Ocean Wave Energy in Australia

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Abstract—**This paper presents a comprehensive overview of the status and opportunities for wave energy in Australia, drawing on a national report completed in 2024. As the country with the largest wave energy resource in the world, Australia has an important role in the development of a global wave energy industry. This paper reviews the international and domestic landscape, Australia's resource and market opportunities, as well as the industry, social and environmental context for an Australian wave energy industry. Based on these findings, a series of actions are recommended to catalyse the growth of an Australian industry, and make the most of the natural advantages the country is endowed with.**

Index Terms—**Australia, environment, market, wave energy**

I. Introduction

In September 2024, the report 'Ocean Wave Energy in Australia' was released by the Blue Economy CRC [1]. This report aimed to summarise the state of the wave energy industry in Australia, critically examine the opportunities which exist and provide recommendations for action. A part of the goal of the report is to bring wave energy in Australia into consideration in contexts where it has been excluded to date, including energy system planning, coastal protection and national environmental studies. As part of promoting and publicising this report, a summary of the report is presented here, with a focus on the Australian aspects, suitable for the EWTEC forum. It is hoped that publicising the report at EWTEC may lead to increased awareness of the opportunities that exist in Australia, encourage other nations which lag world leaders to take similar action, and foment discussion of how to continue to promote and foster the Australian wave energy industry.

The report aims to synthesise the best available information and drive further investment and research by:

- Summarising the national and international wave energy landscapes;
- Reviewing and presenting the national wave energy resource;
- Identifying key applications and market opportunities for wave energy;
- Discussing employment and industry aspects; and
- Evaluating the environmental, planning, social and cultural context for wave energy in Australia.

II. International trends and Australia's position

The modern history of wave energy research can be traced back to the oil crisis of 1973, which ignited a search for other forms of energy. Many fundamental discoveries were made in the 1970s and 1980s. Europe has traditionally been the leader in wave energy, but developers and test sites now exist around the world. Australia commenced wave energy research and development relatively late, but is blessed with the world's largest wave energy resource, and has seen several notable projects, including:

- Carnegie Clean Energy's (CCE) deployment of three grid-connected CETO 5 Wave Energy Converters (WECs) off Garden Island, Western Australia in 2014 [2]. CCE is now progressing deployment of CETO 6 in Europe.
- Wave Swell Energy deployed a grid-connected UniWave 200 Oscillating Water Column (OWC) off King Island in Tasmania for two years, commencing in 2021. Performance is reported in [3].
- An M4 demonstrator was deployed in King George Sound, Albany, Western Australia in summer 2024-2025 [4].

Australia also has many universities active in wave energy research, with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) also prominent. These organisations can support industry in the pre-commercial stages of technology development and testing through research infrastructure such as wave tanks and wave basins. Currently, there are no national grid-connected open-sea test centres for wave energy in Australia.

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Fig. 1. Notable Australian deployments: Wave Swell Energy Uni-Wave 200 (left); Carnegie Clean Energy CETO 5 array (right).

The International Energy Agency's (IEA) Technology Collaboration Programme for Ocean Energy roadmap [5] calls for deploying 180 GW of wave energy generation capacity worldwide by 2050. Together with 120 GW of tidal energy, achieving this target would deliver 680,000 jobs, USD 340 billion Gross Value Added and a 500 million tonne reduction in carbon emissions worldwide. Activity may be dominated by 20 or fewer countries driving this new industry. Australia is not presently playing a large enough role to be one of these major players.

Around the world, international jurisdictions have strong and specific targets for wave energy. For example, the EU has a dedicated Strategy on Offshore Renewable Energy, and is targeting 100 MW of ocean energy by 2027, 1 GW by 2030 and 40 GW by 2050.

Australia, on the other hand, does not have national policies or targets concerning ocean energy. The Government's goal is to reduce emissions to 43% below 2005 levels by 2030, by generating 82% of the national electricity supply from renewables by this date, and ultimately reach net zero by 2050. In service of this goal, the Australian Energy Market Operator (AEMO) expects to triple the 2024 capacity of variable renewable generation by 2030, and increase it six-fold by 2050 [6]. Achieving these targets will require a strategic focus on diversifying the renewable energy portfolio.

The 2023 Energy Policy Review by the IEA [7] suggests that Austalia's current trajectory is inconsistent with these targets. The IEA recommends increasing investment in diverse renewable technologies, development of a green industrial strategy and strengthening public funding of RD&D, which currently is only half the IEA average.

Current government plans and policies include the AUD 23 billion Powering Australia plan and the Future Made in Australia policy. Neither of these currently mention wave energy. The Australian Renewable Energy Agency (ARENA) has invested AUD 2.25 billion in grants to renewable energy since 2012. A breakdown of funding for ocean energy projects funded (which include those in Fig. 1) is given in Fig. 2 below. Australia is currently drafting a Sustainable Ocean Plan to guide Australia's future ocean management. This important task will influence the domestic blue economy, worth AUD 118 billion per year. The Blue Economy Co-operative Resarch Centre (CRC) was funded in 2019 with a 10-year term and more than AUD 300 million in support. It has funded key projects including the M4 Wave Energy demonstrator.

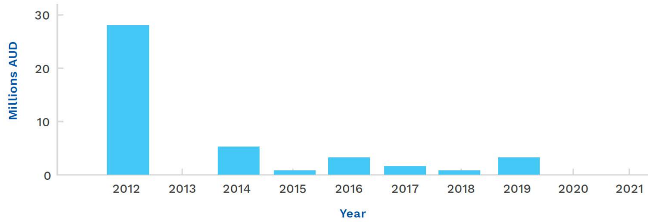

Fig. 2. ARENA funding for wave energy in Australia 2012-2021.

III. Australian ocean wave resource

Australia has the world's largest wave energy resource, with the energy delivered to the coast by waves more than ten times as large as current annual electricity generation nationwide. The most comprehensive study of the Australian resource to date is the Australian Wave Energy Atlas [8]. This study covers the period 1979-2010 using hindcast modelling. As shown in Fig. 3, wave power levels of 20-60 kW/m are common along the south coast of Australia. These waves are relatively long, with energy periods of typically 11 seconds. The east coast has generally lower, but still useful, power levels, associated with shorter waves (energy periods 7-8 seconds). The north coast is generally not suitable for wave energy developments. Australia has recently passed the Offshore Electricity Infrastructure Act 2021, and declared its first Offshore Wind Zones. These areas are on the south and east coasts, and hence typically co-located with moderate to substantial wave energy resources (10-50 kW/m, depending on location).

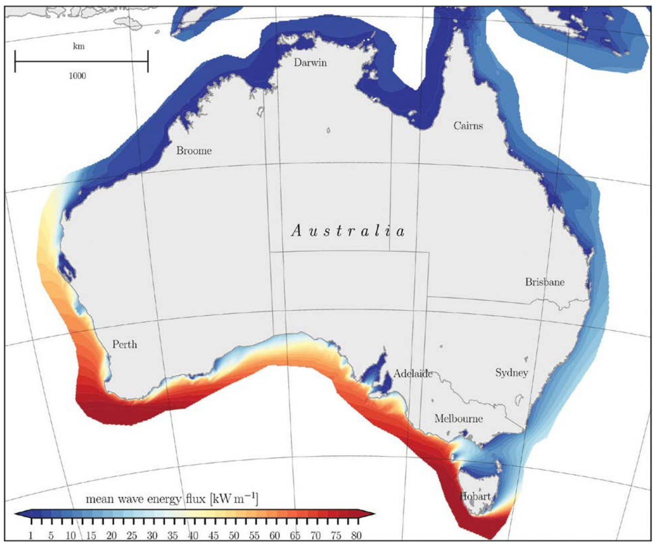

Fig. 3. Australian national wave energy resource (from [8]).

In Table I, the resource is divided into state portions, and compared to each state's electricity generation (2022 figures). For each region there is more wave energy available than electricity generated.

TABLE I
ANNUAL MEAN WAVE ENERGY FLUX ACROSS GIVEN DEPTH CONTOURS (TWH/YR) FOR EACH STATE, COMPARED TO ELECTRICITY GENERATION (TWH/YR).

Region	25-m contour	50-m contour	Electricity generation (2022)
Western Australia	754	1156	44.8
South Australia	385	631	14.8
Victoria	158	184	54.5
Tasmania	272	333	10.9
New South Wales	79	79	73.2
Queensland	140	237	69.6
Northern Territory	17	18	5.3

In addition to the size of the raw resource, temporal variability is important. Australia's wave energy resource on the south coast has low variability by international standards, with mean monthly energy flux in winter being less than twice the mean monthly energy flux in the less energetic summer months. Furthermore, days with very little wave energy (wave heights < 1m) are extremely rare, and extremes are relatively benign compared to the North Atlantic, for example.

However, there is uncertainty in estimates of extremes, due to a lack of long wave data records [9]. This deficit cannot easily be made up with existing models, which may not predict historical extremes well [8].

There are also seasonal and inter-annual oscillations in the wave climate. The El Nino Southern Oscillation (ENSO) has many effects across Australia. ENSO has been shown to influence wave climate on both the east and south coasts due to changes in wave direction [10], [11] and to also affect storm frequency on the former. The Southern Annular Mode (SAM) affects wave heights and direction on the south coast [12]. In future, climate change is expected to lead to increases in wave period along the south coast and wave directions becoming more southerly [13], for example.

IV. Market Opportunities, Applications and Integration

A. The value of dispatchability

Wave energy can cost-effectively support solar and wind energy resources to improve power supply reliability. Wave energy can help to overcome the intermittency inherent in solar and wind energy—which can manifest as wind or solar droughts [14]. Wave energy can also help with variability—i.e. predictable changes, such as seasonality. Intermittency and variability may be managed using energy storage, so that the value of wave energy is closely connected to costs of storage.

In the report, the term dispatchability is used, where dispatchability is the ability to supply power whenever needed up to a power demand limit set by the electricity purchaser or a power generation limit set by the electricity supplier. A related concept is the dispatch threshold, which is the maximum power that can be guaranteed divided by the average power generated [15]. This concept is closely linked to that of 'Plant Availability', used by AEMO to describe the power output of scheduled and semi-scheduled generators.

Using methods described in [15], along with projected costs from [16], [17], wave data from [8] at the location of Carpenter Rocks, South Australia and a power matrix from Wave Swell Energy, 2050 CAPEX values for hybrid power systems (per MW) were determined as a function of the required dispatch threshold (Fig. 4). It is clear that the cheapest solutions at higher dispatchabilty involve wave energy, and that the CAPEX saving is very significant. This result is due to the persistence of wave energy across time, as well as its high complementarity with solar on a seasonal basis. These results are similar to those of the EVOLVE study [18].

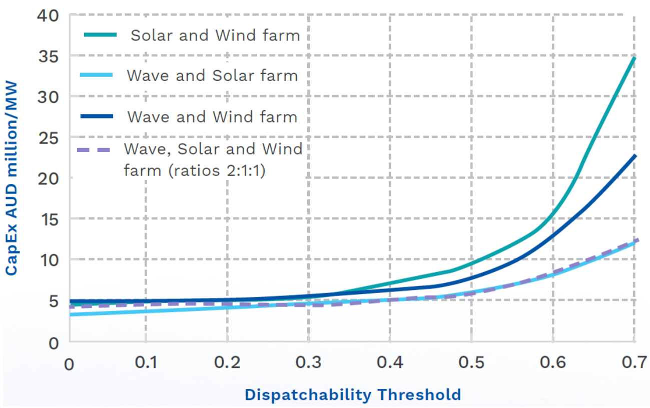

Fig. 4. CAPEX 2050 estimates per MW average power, for a range of hybrid renewable energy resources to achieve dispatch thresholds up to 0.7. Location Carpenter Rocks, SA. The CAPEX for dispatchabilities of zero reflect the cost of the generators rather than energy storage, except for solar arrays where some energy storage is included to allow for the diurnal average.

Australia's National Electricity Market (NEM) will require significant dispatchable capacity in future. The Integrated System Plan [6] suggests that the NEM is providing a dispatch threshold of 0.8 at present, falling to 0.7 in 2030 and 0.6 in 2050. This gap is indicated by the 'A' in Fig. 5, which suggests a market for wave energy. Further, the projected storage component of dispatchable capacity will reach almost 50 GW by 2050, indicated by the 'B' in Fig. 5. Wave energy could reduce the size, and hence cost, of this requirement.

B. Wave energy for coastal protection

Australia has an immense coastline and population concentrated on the coast. Man-made coastal assets valued at over AUD 25 billion were assessed as being at risk in 2022 [19]. Coastal protection is required to prevent or mitigate wave-induced damage due to coastal flooding and erosion and other coastal hazards. Wave energy, uniquely, can serve a dual purpose of power generation and coastal protection, by removing energy from the wave field [20]. Traditional coastal protection involves erecting barriers to wave energy, and is associated with known impacts [21]. While including wave energy in such infrastructure (along the lines of the Mutriku plant [22]) can lead to positive outcomes, the use of dedicated dual-purpose arrays is a new opportunity.

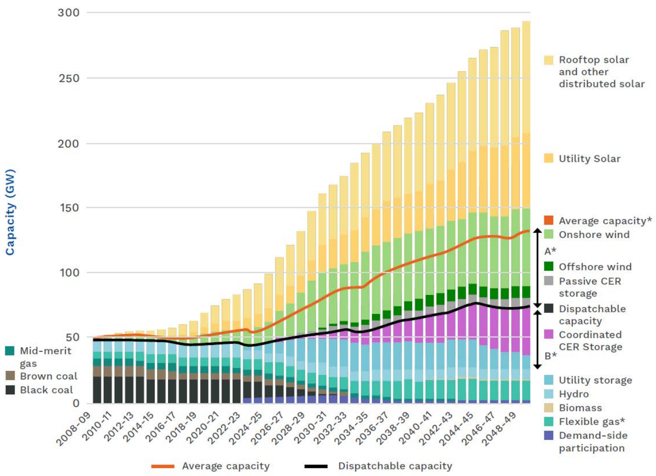

Fig. 5. NEM Average and Dispatchable power Projected to 2050. © AEMO [6]. Reproduced with the permission of AEMO. The orange line - average capacity, black line - dispatchable capacity, and 'A' and 'B' were added to the original figure.

Hence, a nine-step procedure is recommended for asessing and designing such dual-purpose wave energy arrays in Australia. In practice, such a procedure will need to involve iteration—for example, community engagement according to the guidance in Section VI would occur throughout a project.

1) Measure oceanographic and geomorphological data: this data is required across time, to understand the many timescales and processes involved. Wave conditions associated with erosion (or other impacts) should be identified.
2) Calculate desired WEC operating parameters: key points are WEC natural frequency and damping when operating, as well as effect on the wave field when turned off.
3) Select preferred class of WEC: first the preferred class of WEC [20], then the preferrred technology type, should be selected based on local factors such as water depth, wave climate, etc.
4) Optimise array layout: it is overall array effects which will influence the coast, and the layout can affect WEC interactions and hence coastal protection [23].
5) Produce engineering-costing relations: costs of key components and processes including fabrication, installation, etc. need to be determined.
6) Produce finance-costing relations: the cost of financing must be added to the engineering cost.
7) Produce revenue relations: it is necessary to understand how much revenue the array could generate, and the interaction between generation and desired coastal protection outcomes.
8) Determine community benefits: these include property values and insurance costs, changes to tourism, etc.
9) Empower community decision making: the ultimate decisions on the shape of any project should be taken by the community.

C. Co-location opportunities

1) Offshore wind: Australia commenced awarding feasibility licences for offshore wind in 2024. As noted above, these licence areas coincide with high to moderate wave energy flux. A study of co-locating wind and wave energy at 8 locations around Australia examined the economic potential of one particular hybrid wind-wave combination (5 MW wind turbine and 4 × 600 kW WECs as a unit) compared to wind alone [24]. It was found that in 7 of 8 cases the LCOE of the combined system was lower than offshore wind alone.

2) Aquaculture and fisheries: A recent estimate valued Australian fisheries and aquaculture production at AUD 3.48 billion per year [25]. Sea-cage aquaculture systems require electricity for feed barges, lighting, ventilation, etc. The Australian aquaculture industry is planning to expand activities offshore, where diesel fuel costs more, and wave energy is higher. Under these circumstances, wave energy already has an LCOE competitive with diesel [17], with wave expected to become substantially cheaper in future.

Powering offshore aquaculture could involve co-locating existing WECs or modifying existing aquaculture infrastructure. Benefits of the former approach were investigated in an Australian concept [26], with significant savings in CO_2 and battery capacity forecast. The latter approach has been taken by CCE, in developing the MoorPower concept to retrofit feed barges with power take-off units. A reduced-scale demonstrator (Fig. 6) was successfully tested in 2024.

Fig. 6. The MoorPower demonstrator.

3) Off-grid solutions for remote coastal communities: Australia has a significant number of remote and island communities, who use energy at a higher rate, and higher cost, than the national average. Remote generation is shown in Fig. 7. Microgrids are appropriate for these communities, and represent promising nursery markets for wave energy. Wave Swell Energy's Uni-Wave 200 was successfully integrated with the existing microgrid on King Island in Tasmania.

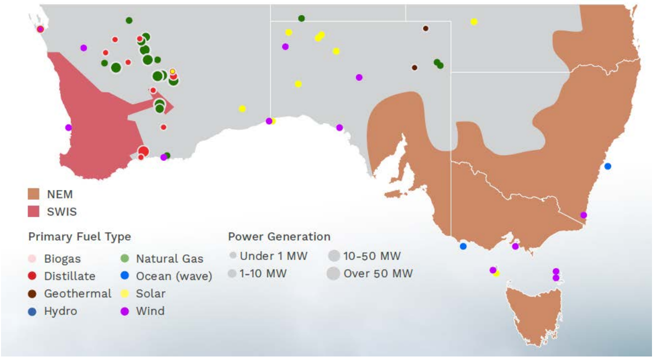

Fig. 7. Off-grid power generation in Australia [27]. The shaded red and orange regions demarcate the SWIS and NEM networks. The circles represent different remote microgrids.

V. Developing a Wave Energy Industry

Almost 90% of Australia's population lives within 50 km of the coast. However, large distances between population centres on the coast and the next major city still represent logistical challenges for supply chains. Establishing a wave energy industry will entail challenges in the supporting industry, workforce and research capability needed.

At present the Australian Bureau of Statistics tracks power generation from marine renewable energy, but not employment. At a national level, most of the workforce initiatives and targets do not mention wave energy.

At a state level, Victoria lists wave energy as an emerging technology which may support its target of 95% emissions reduction (on 2005 levels) by 2035. The State also has a Clean Energy Workforce Development Strategy and an existing oil and gas workforce which may be able to transition to wave energy. Outside Victoria, a large part of the national offshore oil and gas expertise resides in Western Australia, where wave energy currently does not feature in official policies.

Considering supply chains, the three key projects mentioned in Section II can be considered examples. The CCE CETO 5 units were largely sourced from overseas, with both the buoyant actuator hulls and power take-offs coming from overseas. Installation and approvals were based locally. For Wave Swell Energy's UniWave 200 unit, the concrete and steel gravity structure was constructed in Launceston and Port of Bell Bay, Tasmania. The M4 demonstrator was fabricated locally in Albany (of steel), but the power take-off imported. All example projects were able to utilise local workforces to support their offshore deployment and marine operations. These examples suggest that as components of wave energy converters become more specialised (with power take-offs perhaps the most unique), the challenges of local fabrication increase.

Ports around Australia will be significant in development of a wave energy industry. Ports such as Hastings, Victoria, and Bunbury, Western Australia, are currently reviewing port infrastructure and readiness to support offshore wind. Similar capabilities would help to support wave deployments.

VI. Environmental and Social Aspects

A. Environment

As the wave energy industry is at an early stage, realised environmental impacts are limited and highly localised. Future expansion requires consideration of potential environmental impacts and warrants consideration, regulation and management. There have been limited studies of the environmental impacts of wave energy in Australia.

Key potential impacts identified are:

1) Physical oceanographic change - including altered wave and current fields;
2) Underwater noise - WEC noise is generally expected to be lower than other sources, though noise is currently poorly monitored in Australia [28];
3) Electromagnetic fields (EMFs) - can be detected by many types of marine fauna, particularly if they remain near cables;
4) Collision - both in the water and air;
5) Entrapment - is not possible for most devices;
6) Entanglement - from mooring lines and cables;
7) Habitat displacement - from physical presence, or noise, EMFs;
8) Habitat impacts - on benthic, pelagic and coastal habitats; and,
9) Pollution - either released or captured by the WEC.

These potential impacts are indicated schematically in Fig. 8. For these impacts, most focus has been on the operational phase. Impacts may also occur during installation or decommissioning.

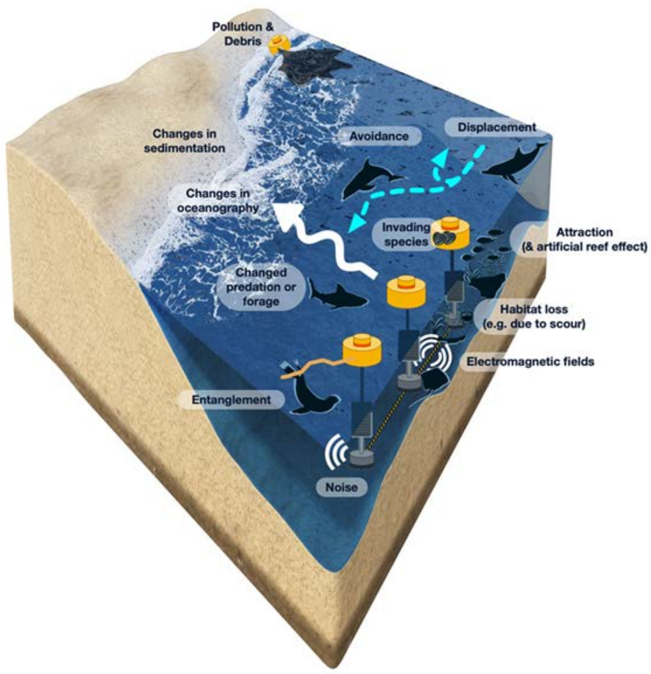

Fig. 8. Conceptual diagram of potential environmental effects of wave energy converters.

Australia can draw on the global literature in these areas, though there are no long-term datasets due to the early stage of technology development. Global studies have focussed on impacts on habitat-forming species and marine mammal megafauna (incl. whales, dolphins, pinnipeds), as well as fish and seabird interactions [29], [30]. In Australia, consideration also needs to be given to other species of conservation concern, such as sharks, rays, penguins and marine reptiles including sea turtles and sea snakes. Globally there is little information available for impacts on tropical or sub-tropical species. These ecosystems have higher biodiversity and more complex food webs, necessitating additional research and alternative assessment approaches [31].

Overall, studies to date suggest that small-scale wave energy projects pose a low risk of environmental impact, provided the site is chosen with due care. Methods of monitoring, modelling and adaptive management should continue to be developed, and cumulative impacts considered, as the sizes of projects grow.

B. Planning

Australia's federal system makes it likely that any wave energy project in Australian waters will involve multiple jurisdictions. A large project more than 3 nautical miles from shore will fall in Commonwealth waters, but cross the State (or Territory) controlled coastal waters further inshore and connect to onshore infrastructure in Local Government areas. Planning frameworks in these jurisdictions fall into sector-specific and cross-sectional categories, which will need to be navigated by proponents for approvals and licences. Key acts at the Commonwealth level are the Offshore Electricity Infrastructure Act 2021 and the Environment Protection and Biodiversity Conservation Act 1999.

The planning and regulatory landscape in Australian waters is complex. Victoria has recently adopted a Marine Spatial Plan (MSP) [32], which is a good example of managing the ocean estate. According to the Intergovernmental Oceanographic Commission, marine spatial planing is 'a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that have been specified through a political process'. Its use is currently not widespread in Australia, but research continues [33] to develop MSP tools for areas of high use where it may be required. Further simplification, following a pathway like the combined State and Commonwealth governance in the Great Barrier Reef Intergovernmental Agreement 2009 would be of benefit.

C. Ethics and social licence

Ethics is particularly important for wave and renewable energy, because some reasons for investing in wave energy development are based in ethics—i.e. carbon mitigation and associated reduction in (unequally distributed) harms and impacts. Ethical goals to establish renewable energy pathways may contribute to social expectations that wave energy projects will be executed fairly and responsibly. A national consensus for coastal adaptation will help combine short term ethical 'urgencies' with long-term planning for climate and other anthropogenic pressures [34].

Seven blue economy ethical principles [35] are relevant to wave energy:

- Environmental Sustainability;
- Stakeholder Participation;
- Fairness;
- Harm Prevention;
- Beneficence;
- Integrity; and
- Place Attachment.

These principles are intrinsic and distinct sources of ethical value. Hence, though the principles may be inter-related, it is possible to succeed on some and fail on others. Further, there may be ethical trade-offs, even within a single principle. A successful wave energy industry in Australia will therefore require complex negotiations between and within stakeholder groups to avoid ethical risks (many shared with other renewables) that would lead to failing on these principles.

Social Licence to Operate (SLO) refers to community acceptance of industry operations (especially at a local level). It is increasingly implied that industry operations should have such community acceptance [36]. SLO exists on a continuum (see Fig. 9), and industries aspire to more than mere tolerance.

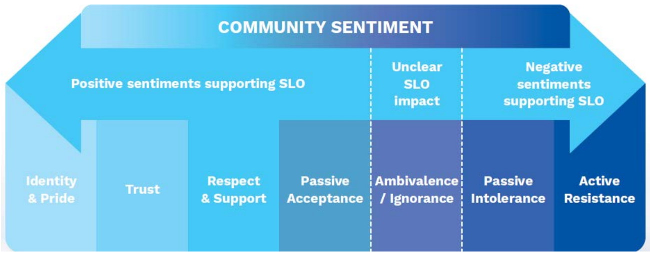

Fig. 9. Social licence to operate and the continuum of community sentiment.

Offshore renewable energy involves large investments, complex projects, large-scale infrastructure and sophisticated technology. These factors can make it difficult for communities to feel ownership of, or involvement in, such projects. In Australia, offshore wind developments have broad overall support, but some communities have felt excluded from the decision making progress [37]. As an emerging industry, wave energy has an opportunity to operate differently, and for SLO to become a cultural practice bringing stakeholders and communities together in dialogue to form lasting relationships [38].

To ensure social acceptance, public consultation and community engagement are key. There are different levels of community engagement: Inform - Consult - Involve - Collaborate - Empower. The first three of these are fundamental, and will always be required for wave energy. Greater levels of engagement will be needed when:

- nearby communities are impacted directly (visually, by noise, etc.);
- impacts on local ecology may be significant;
- the project is large/commerical in scale/nature; or

- the development will remain for a long time (many years).

The timing of consultation and engagement is key—earlier is better. The engagement should also be transparent and dynamic.

In the Australian context, it will be important to start with small projects, which offer the opportunity to build knowledge and trust. A diversity of types of project may offer better options for future developments, given diverse environments and communities. It is important for projects to have trusted research partners, and for progress to be gradual, so that the knowledge and trust can keep up.

D. Cultural licence

Indigenous people have lived in Australia for millenia, developing strong connections to important places and significant knowledge of land and marine scapes. From an indigenous perspective, the customary territory is understood to be continuous and include submerged offshore landscapes. Hence, the wave energy sector has the potential to be seen as a new regime of occupation of customary territories.

Principles which enable conditions under which cultural licence to operate may be granted include:

1) Interacting with Indigenous Peoples as rights holders, not stakeholders. Indigenous people have unique knowledge, relationships to neighbours and future generations, perspectives on partnerships and responsibilities [39], [40].
2) Focussing on partnership pathways which emphasise relationships, meaningful consultation, negotiation and dialogue [41].
3) Adopting the language of the United Nations Declaration on the Rights of Indigenous Peoples and its principles of Free Prior and Informed Consent (FPIC) for any development on Indigenous territory [42].

With these principles in mind, guiding frameworks for partnership with Indigenous groups can be adopted. One of these was developed by Wyatt [43] and consists of Path elements and Collaborative arrangements. Hunter et al [44] identify seven pillars specific to cultural partnership pathways in the blue economy, and note that cultural licence is ongoing and can be withdrawn.

VII. Conclusions and Recommendations

Australia has the world's largest national wave energy resource, and is well-placed to lead in wave energy. However, Australia is currently not keeping pace with global progress and therefore not realising the economic, social and environmental benefits that wave energy could deliver.

Australia's resource is not just the largest, but is highly persistent, and complementary to solar energy, and therefore has considerable value in the future energy mix. This value extends to meeting national targets for decarbonisation and supporting Australia's economy. Meanwhile, wave energy may also provide coastal protection and offers an opportunity to lead best practice in environmental impact assessment and social and cultural engagement.

Australia currently has not devoted the funding to wave energy needed to become a serious player on the world stage, but has all the pieces necessary to do so. Australia has the capacity to lead in this space and the time for action is now.

The overarching recommendation emerging from this work 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.

Several recommendations have emerged from this work:

1) The Australian Renewable Energy Agency should fund a study to determine the national benefit of developing a wave energy industry.
2) The Australian Energy Market Operator's Integrated System Plan (ISP) should evaluate wave energy possibilities.
3) Wave energy should be included in the Sustainable Ocean Plan and considered alongside other renewable energy technologies.
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.
5) An integrated study to establish national guidelines for using wave energy for coastal protection should be carried out.
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.
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.

Encouraging and facilitating action on these recommendations is an ongoing process, and requires continued promotion and action by the authors of this paper and surrounding wave energy community.

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References

[1] H. Wolgamot, W. Ebeling, J. Orszaghova, A. Kurniawan, K. McInnes, R. Manasseh, P. Osman, N. Sergiienko, R. Trebilco, P. Marsh, H. Breakey, P. Lyons *et al.*, "Ocean wave energy in Australia," Blue Economy Cooperative Research Centre, Tech. Rep., 2024. [Online]. Available: https://blueeconomycrc.com.au/project/ocean-wave-energy-in-australia

[2] J. Fiévez and T. Sawyer, "Lessons learned from building and operating a grid connected wave energy plant," in *Proceedings of the 11th European Wave and Tidal Energy Conference, Nantes, France*, 2015, pp. 6–11.

[3] F. T. Rollano, A. Santos, R. J. Cavagnaro, S. Hunter, and T. Denniss, "Efficiency analysis of the wave-to-grid energy conversion of the UniWave200 wave energy converter," *IEEE Transactions on Sustainable Energy*, vol. 16, no. 2, pp. 752–760, 2025.

[4] C. Gaudin, H. Wolgamot, A. Kurniawan, W. Ebeling, N. Fernando, P. Stansby, J. Apsley, C. Shearer, B. Saunders, G. McCauley, and M. Hatcher, "The Albany M4 Project: The first open-access wave energy deployment," in *Proceedings of the ASME 44th International Conference on Ocean, Offshore and Arctic Engineering (OMAE2025)*, Vancouver, British Columbia, Canada, 2025.

[5] IEA-OES, "Ocean energy and net zero: An international roadmap to develop 300GW of ocean energy by 2050." IEA, Tech. Rep., 2023. [Online]. Available: https://www.ocean-energy-systems.org/publications/oes-documents/market-policy-/document/ocean-energy-and-net-zero-an-international-roadmap-to-develop-300gw-of-ocean-energy-by-2050/

[6] AEMO, "Integrated System Plan for the National Electricity Market," AEMO, Tech. Rep., 2024. [Online]. Available: https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2024-integratedsystem-plan-isp

[7] IEA, "Australia 2023: Energy policy review." IEA, Tech. Rep., 2023. [Online]. Available: https://www.iea.org/reports/australia-2023.

[8] M. A. Hemer, S. Zieger, T. Durrant, J. O'Grady, R. K. Hoeke, K. L. McInnes, and U. Rosebrock, "A revised assessment of Australia's national wave energy resource," *Renewable Energy*, vol. 114, pp. 85–107, 2017.

[9] D. J. Greenslade, A. Zanca, S. Zieger, and M. A. Hemer, "Optimising the Australian wave observation network," *Journal of Southern Hemisphere Earth Systems Science*, vol. 68, no. 1, pp. 184–200, 2018.

[10] M. D. Harley, I. Turner, A. Short, and R. Ranasinghe, "A reevaluation of coastal embayment rotation: The dominance of cross-shore versus alongshore sediment transport processes, Collaroy-Narrabeen Beach, southeast Australia," *Journal of Geophysical Research: Earth Surface*, vol. 116, no. F4, 2011.

[11] M. V. Cuttler, J. E. Hansen, and R. J. Lowe, "Seasonal and interannual variability of the wave climate at a wave energy hotspot off the southwestern coast of Australia," *Renewable Energy*, vol. 146, pp. 2337–2350, 2020.

[12] A. G. Marshall, M. A. Hemer, H. H. Hendon, and K. L. McInnes, "Southern annular mode impacts on global ocean surface waves," *Ocean Modelling*, vol. 129, pp. 58–74, 2018.

[13] J. Morim, M. Hemer, X. L. Wang, N. Cartwright, C. Trenham, A. Semedo, I. Young, L. Bricheno, P. Camus, M. Casas-Prat *et al.*, "Robustness and uncertainties in global multivariate wind-wave climate projections," *Nature Climate Change*, vol. 9, no. 9, pp. 711–718, 2019.

[14] D. Richardson, A. Pitman, and N. Ridder, "Climate influence on compound solar and wind droughts in Australia," *npj Climate and Atmospheric Science*, vol. 6, no. 1, p. 184, 2023.

[15] P. Osman, J. Hayward, and J. Foster, "Dispatchability and energy storage costs for complementary wave, wind, and solar pv systems," CSIRO, Tech. Rep., 2022. [Online]. Available: https://doi.org/10.25919/0czw-nr73

[16] P. Graham, J. Hayward, and J. Foster, "GenCost 2023-24: Final report," CSIRO, Tech. Rep., 2024. [Online]. Available: https://doi.org/10.25919/bvtn-0n42

[17] J. Hayward, "Wave energy cost projections: A report for Wave Swell Energy Ltd," CSIRO, Tech. Rep., 2021. [Online]. Available: https://doi.org/10.25919/3ka9-g618

[18] S. Pennock, D. R. Noble, Y. Vardanyan, T. Delahaye, and H. Jeffrey, "A modelling framework to quantify the power system benefits from ocean energy deployments," *Applied Energy*, vol. 347, p. 121413, 2023.

[19] M. Ellis and B. Bajracharya, "Reducing community risk to coastal erosion with managed relocation," *The Australian Journal of Emergency Management*, vol. 38, no. 4, pp. 52–58, 2023.

[20] R. Manasseh, S. Sannasiraj, K. L. McInnes, V. Sundar, and P. Jalihal, "Integration of wave energy and other marine renewable energy sources with the needs of coastal societies," *The International Journal of Ocean and Climate Systems*, vol. 8, no. 1, pp. 19–36, 2017.

[21] R. Ranasinghe and I. L. Turner, "Shoreline response to submerged structures: A review," *Coastal Engineering*, vol. 53, no. 1, pp. 65–79, 2006.

[22] G. Ibarra-Berastegi, J. Sáenz, A. Ulazia, P. Serras, G. Esnaola, and C. Garcia-Soto, "Electricity production, capacity factor, and plant efficiency index at the Mutriku wave farm (2014–2016)," *Ocean Engineering*, vol. 147, pp. 20–29, 2018.

[23] L. Cui, N. Y. Sergiienko, J. S. Leontini, N. Cohen, L. G. Bennetts, B. Cazzolato, I. L. Turner, F. Flocard, A.-R. Westcott, F. Cheng *et al.*, "Protecting coastlines by offshore wave farms: On optimising array configurations using a corrected far-field approximation," *Renewable Energy*, vol. 224, p. 120109, 2024.

[24] Q. Gao, S. S. Khan, N. Sergiienko, N. Ertugrul, M. Hemer, M. Negnevitsky, and B. Ding, "Assessment of wind and wave power characteristic and potential for hybrid exploration in Australia," *Renewable and Sustainable Energy Reviews*, vol. 168, p. 112747, 2022.

[25] M. Freeman, L. Garavelli, E. Wilson, M. Hemer, M. Abundo, and L. E. Travis, "Offshore aquaculture: a market for ocean renewable energy," *Report for Ocean Energy Systems (OES)*, 2022.

[26] AOEG, "Project AquaGrid," AOEG, Tech. Rep., 2024. [Online]. Available: https://oceanenergygroup.org.au/aquagrid-2/

[27] AECOM, "Australia's off-grid clean energy market research paper." AECOM, Tech. Rep., 2014. [Online]. Available: https://arena.gov.au/knowledge-bank/australias-offgrid-clean-energy-market-research-paper/

[28] K. Evans, C. Erbe, D. Giltrap, C. Lamont, D. Peel, and K. Tropman, "Anthropogenic marine noise: Expert pressure assessment for the 2021 State of the Environment Report, Australia." IEA, Tech. Rep., 2021. [Online]. Available: https://doi.org/10.26198/YGRP-DA33

[29] A. E. Copping and L. G. Hemery, "OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES)," Pacific Northwest National Lab.(PNNL), Richland, WA (United States), Tech. Rep., 2020.

[30] L. Garavelli, A. E. Copping, L. G. Hemery, and M. C. Freeman, "OES-Environmental 2024 State of the Science report: Environmental Effects of Marine Renewable Energy Development Around the World. Report for Ocean Energy Systems (OES)," Pacific Northwest National Laboratory (PNNL), Richland, WA (United States), Tech. Rep., 2024.

[31] E. Fulton, L. Hemery, A. Copping, H. Farr, J. Fox, L. Garavelli, D. Hasselman, R. Miller, and A. O'Hagan, "Marine renewable energy and cumulative effects assessments: Summary of the state of play," in Review.

[32] DEECA, "Marine Spatial Planning Guidelines. The State of Victoria Department of Energy, Environment and Climate Action," Victoria State Government, Tech. Rep., 2023. [Online]. Available: https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0031/681934/MSP-Guidelines-_FINAL.pdf

[33] F. Flocard, D. Ierodiaconou, and I. R. Coghlan, "Multi-criteria evaluation of wave energy projects on the south-east Australian coast," *Renewable Energy*, vol. 99, pp. 80–94, 2016.

[34] A. Sánchez-Arcilla, V. Gracia, C. Mösso, I. Cáceres, D. González-Marco, and J. Gómez, "Coastal adaptation and uncertainties: The need of ethics for a shared coastal future," *Frontiers in Marine Science*, vol. 8, p. 717781, 2021.

[35] F. Croft, H. Breakey, M. Voyer, A. Cisneros-Montemayor, I. Issifu, M. Solitei, C. Moyle, B. Campbell, K. Barclay, D. Benzaken *et al.*, "Rethinking blue economy governance–a blue economy equity model as an approach to operationalise equity," *Environmental Science & Policy*, vol. 155, p. 103710, 2024.

[36] J. Cooney, "Reflections on the 20th anniversary of the term 'social licence'," *Journal of Energy & Natural Resources Law*, vol. 35, no. 2, pp. 197–200, 2017.

[37] A. Spencer-Cotton, "Public social licence to operate offshore wind in Australia. Project factsheet," The University of Western Australia Oceans Institute., Tech. Rep., 2024.

[38] L. Bossi, "How a sense of place may return the social license to operate concept back to an ethics of responsibility within a neoliberal framework—Tasmanian salmon story," in *Social Licence and Ethical Practice*. Emerald Publishing Limited, 2023, pp. 25–46.

[39] V. Dekoninck, "Deconstructing the stakeholder: A case study from Garig Gunak Barlu National Park, Australia," *The Interna-*

tional Journal of Biodiversity Science and Management, vol. 3, no. 2, pp. 77–87, 2007.
[40] K. Ruckstuhl, M. Thompson-Fawcett, and H. Rae, "Māori and mining: Indigenous perspectives on reconceptualising and contextualising the social licence to operate," *Impact Assessment and Project Appraisal*, vol. 32, no. 4, pp. 304–314, 2014.
[41] C. O'Faircheallaigh, "Shaping projects, shaping impacts: community-controlled impact assessments and negotiated agreements," in *New Mechanisms of Participation in Extractive Governance*. Routledge, 2018, pp. 139–155.
[42] T. Mitchell, C. Arseneau, D. Thomas, and P. Smith, "Towards an indigenous-informed relational approach to free, prior, and informed consent (FPIC)," *International Indigenous Policy Journal*, vol. 10, no. 4, pp. 1–28, 2019.
[43] S. Wyatt, "Aboriginal people and forestry companies in Canada: possibilities and pitfalls of an informal 'social licence' in a contested environment," *Forestry: An International Journal of Forest Research*, vol. 89, no. 5, pp. 565–576, 2016.
[44] C. Hunter, E. Lee, W. Wood, A. Marsh, and M. Fischer, "Cultural licence to operate in the blue economy. Final project report," Blue Economy Cooperative Research Centre, Tech. Rep., 2024. [Online]. Available: https://blueeconomycrc.com.au/project/cultural-licence-to-operate-in-the-blue-economy/