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White Paper Template

Energy Security, Diversification, and achieving Net-Zero

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<u>Abstract (200 words)</u>

Australia stands at a critical juncture in its climate transition, aiming for net zero emissions by 2050 with an interim target of a 43% reduction by 2030. As of 2024, onshore renewable energy sources supplied approximately 39% of Australia's total electricity generation, with solar and onshore wind making up the majority of this share. Commonwealth and State Government governments are facilitating the sustainable development of offshore energy industries in Australia, with licencing and regulatory processes developing for offshore wind in six declared areas in Commonwealth waters. While geological Carbon Capture and Storage (CCS) has been explored to decarbonise Australia's hard-to-abate sectors, it has yet to meet its anticipated milestones and deliver on its full potential. Marine-based solutions—offshore wind energy, blue carbon ecosystems, and emerging marine carbon dioxide removal (mCDR) technologies offer significant, underutilised potential to meet these goals while supporting economic prosperity and environmental resilience. Offshore wind can provide reliable, high-capacity renewable energy near key demand centres, complementing existing solar and onshore wind, and create opportunities for the production of critical energy transition minerals and green fuels. Blue carbon habitats, including mangroves, seagrasses, and saltmarshes, are effective natural carbon sinks with additional biodiversity and coastal protection benefits.
Realising these opportunities demands coordinated national action, investment in infrastructure, regulatory frameworks, scientific research, and workforce development. The National Marine Science Committee (NMSC) is well positioned to lead cross-sector integration. Key dependencies include governance coordination, robust monitoring and verification systems, and community engagement, particularly with Indigenous groups. Australia's ocean is no longer just a climate victim but a critical climate solution. Leveraging its marine domain can help

achieve net zero targets, strengthen regional economies, and position the nation as a global leader in sustainable, ocean-based climate action.

Background and relevance

Australia is entering a decisive decade in its response to climate change. With a national commitment to net zero emissions by 2050, including an interim target of 43% reduction by 2030, the challenge lies not only in reducing greenhouse gas emissions, but in doing so rapidly while maintaining economic prosperity, energy reliability, and international competitiveness. Australia's ocean estate is vast, energy-rich, and biologically diverse. It presents two of the most promising but underdeveloped opportunities in the transition to net zero: (1) deployment of marine-based renewable energy, particularly offshore wind; and (2) large-scale carbon sequestration through blue carbon and emerging marine technologies. Offshore wind can provide high-capacity renewable energy near major industrial and population centres, complementing solar and onshore wind. Its development has great potential to contribute to powering coastal industries, produce energy to support production of critical energy transition minerals and green fuels, and decarbonise coastal supply chains. Wave and tidal energy are also in high abundance. Technology is approaching commercial maturity and the complementarity of the resource profile with wind and solar offers a unique opportunity for Australia to improve the dispatchability of green electricity and grid stability, while reducing the requirements for long term storage, therefore improving energy security and affordability (Wolgamot et al. 2025).
Simultaneously, Australia's coastal and ocean ecosystems—including mangroves, seagrasses, and saltmarshes—are among the most effective natural carbon sinks on the planet. These "blue carbon" habitats store carbon in plants and sediments at rates far exceeding terrestrial forests. When restored or protected, they offer durable carbon sequestration with additional benefits for biodiversity, fisheries, and coastal resilience. Emerging marine carbon dioxide removal (mCDR) technologies—such as seaweed farming, microalgae cultivation, ocean alkalinity enhancement—also offer high-potential pathways for long-term atmospheric CO_2 removal. Details on mCDR knowledge gaps and research and developments needs are presented in the white paper on *Marine Climate Interventions*.
Methods for geological carbon capture and storage (CCS) are also developing internationally and within Australia, with research required to support earth system science, modelling capabilities, environmental impact, and frameworks for monitoring and verification. The contribution of technological solutions for greenhouse gas removal will be in part influenced by limitations of models to quantify uptake, implementation and access data from commercial-in-confidence projects. Similar to other technologies, there are a range of economic, engineering, social and environmental aspects that will require research investment, as well as a coordinated legislative and regulatory framework for offshore geological storage.
"Green shipping" solutions can also contribute to Australia's global greenhouse gas emission reduction goals, with global marine trade representing around 3% of global CO_2 emissions. These include alternative bio-fuels, onboard carbon capture, electrification (including hybrid systems) and energy consumption reduction (e.g. wind assist).
In parallel, marine-based renewable energy can also support the development of green fuels, reducing dependency on land-based renewables, often constrained by space and social acceptance, but also enabling the development of coastal hydrogen hubs, facilitating easier integration with ports, heavy industries and export infrastructure (IRENA, 2020). Green hydrogen produced from local marine-based renewable energy resources can produce both electricity and hydrogen to meet local demand, enhancing energy sovereignty and reducing carbon emissions (CSIRO, 2021).

Despite their potential, these marine-based climate solutions are under-developed and under-funded in Australia. The development of offshore wind faces early-stage regulatory, financial, technical, and social barriers, while blue carbon restoration and marine CDR are limited by fragmented governance, a lack of consistent monitoring standards, and insufficient integration with climate and energy policy. Moreover, recent softening or removal of financial safeguards and policy mechanisms designed to drive renewable energy investment have contributed to a diversion of private and institutional capital away from renewables and innovation, reducing momentum in Australia's clean energy transition.

A coordinated national approach is needed to realise the full potential of Australia's marine domain in the climate transition and will require important science gaps to be addressed and research capabilities to be built (Appendix 1).

The National Marine Science Committee (NMSC) is well positioned to lead this integration—bringing together science, policy, industry, and community to accelerate climate-aligned investment in both marine energy and carbon sequestration. A national program can support innovation, build regional capability, and guide the sustainable development of Australia's offshore assets for maximum climate and economic return.

By embedding the ocean as a key pillar of the net zero strategy, Australia can simultaneously meet its international climate commitments, support low-carbon industry, and create enduring environmental and social value. The ocean is no longer just a victim of climate change—it must now be recognised as a vital part of the solution.

Infrastructure and Capability Needs

To realise the ocean's full potential in Australia's net zero transition, significant investment in infrastructure and capability is needed—particularly in offshore wind energy and marine carbon sequestration.

For offshore wind, priority infrastructure includes high-capacity grid connections from offshore zones to onshore demand centres, upgraded ports for construction and servicing, and access to specialised installation vessels. This will require enhanced research capabilities reflecting the emergence of this new industry in Australia, such as offshore monitoring systems (e.g. LiDAR, metocean buoys, tags for marine fauna), which are essential for site assessment and development.

Simultaneously, enabling infrastructure for blue carbon includes coastal restoration equipment, marine MRV (monitoring, reporting, verification) stations, and scalable methods supported by emerging technologies.

In general, Australia must also build scientific and technical capabilities, including expertise in ocean carbon science, offshore engineering, bio-fuel development, restoration ecology, and digital MRV systems. Investment in regulatory capacity is equally vital: streamlined approvals, consistent carbon accounting methods, and clear governance frameworks are needed to reduce risk and accelerate deployment. Further research is needed to understand what this deployment will look like from a place-based and regional perspective. What influences the responsible deployment of these infrastructure is a key area to ensure social acceptance and community wellbeing.

Development of research data and analytics infrastructure to support research conducted by institutions, government and industry is an essential element to ensure that there is an effective data supply chain. Such infrastructure is well developed in Australia to manage a number of key data products (e.g. oceanography, bathymetry), but require considerable investment in other areas (e.g. cetaceans, social data).

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A trained workforce—from coastal restoration crews to offshore wind technicians—will underpin delivery, alongside community and Indigenous capacity to co-lead projects. Enabling systems such as open data platforms, green finance mechanisms, and a coordinated national strategy (potentially led by NMSC) will ensure alignment across sectors.

Together, these infrastructure and capability investments will create the foundation for ocean-based climate solutions that deliver reliable energy, long-term carbon sequestration, and lasting economic and environmental benefits for Australia. This will require using a whole system approach and implementing coordinated efforts among engineers, environmental scientists, social scientists, policymakers, and industry stakeholders, as well as State and Federal Governments. Continued research and pilot projects in Australia are essential to bridge these gaps and realise the full potential of marine-based renewable energy technologies.

Research Priorities

A coordinated acceleration of climate-aligned research in both marine energy and carbon sequestration at scale to activate the ocean's role in Australia's net zero transition requires a range of science gaps to be addressed. These are technological, environmental and societal, with some specific to Australia (Table 1).

For offshore wind, research priorities include regional wind resource assessments, marine regional planning and integrated studies that extend across ecosystems (benthic and pelagic), species (particularly birds and cetaceans), and examine a range of stressors and impacts (particularly underwater noise, habitat disturbance, vessel interactions). Knowledge on seascape and visual amenity impacts, and displacement of existing activities and users also require research investment. These priorities are guided by the key environmental factors associated with offshore wind in Australia as detailed in DCCEEW (2023). An initial inventory of existing environmental data and best-practice monitoring standards to support efficient and legally compliant regulatory decision-making for offshore wind development has progressed (McLean et al. 2025). Additional key areas requiring significant research effort include advancing floating wind and wave technologies, and addressing engineering challenges such as installation, survivability, and life cycle costs, supporting local manufacturing, workforce development, Indigenous collaboration, and protecting cultural heritage to enable a sustainable offshore wind sector.

This science will guide optimal site selection, develop best practice for existing sites and is common to ocean based renewable energy as developed in the Environmental OES State of the Science report (Garavelli and al., 2024).

Understanding the carbon sequestration potential of blue carbon ecosystems—such as mangroves, seagrasses, and saltmarshes—is essential. This includes mapping their extent, measuring sequestration rates, and assessing long-term storage and vulnerability under climate stress. Improved mapping of blue carbon habitats and their degradation or restoration status is also critical for national carbon inventories.

Equally important are advances in carbon credit accounting frameworks to ensure transparency, consistency, and eligibility in domestic and international markets. Challenges remain in integrating blue carbon into existing carbon trading schemes due to complexities in permanence, additionality, and leakage. Social and governance research is needed to support inclusive approaches that embed Indigenous rights, knowledge, and leadership in project design and stewardship. Co-management models and culturally appropriate benefit-sharing mechanisms are essential to align climate action with community priorities. Protecting blue carbon habitats from development and climate impacts must also be a research and policy focus.

Cross-cutting all areas is the need for robust monitoring, reporting, and verification (MRV) systems. Developing scalable MRV tools using remote sensing, autonomous platforms, and AI will be key to ensuring efficiency, transparency and integrity in both carbon sequestration and energy outcomes.

Finally, integrated governance research—including co-design with Indigenous communities and economic modelling for blue carbon markets—will be critical to ensuring socially and environmentally sustainable marine climate solutions. Science must lead and guide the pathway forward.

Table 1. Summary of technological, environmental and societal science gaps relating to energy security and diversification

Science gaps	**Nature/Type**	**Examples**
Resources	Assessment/modelling	- High resolution regional resources mapping - Resource forecast modelling
Technological	Technology readiness	- Floating wind technology still in development - Tidal turbines and wave energy converters not yet at commercial maturity - Survivability/longevity in the Australian environment (e.g. cyclones, biofouling, etc.)
	Installation	- Installation in calcareous seabeds is challenging - Lack of specialised vessels availability
	Cost and maintenance	- Life cycle cost must be reduced - Decommissioning requirements unknown
	Port infrastructure	- No ports with required berthing capabilities - Distance to developments may increase cost - Changes to fuel supply chains and infrastructure
	Grid integration	- Distance to grid and transportation network can increase cost - Need to improve dispatchability and reliability
	Decommissioning	- Environmental impact assessment of remaining infrastructure - Decision framework
Environmental	Marine ecosystems	- Potential biodiversity and habitat disruption (benthic and pelagic) - Turbine interactions (i.e. collision and displacement to birds and bats, impact of underwater turbines) - Electromagnetic fields (scientific uncertainty) - Noise and vibration effects on fish and mammal life - Impact on nesting, foraging and migration of seabirds - Assessment of cumulative impact
	Baseline environmental data and monitoring	- Lack of accurate site-specific environmental baseline data

		- Lack of population specific environmental baseline data (e.g. humpback population spatial and temporal distribution, behaviour and reproduction) - Need for long term monitoring programme, with consistent methods across State boundaries
	Hydrodynamic and sediment dynamics	- Impact of hydrodynamic mixing on nutrient distribution - Impact of sediments transport on benthic habitats and population
	Coastal processes	- Impact of wave attenuation on coastal geomorphology
Societal	Social licence	- Acceptance from local communities can be challenging - Deployment frameworks that uphold to principles of just transition is limited for ocean-based interventions
	Knowledge priorities and capacity assessment	- Identifying what local stakeholders' information needs are to have an informed opinion about the ocean-based climate interventions. - Some capacities and skills may already be available. Need for mapping these capacities and identify gaps for skill improvement.
	Regulatory framework and policies	- Need for clear and more streamline approval processes - Better coordination between Federal-State, between Industries-Research
	Human and ecological interaction	- Co-usage with other stakeholders (e.g. shipping, fishing, recreation and tourism, etc.)
	Supply chain and workforce	- Lack of production capacity for domestic manufacturing - Need for training, upskilling and reskilling programmes
	Indigenous engagement	- Co-design with Indigenous communities - Need to leverage Indigenous knowledge - Need to protect underwater cultural heritage

Progress and Impact Measurement

Effective monitoring and measurement are essential to track the progress, impact, and credibility of marine-based climate solutions. For offshore wind, key metrics to evaluate carbon reduction will include electricity generation, capacity factors, and emissions avoided by displacing fossil fuel use. Environmental factors will require assessment and monitoring to evaluate broader impacts of marine infrastructure and operations. Challenges relate to the diverse range of factors requiring evaluation, including changes in oceanography, impacts of threatened species with highly variable life-histories and dependencies (i.e. birds, cetaceans), and benthic habitats. Social and economic metrics include regional job creation, Indigenous participation, co-benefits like shoreline protection, and levels of investment.

For blue carbon, this includes establishing baselines using field surveys and remote sensing to map habitat extent and carbon stocks. Long-term monitoring of carbon fluxes—through sediment sampling and water chemistry—is used to quantify sequestration rates. Verified MRV frameworks, such as those under the Australian Carbon Credit Unit (ACCU) scheme, ensure consistency and integrity in reporting.
Digital tools such as satellite imagery, autonomous vehicles, and AI-driven analytics can support large-scale, cost-effective monitoring. Independent audits and public reporting ensure transparency and accountability. Establishing time-bound benchmarks and adaptive feedback loops enables continuous learning and improvement—ensuring ocean-based climate solutions deliver meaningful outcomes for carbon, nature, and communities. Reporting frameworks to support these will need to integrate with existing processes (e.g. Environmental Impact Assessments, State of the Environment reporting, environmental accounts, Sustainable Development Goals). These will require new decision support tools and enhanced data products.

Dependencies

To successfully implement ocean-based climate solutions, Australia must navigate a complex landscape of dependencies. These are the critical enablers and conditions that must be in place for these initiatives to scale effectively, credibly, and sustainably.

1. Policy and Regulatory Frameworks

A foundational dependency to support ocean-based climate solutions is the development of clear, consistent, and supportive policy and regulatory frameworks. For blue carbon this includes recognised carbon accounting methodologies under the Australian Carbon Credit Unit (ACCU) scheme or equivalent international standards. Currently, there are few established methods for marine carbon projects, creating uncertainty for investors and project developers. For offshore wind, clear, aligned State and National policies, streamlined approvals, and long-term marine spatial plans which seek to derisk conflicting uses of the marine environment, are essential to reduce project risk and attract capital investment.

2. Governance and Coordination

Cross-jurisdictional coordination between Commonwealth, state, and territory governments is a key dependency. The governance of marine space—across climate, energy, environment, Indigenous rights, and industry—is fragmented. A whole-of-government and cross-sector approach is required, potentially led by a national coordination mechanism (e.g. through the NMSC) to align marine science, regulation and investment. This includes governance related to data sharing and model integration. Collaboration with Traditional Owners, industry and local communities is also critical to build social licence and ensure equitable benefit-sharing.

3. Scientific Evidence and Standards

Robust, peer-reviewed science is a cornerstone dependency. This includes ecological and biogeochemical data to quantify carbon sequestration, assess ecological risks, and inform project design. For offshore wind, this means comprehensive wind and oceanographic assessments, biodiversity baselines and impact studies. Science must underpin the development of monitoring, reporting, and verification (MRV) standards for both carbon removal and storage, and environmental impacts. Without trusted science, projects risk delays, rejection, or reputational damage.

4. Infrastructure and Technology

Enabling infrastructure—such as port upgrades, grid connections, carbon monitoring platforms, and installation vessels—is a dependency for both offshore wind and mCDR. Many of these assets require long lead times, high capital investment, and coordination across public and private sectors. Technology readiness is another factor: habitat restoration, carbon storage and ocean energy production, and digital MRV infrastructure must be proven at scale and suited to Australian conditions.

5. Investment and Finance
Scaling ocean climate solutions depends on mobilising both public and private finance, with a strategic emphasis on prioritising investment in marine-based renewable energy. Public funding remains essential for foundation research, demonstration projects, and capacity building in emerging technologies. In parallel, carbon markets, green finance, and concessional loans play a critical role in enabling the commercialisation of mature solutions.. However, to catalyse meaningful capital flows into ocean-based solutions, investors depend on policy certainty, credible MRV systems, and robust risk reduction mechanisms. In particular, directing private capital towards marine-based renewable energy is essential for reducing reliance on fossil fuels and ensuring long-term climate resilience. Targeted research can further support the de-risking of investments by quantifying and mitigating environmental and financial risks, while also evaluating and communicating the broader socio-economic and environmental benefits of these investments.

6. Prioritisation
With multiple decarbonisation pathways available and acknowledging the urgency in reducing CO_2 emissions, investments should be prioritised based on an assessment of the emissions reduction potential, on an evaluation of the technology readiness and innovation needs, on the alignment with national strength, and ensuring a comparative advantage while maximising co-benefits and minimising trade-off.

7. Workforce and Capability
A skilled workforce across marine science, engineering, restoration, and community engagement is essential. Australia currently lacks sufficient trained personnel to deliver large-scale marine climate projects. Education, training, and workforce development programs are necessary dependencies to build long-term capability.

8. Community Support and Social Licence
Lastly, social acceptance and local ownership are vital. Dependencies include meaningful engagement with Indigenous communities, transparency in decision-making, and visible co-benefits. Without social licence, projects may be delayed, challenged, or stopped altogether.

Conclusion

Australia has a unique and powerful opportunity to leverage its vast marine estate to accelerate progress toward energy security and net zero emissions. However, realising this opportunity will require deliberate and coordinated actions supported by a long term vision and targeted investments.

1. **Vast Untapped Potential**
   The ocean offers immense renewable energy resources—wave, tidal, and offshore

wind—that remain underutilised. Unlocking these stable and predictable energy sources will diversify the clean energy mix and enhance grid resilience.

2. **High Carbon Sequestration Efficiency**
   Blue carbon ecosystems (e.g. mangroves, seagrasses, saltmarshes) sequester carbon up to 10 times faster than terrestrial forests. Quantifying, protecting, and restoring these systems at scale will significantly enhances Australia's ability to reach its net-zero targets.
3. **Dual Climate and Biodiversity Benefits**
   Ocean-based climate solutions provide co-benefits such as coastal protection, habitat restoration, and fisheries support. Ensuring these solutions are implemented sustainably will deliver multiple environmental outcomes.
4. **Australia's Natural and Strategic Advantage**
   With one of the world's largest marine territories and exceptional wave and offshore wind resources, Australia is uniquely positioned to lead in ocean climate technologies, becoming a knowledge and export industry.
5. **Addressing Critical Knowledge Gaps**
   Scientific understanding of ocean energy systems, ecosystem carbon dynamics, and monitoring technologies remains limited. Closing these gaps will de-risk deployment and enable credible carbon accounting frameworks.

Science must lead, providing the evidence base for effective interventions and robust measurement systems. Governance must evolve, enabling integration across jurisdictions, sectors, and community interests. And investment—both public and private—must be unlocked to scale infrastructure, technology, and capability.

The National Marine Science Committee (NMSC) is well positioned to play a central role in guiding this transformation. By fostering collaboration across research, government, industry, and Traditional Owners, the NMSC can drive a national marine innovation agenda that aligns with climate goals and sustainable development.

Now is the time to act. By aligning policy, science, and investment with the scale of the climate challenge, Australia can lead the world in ocean-based climate solutions—delivering net zero outcomes that are not only technically feasible, but socially and environmentally just. The ocean is not just part of the climate problem—it is a critical part of the solution.

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Appendix 1

Key subject areas	Knowledge gap	High level priorities	Infrastructure/Capabilities	Key strategy/policy drivers	Pathways to science delivery
Marine-based renewable energy	Information of abundance, distribution, dynamics and stressors on cetaceans, birds, pinnipeds, fish and sharks. Knowledge of seabed habitats, ecosystems and biodiversity, and vulnerability of stressors. Inadequate baseline data on marine biodiversity, including migration routes, sensitive habitats, and threatened species. Unknown cumulative effects on marine ecosystems and fisheries. Better align social and community values into research. Better understand the drivers of community engagement and trust in information, and how research elements, such as use of best-practice standards, transparent and Findable, Accessible, Interoperable, and Re-useable (FAIR) data provision and research	Conduct baseline environmental assessments. Defining impact pathways and quantifying risk to natural values Investigate cumulative environmental and social impacts through modelling and case studies Developing more transparent decision framework. Responsible science and data in decision making Defining impact pathways and potential risks to cultural values Defining transition pathways, including technology choices, pace and impact. Assist the regulatory community in communicating the risks and trade-offs to the public at large. Refine regulatory and permitting frameworks in collaboration with stakeholders.	Infrastructure to study species dynamics (e.g. tagging, aerial, boat-based, and passive/drone survey tools, acoustic monitoring/modelling) Coordinate and invest in marine data portals to allow research and industry data to move towards adopting data principles of being Findable, Accessible, Interoperable, and Re-useable (FAIR). National research hub or collaborative platform.	Net zero by 2050 plan Sustainable Ocean Plan, UN Sustainable Development Goals, Ocean Decade; Intergovernmental Panel on Climate Change (IPCC), Conference of the Parties (COP), World Ocean Assessment (WOA), National and State governments (e.g. Australia's National Science Research Priorities), industry peak bodies, NGOs, communities, and First Nations peoples. National Energy Performance Strategy Offshore Electricity Infrastructure Act 2021 and associated Declared Areas (Gippsland, Bunbury etc.)	Invest in best practice standards to inform data acquisition and FAIR management of data. Progress cross-sectoral governance and coordination of data collection efforts to inform impact mitigation and management strategies. Develop a coordinated and collaborative marine-based renewable energy research initiative Public-private partnerships for demonstration projects. Funding for cross-disciplinary research (engineering, ecology, policy). International collaboration (e.g. with countries within APAC, the UK, Denmark etc).

Key subject areas	Knowledge gap	High level priorities	Infrastructure/Capabilities	Key strategy/policy drivers	Pathways to science delivery
	independence, interacts with community perceptions and receptiveness to information. Quantify how expected environmental changes might affect other marine users (fishers, recreational users, charter operators etc.), interact with adjacent marine parks, and affect on the local place identify. [economic benefits to society – transparency in economic decision making to assist rational benefit/cost assessment] How traditional values and uses have the potential to be impacted Regulatory frameworks under the Offshore Electricity Infrastructure Act (2021),but still maturing. Need for streamlined permitting, environmental assessment, and inter-agency coordination. Lack of spatial marine planning integrating marine-based renewable energy and other ocean uses.	Develop co-location strategies (e.g. wind + aquaculture). Advance marine spatial planning frameworks for multi-use oceans.			
Blue carbon	Uncertainty in carbon fate and permanency	Developing and standardising Monitoring, reporting and	Marine innovation hubs and living labs.	Net zero by 2050 plan	Interdisciplinary research consortia uniting

Key subject areas	Knowledge gap	High level priorities	Infrastructure/Capabilities	Key strategy/policy drivers	Pathways to science delivery
	Lack of trusted carbon accounting standards specific to blue carbon. Gaps in transparency and integrity of voluntary blue carbon markets—especially for coastal ecosystems. Lack of clarity on ethical trade-offs, such as biodiversity versus carbon sequestration or food security versus climate benefits. Limited understanding on the carbon sequestration capacity and the contribution towards net-zero emissions.	validating (MRV) methodologies to overcome technical complexity and data gaps. Developing methods to measure, report, and verify (MRV) ocean-based carbon sequestration at scale. Clarifying and harmonizing legal and regulatory frameworks to address governance challenges. Developing innovating economic instruments and simplifying carbon credit methodologies to support market development. Enhancing stakeholder engagement by integrating community-based and Indigenous governance. Advancing transdisciplinary research to improve understanding of ecosystem functions and restoration outcomes	Carbon registries: Verified platforms for registering, issuing, and tracking blue carbon credits with transparency and integrity. Market access infrastructure: Platforms for trading blue carbon credits and connecting projects to buyers (voluntary and compliance markets).	National Marien Science Plan Australian Carbon Credit Units (if extended to ocean-based removals) International Carbon Market Alignment (Article 6 of Paris Agreement) Environment Protection and Biodiversity Conservation (EPBC) Act	oceanography, ecology, economics, and policy. Pilot and demonstration projects with open-access data to evaluate real-world performance.
Ocean based green hydrogen	Limited understanding of how seawater impurities (e.g., salts, organic matter, biofouling agents) affect electrolysis efficiency, electrode durability, and hydrogen purity.	Marine Electrolysis Technology Development (Develop and test corrosion-resistant electrodes and membranes optimized for use with untreated or minimally treated seawater).	Research and industry hub focusing on ocean-based hydrogen generation Sensors that can be deployed to measure pCO_2, pH, turbidity, and other changes. 3.	Net zero by 2050 plan National Hydrogen Strategy (2019, under revision 2024–2025) State Hydrogen Strategies	Interdisciplinary testing areas that combine marine science, electrochemistry, and offshore engineering. Marine spatial planning tools to site hydrogen

Key subject areas	Knowledge gap	High level priorities	Infrastructure/Capabilities	Key strategy/policy drivers	Pathways to science delivery
	Corrosion and fouling challenges of electrolysers in marine environments are not yet fully understood. Uncertainty around the impacts of large-scale hydrogen infrastructure (e.g., offshore platforms, pipelines) on benthic habitats and marine species behaviour and migration. Unknown risks of chlorine or hypochlorite by-products formed during direct seawater electrolysis. Gaps in modelling how variable energy inputs (e.g., wind intermittency) affect electrolyser performance and system stability. Lack of understanding of energy and hydrogen storage dynamics in offshore settings (e.g., compressed gas, liquid hydrogen, ammonia). Incomplete knowledge on leakage risks of hydrogen in marine conditions and its interactions with seawater chemistry.	Ecological Impact Assessments (Investigate effects of hydrogen leakage, seawater electrolysis by-products, and operational noise on marine ecosystems). System Integration and Energy Optimization. Model integrated offshore systems combining wind, solar, wave energy with hydrogen production. Infrastructure and Logistics Advance marine engineering of hydrogen storage and transport infrastructure (e.g., subsea pipelines, storage caverns, floating platforms). Investigate alternative hydrogen carriers like ammonia or LOHCs (liquid organic hydrogen carriers) in marine environments. Monitoring, Safety, and Risk Management. Develop real-time monitoring systems for hydrogen leakage, electrochemical by-products, and marine ecosystem health. Establish risk assessment frameworks for extreme weather, corrosion, and operational failure	Automatic samplers to collect information about the microbial populations driving carbon sequestration (or conversely, respiration)	Bilateral hydrogen agreements (e.g., with Japan, Germany, Singapore, South Korea)	production with minimal ecological disruption. Policy and governance research on enabling international standards for ocean-based hydrogen production and trade.

Key subject areas	Knowledge gap	High level priorities	Infrastructure/Capabilities	Key strategy/policy drivers	Pathways to science delivery
	Safety concerns and unknowns in subsea hydrogen pipeline materials and their performance under high pressure and salinity. Regulatory gaps concerning zoning, environmental impact assessment, and maritime safety for offshore hydrogen projects. Lack of standardization for hydrogen leakage detection, emissions monitoring, and spill response at sea.				
Green shipping	Socio-techno economic study on ocean hydrogen and feasibility of green shipping Incomplete understanding of the operational reliability and scalability of alternative fuels (e.g., ammonia, hydrogen, biofuels). Limited data on lifecycle emissions of green technologies (e.g., battery-powered vessels, wind-assist propulsion). Fragmented global regulations and lack of harmonization between IMO (International Maritime Organization) and national policies.	Strategic assessment of all shipping to/from and within Australia considering the feasibility of the potential solutions and the required infrastructure to support it. Piloting and validating integrated fuel and electrification pathways Socio-techno economic study on green shipping Conduct toxicity and biodegradability studies on ammonia, methanol, and hydrogen in saltwater environments. Assess fuel spill response strategies for alternative fuels in cold and deep-sea environments.	Laboratory and field expertise in assessing the toxicity of alternative fuels and their by-products on marine organisms at different trophic levels. Capacity to conduct chronic exposure studies and ecosystem-scale impact modelling. Competence in GIS, marine spatial analysis, and cumulative impact modelling. Capability to integrate shipping data into ecosystem-based management tools.	International Maritime Organization (IMO) Regulations	Strong cooperation among marine scientists, engineers, climate scientists, regulators, and industry stakeholders. Establishment of joint platforms (e.g., science-policy hubs, maritime innovation centers) to align research with industry needs and regulatory frameworks. Creation of open-access data platforms combining shipping activity, emissions data, ecological data, and oceanographic observations.

Key subject areas	Knowledge gap	High level priorities	Infrastructure/Capabilities	Key strategy/policy drivers	Pathways to science delivery
	Insufficient understanding of the long-term ecological impacts of alternative fuels (e.g., ammonia leakage, noise pollution from electrification). Limited data on the toxicity and behaviour of new fuels (e.g., ammonia, hydrogen, methanol) when accidentally released into marine environments.	Integrate green shipping into marine spatial planning frameworks to assess cumulative environmental impacts from multiple maritime sectors.			