opportunities -
    e. Educate and guide alignment across regulators, carbon markets experts and scientists on readiness of research and methodologies in the ocean carbon sector;
    f. Align and collaborate across blue and ocean carbon industry groups, on mission, priorities and awareness of progress.
3. Greater transparency of financial investment criteria and associated assurance requirements targeting ocean carbon investments:
    g. Knowledge sharing across potential project developers to confirm what funds are accessible for projects so there is greater supply through alignment with performance criteria;
    h. Prompt standardised methods to quantify and value co-benefits (social, economic and environmental benefits) that align to investible metrics for ocean carbon projects;

Image courtesy of Star of the South

4.1. Blue Economy CRC Opportunities and Role

The following recommendations on "options" for the role of the Blue Economy CRC to play as the industry matures, will enable activities that will accelerate adoption and lower the barriers of participation and to the development of the market/industry.

For consideration, options (ranked by stakeholder preference) for the Blue Economy CRC:

1. Conduct the research necessary to underpin robust and defensible ocean carbon accounting methodologies, and to demonstrate the potential of offshore activities undertaken by existing and future participants of carbon markets.
2. Expand the role of **Blue Economy Zones**, championed by the Blue Economy CRC, to support ocean carbon technologies seeking testbed sites for trialling all aspects of developing sustainable economic activities offshore.
3. Represent stakeholder groups to government bodies with feedback on ocean carbon market opportunities and suggestions on how to accelerate / address regulatory challenges that delay and prevent development.
4. Facilitate introductions and networking opportunities for industry sponsors, project developers, investors, technology providers.
5. Prompt cross industry/sector engagement on specific project development opportunities that have large scale impact
6. Provide pro-bono carbon accounting or natural capital accounting (and other project assurance activities) for project developers i.e solicit sponsorship from philanthropic or impact investors to enable project development activity.
7. Create a register of active investment and project development opportunities, with key project metrics, to be accessible by industry partners and investors.
8. Further investigate ocean-based carbon project collectives and other investible portfolios of projects
9. Directly engage and collaborate with leading ocean carbon research and industry groups globally and in Australia and New Zealand:
    a. Australia's **Carbon Market Institute** and its Blue Carbon Working Group, on sharing news of projects Project Registry | Australia's Carbon Marketplace (carbonmarketinstitute.org) and prioritising research and project development efforts.
    b. **Climate Active.** Homepage | Climate Active. Climate Active is an ongoing partnership between the Australian Government and Australian businesses to drive voluntary climate action. The brand represents Australia's collective effort to measure, reduce, and offset carbon emissions to lessen our negative impact on the environment.
    c. **Oceans Negative Emissions Technologies** (OceanNETs) OceanNETs – ocean-based negative emissions technologies.
    d. **Oceans 2050.** Oceans 2050. With a focus is on five ocean recovery programs for the regeneration of oceans including a ground-breaking global study that advances climate restoration through seaweed aquaculture.
    e. **Greenwave** https://www.greenwave.org. Representing a global network of regenerative ocean farmers, and a goal of 10,000 ocean farmers in the next 10 years.

Other suggestions offered by survey contributors:

- "Educating the sector on valuing biodiversity risk and opportunity"
- "Coordinate and plan required scientific research."
- "Promote finance research - you have amazing research institution; increase labour skills; invest in ocean tech; create training schools; educate policy makers;"

Other next steps for the Blue Ec onomy CRC:

- Promote the study and defined opportunity to a range of stakeholders
- Conduct a review/audit of the current projects in development by the Blue Economy CRC against globally and locally applicable voluntary carbon standards and hence assess eligibility for carbon offset investments
- Implementation planning and execution of any of the above.
- Consider collaborating with key international and local Australian and New Zealand ocean market champions.

5. Acknowledgements

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This research was conducted under approval by the University of Tasmania Human Research Ethics Committee as a project "Ocean Based Carbon Markets" (Project ID: 26600). This research complied with the National Statement on Ethical Conduct in Human Research 2007 (updated 2018).

Participants of the survey were de-identified, so we can not name them but we can acknowledge their valuable contributions.

Many contributors from a range of stakeholder groups generously provided their practical insights and perspectives from their experiences and research. We thank them for sharing generously.

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10. Appendix A
Project Synopsis

Project Leader	Project Team
Marni Oaten - Project/Theme Leader. Key Researcher/ Manager	Marcus Haward, Program Leader, Sustainable Offshore Developments Blue Economy CRC & University of Tasmania Associate Professor Dr Sebastian Leuzinger, Department of Environmental Science, School of Science, Auckland University of Technology. Management and monitoring of research. Marni Oaten, Blue Economy CRC, Project/Theme Leader, Key Researcher and Manager. Carbon Markets Advisor and Net Zero Industry Collaborator, OCT Emissions Solutions Pty Ltd Vere Michiels, Ocean carbon analyst and marine scientist, OCT Emissions Solutions Pty Ltd
Report Author(s)	
University of Tasmania Auckland University of Technology OCT Emissions Solutions Pty Ltd	
Date Reported to the BE CRC	
Project Objective(s)	**BE CRC Milestones**
	Milestones 1-5: Milestone Output 1 – Blue (Ocean) Carbon Definition and Methodologies Development Time line / Assurance Plan Milestone Output 2 – Market Size (Supply/Demand) Milestone Output 3 – Risk Assessment Milestone Output 4 – Investment models, reference to Blue Economy CRC current Projects Milestone Output 5 – Blue Economy CRC Opportunities and Role

Utilisation/Commercialisation Opportunities

There is unmet demand for ocean based carbon offset projects which created an opportunity to align, training and position key players to take advantage of this opportunity. This scoping study is an industry lens, linking investment opportunities across various sectors of industry to commercially viable project development opportunities that support accelerated emissions. Some key uses of the insights documented in this study include:

- Policy makers: consider the scale and nuances of the opportunity to include ocean based carbon in blue carbon methods (by clean energy regulators etc.)
- Investors: criteria for nature-based solutions investment funds
- Project developers: focus on methodologies that are approved or flagged for future approvals
- Industry sponsors: can explore the purchase of off take agreement for expected future supply of carbon units
- Scientists/Researchers: can apply for grants to address key areas of further development
- Businesses: can invest in commercialising related technology and financial models to encourage investment and participation

Intellectual Property

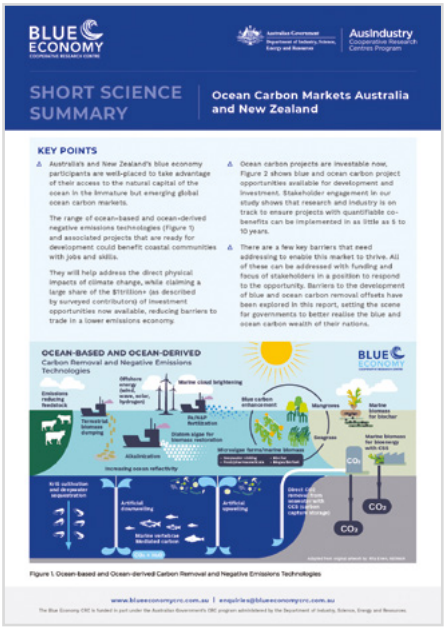
q. Developed charts/graphics/tables

Confidentiality

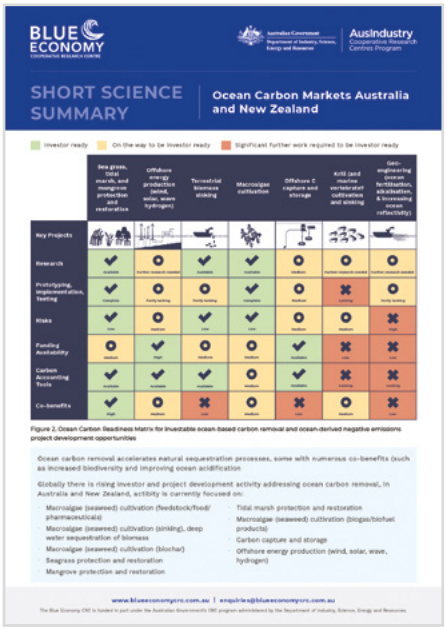
Does this report include confidential information? Yes ☐ or No ☑
None as per Ethics guidelines including non-identifiable contributions.

11. Appendix B
Short Science Summary

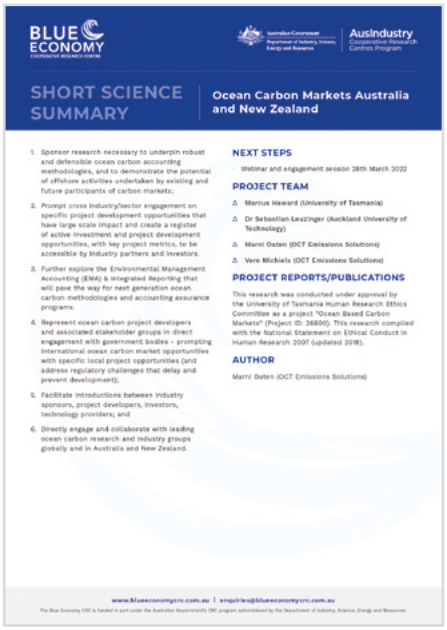
View the full report here


BLUE ECONOMY
AusIndustry
SHORT SCIENCE SUMMARY
Ocean Carbon Markets Australia and New Zealand
KEY POINTS
OCEAN-BASED AND OCEAN-DERIVED
Carbon Removal and Negative Emissions Technologies
Figure 1. Ocean-based and Ocean-derived Carbon Removal and Negative Emissions Technologies


BLUE ECONOMY
AusIndustry
SHORT SCIENCE SUMMARY
Ocean Carbon Markets Australia and New Zealand
THE CHALLENGE
OUR RESEARCH
THE OPPORTUNITY


BLUE ECONOMY
AusIndustry
SHORT SCIENCE SUMMARY
Ocean Carbon Markets Australia and New Zealand
Figure 2. Ocean Carbon Readiness Matrix for investable ocean-based carbon removal and ocean-derived negative emissions project development opportunities


BLUE ECONOMY
AusIndustry
SHORT SCIENCE SUMMARY
Ocean Carbon Markets Australia and New Zealand
Outcomes & Recommendations


BLUE ECONOMY
AusIndustry
SHORT SCIENCE SUMMARY
Ocean Carbon Markets Australia and New Zealand
NEXT STEPS
PROJECT TEAM
PROJECT REPORTS/PUBLICATIONS
AUTHOR

12. Appendix C
Definitions explored within the study

Definitions adapted by stakeholder feedback were adopted for the purpose of this study:

Blue Carbon is the total inorganic and organic carbon pool found in the oceans, coastal and shallow water ecosystems.

Ocean Carbon is the total inorganic and organic carbon pool found in oceans derived from ocean and atmospheric carbon transfer.

Ocean-based and Ocean-derived Carbon Removal and Negative Emissions Technologies: is the sequestration of carbon dioxide from the earth's atmosphere. Solutions focus on oceanic, coastal and shallow water ecosystems, and include deep water biological and geological sequestration and storage as well as offshore energy production.

Carbon Markets or Emissions Trading Systems (ETS) enable the trading of carbon credits, also referred to as carbon offsets. One carbon credit is equivalent to one metric ton of greenhouse gas (CO2-equivalent emissions). Compliance carbon markets are determined by the regulating authority, while voluntary carbon markets tend to address a broader range of environmental and social issues (such as climate adaptation, biodiversity or poverty). In Australia, the Clean Energy Regulator administers national carbon markets. Participation in the Emissions Reduction Fund is voluntary. Internationally, the number of ETS around the world is increasing. Besides the EU emissions trading system, national or sub-national systems are already operating or under development in Canada, China, Japan, New Zealand, South Korea, Switzerland and the United States.

Ocean Carbon Markets are carbon markets where carbon offsets units are traded as verified ocean-based (nature-based solutions) and ocean-derived carbon removal projects.

Carbon offset methodologies and compliance. There are no globally consistent standards for determining the criteria of an offset. Offsetting methodologies generally require projects to provide an authentic and verifiable removal, reduction, or avoidance of emissions beyond what would have occurred if the offsetting project had not taken place. There are common requirements for projects to permanently remove emissions so they cannot be released later. Other common requirements include addressing issues of double-counting and additionality.

13. Appendix D

Ocean Carbon Research Programs and Outcomes

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Artificial downwelling	GESAMP (2019). "High level review of a wide range of proposed marine geoengineering techniques".(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/ UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p.	OceanNETs	Not currently available.
Artificial upwelling	Aure, J., Strand, Ø., Erga, S.R. and Strohmeier, T., 2007. Primary production enhancement by artificial upwelling in a western Norwegian fjord. Marine Ecology Progress Series, 352, pp.39-52. Baumann, M., Taucher, J., Paul, A.J., Heinemann, M., Vanharanta, M., Bach, L.T., Spilling, K., Ortiz, J., Arístegui, J., Hernández-Hernández, N. and Baños, I., 2021. Effect of Intensity and Mode of Artificial Upwelling on Particle Flux and Carbon Export. Frontiers in Marine Science, p.1579. GESAMP (2019). "High level review of a wide range of proposed marine geoengineering techniques".(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/ UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p. Pan, Y., You, L., Li, Y., Fan, W., Chen, C.T.A., Wang, B.J. and Chen, Y., 2018. Achieving highly efficient atmospheric CO2 uptake by artificial upwelling. Sustainability, 10(3), p.664. Casareto, B.E., Niraula, M.P. and Suzuki, Y., 2017. Marine planktonic ecosystem dynamics in an artificial upwelling area of Japan: Phytoplankton production and biomass fate. Journal of Experimental Marine Biology and Ecology, 487, pp.1-10.	Climateworks, in conjunction with macroalgae growth Ocean artup https://www.geomar.de/en/research/fb2/fb2-bi/research-topics/ocean-artificial-upwelling OceanNETs	Not currently available.
Direct (ocean) capture	Meyer, A.M. and Spalding, M.J., 2021. A Critical Analysis of the Ocean Effects of Carbon Dioxide Removal via Direct Air and Ocean Capture–Is it a Safe and Sustainable Solution? GESAMP (2019). "High level review of a wide range of proposed marine geoengineering techniques".(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/ UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p..	Three arpa-e projects currently running: https://arpa-e.energy.gov/technologies/exploratory-topics/direct-ocean-capture	Not currently available.

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Krill cultivation and deepwater sequestration	Cavan, E.L., Belcher, A., Atkinson, A., Hill, S.L., Kawaguchi, S., McCormack, S., Meyer, B., Nicol, S., Ratnarajah, L., Schmidt, K. and Steinberg, D.K., 2019. The importance of Antarctic krill in biogeochemical cycles. Nature communications, 10(1), pp.1-13. Manno, C., Fielding, S., Stowasser, G., Murphy, E.J., Thorpe, S.E. and Tarling, G.A., 2020. Continuous moulting by Antarctic krill drives major pulses of carbon export in the north Scotia Sea, Southern Ocean. Nature communications, 11(1), pp.1-8.	Australian Antarctic Division and PEL Institute	Not currently available.
Macroalgae cultivation (biochar)	Ajith, S., Rojith, G., Zacharia, P.U., Nikki, R., Sajna, V.H., Liya, V.B. and Grinson, G., 2019. Production, Characterization and Observation of Higher Carbon in Sargassum wightii Biochar From Indian Coastal Waters. Journal of Coastal Research, 86(SI), pp.193-197. Roberts, D.A., Paul, N.A., Dworjanyn, S.A., Bird, M.I. and de Nys, R., 2015. Biochar from commercially cultivated seaweed for soil amelioration. Scientific reports, 5(1), pp.1-6. Sörbom, J., 2020. Utilizing beach-cast seaweed for biochar production in Gotland: A study of energy and carbon balances of algal biochar. Duarte, C.M., Wu, J., Xiao, X., Bruhn, A. and Krause-Jensen, D., 2017. Can seaweed farming play a role in climate change mitigation and adaptation?. Frontiers in Marine Science, 4, p.100.	Southern Ocean Carbon Company Monash carbon capture student team wins US$250,000 XPRIZE | Ministers for the Department of Industry, Science, Energy and Resources Biochar Capacity Building Program - DAWE SMO Solar Process	Being developed: VCS methodology (https://verra.org/wp-content/uploads/2021/08/210803_VCS-Biochar-Methodology-v1.0-.pdf) & biochar protocol (https://gecaenviro.com/biochar-carbon-credits/#our-bcc)
Macroalgae cultivation (biogas/biofuel products)	Alvarado-Morales, M., Boldrin, A., Karakashev, D.B., Holdt, S.L., Angelidaki, I. and Astrup, T., 2013. Life cycle assessment of biofuel production from brown seaweed in Nordic conditions. Bioresource technology, 129, pp.92-99. PROS AND CONS SEAWEED FOR BIOFUEL Duarte, C.M., Wu, J., Xiao, X., Bruhn, A. and Krause-Jensen, D., 2017. Can seaweed farming play a role in climate change mitigation and adaptation?. Frontiers in Marine Science, 4, p.100. Navarrete, I.A., Kim, D.Y., Wilcox, C., Reed, D.C., Ginsburg, D.W., Dutton, J.M., Heidelberg, J., Raut, Y. and Wilcox, B.H., 2021. Effects of depth-cycling on nutrient uptake and biomass production in the giant kelp Macrocystis pyrifera. Renewable and Sustainable Energy Reviews, 141, p.110747.	Climate Foundation - Marine Permaculture - have begun small scale trials USC Wrigley Institute | Kelp Biofuel Project > Wrigley > USC Dana and David Dornsife College of Letters, Arts and Sciences Advanced biofuels and algae research Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets (Marine BioEnergy) Marine BioEnergy, Inc.: Home	Not currently available.

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Macroalgae cultivation (deep water sequestration of biomass)	Agarwal, S., Banerjee, K., Saha, A., Amin, G. and Mitra, A., 2016. Can seaweed be a potential sink of carbon?. Int J Res Appl Sci Eng Technol, 4(8), pp.217-225. Duarte, C.M., Wu, J., Xiao, X., Bruhn, A. and Krause-Jensen, D., 2017. Can seaweed farming play a role in climate change mitigation and adaptation?. Frontiers in Marine Science, 4, p.100. Sondak, C.F., Ang, P.O., Beardall, J., Bellgrove, A., Boo, S.M., Gerung, G.S., Hepburn, C.D., Hong, D.D., Hu, Z., Kawai, H. and Largo, D., 2017. Carbon dioxide mitigation potential of seaweed aquaculture beds (SABs). Journal of Applied Phycology, 29(5), pp.2363-2373. Krause-Jensen, D. and Duarte, C.M., 2016. Substantial role of macroalgae in marine carbon sequestration. Nature Geoscience, 9(10), pp.737-742. Queirós, A.M., Stephens, N., Widdicombe, S., Tait, K., McCoy, S.J., Ingels, J., Rühl, S., Airs, R., Beesley, A., Carnovale, G. and Cazenave, P., 2019. Connected macroalgal-sediment systems: blue carbon and food webs in the deep coastal ocean. Ecological Monographs, 89(3), p.e01366.	RunningTide - monitoring their efforts for 2.5 years (with help from OceanVisions) Oceans2050 Quantifying Blue Carbon: kelp contribution to carbon sequestration in marine sediments at Victoria University of Wellington on FindAPhD.com Forensic carbon accounting: Assessing the role of seaweeds for carbon sequestration Catriona L Hurd, Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia (2022)	Draft methodology expected to be under review in 2022 (according to https://faircarbon.org/content/fc/introtobc)
Macroalgae cultivation (food/pharmaceuticals)	Hoegh-Guldberg. O., et al. 2019. "The Ocean as a Solution to Climate Change: Five Opportunities for Action." Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate Sondak, C.F., Ang, P.O., Beardall, J., Bellgrove, A., Boo, S.M., Gerung, G.S., Hepburn, C.D., Hong, D.D., Hu, Z., Kawai, H. and Largo, D., 2017. Carbon dioxide mitigation potential of seaweed aquaculture beds (SABs). Journal of Applied Phycology, 29(5), pp.2363-2373.	Seaweed solution nets $250K student prize - Institute for Marine and Antarctic Studies | University of Tasmania Monash carbon capture student team wins US$250,000 XPRIZE | Ministers for the Department of Industry, Science, Energy and Resources Seaweed and solar energy join hands at sea | News | CORDIS | European Commission Climate Foundation - Marine Permaculture - have begun small scale trials Biopac, Lolliware, Sway	Not currently available.

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Macroalgae cultivation (methane reduction)	Roque, B.M., Venegas, M., Kinley, R.D., de Nys, R., Duarte, T.L., Yang, X. and Kebreab, E., 2021. Red seaweed (Asparagopsis taxiformis) supplementation reduces enteric methane by over 80 percent in beef steers. Plos one, 16(3) Duarte, C.M., Wu, J., Xiao, X., Bruhn, A. and Krause-Jensen, D., 2017. Can seaweed farming play a role in climate change mitigation and adaptation?. Frontiers in Marine Science, 4, p.100. Roque, B.M., Brooke, C.G., Ladau, J., Polley, T., Marsh, L.J., Najafi, N., Pandey, P., Singh, L., Kinley, R., Salwen, J.K. and Eloe-Fadrosh, E., 2019. Effect of the macroalgae Asparagopsis taxiformis on methane production and rumen microbiome assemblage. Animal Microbiome, 1(1), pp.1-14. Brooke, C.G., Roque, B.M., Shaw, C., Najafi, N., Gonzalez, M., Pfefferlen, A., De Anda, V., Ginsburg, D.W., Harden, M.C., Nuzhdin, S.V. and Salwen, J.K., 2020. Methane reduction potential of two pacific coast macroalgae during in vitro ruminant fermentation. Frontiers in Marine Science, 7, p.561. Vijn, S., Compart, D.P., Dutta, N., Foukis, A., Hess, M., Hristov, A.N., Kalscheur, K.F., Kebreab, E., Nuzhdin, S.V., Price, N.N. and Sun, Y., 2020. Key considerations for the use of seaweed to reduce enteric methane emissions from cattle. Frontiers in Veterinary Science, 7, p.1135. Kinley, R.D., de Nys, R., Vucko, M.J., Machado, L. and Tomkins, N.W., 2016. The red macroalgae Asparagopsis taxiformis is a potent natural antimethanogenic that reduces methane production during in vitro fermentation with rumen fluid. Animal Production Science, 56(3), pp.282-289.	Climate Foundation - Marine Permaculture - have begun small scale trials Sea Forest CSIRO (FutureFeed) Symbrosia	VCS VM0041
Macroalgae general	https://arpa-e.energy.gov/technologies/projects/nautical-offshore-macroalgal-autonomous-device A seaweed aquaculture imperative to meet global sustainability targets GESAMP (2019). “High level review of a wide range of proposed marine geoengineering techniques”.(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p.	https://arpa-e.energy.gov/technologies/projects/scalable-coastal-and-offshore-macroalgal-farming https://arpa-e.energy.gov/technologies/projects/ocean-energy-macroalgae CSMP IMTA – blueCarbon	

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Mangrove protection and restoration	Alongi, D. M. Carbon cycling and storage in mangrove forests. Annu. Rev. Mar. Sci. 6, 195–219 (2014). Alongi, D. M. Carbon sequestration in mangrove forests. Carbon Manag. 3, 313–322 (2012). Macreadie, P. I. et al. The future of blue carbon science. Nat. Commun. 10, 3998 (2019). Macreadie, P.I., Costa, M.D., Atwood, T.B., Friess, D.A., Kelleway, J.J., Kennedy, H., Lovelock, C.E., Serrano, O. and Duarte, C.M., 2021. Blue carbon as a natural climate solution. Nature Reviews Earth & Environment, pp.1-14 Hoegh-Guldberg. O., et al. 2019. "The Ocean as a Solution to Climate Change: Five Opportunities for Action." Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate Serrano, O. et al. (2019) "Australian vegetated coastal ecosystems as global hotspots for climate change mitigation," Nature Communications, 10(1), pp. 1–10. doi: 10.1038/s41467-019-12176- 8 Zeng, Y., Friess, D.A., Sarira, T.V., Siman, K. and Koh, L.P., 2021. Global potential and limits of mangrove blue carbon for climate change mitigation. Current Biology, 31(8), pp.1737-1743. Moritsch, M.M., Young, M., Carnell, P., Macreadie, P.I., Lovelock, C., Nicholson, E., Raimondi, P.T., Wedding, L.M. and Ierodiaconou, D., 2021. Estimating blue carbon sequestration under coastal management scenarios. Science of The Total Environment, 777, p.145962. De Paula Costa, M.D., Lovelock, C.E., Waltham, N.J., Moritsch, M.M., Butler, D., Power, T., Thomas, E. and Macreadie, P.I., 2022. Modelling blue carbon farming opportunities at different spatial scales. Journal of Environmental Management, 301, p.113813	CSIRO's 'Estimating Australia's blue carbon potential" Ongoing research by the Blue Carbon Lab.	CDM's AR-AM0014, AR-AMS0003, Gold Standard's "Afforestation/ Reforestation (A/R) GHG Emissions Reduction & Sequestration Methodology", VCS's VM0007, VM0024
Marine Geoengineering (Marine cloud brightening, increasing ocean reflectivity)	GESAMP (2019). "High level review of a wide range of proposed marine geoengineering techniques".(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p.		These techniques do not directly sequester carbon, thus no methodologies are available.
Marine vertebrae mediated carbon	Lutz SJ, Martin AH. 2014. Fish Carbon: Exploring Marine Vertebrate Carbon Services. Published by GRID-Arendal, Arendal, Norway.		Not currently available.
Ocean acidification mitigation through electrochemical approaches	Zenz House K, House CH, Schrag DP, and MJ Aziz (2007) Electrochemical Acceleration of Chemical Weathering as an Energetically Feasible Approach to Mitigating Anthropogenic Climate Change (2007) Environmental Science and Technology https://pubs.acs.org/doi/full/10.1021/es0701816 Caserini S, et al. Potential of Maritime Transport for Ocean Liming and Atmospheric CO2 Removal (2021). Frontiers in Climate - Negative Emissions Technology https://doi.org/10.3389/fclim.2021.575900		Not currently available.

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Ocean alkalinisation	GESAMP (2019). "High level review of a wide range of proposed marine geoengineering techniques".(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p. González, M.F. and Ilyina, T., 2016. Impacts of artificial ocean alkalinization on the carbon cycle and climate in Earth system simulations. Geophysical Research Letters, 43(12), pp.6493-6502. Mongin, M., Baird, M.E., Lenton, A., Neill, C. and Akl, J., 2021. Reversing ocean acidification along the Great Barrier Reef using alkalinity injection. Environmental Research Letters, 16(6), p.064068. Ocean Alkalinity Enhancement	XPRIZE Team EnviroHome Cquestr8 Project Vesta OceanNETS Ocean visions funding for research https://oceanvisions.org/request-for-proposals-ocean-alkalinity-enhancement/ , proposals due feb 25	Working on inclusion in VCS methodology
Ocean fertilisation	Boyd, P.W. and Law, C.S., 2001. The Southern Ocean iron release experiment (SOIREE)—introduction and summary. Deep Sea Research Part II: Topical Studies in Oceanography, 48(11-12), pp.2425-2438 Bowie, A.R., Maldonado, M.T., Frew, R.D., Croot, P.L., Achterberg, E.P., Mantoura, R.F.C., Worsfold, P.J., Law, C.S. and Boyd, P.W., 2001. The fate of added iron during a mesoscale fertilisation experiment in the Southern Ocean. Deep Sea Research Part II: Topical Studies in Oceanography, 48(11-12), pp.2703-2743. Emerson, D., 2019. Biogenic iron dust: a novel approach to ocean iron fertilization as a means of large scale removal of carbon dioxide from the atmosphere. Frontiers in Marine Science, 6, p.22. GESAMP (2019). "High level review of a wide range of proposed marine geoengineering techniques".(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p.	OceanNETs	The current legal framework prohibits OIF in international waters because of a perceived threat of environmental damage by profit-motivated enterprises. Specifically, regulations from 2008 and 2013 categorize OIF as marine geo-engineering and thus it is not allowed at large scale (>300 sq km) or commercially.
Offshore carbon capture and storage, deepwater storage of CO2	Adams, E.E. and Caldeira, K., 2008. Ocean storage of CO2. Elements, 4(5), pp.319-324. Caldeira, K., Akai, M., Brewer, P.G., Chen, B., Haugan, P.M., Iwama, T., Johnston, P., Kheshgi, H., Li, Q., Ohsumi, T. and Pörtner, H., 2005. Ocean storage. Goldthorpe, S., 2017. Potential for very deep ocean storage of CO2 without ocean acidification: a discussion paper. Energy Procedia, 114, pp.5417-5429. GESAMP (2019). "High level review of a wide range of proposed marine geoengineering techniques".(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p. Hoegh-Guldberg. O., et al. 2019. ''The Ocean as a Solution to Climate Change: Five Opportunities for Action.'' Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate Sleipner partnership releases CO2 storage data - equinor.com	XPRIZE Team Honu Engineering Ebb Carbon	*Carbon Credits (Carbon Farming Initiative – Carbon Capture and Storage)* Methodology Determination 2021 (Method) currently being reviewed. This ACCU method will include carbon capture and storage projects.

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Offshore hydrogen energy storage/ generation	Howarth, R.W. and Jacobson, M.Z., 2021. How green is blue hydrogen?. Energy Science & Engineering, 9(10), pp.1676-1687. Hydrogen Storage and Distribution - Blue Economy Cooperative Research Centre Hassanpouryouzband, A., Joonaki, E., Edlmann, K. and Haszeldine, R.S., 2021. Offshore Geological Storage of Hydrogen: Is This Our Best Option to Achieve Net-Zero?. ACS Energy Letters, 6, pp.2181-2186. Calado, G. and Castro, R., 2021. Hydrogen Production from Offshore Wind Parks: Current Situation and Future Perspectives. Applied Sciences, 11(12), p.5561.	Australia's National Hydrogen Strategy Cutting-edge hydrogen research in Australia Study launched on offshore production of green hydrogen SMO Solar Process Planetary Hydrogen	Clean hydrogen listed as a priority for method development in 2022 for the ERF
Offshore solar energy generation	Hoegh-Guldberg. O., et al. 2019. ''The Ocean as a Solution to Climate Change: Five Opportunities for Action.'' Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate Melikoglu, M., 2018. Current status and future of ocean energy sources: A global review. Ocean Engineering, 148, pp.563-573.	"Offshore solar" to feature in hybrid marine energy demonstration plant Desolenator Swimsol SolarSea	Renewable Energy (Electricity) Act 2000
Offshore wave energy generation	Hoegh-Guldberg. O., et al. 2019. ''The Ocean as a Solution to Climate Change: Five Opportunities for Action.'' Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate Hemer, M.A., Zieger, S., Durrant, T., O'Grady, J., Hoeke, R.K., McInnes, K.L. and Rosebrock, U., 2017. A revised assessment of Australia's national wave energy resource. Renewable Energy, 114, pp.85-107. Melikoglu, M., 2018. Current status and future of ocean energy sources: A global review. Ocean Engineering, 148, pp.563-573.	Seeding Marine Innovation in WA with a Wave Energy Deployment in Albany Mooring Tensioner for WECs - MoTWEC | Offshore Renewable Energy CorPower Ocean E-Wave Technologies Eco Wave Power Oneka Technologies	Renewable Energy (Electricity) Act 2000
Offshore wave energy generation	Offshore Wind Potential for Australia | RP3 Research Project (blueeconomycrc.com.au) IEA (2019), *Offshore Wind Outlook 2019*, IEA, Paris https://www.iea.org/reports/offshore-wind-outlook-2019 Hoegh-Guldberg. O., et al. 2019. ''The Ocean as a Solution to Climate Change: Five Opportunities for Action.'' Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate Offshore Wind Potential for Australia | RP3 Research Project Melikoglu, M., 2018. Current status and future of ocean energy sources: A global review. Ocean Engineering, 148, pp.563-573.	BW Ideol's patented Damping Pool ® floating foundation (36 square meters, draught of 7.5 meters), world's first floating barge designed for offshore wind. Suitable for any environment – >30 meter water depth, any wave conditions, seabed conditions, and wind turbine Demonstration projects with: HexaFloat, Marine Power System, Saitec, Principle Power, Hexicon, HyWind, WindSub, Windfloat, etc Oneka Technologies	Renewable Energy (Electricity) Act 2000 Offshore Electricity Infrastructure Act 2021

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Seagrass protection and restoration	Fourqurean, J. W. et al. Seagrass ecosystems as a globally significant carbon stock. Nat. Geosci. 5, 505–509 (2012). Duarte, C. M. et al. Seagrass community metabolism: assessing the carbon sink capacity of seagrass meadows. Glob. Biogeochem. Cycles 24, GB4032 (2010). Macreadie, P. I. et al. The future of blue carbon science. Nat. Commun. 10, 3998 (2019). Hoegh-Guldberg. O., et al. 2019. ‘‘The Ocean as a Solution to Climate Change: Five Opportunities for Action.’’ Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate Macreadie, P.I., Costa, M.D., Atwood, T.B., Friess, D.A., Kelleway, J.J., Kennedy, H., Lovelock, C.E., Serrano, O. and Duarte, C.M., 2021. Blue carbon as a natural climate solution. Nature Reviews Earth & Environment, pp.1-14. Serrano, O. et al. (2019) “Australian vegetated coastal ecosystems as global hotspots for climate change mitigation,” Nature Communications, 10(1), pp. 1–10. doi: 10.1038/s41467-019-12176- 8 Moritsch, M.M., Young, M., Carnell, P., Macreadie, P.I., Lovelock, C., Nicholson, E., Raimondi, P.T., Wedding, L.M. and Ierodiaconou, D., 2021. Estimating blue carbon sequestration under coastal management scenarios. Science of The Total Environment, 777, p.145962. De Paula Costa, M.D., Lovelock, C.E., Waltham, N.J., Moritsch, M.M., Butler, D., Power, T., Thomas, E. and Macreadie, P.I., 2022. Modelling blue carbon farming opportunities at different spatial scales. Journal of Environmental Management, 301, p.113813	WindFloatrCSIRO’s ‘Estimating Australia’s blue carbon potential” Ongoing research by the Blue Carbon Lab.	Gold Standard new methodology underway for blue carbon ecosystems, VCS’s VM0033, VM0024
Terrestrial biomass sinking	GESAMP (2019). “High level review of a wide range of proposed marine geoengineering techniques”.(Boyd, P.W. and Vivian, C.M.G., eds.) (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UN Environment/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 98, 144 p. Miller, L.A., Orton, P.M. Achieving negative emissions through oceanic sequestration of vegetation carbon as Black Pellets. Climatic Change 167, 29 (2021). https://doi.org/10.1007/s10584-021-03170-5		Covered by the existing category of wastes “Organic material of natural origin” in Annex I of the London Protocol and “Uncontaminated organic material of natural origin” in Annex I of the London Convention (IMO, 2016). MARPOL conflict?

Category of Ocean Carbon	Research (published)	Research (in progress)	Related carbon accounting methodologies
Tidal marsh protection and restoration	Macreadie, P. I. et al. The future of blue carbon science. Nat. Commun. 10, 3998 (2019). Macreadie, P.I., Costa, M.D., Atwood, T.B., Friess, D.A., Kelleway, J.J., Kennedy, H., Lovelock, C.E., Serrano, O. and Duarte, C.M., 2021. Blue carbon as a natural climate solution. Nature Reviews Earth & Environment, pp.1-14 Hoegh-Guldberg. O., et al. 2019. ''The Ocean as a Solution to Climate Change: Five Opportunities for Action.'' Report. Washington, DC: World Resources Institute. Available online at http://www.oceanpanel.org/climate Serrano, O. et al. (2019) "Australian vegetated coastal ecosystems as global hotspots for climate change mitigation," Nature Communications, 10(1), pp. 1–10. doi: 10.1038/s41467-019-12176- 8 Moritsch, M.M., Young, M., Carnell, P., Macreadie, P.I., Lovelock, C., Nicholson, E., Raimondi, P.T., Wedding, L.M. and Ierodiaconou, D., 2021. Estimating blue carbon sequestration under coastal management scenarios. Science of The Total Environment, 777, p.145962. De Paula Costa, M.D., Lovelock, C.E., Waltham, N.J., Moritsch, M.M., Butler, D., Power, T., Thomas, E. and Macreadie, P.I., 2022. Modelling blue carbon farming opportunities at different spatial scales. Journal of Environmental Management, 301, p.113813	CSIRO's 'Estimating Australia's blue carbon potential" Ongoing research by the Blue Carbon Lab.	CDM's AR-AMS0003, Gold Standard new methodology underway for blue carbon ecosystems, VCS's VM0033, VM0024
Other		XPRIZE Team Atmoo - Algae farming CyanoCapture: Home - Genetically modified cyanobacteria to capture more CO2	

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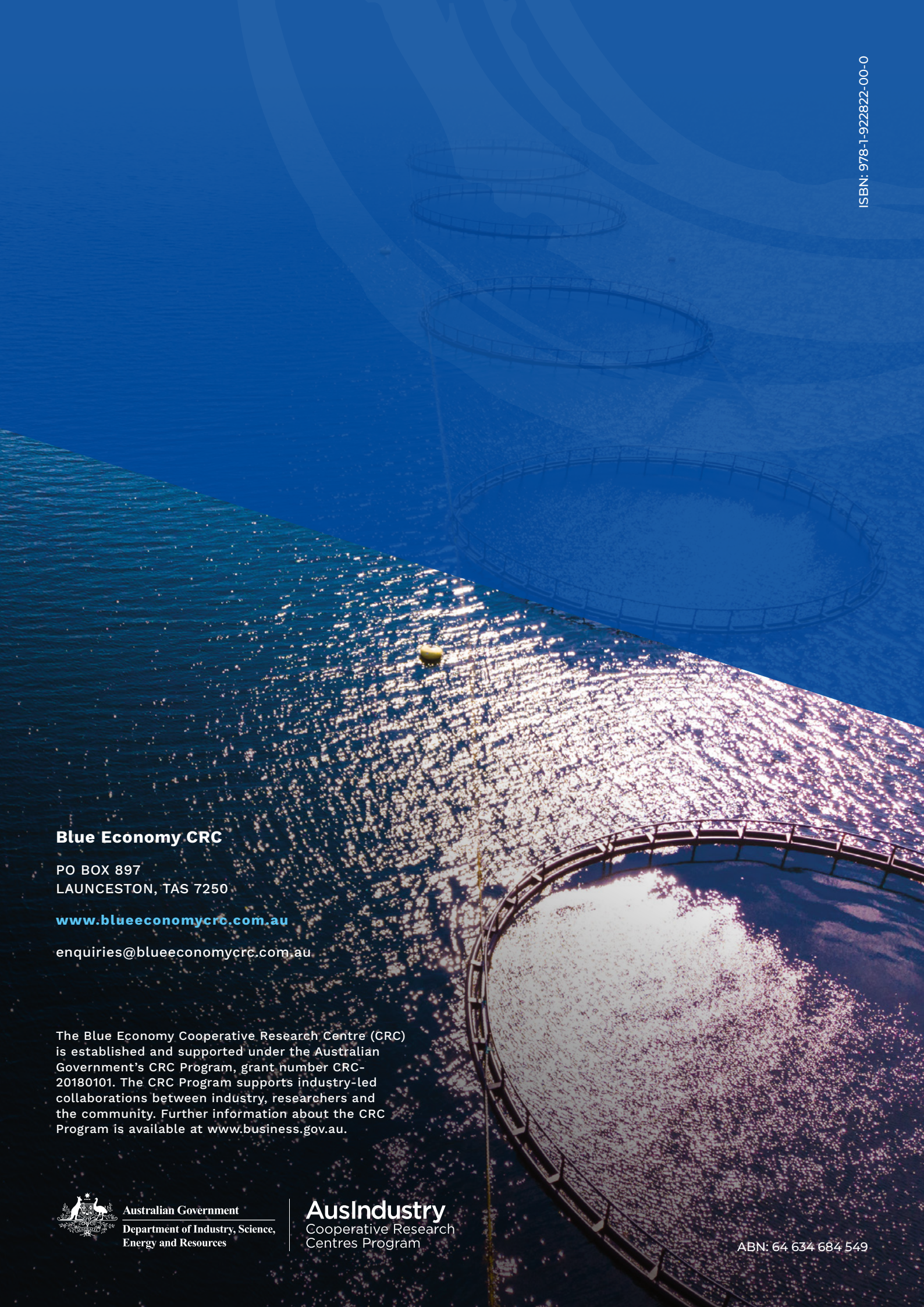

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PO BOX 897
LAUNCESTON, TAS 7250

www.blueeconomycrc.com.au

enquiries@blueeconomycrc.com.au

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