BLUE ECONOMY
COOPERATIVE RESEARCH CENTRE

OCEAN WAVE ENERGY IN AUSTRALIA

EXECUTIVE SUMMARY

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Department of Industry, Science and Resources

Cooperative Research Centres Program

The Blue Economy CRC

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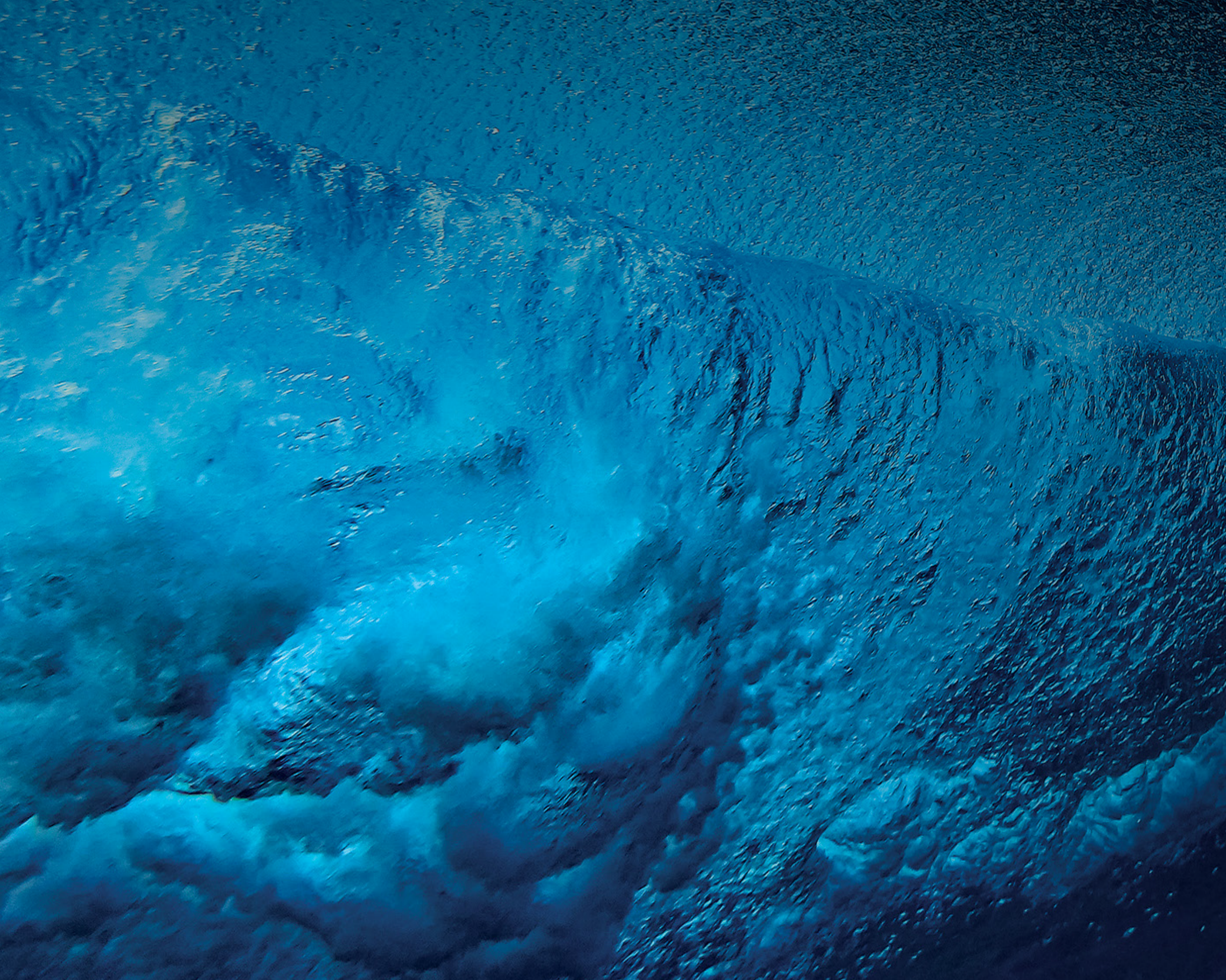

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Dedication

This report is dedicated to two wave energy pioneers who passed away in 2024. Stephen Salter and Johannes Falnes laid much of the groundwork for the modern wave energy industry and their vision continues to inspire innovators in Australia and worldwide.

Executive Summary

Ocean wave energy is undergoing a renaissance, with significant funding and effort worldwide devoted to this source of clean energy. This is driven by multiple factors, including the need for decarbonisation and renewable energy development in the face of climate change, the recognition of the diverse benefits of ocean wave energy as part of clean energy systems and a burgeoning Blue Economy.

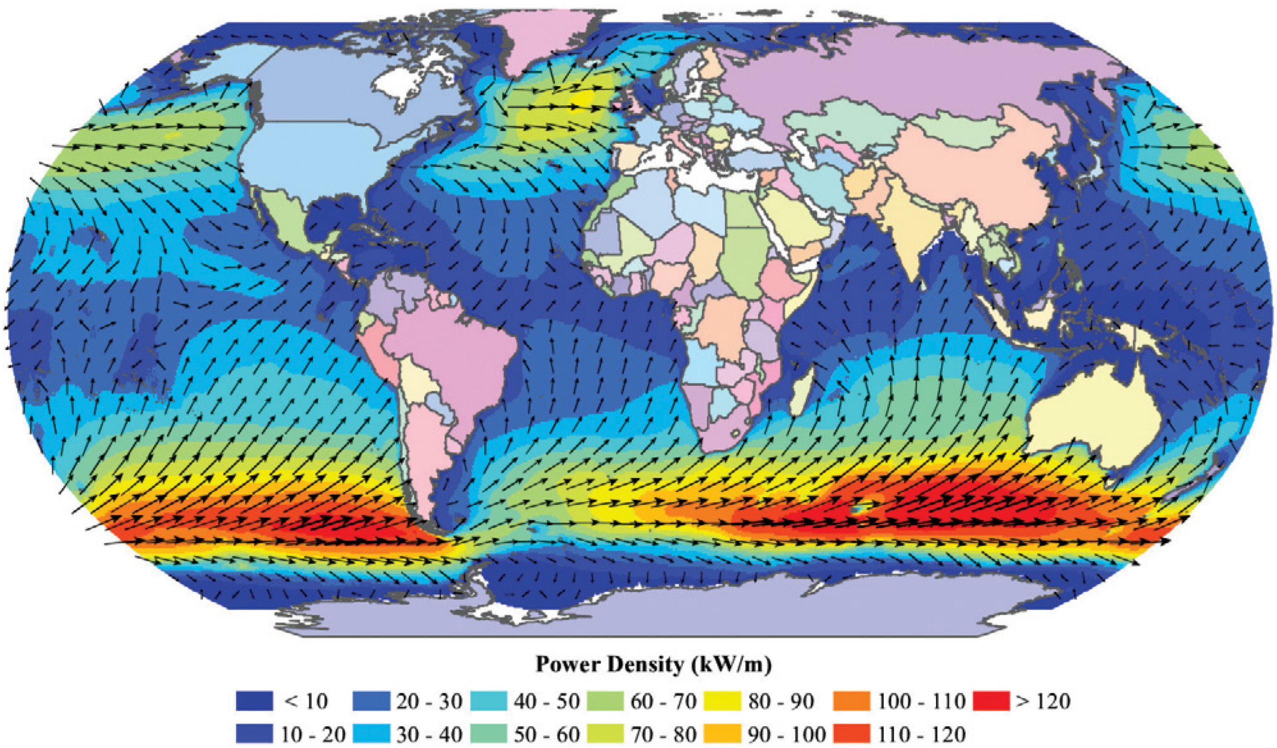
The establishment of a global offshore wind industry provides an example and opportunity for the development and scaling up of other types of offshore renewable energy generation, including wave energy. With the world's largest national wave energy resource, Australia is uniquely well-placed to lead in this space, but is not keeping pace with global developments. Consequently, Australia is not realising the financial, social, and environmental benefits that could result from the development of a robust and sustainable ocean wave energy industry.

Australia has the largest wave energy resource of any country in the world.

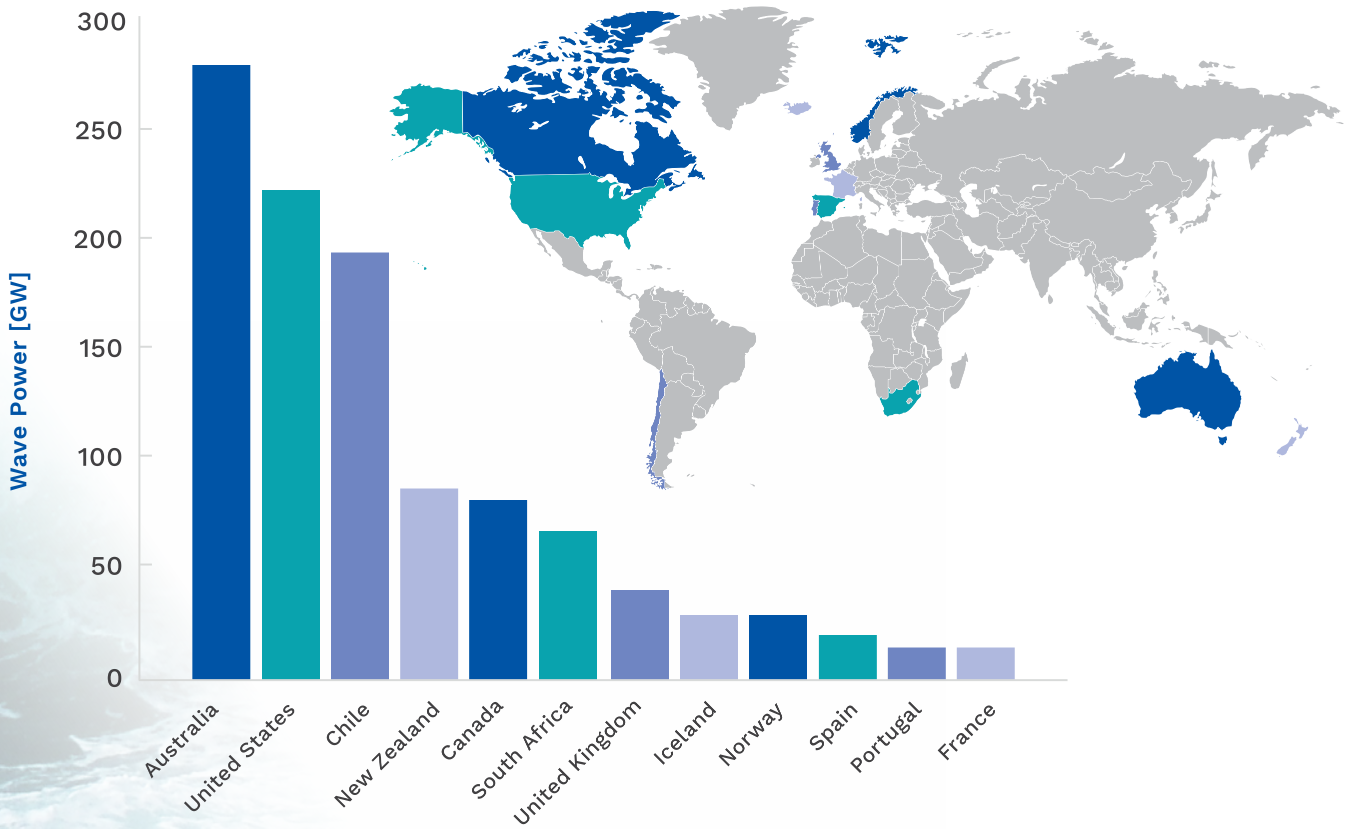
The average power of the ocean waves crossing the perimeter of Australia's continental shelf is estimated at around 300 GW, ten times Australia's average rate of electricity consumption. The enormity of the national resource results from the extensive coastline directly facing the Southern Ocean. Persistent strong winds in this vast oceanic expanse concentrate energy in large waves which bring renewable energy towards the shores virtually continuously. The south and south-west mainland coastline and the south-west coast of Tasmania in particular experience the highest wave power levels, with exceptionally high-quality waves, exhibiting minimal intermittency and small extreme-to-mean wave height ratios, two characteristics essential for uninterrupted energy production.

Figure 1. Australia has the largest wave energy resources in the world, based on data from Gunn and Stock-Williams (2012).

World map of wave power density.



Wave power resource for selected countries.



Wave energy is persistent and highly complementary to solar; it therefore has a role to play in the future energy mix.

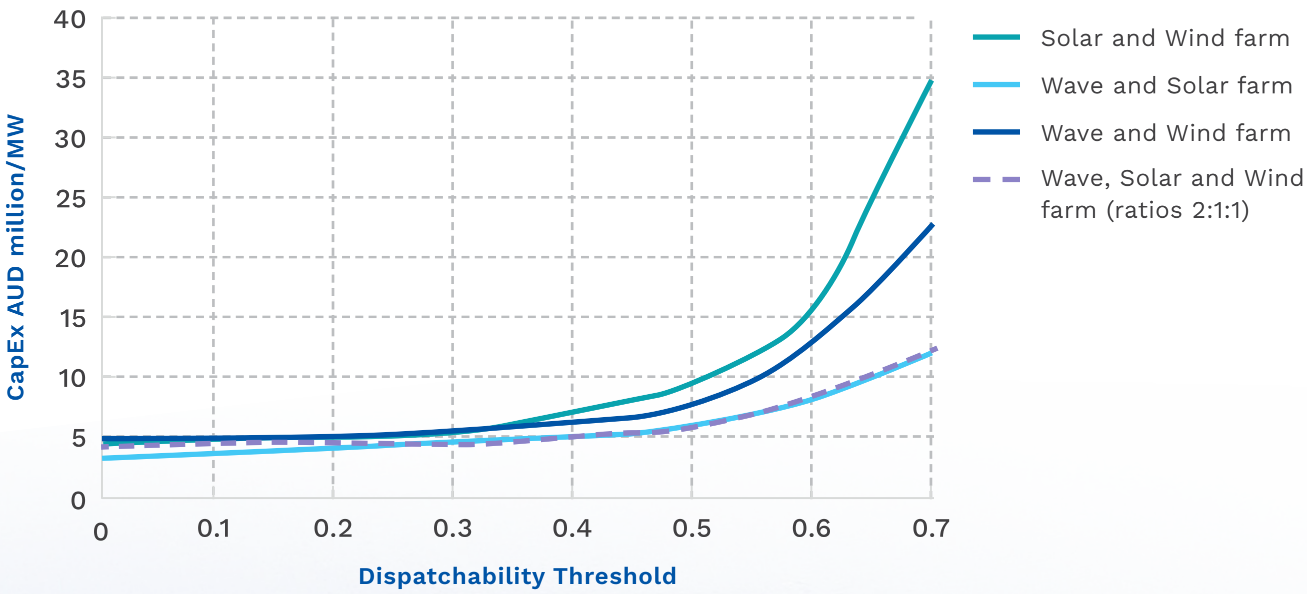
When combined with other renewables, wave energy decreases the cost of reaching a given level of dispatchability – the ability to guarantee power supply at a certain level. Results from Australia and around the world show that this is because combining the latest wave energy technology with wind and solar can cost-effectively reduce the need for energy storage. The example in Figure 2 shows a 50% reduction in the CapEx required to reach 0.6 dispatchability if wave is added to the energy mix, compared to solar and wind alone.

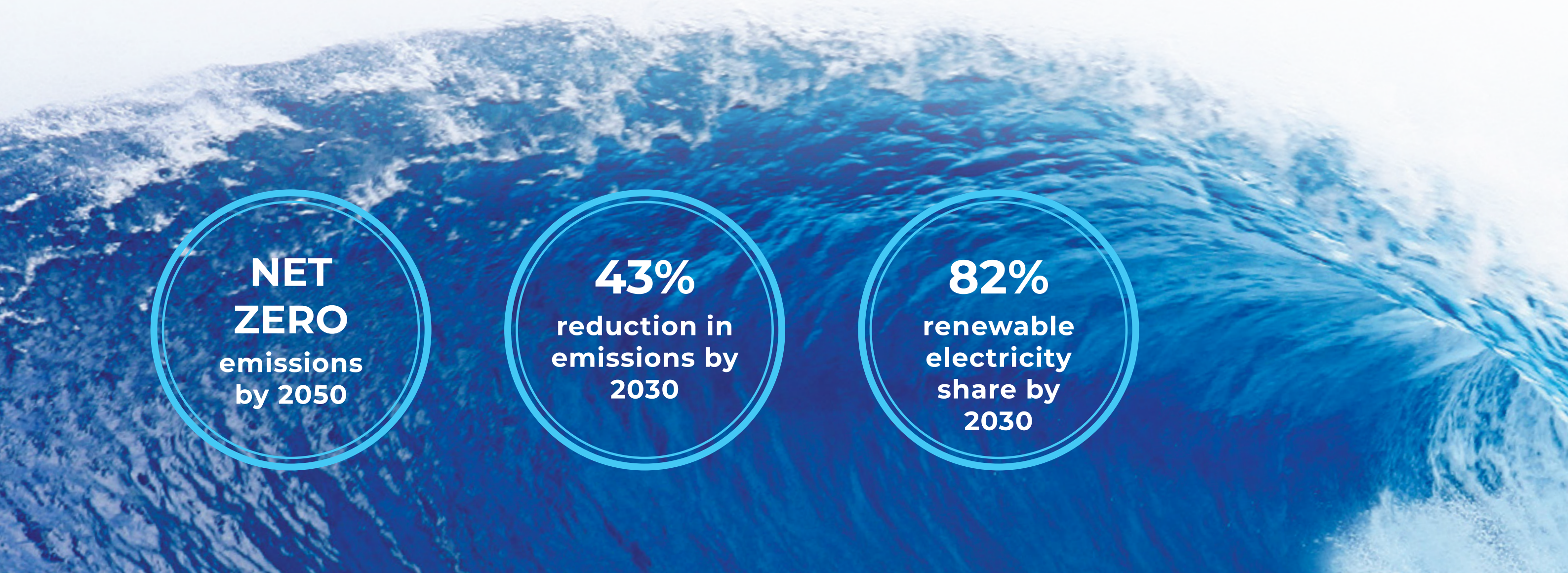
Promising electricity markets for wave energy in Australia include:

- introducing more cost effective dispatchability into national and State grid networks;
- combining wind, wave and solar for towns (particularly on the south and west coasts) which could provide standalone power or more opportunities to trade dispatchable electricity on the spot market.

Combined solar and wave systems can also provide standalone dispatchable power for remote communities on the east and west coasts.

Figure 2. CapEx 2050 estimates per MW average power, for a range of hybrid renewable energy resources to achieve dispatchability thresholds (ratio of guaranteed to average power) of 0.1 to 0.7. Location Carpenter Rocks, South Australia. As the dispatchability threshold increases, inclusion of wave energy dramatically reduces the costs compared to wind-solar solutions.





Wave energy can be a critical enabler in helping Australia achieve its net zero targets.

Australia's climate strategy focuses on achieving net zero emissions by 2050, with interim goals including a 43% reduction in emissions by 2030 and an 82% renewable electricity share by 2030.

The strategy includes initiatives like the Powering Australia plan, which aims to expand renewable energy and create jobs.

National Electricity Market (NEM) forecasts for 2050 suggest an enormous expansion in renewable energy capacity but also a shortfall in dispatchable power. Wave energy could therefore play a key role in future electricity grids.

Wave energy has the potential to support Australia's economy with world-class research and innovation capabilities and expertise, and a skilled workforce.

Australia has many elements necessary for wave energy, including existing skills in the workforce for offshore infrastructure and renewable industries.

High-level capabilities exist in Australia's research and innovation sector (e.g. in universities, CSIRO, industry, etc). Examples from around the world have demonstrated an economic value of wave energy industries, especially in coastal regions.

Wave energy has the potential to provide market and supply chain opportunities given the diversity in technologies, which range from grid connection to powering remote aquaculture facilities. Based on the few wave energy prototype projects completed, or currently conducted, Australia has an opportunity to leverage wave energy, supporting the growth of the AUD 118 billion Australia blue economy, especially in coastal regions, and utilise an existing skilled workforce to support fabrication, installations, and marine operations.

Image courtesy of University of Western Australia.

Photograph by Richard Manassen, with thanks to Wade Greenaway, Mid-West Ports Authority.

Wave energy converters may also be a useful tool in providing coastal protection, at the same time as generating electricity.

Waves are a key driver of coastal impacts due to flooding and erosion which will increase in frequency and intensity with climate change. Waves can be reduced or altered in a controlled manner by wave energy installations, protecting coastal communities and assets worth up to AUD 25 billion. Efforts are required to understand the interconnectivity between wave energy generation and coastal protection, as well as social acceptance to leverage this opportunity.

Wave energy developments in Australia can lead best practice in environmental impact assessment and social and cultural engagement.

Wave energy projects can leverage existing knowledge and data in environmental assessment and planning from other offshore developments.

Potential environmental impacts will be entirely dependent on the type, scale and location of the wave energy development, and other activities present and planned in the area.

Key areas likely to require some investigation in relation to smaller projects include interactions with seabed habitats and marine life during both construction and operation, particularly those associated with underwater noise, entanglement risk with mooring systems and potential interactions with other sea users. For larger developments, other potential interactions that may need to be addressed include those associated with changes in physical oceanography and displacement of sensitive species.

Coordinated strategic environmental and social research and monitoring programs developed through collaboration between Government, regulators, industry, and academia can de-risk the approvals process and help facilitate the sustainable and equitable development of the sector. Early and ongoing engagement with local communities, including Indigenous Peoples in places of cultural significance, is critical to gaining and maintaining the Social and Cultural Licences to Operate.

Image courtesy of Corpower.

Meanwhile, Europe and other regions are advancing wave energy with support and policy, anticipating significant growth by 2050.

With rapid technological advances and the International Energy Agency Ocean Energy Systems (IEA-OES, 2023) roadmap projecting 300 GW of ocean energy by 2050, the wave energy sector is set to expand significantly – creating ~680,000 jobs, boosting economic value by USD 340 billion, and reducing carbon emissions by ~500 MT p.a. worldwide. Both market pull and technology push mechanisms have been identified as necessary if wave energy is to play a substantial role by 2050.

The EU leads in wave energy technology development, holding 44% of global patents and investing significantly in R&D, with projections for ocean energy contributing EUR 5.8 billion to the economy by 2030 and creating substantial economic activity and jobs by 2050.

Strategic roadmaps at both EU and national levels guide efforts in wave energy. The EU's offshore renewable energy strategy targets 100 MW of ocean energy by 2027, 1 GW by 2030, and 40 GW by 2050. The European Commission plans to support this through a robust legal framework, funding, and supply chain improvements.

The UK predicts the installation of 6 GW of wave energy by 2050. This development could meet 15% of the UK's electricity demand and contribute GBP 6 - 21 billion to the economy, creating up to 8,100 jobs by 2040. The UK holds 35% of Europe's wave energy resource and has significantly invested in the sector, with EUR 32 million in public funding from 2022 to 2025.

The US Government has substantially increased funding for ocean energy research, with a record USD 120 million allocated in 2023 and a total of USD 520 million since 2019, surpassing European investment. State-level support is also growing, with California and Oregon advancing ocean energy laws.

Major technology developers span across Europe, the US, Australia, Canada, and Asia, showcasing a diverse range of concepts. Grid-connected test centres worldwide, such as those in the UK, US, and China, support technology trials under real-world conditions.

Despite all its strategic advantages, Australia currently lacks the level of support and funding needed to match its immense potential.

Since its inception in 2012, the Australian Renewable Energy Agency (ARENA) has invested AUD 2.25 billion in 663 projects, with around AUD 44 million (<2%) allocated to ocean energy (wave and tidal) projects. Notable funded projects include the Australian Wave Energy Atlas, the Perth Wave Energy Project, and the UniWave200 King Island Project.

The Blue Economy Cooperative Research Centre has supported small-scale wave energy projects such as Carnegie Clean Energy's MoorPower and the M4 Albany Wave Energy Demonstration Project. However, there are currently no dedicated roadmaps for wave energy in Australia and it is not included in the latest Integrated System Plan. There is a mismatch between the scale of Australia's opportunity and the national funding support and effort in wave energy.

Compared to other jurisdictions, the lack of a focused strategy represents a missed opportunity to diversify the renewable energy portfolio and enhance the Blue Economy.

Rapid development of wave energy in Australia is possible.

Several Australian agencies have recently issued their strategic plans for renewable energy technology development, emission reductions, job creation, and infrastructure upgrades. The national Sustainable Ocean Plan is currently being drafted.

These initiatives show that significant momentum is building and that an opportunity to integrate wave energy within energy and coastal protection plans exists. No environmental, social or cultural barriers have been identified which would prevent a well-managed, sustainable and socially acceptable wave energy industry from developing. Streamlining and optimising regulatory and planning processes, including across jurisdictions, while providing incentives and early support to the wave energy industry, can accelerate the development of wave energy towards full commercialisation.

Australia has the capacity to be a leader in the wave energy sector and the time for action is now.

Image courtesy of Carnegie Clean Energy.

Recommendations

The overarching recommendation of this report is:

Federal and State Governments in Australia should take a strategic view of the wave energy industry in order to achieve the maximum national benefit from this potentially critical national resource.

Underneath this umbrella, this report details seven recommendations across three key themes for the development of wave energy in Australia:

Area	Detailed Recommendations
Wave energy should be incorporated into national and State planning.	**1. The Australian Renewable Energy Agency (ARENA) should fund a study to determine the national benefit of developing a wave energy industry, including benefits to economic and social development, sovereign capability, environmental sustainability and export capacity through the development of a leading domestic industry.** This report indicates significant benefits from wave energy in multiple areas. Further substantial work remains to more accurately quantify many of these benefits and to identify mechanisms to seed, support and accelerate the industry. The benefits of alignment with the considerable international momentum in wave energy should be considered, including Australian alignment with the International Energy Agency Ocean Energy Systems roadmap for 2050. This should include consideration of 'market pull' mechanisms to encourage long-term investor confidence in the sector. A domestic wave energy industry is aligned with government policies including Powering Australia, Future Made in Australia and Net Zero targets.
	2. The Australian Energy Market Operator's Integrated System Plan (ISP) should evaluate wave energy possibilities, and in particular include and evaluate the impact of wave energy on 2050 requirements for energy storage. The Australian Energy Market Operator's (AEMO) Integrated System Plan (ISP) presently does not consider wave energy in any form. The EVOLVE study of the UK market (EVOLVE, 2023) concluded that installing 10 GW of wave energy could lead to annual cost savings of up to AUD 2.76 billion (GBP 1.46 billion) by 2040 due to reduced needs for storage and other generation. Findings in the present report similarly show that for Australian conditions introducing wave energy is associated with large reductions in storage capacity required. This translates directly to lower cost through the reduced cost of storage. Modelling for the local grids of three locations on the south coast of Australia returns very similar dispatchability and cost results, while resource modelling shows a high degree of similarity in the wave resource across Australia's southern margin. This provides confidence that the results in this report can be replicated at a larger scale. The system-wide implications of wave energy can only be reliably assessed by an integrated approach.

Area	Detailed Recommendations
	3. Wave energy should be included in the Sustainable Ocean Plan and considered alongside other renewable energy technologies. Funding schemes for wave energy projects will revitalise the connection between Australia's technology developers, research institutions, markets and investors, regional councils, and planning bodies. With State and federal Government support committed and sustained, training and transitioning of jobs in the offshore energy sector towards wave energy and other marine renewables can create employment and revenue. Cross-sector and cross-departmental collaboration can increase impact and benefits through education, R&D, and business activity. Australia's rural, regional, remote (RRR) coastal areas can play a major role.
Funding effort should be consistent and at scale to de-risk and accelerate deployments.	**4. Projects on different scales and across different market applications should be funded to validate wave energy technology and to demonstrate its national benefits over longer periods.** A key benefit of wave energy is dispatchability. The Australian wave resource has exceptionally favourable characteristics, but projects to date have not been designed to demonstrate reliable supply over multi-year periods. Field demonstrations over an extended period with permanently connected device(s) should be funded at different scales: decarbonising offshore facilities such as aquaculture; small scale supply to an isolated community; at larger (perhaps MW) scale with solar and wind to a remote (but grid-connected) community to improve dispatchability of the local grid; and ultimately at larger scale to national or State grids. Such 'technology push' funding to accelerate wave energy development is identified as a key mechanism by the International Energy Agency Ocean Energy Systems roadmap. Further, multi-year deployments will offer a key opportunity to evaluate environmental and social impacts.
	5. An integrated study to establish national guidelines for using wave energy for coastal protection should be carried out. Coastal protection is typically dealt with by local councils without the resources to study the possible benefits of wave energy. National guidelines to enable rigorous assessment and ensure public confidence in decision making about whether and how to use wave energy for coastal protection would provide significant benefit and enable uptake of wave energy solutions. This can provide benefit in both climate change mitigation and adaptation.

Area	Detailed Recommendations

Area: Sharing non-competitive information will accelerate the local industry.

6. Baseline data, data sharing across jurisdictions and collaborations, and community engagement should be incentivised by federal and State Governments as key to the success of wave energy projects.

Government has a key role to play in collecting baseline data (or mandating sharing from other industries or sources), to reduce the burden on project developers. Site selection of wave energy development sites will be guided by multiple, potentially competing, factors and includes aspects of environmental assessment, planning and regulation, social acceptability, and the cultural licence to operate. The weighting of these factors will depend on the size of the project, from single small wave energy converter (WEC) deployments to utility-scale arrays. Collaboration across Australian governmental jurisdictions, and publication of guidance documents and policies, can improve alignment and approvals processes, science-based assessment, and inclusion of wave energy in existing marine estate management plans. A coordinated strategic environmental research plan should be developed to de-risk the approvals process and facilitate the sustainable development of the sector. An example of such a plan is the ORJIP Ocean Energy plan in the UK (Aquatera, 2016).

Community engagement should follow a coherent plan across all relevant layers of Government and industry bodies and prioritise opportunities for trustworthy and independent research and learning, and knowledge-sharing between communities and developers. Indigenous Peoples should be included as decision-making partners, and monitoring and evaluation of, and learning through, this partnership will benefit projects and the industry.

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7. Validated, high-resolution, long-term analyses of wave climate should be carried out for the declared offshore wind zones and for strategic wave energy hot spots.

For wave energy developments to proceed, more research is needed, building on the invaluable information on the wave climate delivered by the Australian Wave Energy Atlas and subsequent studies in south-west Western Australia, the Bass Strait, and the south-east coast.

In shallow water regions, where wave energy converters are likely to be deployed first, high-resolution models (with grid sizes in the tens of metres) are needed in order to correctly simulate the complex interaction of waves with the variable underwater bathymetry. Such detailed wave climate studies are needed but are rare and require expertise. In addition to quantifying the resource and its temporal characteristics, the studies should focus on:

- Reliable estimates of extreme wave conditions needed in engineering design such as the 50-year wave conditions. These estimates are also needed by the offshore wind industry, which follows similar design guidelines.
- Wave directional characteristics, such as wave spreading around the mean propagation direction, as these are rarely taken into account when WEC performance and energy yield calculations are carried out.
- Weather windows for safe installation and maintenance. The exceptional persistence of waves along the southern margin, while desirable for energy production, could be problematic if the available weather windows are insufficiently frequent and/or insufficiently long.

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