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Summary of Findings and Lessons Learned

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International WaTERS: Summary of Findings and Lessons Learned

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Executive Summary

The International WaTERS network has spent the past decade building a global platform for collaboration, knowledge sharing, and innovation among marine energy test centres. These centres have evolved from single-technology wave and tidal facilities into multi-technology innovation hubs with advanced environmental monitoring capabilities. This evolution reflects the sector's response to growing technical complexity, market demand, and policy priorities.

Adaptability, collaboration, and evidence-based planning have been key to tackling technical, operational, regulatory, and financial challenges. Test centres with modular infrastructure and flexible service models have remained resilient and financially sustainable while supporting diverse technologies and developer needs. Operational performance has improved through digital tools, remote monitoring, autonomous systems, and strong local supply chains, while lessons from both successes and failures are shared across the network. Flexible certification pathways have lowered barriers for early-stage developers, supporting progression from trial to full compliance.

Test centres have taken a leading role in environmental monitoring, adaptive management, and risk-based consenting, advocating for open data sharing and standardised protocols to reduce regulatory friction. Early, transparent engagement with communities, fisheries, and regulators is central to securing social licence and building long-term trust. Collaboration across the network including shared databases, risk registers, lessons-learned logs, joint procurement, staff exchanges, and harmonised protocols has accelerated innovation, reduced duplication, and strengthened sector-wide resilience. Diversified business models and strategic partnerships have improved financial stability, enabling centres to act as conveners, educators, and innovation catalysts. Proactive decommissioning and end-of-life planning ensures responsible site stewardship, while structured workshops and digital collaboration platforms sustain coordination, knowledge transfer, and problem-solving.

Looking ahead, priorities include expanding shared resources, standardising monitoring and operational protocols, promoting mutual recognition of regulatory data, and advancing collaborative R&D and staff exchanges focused on emerging technologies. Strengthening funding models and business strategies is critical to long-term sustainability, while inclusive, transparent stakeholder engagement and adaptive regulation support social acceptance and responsible growth. By positioning test centres as strategic partners in policy, funding, and technology deployment, the network can accelerate marine energy development, delivering economic, environmental, and social benefits globally.

The International WaTERS network demonstrates that coordinated action, shared learning, and evidence-based approaches are essential for advancing marine energy toward commercial maturity. Continued investment in infrastructure, collaboration, and capacity building will ensure that test centres remain at the forefront of safe, sustainable, and socially supported deployment of marine energy technologies worldwide.

1 Introduction

The International WaTERS (Wave and Tidal Energy Research Sites) network, established in 2013, brings together a global consortium of open-water marine energy test centres. Through annual or biennial workshops, delegates from Europe, Asia, North America, and beyond have convened over the past decade to share challenges, best practice, and collaborative strategies aimed at accelerating the commercialisation and impact of ocean energy technologies.

This report consolidates the key learnings and findings from all International WaTERS meetings and reports spanning 2013 to 2024. It provides a structured summary of the network's evolution, the recurring and emerging themes discussed across workshops, and the practical insights that have shaped policy, operations, and innovation in the sector.

Created to support future planning and strategic investment, the report also serves as a foundation for evidence-based policy recommendations. These recommendations aim to advance regulatory frameworks, streamline consenting processes, strengthen stakeholder engagement, improve offshore operations, and promote data sharing. By capturing the collective experience of test centres and their partners, this report seeks to reinforce international collaboration and accelerate the development of sustainable ocean energy technologies.

2 Background and objectives

Open-sea test centres are at the leading edge of the emerging wave and tidal energy industry. Test centres help develop the sector in many ways. They help developers to test their devices in a (semi-)controlled environment, identify potential cost reductions and streamline test programmes for technology developers, and they are often the first to encounter regulatory barriers like permitting and are therefore a key node for knowledge sharing within the sector. They also provide a local/regional focal point encouraging job creation and supply chain growth.

International WaTERS was founded to facilitate knowledge exchange, reduce duplication of effort, and cultivate a collaborative ecosystem for wave and tidal energy test sites. Its core objectives have consistently included:

- Sharing updates on progress and challenges
- Identifying common challenges and opportunities in areas such as consenting, standards, and developer engagement
- Discuss key R&D topics
- Identifying actions to forge relationships and knowledge transfer between test sites, and drive collaborative action

3 Evolution of the network and participation

The world's first marine energy test site, EMEC (European Marine Energy Centre), established the International WaTERS network. As part of its 10th anniversary, EMEC hosted an International Test Centre Symposium in Orkney, Scotland, inviting operational and planned test sites from around the world to discuss common issues and agree actions for collaborating for the good of the marine energy sector.

Figure 1 - International Test Centre Symposium in Orkney, Scotland

Since the inaugural 2013 symposium in Orkney, International WaTERS has expanded its reach and impact.

Attendance has grown steadily, with recent events drawing over 70 delegates from more than 17 countries (see Appendix A and Figure 2).

Meetings have been held in Scotland, Canada, Spain, Chinese Taipei, Portugal, and virtually, with participation from Europe, Asia, North America, and observers from regulatory and research bodies (see Appendix B).

The network has matured from introductory knowledge sharing to focused thematic discussions and strategic working groups, enabling deeper engagement on technical, regulatory, and operational issues.

The network has proven to generate collaborative research projects, for example the Interreg NWE OceanDEMO[1] and BlueGIFT[2] projects, and funding programmes such as US TEAMER[3], as tangible knowledge exchange between test sites.

[1] Interreg North-West Europe – Ocean Demo (n.d) Available at: https://vb.nweurope.eu/projects/project-search/oceandemo-demonstration-programme-for-ocean-energy-pilot-farms-and-supporting-technologies/

[2] Interreg Atlantic Area – Blue Gift. (n.d). Available at: https://bluegift.eu/

[3] US Testing & Expertise for Marine Energy (n.d). Available at: https://teamer-us.org/

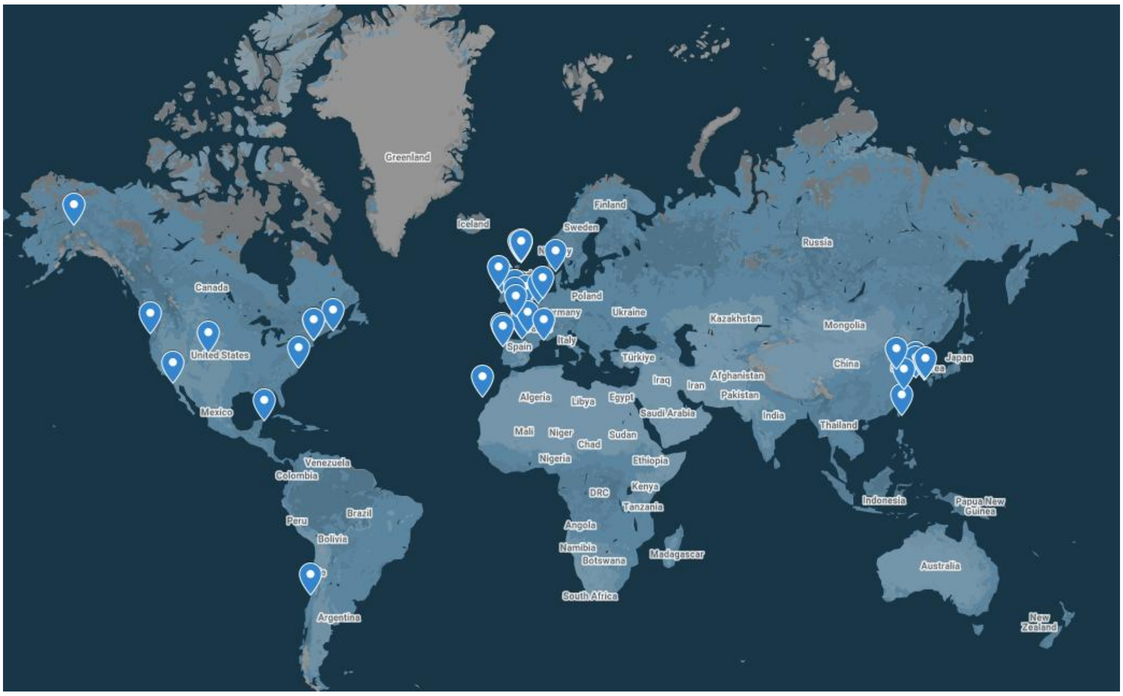

Figure 2 - A map of international open-sea test centres

4 Key themes and consolidated learning

4.1 Test centre technical evolution and diversification

Marine energy test centres have evolved from wave and tidal facilities into multi-technology innovation hubs, now integrating floating wind, hydrogen, energy storage, and advanced sensor platforms. This diversification is driven by both market demand and policy priorities, with centres adapting their service offerings to remain financially sustainable, support the energy transition, and respond to evolving developer needs.

4.1.1 Key challenges

The transition to multi-technology hubs has presented a range of challenges, both common across the network and site-specific. Many centres faced infrastructure limitations, as facilities originally designed for single-technology testing required substantial upgrades to accommodate floating wind, hydrogen systems, and hybrid platforms. For example, EMEC invested in modular cabling and enhanced grid connections, while Fundy Ocean Research Centre for Energy (FORCE)[4] developed hybrid mooring platforms and expanded data acquisition capabilities.

Financial sustainability also posed a challenge, with diversification often demanding capital investment without guaranteed revenue. Centres responded by developing tiered service models, consultancy offerings, strategic partnerships, and flexible infrastructure to support multiple technologies.

[4] Fundy Ocean Research Center for Energy (n.d.) FORCE. Available at: https://fundyforce.ca/

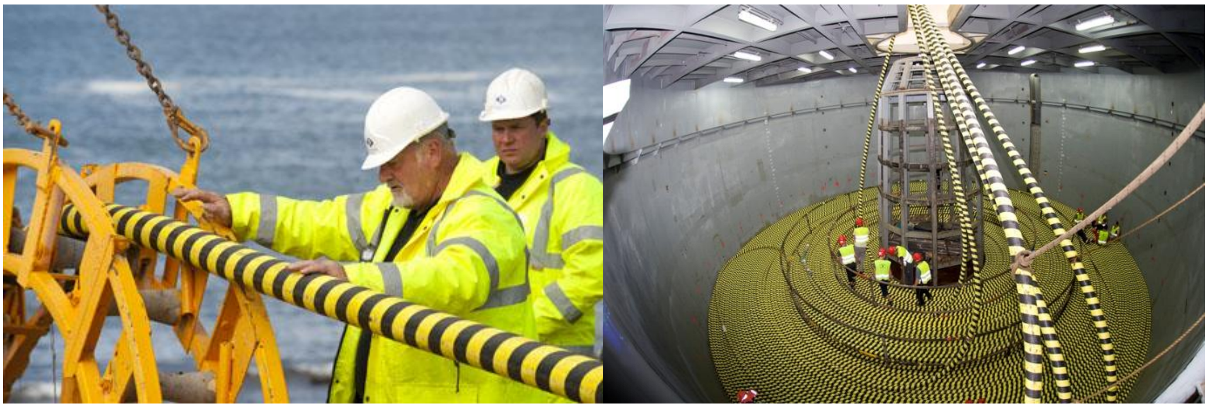

Figure 3 - EMEC subsea cable and cable laying

Operational complexity increased with new technologies, introducing novel risks, logistics, and maintenance requirements beyond the original scope of many centres. While some challenges, such as harsh marine conditions and limited vessel access, are common, others like regulatory hurdles and grid connectivity are highly localised.

Practical solutions implemented across the network include infrastructure upgrades, flexible service models aligned with developer readiness, regional coordination, enhanced environmental and technical monitoring, and pre-consented testing zones to streamline deployment and reduce administrative burdens.

4.1.2 Insights and lessons learned

The evolution of test centres has generated several key insights.

Adaptability is essential; centres that embraced modular infrastructure and diversified service offerings have remained both relevant and financially sustainable. This flexibility has enabled them to support a wider array of technologies while responding effectively to evolving developer needs and policy priorities.

Cross-sector learning has also proven invaluable, with operational practices from offshore wind, oil and gas, and aquaculture helping to improve safety, reduce downtime, and optimise maintenance planning. For example, cable management and vessel logistics strategies from offshore wind, and remote monitoring techniques from aquaculture, have been successfully integrated into marine energy operations.

Another critical insight is the importance of **tailored developer support**; bespoke testing pathways such as Pacific Marine Energy Centre's (PMEC) modular support and Biscay Marine Energy Platform's (BiMEP) tiered service packages are vital for accommodating varying levels of technology readiness and developer capacity. These tailored models foster trust, improve outcomes, and lower barriers to entry.

Finally, **collaboration**, shared experiences, joint procurement, and peer learning have enabled centres to navigate uncertainty and scale their impact. Centres actively engaged in the International WaTERS network benefit from real-time problem-solving and strategic alignment, reinforcing the value of collaboration in advancing marine energy testing.

4.1.3 Future focus areas

To overcome barriers and support sector growth, test centres should consider:

- **Investing in multi-technology infrastructure**: enabling seamless integration of floating wind, hydrogen, and digital monitoring systems.
- **Develop flexible service models:** offering tiered support for developers at different stages, including non-accredited verification and data validation.
- **Strengthen operational resilience:** improving access to vessels, contractors, and logistics through shared procurement and regional coordination.
- **Enhance data systems and knowledge sharing**: building interoperable platforms for environmental, technical, and safety data to support evidence-based decision-making and reducing duplication of effort. The creation of a centralised online database for test centre infrastructure, services, and test programmes is a current International WaTERS initiative.
- **Streamline consenting and regulatory processes:** securing broad, pre-consented envelopes for test sites and working closely with regulators to maintain flexibility are key.
- **Foster collaboration and international partnerships:** continued joint projects like OceanDEMO and BlueGIFT, and technical working groups, to avoid overlaps and build complementary facilities.

  Promote skills development and knowledge transfer: investing in staff training, cross-sector learning, and educational partnerships to build capacity in emerging areas such as digitalisation, environmental monitoring, and stakeholder engagement.

4.2 Accredited testing, standards, and certification

The adoption of technical specifications (e.g., IEC TC 114) have progressed, but practical barriers remain, particularly for smaller developers or early-stage technologies. Test centres recognise the need for non-accredited, staged approaches to verification, supporting developers build robust data and confidence on the pathway to full certification. Collaboration on common test processes, and feedback loops to standards bodies, have been identified as crucial for ensuring relevance and lowering barriers to participation.

4.2.1 Key challenges

Access and affordability remain major concerns, with formal certification processes, such as those under IEC TC 114/IECRE, often proving prohibitively expensive and time-consuming for small developers and early-stage technologies. Standardised protocols, while essential for consistency, may lack the flexibility for novel or site-specific deployments, resulting in misalignment between testing requirements and developer needs.

Fragmentation across national standards, regulatory expectations, and test centre capabilities further complicates efforts, creating barriers to cross-border recognition and market entry. These issues are not new; they have recurred over time, prompting some test centres to introduce staged or non-accredited pathways that allow developers to build confidence and generate robust data progressively. While certain barriers are specific to local regulatory contexts, challenges related to cost, complexity, and developer readiness are widely shared across the international network, highlighting the need for coordinated and inclusive approaches to certification.

4.2.2 Insights and lessons learned

Many test centres operating in international waters have embraced a **staged verification model**, offering modular services that enable developers to transition from non-accredited trials to full certification as their technologies evolve. This flexible approach reduces barriers to entry and fosters innovation, while still upholding rigorous standards. Centres often provide both accredited and non-accredited inspection reports, tailored to the specific needs of developers. Crucially, these centres can serve as conduits for practical feedback to standards organisations (and projects such as IEA-OES Performance Metrics International Framework for Ocean Energy), helping to ensure that evolving specifications remain grounded in the realities of marine energy testing. This feedback loop bridges the gap between academic standards development and operational requirements.

Collaboration among test centres, can reduced duplication, lowered costs, and accelerated progress towards accreditation. Initiatives such as International WaTERS network support this exchange, encouraging centres to participate in the IEC/IECRE systems. Ultimately, certification is recognised as a journey, with developers benefiting from clear roadmaps and structured support that guide them from prototype to full compliance.

Figure 4 - Group discussion at International WaTERS 2023

4.2.3 Future focus areas

To overcome current barriers and support broader adoption of accredited testing:

- **Develop flexible certification pathways**: introducing tiered models that allow developers to progress through stages of verification aligned with technology maturity.
- **Enhance support for early-stage developers**: providing technical guidance, funding access, and tailored testing services to reduce entry barriers.

- **Promote harmonisation across centres**: aligning test protocols and reporting formats to enable mutual recognition and reduce duplication (feeding into projects such as IEA-OES Performance Metrics International Framework for Ocean Energy).
- **Strengthen engagement with standards bodies**: Ensure that evolving standards reflect real-world deployment conditions and innovation trends.

4.3 Environmental monitoring and consenting

Test centres have become leaders in environmental monitoring, advancing methods for acoustic, ecological, and seabed impact assessments. Consenting remains a major challenge, with administrative and regulatory complexities varying by country. Pre-consented “envelopes” offer flexibility, but there is a need for streamlined adaptive approaches. Sharing environmental data and standardising monitoring protocols are seen as key to accelerating deployments and reducing regulatory friction, though regional differences in regulatory acceptance (e.g., non-transferability of data over short geographic distances) remains a significant hurdle.

4.3.1 Key challenges

Environmental monitoring and consenting face a combination of shared and site-specific challenges. Regulatory uncertainty and often slow permitting processes discourage investment, delay deployments. Many jurisdictions lack a coordinated “one-stop-shop” for marine energy permitting. Even mature test centres such as FORCE and EMEC, report shifting requirements and timelines, with regulators sometimes demanding proof of “no risk” before deployment.

Common challenges include the need for robust environmental monitoring, stakeholder engagement, and adaptive management. Others are site-specific. For example, FORCE must address the unique ecological and cultural context of the Bay of Fundy, including collaboration with Mi’kmaq organisations and federal agencies. In Korea, test centres face complex, multi-step permitting processes and must secure agreements with local residents and fishing societies. EMEC has worked closely with Marine Scotland and statutory advisors to implement a streamlined consenting regime, including site-wide environmental impact assessments and navigation risk assessments.

Early workshops focused on the basics of environmental monitoring and the need for baseline data. More recent discussions have shifted towards adaptive management, risk-based consenting, and the integration of new monitoring technologies. There is now greater emphasis on collaboration, both within the network and with external partners, to share data, harmonise methodologies, and advocate for proportionate, evidence-based regulation.

4.3.2 Insights and lessons learned

A key insight is that test centres are not just infrastructure providers, they are conveners, who facilitating transparent dialogue and evidence-based decision-making. Their leadership in environmental monitoring has advanced methods for acoustic, ecological, and seabed impact assessments, and their experience has shown that early, inclusive, and transparent stakeholder engagement builds trust, reduces conflict, and enhances the legitimacy of marine energy projects.

Adaptive management enables proportionate, evidence-based regulation that supports innovation while safeguarding the environment. Rather than requiring proof of no risk before deployment, regulators and test centres are increasingly adopting a survey, deploy, monitor approach. This allows for learning and adjustment as new evidence emerges and is particularly important for novel or first-of-a-kind devices. Scotland's one-stop consenting process and EMEC's pre-consented envelopes offer replicable frameworks for other jurisdictions.

Figure 5 - Acoustic monitoring at Fall of Warness, Orkney

Sharing environmental data and standardising monitoring protocols accelerates deployments and reduces regulatory friction, though regional differences remain a significant hurdle. The network itself is a platform for sharing lessons learned and best practices in environmental monitoring and consenting.

4.3.3 Future focus areas

Looking ahead, several focus areas are critical for progress:

- **Streamlining and harmonising consenting:** Adopt adaptive, risk-based, and proportionate regulatory models. Replicate pre-consented envelopes and streamlined processes.
- **Open data and standardisation:** Develop interoperable platforms for environmental, technical, and safety data. Continue to collaborate to standardise data collection, reporting, and sharing, enabling evidence-based decision-making and reduce duplication.

- **Stakeholder engagement:** Early, inclusive, and transparent engagement with communities, and other stakeholders must remain a priority. Narrative development and public education are increasingly important for building social licence.
- **International collaboration:** Continued collaboration through the WaTERS network and joint projects (e.g., OceanDEMO, BlueGIFT) is vital for sharing knowledge, harmonising approaches, and developing robust, globally relevant best practices.
- **Skills and capacity building:** Invest in staff training, cross-sector learning, and educational partnerships will ensure centres remain at the forefront of innovation and can support the evolving needs of developers and policymakers.

4.4 Operations, maintenance, and marine logistics

Test sites face a diversity of challenges ranging from harsh weather windows and seabed variability to limited access to specialist vessels and contractors. There is no one-size-fits-all approach, and sharing of practical solutions (e.g., AUVs, cable management, connector innovations) and failures has become a valued part of the network's knowledge base.

4.4.1 Key challenges

Operations and maintenance (O&M) face both shared and site-specific challenges. Harsh weather conditions, unpredictable sea states, and short operational windows are common across many sites, particularly those in high-energy environments such as Orkney, the Bay of Fundy, and Jeju Island. Seabed variability adds further complexity, affecting moorings, anchors, and cabling systems. Limited access to specialist vessels, experienced contractors, and marine logistics support can delay deployments and increase costs, especially for remote or less-developed sites.

Figure 6 - Orkney supply chain vessels

These challenges are recurring but have evolved over time. Early test centres often relied on local fishing or supply vessels, but as the sector has matured, there has been a shift towards purpose-built vessels, remote-operated vehicles (ROVs), and autonomous underwater vehicles (AUVs) for inspection, maintenance, and data collection. The need for robust cable management, innovative connectors, and rapid-response maintenance protocols has become more pronounced as deployments have scaled up and diversified.

Some barriers are unique to specific sites. For example, EMEC's exposed locations require careful planning around weather windows and vessel availability, while FORCE must contend with extreme tidal flows and sediment transport. In Korea, regulatory requirements for vessel safety and environmental protection add further layers of complexity. Despite these differences, the underlying themes of unpredictability, resource constraints, and the need for operational resilience are widely shared.

To address these challenges, test centres have increasingly turned to knowledge sharing both within the network and through bilateral collaborations. Sharing practical solutions, lessons learned from failures, and innovations in logistics has become a valued part of the network's culture.

4.4.2 Insights and lessons learned

There is no universal template for marine operations and maintenance, strategies must be tailored to each site's environment, resources, and regulatory context. Exchanging operational experience both successes and failures has proven invaluable.

For example, the adoption of AUVs and ROVs for cable inspection and seabed surveys has reduced reliance on weather-dependent vessel operations and improved safety. Innovations in cable management, such as modular connectors and rapid-deployment systems, have helped mitigate the risks of cable damage and downtime.

Strong relationships with local supply chains, vessel operators, and contractors are critical. Centres investing in local capacity building and long-term partnerships have been better able to respond to operational challenges and adapt to changing conditions. The network has also highlighted the value of documenting and sharing near-miss incidents, maintenance protocols, and equipment failures, enabling centres to learn from each other and avoid repeating costly mistakes.

4.4.3 Future focus areas

Looking ahead, several focus areas are critical for advancing operations, maintenance, and marine logistics:

- **Resilience and flexibility:** invest in robust infrastructure, flexible maintenance protocols, and rapid-response capabilities to cope with unpredictable marine environments.
- **Technology adoption:** integrate digital tools, remote monitoring systems, and autonomous vehicles to improve efficient and safe operations, especially as deployments scale up.

- **Supply chain development:** maintain strong relationships with local and regional supply chains, vessel operators, and contractors will be key to ensuring timely and cost-effective operations.
- **Knowledge sharing:** Continue documenting and openly share operational experience, including failures and near-misses, to improve safety, efficiency, and reliability.
- **Standardisation and best practice:** Develop and adopt best practice guidelines for O&M, tailored to different site contexts, will support consistency and continuous improvement across the network.

Figure 7 - ADCP recovery at EMEC

4.5 Health and safety

All test centres prioritise safety, but operational responsibilities differ with some taking a hands-on oversight role and others relying on developer-led practices. There is universal recognition that major incidents would be damaging to the sector's credibility. Sharing safety alerts, training standards, and lessons learned is seen as essential, especially as less experienced developers enter the space.

4.5.1 Key challenges

Health and safety management is complicated by diverse operational contexts and the lack of standardisation across sites. Each test centre operates under different regulatory regimes, environmental conditions, and organisational structures, which makes it difficult to apply uniform safety protocols. For example, test sites require robust emergency response planning and coordination with local services.

Variability in developer experience adds another layer of complexity. As new entrants join the sector, test centres often find themselves working with teams unfamiliar with marine operations, risk assessments, or safety compliance. This increases the burden on test centres to provide guidance, oversight, and sometimes direct intervention. Test centres that rely on developer-led safety practices may face gaps in training, documentation, or incident reporting.

Early workshops focused on basic safety protocols and emergency planning. More recent discussions have highlighted the need for proactive risk management, cross-centre coordination, and the need for the development of shared safety resources. The emergence of new technologies such as autonomous vehicles, floating platforms, and hydrogen systems has introduced additional safety considerations, requiring updated procedures and specialised training.

Figure 8 - Tabletop exercise for emergency response planning

4.5.2 Insights and lessons learned

Safety must be embedded into every aspect of test centre operations, from site design and deployment planning to daily maintenance and decommissioning. Test centres that integrate safety into their organisational culture, rather than treating it as a compliance requirement, report stronger outcomes and fewer incidents.

Safety is not just about physical risk; it includes reputational and regulatory risk. A single incident can undermine public trust, delay permitting, and jeopardise funding. As such, centres are increasingly investing in communication strategies, stakeholder engagement, and scenario planning to manage broader safety implications.

4.5.3 Future focus areas

To strengthen health and safety across the sector, test centres should:

- **Standardisation of safety protocols:** Develop shared guidelines and minimum standards for safety procedures, training, and documentation.
- **Developer support and oversight:** Provide structured onboarding, safety briefings, and operational checklists for developers.
- **Incident reporting and data sharing:** Establish a centralised system for reporting, analysing, and disseminating safety incidents and lessons learned.
- **Integration of new technologies:** Update safety frameworks to account for emerging risks associated with autonomous systems, hydrogen production, and floating platforms.
- **Workforce development:** Invest in health and safety training for staff, contractors, and developers, with a focus on marine-specific risks and emergency response.

4.6 Decommissioning and end-of-life planning

Decommissioning and end-of-life planning are now recognised as integral to marine energy project development. Test centres increasingly address these considerations from the outset, incorporating financial bonding, regulatory agreements, and technical strategies for infrastructure removal or environmental integration. While approaches vary internationally, the network highlights the value of shared experience, mutual preparation, and proactive planning to ensure that marine energy remains a responsible and sustainable sector.

4.6.1 Key challenges

Historically, decommissioning was treated as a final-phase concern, often addressed reactively. However, as the sector has matured, it has become clear that end-of-life planning must be embedded from the beginning of a project's lifecycle. A major challenge is the lack of harmonised regulatory frameworks across jurisdictions. Requirements for decommissioning bonds, environmental restoration, and infrastructure removal vary widely, creating uncertainty for developers and test centres alike.

Financial planning is another recurring barrier. Securing adequate bonding or insurance to cover decommissioning costs can be difficult, particularly for early-stage developers or small-scale projects. Technical challenges also persist, especially in high-energy environments where retrieval of anchors, cables, or foundations may be complicated by sediment movement, seabed conditions, or weather constraints.

These challenges are shared across the network but manifest differently depending on site conditions and national policy. For example, EMEC has developed clear protocols for communicating responsibilities and liabilities with developers, ensuring that infrastructure ownership and removal obligations are contractually defined. FORCE has integrated decommissioning into its environmental monitoring and stakeholder engagement strategies, recognising that long-term credibility depends on responsible site stewardship.

Figure 9 - Open hydro platform decommissioning at EMEC tidal test site

4.6.2 Insights and lessons learned

Experience across the network shows that proactive decommissioning planning reduces risk, builds trust, and supports long-term sector credibility. Test centres that engage with regulators, developers, and communities early in the project lifecycle are better positioned to manage expectations and avoid last-minute complications. EMEC's experience shows that standardising internal processes and operational procedures can streamline licensing and ensure that decommissioning obligations are clearly understood.

Transparency and shared learning are also critical. The network has facilitated the exchange of decommissioning strategies, and lessons learned, helping centres to refine their approaches and avoid repeating mistakes. There is also growing recognition that decommissioning is not always about removal; in some cases, infrastructure may be repurposed or used for ongoing research and monitoring.

4.6.3 Future focus areas

To strengthen decommissioning and end-of-life planning test centres should focus on:

- **Lifecycle integration:** Embedding decommissioning considerations from the outset of project planning, with clear milestones, financial provisions, and technical strategies.

- **Contractual clarity:** Developing and sharing standardised contract language that clearly defines roles, responsibilities, and liabilities for infrastructure removal.
- **Technical innovation:** Research into low-impact removal techniques, modular infrastructure, and environmentally integrated designs.
- **Regulatory alignment:** Promote greater harmonisation of decommissioning requirements across jurisdictions to reduce uncertainty
- **Knowledge sharing:** Continuing to document and exchange of decommissioning experiences, including failures and successes, to support sector maturity.

4.7 Stakeholder engagement and community relations

Early, transparent engagement with local communities, regulators, and stakeholders, including fisheries, and environmental organisations, is now recognised as essential for securing social licence and project success. Test centres have increasingly act as conveners, facilitating trust-building, education, and dialogue alongside technology demonstration. As the sector grows and diversifies, stakeholder engagement has become a strategic priority, not just a regulatory requirement.

4.7.1 Key challenges

A persistent challenge is the lack of consistent frameworks across jurisdictions. While some regions have established consultation processes, others rely on ad hoc or developer-led outreach, increasing the risk of miscommunication and resistance. Test centres must navigate with multiple stakeholder groups, each with distinct concerns, histories, and expectations.

These challenges are widely shared but context specific. FORCE in Canada must engage with Mi'kmaq communities, fisheries stakeholders, and federal regulators, often balancing cultural, ecological, and economic priorities. Whereas, EMEC works closely with Orkney Island Council and local residents, using sustained, face-to-face engagement to build long-term trust. In Korea, centres face lower public awareness and community buy-in, compounded by regulatory complexity and competing marine interests

Engagement practices have evolved from reactive, focused on mitigating opposition. Expanded use of public consultations, digital communication, and community science has improved transparency but also raised expectations for responsiveness and accountability.

4.7.2 Insights and lessons learned

Stakeholder engagement must be continuous, rather than episodic. Test centres that maintain regular contact with communities, through newsletters, site visits, workshops, and informal conversations, report stronger relationships and fewer conflicts.

Another lesson is the importance of storytelling and education. Many stakeholders are unfamiliar with marine energy technologies and may perceive them as risky or unnecessary. Centres that invest in public education, including visitor centres, school programmes, and media outreach, help demystify the technology and highlight its potential benefits. For example, FORCE's public visitor centre and EMEC's community engagement efforts have helped position marine energy as a source of local pride and opportunity.

Engagement must be tailored. Fisheries, environmental groups may have different priorities and expectations. Recognising and respecting these differences is essential for building inclusive and effective relationships.

Figure 10 - Breakout group at International WaTERS workshop 2023

4.7.3 Future focus areas

To strengthen stakeholder engagement and community relations, test centres should focus on:

- **Early and inclusive engagement:** Initiating dialogue at the earliest project stages and ensuring all relevant voices included.
- **Transparent communication:** Providing clear, accessible information about project objectives, timelines, risks, and benefits.
- **Education and outreach:** Investing in public education, community events, and digital communications to support informed dialogue.
- **Capacity building:** Supporting stakeholders participation through training, resources, and involvement in monitoring and research.
- **Feedback mechanisms:** Establishing clear channels for feedback, grievance resolution, and adaptive management.

4.8 Collaboration, data sharing, and networked action

Collaboration and data sharing are defining strengths of the International WaTERS network. Across workshops and reports, test centres have repeatedly identified the need for shared databases, risk registers, and lessons learned logs, covering technical performance, contracting experiences, safety incidents, and environmental data.

The EU-funded H2020 MARINERG-i project is developing plans for an integrated European Research Infrastructure as an independent legal entity to support the growth of the Offshore Renewable Energy sector. Project partners, including EMEC and PLOCAN are completing the preparatory work to establish this pan-European infrastructure, focusing on expanding member state participation and securing long-term support, updating the scientific programme, developing the technical and data infrastructure, and producing a clear business and implementation plan.

These tools support operational efficiency while building trust, reducing duplication, and accelerating sector-wide learning. Initiatives such as mutual recognition of standards, shared procurement, and staff exchanges further strengthen networked action and support sector growth

4.8.1 Key challenges

Despite strong commitment to collaboration, several barriers remain. A significant challenge is the lack of standardised platforms and protocols for data sharing. Test centres often collect similar data on environmental impacts, operational performance, and safety but use different formats, methodologies, and storage systems, limiting comparability or cumulative learning.

Data sensitivity also constrains collaboration. Commercial confidentiality, regulatory requirements, and reputational concerns can reduce willingness to share information about failures, near-misses, or contracting disputes. Without clear frameworks for anonymisation, data governance, and mutual benefit, collaboration can stall.

These challenges vary in intensity depending on national policy, funding structures, and organisational culture. For example, centres with strong public mandates (e.g., EMEC, FORCE) may be more open to sharing, while those operating under commercial constraints may be more cautious. The issues are recurring but have evolved over time, from initial hesitancy to growing interest in structured, secure, and reciprocal data exchange.

To address these barriers, the network has proposed several initiatives, including the creation of a centralised SharePoint site, the development of a common risk register, and the establishment of a lessons-learned log. These efforts aim to formalise collaboration and make shared learning a routine part of test centre operations.

4.8.2 Insights and lessons learned

Collaboration is most effective when it is intentional and supported by shared tools. Informal exchanges remain valuable but must be complemented by formal mechanisms for documenting, storing, and disseminating knowledge. The network has learned that even simple tools, such as shared templates for incident reporting or procurement checklists, can have a significant impact when adopted consistently.

Mutual recognition of monitoring standards, safety protocols, and operational procedures can reduce duplication, streamline permitting, and support cross-border deployments. Staff exchanges and joint training programmes have also proven effective in building trust, transferring skills, and fostering a sense of shared purpose.

The network has also recognised that collaboration is not just technical, it is cultural. Building a collaborative ethos requires transparency, humility, and a willingness to learn from both successes and failures. Test centres that embrace this mindset report stronger relationships, more resilient operations, and greater influence in policy and funding discussions.

Figure 11 - Site visit to EMEC's wave test site

4.8.3 Future focus areas

To strengthen collaboration and data sharing, test centres should focus on:

- **Shared infrastructure:** Developing centralised platforms for data exchange, risk tracking, and lessons learned, accessible to all network members.
- **Standardisation:** Align monitoring protocols, safety procedures, and reporting formats to enable comparison and mutual recognition.
- **Governance and trust:** Establishing clear frameworks for data ownership, confidentiality, and attribution.
- **Capacity building:** Investing in staff exchanges, joint training, and collaborative research initiatives.
- **Operational integration:** Embedding collaboration into routine workflows, including, procurement, contracting, incident reporting and performance evaluation.

4.9 Funding, sustainability, and business models

Marine energy test centres continue to face persistent challenges in securing sustainable funding. Balancing public investment, client fees, and collaborative grant projects remains complex and uncertain. While some centres benefit from national sponsorship or long-term institutional support, many operate on project-based funding cycles, making strategic planning difficult.

4.9.1 Key challenges

A significant challenge is the lack of consistent, long-term funding. Reliance on short-term grants or demonstration projects, can create gaps between funding cycles. This instability affects staffing, infrastructure maintenance, and the ability to support developers consistently. Test centres such as EMEC, FORCE, and PacWave have highlighted the difficulty of maintaining core operations without predictable revenue streams.

Limited commercial maturity of the marine energy sector compounds this challenge. With few technologies reaching full commercial deployment, client fees alone are insufficient to sustain test centres. Early-stage developers often require subsidised access, technical support, and flexible payment models, placing additional strain on the test centre budgets. Moreover, the administrative burden of applying for competitive grants, often with low success rates, diverts time and resources from core activities.

These challenges are widely shared across the network and have evolved over time. While early centres were often fully publicly funded, there is now a shift towards hybrid models that combine public support with commercial services, research partnerships, and international collaboration. However, the transition remains uneven, and many centres continue to operate in a financially precarious environment.

4.9.2 Insights and lessons learned

A key insight is that financial sustainability depends on diversification. Centres that rely on a single funding source whether public or private, are more vulnerable to policy changes, market fluctuations, and project delays. More resilient centres have developed mixed-income models that combine government grants, developer fees, research contracts, and strategic partnerships.

Another lesson is the importance of aligning business models with mission. Test centres that position themselves as innovation hubs, conveners, and providers of public value are better positioned to attract long-term institutional support. EMEC's non-profit status and role in hydrogen and floating wind R&D have helped it access funding streams beyond marine energy.

The network has also recognised the value of collaborative funding. Joint bids for international projects, shared infrastructure investments, and pooled resources for training and outreach can reduce duplication and increase impact.

4.9.3 Future focus areas

To strengthen funding and sustainability across the sector, test centres should prioritise:

- **Diversified revenue models:** Expanding hybrid funding strategies that combine public investment, commercial services, and collaborative grants.
- **Strategic partnerships:** Building long-term relationships with universities, national labs, and industry consortia and other test centres.

- **Shared infrastructure and procurement:** Joint investment in monitoring equipment, and digital platforms.
- **Capacity building for fundraising:** Investing in dedicated staff and systems to manage grant applications, reporting, and financial planning.
- **Transparent business planning:** Clear communication of mission, value proposition, and financial needs can improve stakeholder confidence and attract support.

4.10 Workshop and network development

The International WaTERS network has matured significantly since its inception, with annual and biannual workshops evolving from broad knowledge exchanges into structured, thematic convenings. Recent workshops have included panels focused on public sector engagement, supply chain integration, and breakout sessions on technical and regulatory topics. Site-specific working groups have also emerged, allowing centres to address local challenges while contributing to global learning.

There is strong appetite across the network for more frequent, role-focused workshops and virtual engagement to maintain momentum between in-person events. The establishment of ongoing online forums such as Slack channels, and webinars, is under active consideration to facilitate real-time problem-solving and collaborative action planning.

Figure 12 - Test site updates at International WaTERS workshop

4.10.1 Key challenges

A central challenge in network development is maintaining continuity and engagement between workshops. While in-person events are highly valued, the long intervals between them can lead to missed opportunities for collaboration, delayed follow-up on action items, and loss of momentum. The network has expressed a need for more frequent touchpoints, especially for role-specific discussions (e.g., permitting leads, operations managers, data analysts).

Another barrier is the diversity of time zones, languages, and organisational structures across the network. Coordinating virtual meetings that accommodate participants from North America, Europe, and Asia requires careful planning and flexible formats. Additionally, not all centres have equal access to digital collaboration tools or the capacity to participate in ongoing online forums.

These challenges are shared across the network and have evolved over time. Early workshops were largely informal and focused on relationship-building. More recent events have introduced structured agendas, thematic panels, and breakout groups, reflecting the sector's growing complexity and the need for targeted dialogue. The network has responded by exploring digital platforms and asynchronous engagement models to complement live events.

4.10.2 Insights and lessons learned

A key insight is that effective convening goes beyond information exchange, it's about building trust, fostering alignment, and enabling coordinated action. Workshops that include diverse formats, such as site tours, roundtables, and breakout sessions, create space for both strategic discussion and practical problem-solving. The inclusion of public sector representatives, supply chain representatives, and regulators has enriched the dialogue and helped bridge gaps between policy and practice.

Another lesson is the value of role-specific engagement. Participants have consistently requested sessions tailored to their responsibilities, such as permitting, environmental monitoring, operations, and communications. These focused discussions allow for deeper exchange, peer learning, and the development of shared tools and templates.

The network has also recognised that digital collaboration must be intentional. Simply creating a Slack channel or SharePoint site is not enough, there must be clear governance, facilitation, and incentives for participation. Centres that have experimented with online forums report that structured prompts, regular updates, and thematic threads help sustain engagement.

4.10.3 Future focus areas

To strengthen workshop and network development, several focus areas have emerged:

- **More frequent engagement:** Introduce quarterly virtual meetings, role-specific webinars, and asynchronous discussion threads to maintain momentum between in-person events.
- **Digital collaboration infrastructure:** Establish and maintain online platforms (e.g., SharePoint, slack, teams) with clear governance, moderation, and content curation.
- **Role-based communities of practice:** Create working groups for permitting operations, data management, and stakeholder engagement to support targeted collaboration.
- **Action-oriented convenings:** Ensure that workshops result in tangible outputs such as shared templates, joint statements, or collaborative funding proposals.
- **Inclusive participation:** Design engagement formats that accommodate diverse time zones, languages, and organisational capacities, ensuring participation from all test centres.

5 Policy asks

As the pace of technological change accelerates, our policy support for test centres must evolve to remain fit for purpose. Diversification – both in capability and geography – is essential to meet demand, ensure resilience and support inclusive access to innovation and commercialisation.

5.1 Enabling role of test centres

Test centres are at the forefront of innovation in offshore renewable energy, acting as critical enablers for technology development, risk reduction, and market confidence. Their unique position bridging research, industry, and regulatory practice means they generate real-world insights that can inform proportionate, adaptive, and future-proof policy frameworks.

By embedding test centres into policy development, governments can accelerate technology deployment, reduce consenting bottlenecks, and ensure that environmental and safety standards evolve alongside innovation. The International WaTERS network offers:

- **Practical expertise:** Test centres operate in complex marine environments, providing evidence-based understanding of technical, environmental, and operational challenges.
- **Risk reduction:** Early-stage testing mitigates technology risks for developers and investors, supporting climate change targets.
- **Data leadership:** Centres collect and share high-quality environmental and performance data, enabling informed regulatory decisions and reducing duplication.
- **Stakeholder engagement:** As trusted intermediaries between industry, regulators, and communities, fostering social licence and collaborative solutions.

5.2 Thematic asks

To support the evolution and impact of marine energy test centres, the International WaTERS network's combined experience recommends the following policy actions across key thematic areas:

Theme	Policy action
1. Test Centre Evolution and Diversification	Develop adaptive regulatory frameworks for multi-technology environments.
	Streamline consenting processes, including pre-consented envelopes and mutual recognition of environmental data.
	Fund inclusive stakeholder engagement.
	Invest in offshore operational innovation and shared infrastructure.
	Promote open data standards and transparency.
	Support flexible certification models for emerging technologies.

Theme	Policy action
2. Accredited Testing, Standards, and Certification	Link certification outcomes to regulatory approvals.
	Build stakeholder understanding of certification processes.
	Enable scalable testing through infrastructure investment.
	Encourage open access to test results and lessons learned.
3. Environmental Monitoring and Consenting	Advance proportionate, adaptive regulation.
	Enable clear and timely consenting pathways.
	Fund early and inclusive stakeholder dialogue.
	Invest in digital infrastructure and workforce training.
	Promote data sharing across centres and developers.
4. Operations, Maintenance, and Marine Logistics	Fund resilient marine infrastructure and digital systems.
	Support local workforce development and training.
	Encourage sector-wide knowledge exchange.
	Develop flexible regulatory approaches for marine operations.
5. Health and Safety	Standardise safety protocols and training.
	Facilitate cross-centre safety coordination.
	Prioritise safety leadership in funding decisions.
	Promote transparency in safety reporting.
	Invest in safety-critical infrastructure.
6. Decommissioning and End-of-Life Planning	Mandate early planning and financial bonding.
	Harmonise international standards.
	Fund innovation in decommissioning technologies.
	Support adaptive approaches to infrastructure repurposing.
	Promote transparency in lifecycle reporting.
7. Workshop and Network Development	Fund convening infrastructure and digital platforms.
	Recognise network development as strategic work.
	Enable cross-sector dialogue and collaborative outputs.
	Promote international alignment through the WaTERS model.
	Provide stable, multi-year operational funding.

Theme	Policy action
8. Funding, Sustainability, and Business Models	Encourage collaborative grant models.
	Recognise test centres as strategic national assets.
	Streamline administrative processes.
	Allow flexible use of funds across activities.
9. Collaboration, Data Sharing, and Networked Action	Fund shared digital infrastructure and databases.
	Promote standardised monitoring and reporting.
	Support cross-centre collaboration and staff exchanges.
	Incentivise open data initiatives.
	Integrate collaboration metrics into policy frameworks.
10. Stakeholder Engagement and Community Relations	Mandate early and structured engagement plans.
	Fund community participation and education initiatives.
	Promote cross-sector collaboration to minimise conflict.
	Recognise social licence as a strategic asset in policy and funding decisions.

Table 1 - Thematic policy asks for marine energy test centres

5.3 Policy summary and impacts

These policy actions collectively reinforce six key areas of emphasis. First, regulation must remain adaptive and proportionate, evolving in step with technological progress so that new developments are not held back by outdated frameworks. Flexible approaches are particularly important in environments where multiple technologies coexist and where operations take place in challenging marine settings.

A second priority is the streamlining of consenting and certification processes. Clear and timely approval pathways help reduce delays and costs, while closer alignment between certification and regulation can accelerate deployment. Consistent safety standards, transparent reporting requirements, and early planning across the full project lifecycle all contribute to protecting both people and the environment.

Effective policy also relies on strong stakeholder engagement. Structured dialogue, better international alignment, and treating social licence as a strategic asset help build trust, reduce conflict, and reinforce global competitiveness.

Innovation in infrastructure and operations forms another pillar. Investment in resilient marine infrastructure, modern digital systems, and training for local workforces supports operational efficiency and strengthens regional economies.

Equally important is a commitment to data sharing and transparency. Open data standards, shared platforms, and collaborative approaches improve regulatory confidence, reduce duplication, and accelerate collective learning.

Finally, stable funding and long-term strategic recognition ensure that test centres can plan effectively. Multi-year commitments, coupled with streamlined administrative processes, secure their role as nationally significant assets in the energy transition.

Taken together, these priorities will enable faster deployment of new technologies, reduce bottlenecks in the consenting process, lower costs and risks for developers and investors, and improve environmental and safety performance through more evidence-driven regulation. They also offer clear economic benefits through job creation and infrastructure investment, while positioning the sector for global leadership in offshore renewable innovation.

6 Conclusions and recommendations

6.1 Conclusions

A decade of International WaTERS meetings has established a foundation of trust, shared ambition, and practical problem-solving for marine energy test centres worldwide. The network has collectively advanced technical, operational, and regulatory best practices, helping to catalyse the ocean energy sector's journey towards commercial maturity. Sustained collaboration, ongoing innovation, and mutual support will be essential as the sector faces new challenges and opportunities in the drive to deliver clean, renewable marine energy on a global scale.

The report highlights how marine energy test centres have evolved into multi-technology innovation hubs, integrating wave, tidal, floating wind, hydrogen, and advanced monitoring systems. The key findings include:

- **Adaptability and diversification:** Centres that invested in modular infrastructure and flexible service models have remained resilient and financially sustainable, supporting a broader range of technologies and developer needs.
- **Collaboration:** Shared learning, joint procurement, and harmonised protocols have reduced duplication, lowered costs, and accelerated innovation across the network.
- **Tailored support:** Bespoke testing pathways and flexible certification models help developers progress from early-stage trials to full accreditation, lowering barriers to entry.
- **Operational excellence:** Centres have improved operations and maintenance by adopting digital tools, remote monitoring, and strong local supply chain relationships, while sharing lessons learned from both successes and failures.
- **Environmental leadership:** Test centres lead in environmental monitoring and adaptive management, advocating for streamlined, risk-based consenting and open data sharing to support responsible growth.

- **Stakeholder engagement:** Early, transparent engagement with communities and stakeholders is now central to project success and social licence.
- **Continuous improvement:** The network's culture of transparency, knowledge sharing, and standardisation underpins safety, decommissioning, and sustainable business models.

Overall, the report demonstrates that adaptability, collaboration, and evidence-based planning are key to overcoming challenges and advancing the marine energy sector.

6.2 Opportunities and recommendations for future action

- Continue development of shared resources (databases, risk registers, contract templates, procurement logs) to embed learning and reduce duplication.
- Explore joint actions on insurance, supply chain challenges, and resource sharing across test centres.
- Standardise and mutually recognise environmental monitoring protocols; pursue mutual recognition for regulatory data where feasible.
- Advance collaborative R&D and staff exchanges, focusing on emerging challenges such as hydrogen integration, floating wind, and digital monitoring technologies.
- Refine the funding model for the network to ensure sustainable coordination and action.
- Strengthen advocacy with regulators and policy makers, highlighting test centres' evidence for minimal environmental impacts and the need for proportionate, flexible consent regimes.
- Develop a roadmap for test centre and developer readiness, including accessible pathways to standards compliance and certification.
- Continue to scale knowledge-sharing platforms and increase the frequency of focused, actionable discussions.
- Position test centres as strategic partners in policy and funding landscapes to accelerate technology deployment, enable adaptive regulation, and deliver economic, environmental, and social benefits.

Appendix A: Participant list (2013 – 2024)

Test centres	Country/Region
EMEC: European Marine Energy Centre	UK
META: Marine Energy Test Area	UK
Morlais	UK
WaveHub	UK
SmartBay Ireland / BlueWise Marine	Ireland
Marine Institute	Ireland
SEAI: Sustainable Energy Authority of Ireland	Ireland
AMETS	Ireland
DanWEC: Danish Wave Energy Center	Denmark
DMEC: Dutch Marine Energy Centre / POWERDAM-NL / MET-support BV	Netherlands
SEMREV	France
SEENEOH Bordeaux / Paimpol-Brehat	France
BiMEP: Biscay Marine Energy Platform	Spain
Mutriku	Spain
PLOCAN: Oceanic Platform of the Canary Islands	Spain
INESC TEC / WavEC	Portugal
Colab +Atlantic	Portugal
POM West Flanders	Belgium
EVE: Ente Vasco de la Energia	Spain
ICTS-MARHIS	Spain
KIOST: Korea Institute of Ocean Science & Technology	South Korea
KRISO: Korea Research Institute of Ships & Ocean Engineering	South Korea
KRISO-WETS: Wave Energy Test Site	South Korea
NaMICPA: Nagasaki Marine Industry Cluster Promotion Association	Japan
Class NK Nagasaki Prefecture	Japan
Nagasaki University	Japan
NTOU: National Taiwan Ocean University	China Taipei
ITRI: Industrial Technology Research Institute	China Taipei
Taiwan Marine Energy Centre	China Taipei
QNLM: Qingdao National Laboratory Maritime	China
NOTC: National Ocean Technology Center	China
OUC: Ocean University of China / QNLM	China
FORCE: Fundy Ocean Research Centre for Energy	Canada
SNMREC: Southeast National Marine Renewable Energy Center at Florida Atlantic University	USA
AMEC: Atlantic Marine Energy Center	USA
PacWave / PMEC: Pacific Marine Energy Center	USA
NREL: National Renewable Energy Laboratory	USA
Hawaii Natural Energy Institute (HNEI) / WETS	USA
Coastal Studies Institute / Jennette's Pier Wave Energy Test Facility	USA
University of Alaska Fairbanks	USA

DOE: US Department of Energy	USA
PNNL: Pacific Northwest National Laboratory	USA
SANDIA National Laboratories	USA
UNH: University of New Hampshire / Center for Ocean Renewable Energy	USA
Stony Brook University	USA
Lehigh University	USA
MERIC: Marine Energy Research and Innovation Center	Chile
CEMIE Océano	Mexico

Table 2 - International WaTERS participant list (2013 - 2024)

Observers	Country/Region
IEA-OES: International Energy Agency – Ocean Energy Systems	International
IECRE / IEC TC 114	International
OceanDEMO	EU
BlueGIFT	EU
Acadia University	Canada
Ocean Tracking Network	Canada
Confederation of Mainland Mi'kmaq	Canada

Table 3 - International WaTERS observer list (2013 - 2024)

Appendix B: International WaTERS through the years

Figure 13 - EMEC Global Ocean Energy Symposium 2013: Orkney, Scotland

Figure 14 - International Test Centres Workshop 2014: Halifax, Canada

Figure 15 - International WaTERS 2016: Edinburgh, Scotland

Figure 16 - International WaTERS 2017: Gran Canaria, Spain

Figure 17 - International WaTERS 2018: Keelung, Taiwan

Figure 18 - International WaTERS 2019: Orkney Scotland

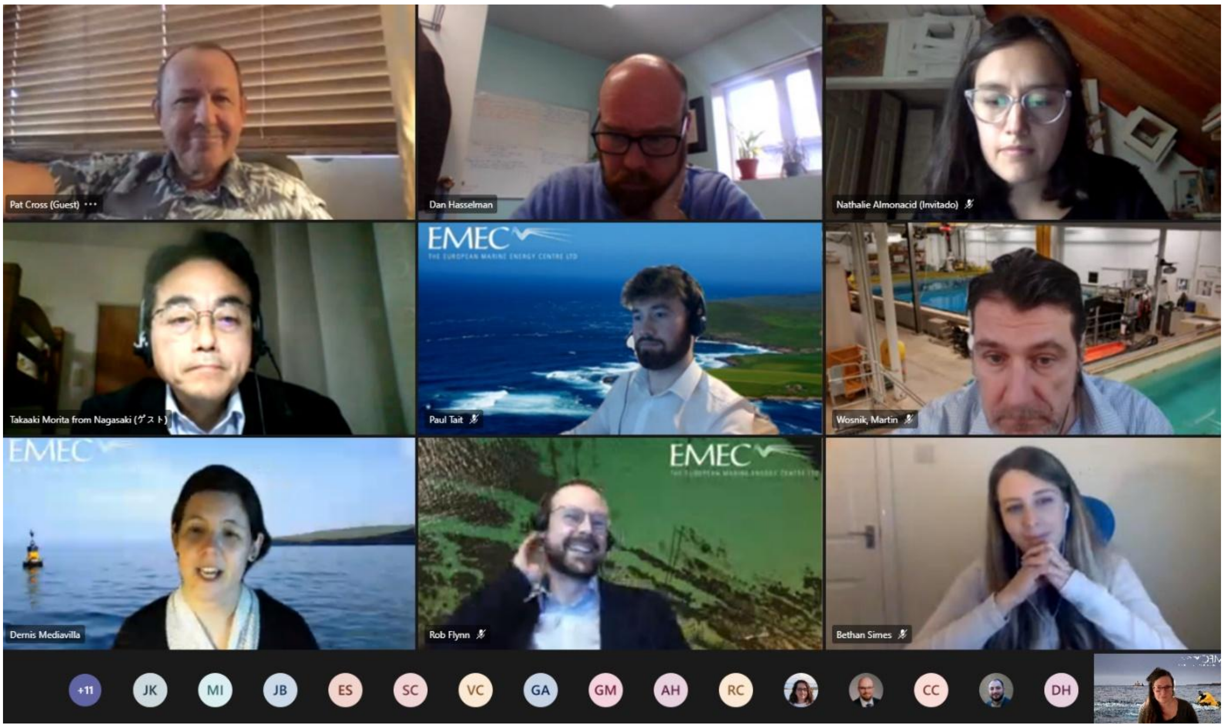

Figure 19 - International WaTERS 2021: Zoom, virtual event

Figure 20 - International WaTERS 2022: Bilbao, Spain

Figure 21 - International WaTERS 2023: Orkney, Scotland

Figure 22 - International WaTERS 2024: Halifax, Canada

Figure 23 - International WaTERS 2025: Funchal, Madeira, Portugal

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