10th PRIMaRE Conference and CCP-WSI Focus Group Workshop

University of Bath, 27th -28th June 2023

The 10th PRIMaRE Conference will take place on the 27th and 28th June 2023 at the University of Bath. The annual PRIMaRE conference provides a forum for exchanging the latest research & development and fostering collaborations in Marine Renewable Energy. We look forward to welcoming you to the University of Bath and enjoying an inspiring and interesting programme of talks, posters and discussions.

Conference Venue and Zoom link:

The registration desk and conference talks, and posters will be held in building 3WN on the campus of the University of Bath (Bath, BA2 7AY, UK). Oral presentations will be held in room 3WN2.1, and poster display and catering will be in room 3WN3.7.

The 10th PRIMaRE conference is a hybrid conference. For those participants who cannot attend the conference in person, please join the conference through the following Zoom link:

Join Zoom Meeting

https://bath-ac-uk.zoom.us/j/5890782958?pwd=d25LUEcxS3pTRzVyTzh0YzZOL1lnQT09

Meeting ID: 589 078 2958

Passcode: 123245

Travel

We hope participants will travel by public transport where possible. You can reach Bath by Train or Coach. If arriving by rail, please get off at Bath Spa Station. Bath is compact, though hilly. If you stay somewhere reasonably central, you may well decide to walk everywhere. You can also take First Bus (https://www.firstbus.co.uk/) around Bath. You can find taxis outside of Bath Spa Station, or call Abbey Taxis (01225 444444), and V Cars (01225 464646).

Some links are given below to help you plan your travel to Bath and to the campus of the University of Bath.

Getting to the city of Bath

https://www.bath.ac.uk/guides/travelling-to-the-city-of-bath/

How to find the University of Bath

https://www.bath.ac.uk/locations/university-of-bath-claverton-down-campus/

Campus map

https://www.bath.ac.uk/publications/claverton-down-campus-map/attachments/university-campus-map.pdf

Traveling by bus to the University of Bath

https://www.bath.ac.uk/guides/travelling-by-bus-to-the-university-of-bath/

Cycling and walking to the University of Bath

https://www.bath.ac.uk/guides/cycling-and-walking-to-the-university-of-bath/

About Bath and Accommodation

Bath is a World heritage City. It ticks pretty much all the boxes for a perfect short break. With sweeping, honey-stone Georgian crescents and terraces spread over a green and hilly bowl, it's a strong contender for England's most beautiful small city.

There are a huge number of hotels and other accommodation options to suit every budget in Bath. For a general guide to Bath go to: https://visitbath.co.uk/ - lots of ideas and deals on where to stay and things to do, such as the Top ten must-sees in Bath, and the Top ten things to do in Bath. Or you can book your accommodations on Booking.com, and airbnb.

Conference Format

We received a large number of excellent abstracts for presentations and posters. Conference presentations, posters, and exhibition stands will take place in the building 3WN on the campus of the University of Bath, or through Zoom meeting.

Oral presentations have been allocated up to 12 minutes including questions. Posters should be A1, portrait format is preferred.

Meals and Conference Gala Dinner

The PRIMaRE Conference is free to attend with the option of attending the gala dinner in their own costs. Lunch and tea & coffee will be provided on both days.

The PRIMaRE Gala dinner will take place on the evening of 27th June 2023. The gala dinner will be paid individually. After the panel discussions, guides will be available to lead those who would like to walk to the gala dinner at the DoubleTree by Hilton Bath (Bath BA1 5BJ).

CCP-WSI Focus Group Workshop 4

The CCP-WSI Focus Group Workshop 4 wil take place on the 28th June, 14:00-16:45. It is an industrial engagement event hosted by the CCP-WSI, focussing on offshore renewable energy applications. The Workshop will bring together CCP-WSI project partners with representatives from the wider WSI Community to develop a priority list of WSI challenges and inform future targeted focus group meetings. The ultimate goal is to develop a roadmap for CCP-WSI activities and inform future funding calls.

More details can be found at
https://ccp-wsi.ac.uk/events/industry_engagement/focus_group_workshop_4/

Supporting organisations & Exhibitors

The PRIMaRE conference could not take place without the support of sponsoring organisations and exhibitors. We are very grateful to all our sponsors listed below to offer their generous supports for this conference.

Exhibitor, Presentation & Poster prize sponsor: Supergen Offshore Renewable Energy Hub

The Supergen Offshore Renewable Energy (ORE) Hub is a £9 Million Engineering and Physical Sciences Research Council (EPSRC) funded consortium of 10 UK leading universities. The Hub is tackling the fundamental engineering research challenges in ORE in order to provide research leadership to connect academia, industry, policymakers and the public, inspire innovation and maximise societal value.

The University of Plymouth leads the Supergen ORE Hub, with Co-Directors from the Universities of Aberdeen, Edinburgh, Exeter, Hull, Manchester, Oxford, Southampton, Strathclyde, and Warwick. The Supergen ORE Hub is one of several Hubs created by EPSRC to deliver sustained and coordinated research on Sustainable PowER GENeration and supply. Find out more about the Supergen ORE Hub at www.supergen-ore.net

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Exhibitor: META (Marine Energy Test Area)

Marine Energy Test Area (META) is a fully consented, pre-commercial testing centre; a flagship Welsh project dedicated to reducing the time, cost and risks associated with deployment and commercialisation. META sits within the Marine Energy Wales portfolio, as Wales' National Test Centre facility. Funded through the Swansea Bay City Deal and a keystone partner of the Pembroke Dock Marine Project, META offers testing in real sea conditions for wave, tidal and FLOW technology in the Milford Haven Waterway and adjoining seas, alongside a world class port, engineering and manufacturing facilities.

Exhibitor: SUT (The Society for Underwater Technology)

The Society for Underwater Technology (SUT) is a multidisciplinary learned society that brings together organisations and individuals with a common interest in underwater technology, ocean science and offshore engineering.

SUT was founded in 1966 and has members from more than 40 countries, including engineers, scientists, other professionals and students working in these areas. In recent decades many of our members have come from the offshore hydrocarbon sector, today we also see growing numbers of members from offshore renewables, marine autonomous systems, and the policy, law and insurance sectors who support offshore activities of many kinds.

The Underwater Association which also commenced operations in 1966 had a long-standing relationship with SUT, and merged with us in 1992, having played a key role in establishing safer diving practices in consultation with the UK Health & Safety Executive. Their legacy can be particularly seen in the work of our Diving & Manned Submersibles Committee.

CCP-WSI Focus Group Workshop

The Collaborative Computational Project in Wave Structure Interaction (CCP-WSI), funded by EPSRC, brings together two computational communities – fluid dynamics and structural mechanics. Established in 2015, CCP-WSI provides leadership for the WSI community in:

- Strategy setting, identifying priorities for WSI code development
- Contributions to knowledge, through internationally recognised Benchmarking Code Comparisons
- Collaborative software development and support.

More details on CCP-WSI can be found at https://ccp-wsi.ac.uk/

10th PRIMaRE Conference and CCP-WSI Focus Group Workshop

Building 3WN, University of Bath, UK

This is a hybrid conference, anyone who is not able to attend the conference in person, please join

Zoom Meeting: https://bath-ac-uk.zoom.us/j/5890782958?pwd=d25LUEcxS3pTRzVyTzh0YzZOL1lnQT09

Meeting ID: 589 078 2958
Passcode: 123245

27th June 2023

8:45-9:15	Arrival and registration (Building 3WN foyer)
9:15-9:30	Welcome & Introduction (PRIMaRE Chair, Jun Zang, Room 3WN2.1)
Session 1	**Offshore wind (Room 3WN2.1)**
9:30-9:50	*An overview of the Cornwall FLOW Accelerator and PDZ project outputs, and the implications for FLOW in the Celtic Sea* Keynote speaker: Steve Jermy (Celtic Sea Power)
9:50-10:02	*Floating Wind Turbine Maintenance by Rapid Swap and Tow* Marcin Kapitaniak (University of Aberdeen)
10:02-10:14	*Conceptual design and optimisation of a novel hybrid device for capturing offshore wind and wave energy* Emilio Faraggiana (Politecnico di Torino)
10:14-10:26	*New Investigations on Wave Loading on Offshore Wind Turbine Foundations* Haoyu Ding (University of Bath)
10:26-10:38	*Review of Analysis Methods for Floating Offshore Wind Turbines under Extreme Environmental Conditions* Lige Zhao ((University of Plymouth)
10:38-10:50	*An experimental investigation of nonlinear wave loading on a vertical cylinder - Stokes type expansion and secondary load cycle* Tianning Tang (University of Oxford)
10:50-11:10	Poster presentations Rachael Smith (Cardiff University) Emma Edwards (University of Plymouth) Simone Michele (University of Plymouth)

Deepak George (Swansea University)

Guangwei Zhao (University of Strathclyde)

Ioannis Polydoros (Swansea University)

Nicholas Petzinna (University of the Highlands and Islands)

Huaqing Jin (University of Plymouth)

Zhixin Zhou (University of Bristol)

11:10-11:40 Coffee break and poster displays (Room 3WN3.7)

Session 2	**Tidal energy**	**(Room 3WN2.1)**
11:40-12:00	*Tidal Stream Energy: Converting the Opportunity - The TIGER Project a Review of the Achievements* Keynote speaker: Simon Cheeseman (ORE Catapult)	
12:00-12:12	*Development of a passive blade-pitch mechanism to reduce the loads on a tidal turbine in high-flow conditions* Tom Summers (University of Edinburgh)	
12:12-12:24	*Cross-comparison of the prediction of resource and turbine fatigue loading at a tidal site from models and multi-point measurements* Hannah Mullings (The University of Manchester)	
12:24-12:36	*Deep Learning for optimal usage of battery storage coupled with tidal farms* Anna Young (University of Bath)	
12:360-12:48	*Are Vortex Generators of interest for tidal turbine blades? A proof-of-concept study* Marinos Manolesos (City University of London)	
12:48-13:00	*Investigating the impact of multi-rotor structure shadowing on tidal stream turbine performance* Bryn Townley (University of Edinburgh)	

13:00-14:00 Lunch and poster displays (3WN3.7)

Session 3	**Design tools and methods in marine renewable energy**	**(3WN2.1)**
14:00-14:20	*Why test? What should govern the choice of a test site and testing regime?* Keynote speaker: Stephen Thompson (META)	
14:20-14:32	*A new robotic investigative tool to aid geotechnical design of offshore renewables: the ROBOCONE*	

	James Creasey (University of Bristol)
14:32-14:44	*Numerical Study of Wave Interaction with Multiple Floating Buoys by qaleFOAM* Yi Zhang (City University of London)
14:44-14:56	*High-fidelity multi-region overset mesh Computational Fluid Dynamics model for offshore renewable energy* Zaibin Lin (University of Aberdeen)
14:56-15:08	*Identifying risk of conflict between fisheries and potential marine renewable energy sites* Matt Lewis (Intertek & Bangor University)
15:08-15:20	*Numerical Simulation of a floating solar farm in waves* Yujia Wei (Cranfield University)
15:20-15:40	Poster presentations Krishnendu Puzhukkil (University of Plymouth) Junxian Wang (Cranfield University) Daniel Coles (University of Plymouth) Chris Pierpoint (Seiche Limited) Jon Hardwick (University of Exeter) K.Thiruvenkatasamy (Bangor University) Xuxin Pooley (University of Exter) Rongquan WANG (dalian University of technology) Yi Huang (University of Strathclyde) Deri Lamb (ORE Catapult – Wales) Jonathan Payman (ORE Catapult – Wales)

15:40-16:10 Coffee break and poster displays (3WN3.7)

Session 4 Challenges and opportunities in marine renewable energy (3WN2.1)

16:10-16:30	*Multi Purpose Interconnectors and Energy Islands: The next stage in offshore wind* Keynote speaker: Paul Taylor (Intertek)
16:30-17:30	Panel discussions
17:45 –19:00	Skyline walk to Bath Central and conference dinner

19:30 Conference dinner (DoubleTree by Hilton Hotel Restaurant)

28th June 2023

Session 5	**Wave energy**
9:00-9:20	*Research and development of wave energy technology at Mocean Energy* Keynote speaker: Alfred Cotton (Mocean Energy)
9:20-10:35	*Motion behavior and wave power absorption of multi-degree-of-freedom floating oscillating water column (OWC) devices* Peiwen Cong (Dalian University of Technology)
9:32-9:44	*Improving WEC Power Performance through Wave Channel Optimisation Approaches* Nian Liu (Mocean Energy / University of Edinburgh)
9:44-9:56	*Optimising the Oscillating Water Column (OWC) to enhance wave energy extraction* Bashir Ahmed (University of Bath)
9:56-10:08	*Mooring design for field demonstration of a large-scale wave energy converter* Faryal Khalid (University of Exeter)
10:08-10:20	*Wave power extraction from a floating elastic disk-shaped wave energy converter* Siming Zheng (University of Plymouth)

10:20-10:50 Coffee break and poster displays (3WN3.7)

Session 6	**Resources and environments (3WN2.1)**
10:50-11:10	*Offshore Renewable Energy Research: Supergen ORE Hub* Keynote speaker: Deborah Greaves (University of Plymouth)
11:10-11:22	*The expansion of offshore windfarms: implications for ecosystem services* Claire Szostek (Plymouth Marine Laboratory)
11:22-11:34	*Deriving Spatial Wave Data from a Network of Buoys and Ships* Jiaxin Chen (University of Exeter)
11:34-11:46	*Investigating the contribution of contaminants by offshore wind farms to the marine environment and implications for aquaculture co-location* Gordon Watson (University of Portsmouth)
11:46-11:58	*An end-to-end approach to estimate Significant Wave height from marine X-band radar backscatter by using deep convolution neural networks* Vahid Seydi (Bangor University)
11:58-12:10	*Satellite wave data for a surrogate wave model for the marine operations of offshore wind farms* Sophie Whistler (University of Exeter)

12:10-12:20 Poster and Oral Presentation Prizes

12:20-12:25 PRIMaRE Chair hand-over to University of Southampton

12:25-12:30 Closing Remarks

12:30-13:30 **Lunch** **(3WN3.7)**

CCP-WSI
a Collaborative Computational Project in Wave Structure Interaction

14:00-16:45	**CCP-WSI + Focus Group Workshop 4**	**(3WN2.1)**
	The CCP-WSI Focus Group Workshop 4 is an industrial engagement event hosted by the CCP-WSI, focussing on offshore renewable energy applications. The Workshop will bring together CCP-WSI project partners with representatives from the wider WSI Community to develop a priority list of WSI challenges and inform future targeted focus group meetings. The ultimate goal is to develop a roadmap for CCP-WSI activities and inform future funding calls. https://ccp-wsi.ac.uk/events/industry_engagement/focus_group_workshop_4/	
14:00-14:15	Welcome and introduction to CCP-WSI	
14:15-14:35	*Floating wind turbines – opportunities, challenges and numerical analysis* Keynote speaker: Alex Argyros (BP Offshore Wind)	
14:35-14:55	*Numerical modelling for floating offshore wind turbines* Keynote speaker: Francesc Fabregas (DNV GL)	
14:55-15:15	**Coffee break**	**(3WN37)**
15:15-15:35	*Better ocean characterisation needed for marine renewables and offshore aquaculture: coupled wave-current mean flows* Keynote speaker: Matt Lewis (Intertek Water & Energy)	
15:35-15:55	*WES driving innovation and cross-sector collaboration* Keynote speaker: Jonathan Hodges (Wave Energy Scotland)	
15:55-16:45	Panel Discussions	
16:45	Close	

Poster Presentations

10:50-11:10 Session 1

1. Impact of lateral turbine spacing on the performance of a multi-rotor tidal energy device

   Rachael Smith (Cardiff University)

2. Key trends in the evolution of floating offshore wind platform designs

   Emma Edwards (University of Plymouth)

3. Floating elastic circular plate in ocean waves

   Simone Michele (University of Plymouth)

4. Computational damage modelling of flexible wave energy convertors

   Deepak George (Swansea University)

5. Recent experimental wave load study on bottom fixed vertical cylinder study at the Kelvin Hydrodynamics laboratory

   Guangwei Zhao (University of Strathclyde)

6. A CFD framework for simulating site-specific tidal and wind turbine arrays

   Ioannis Polydoros (Swansea University)

7. Using low resolution multibeam imaging sonar data to investigate animal underwater behaviour

   Nicholas Petzinna (University of the Highlands and Islands)

8. Low-frequency energy capture and water wave attenuation of a hybrid WEC-breakwater with nonlinear stiffness

   Huaqing Jin (University of Plymouth)

9. Review on determination of thermal soil properties to optimize submarine cable design

   Zhixin Zhou (University of Bristol)

15:20-15:40 Session 3

10. Hydro-elastic response of flexible membrane exposed to regular waves

    Krishnendu Puzhukkil (University of Plymouth)

11. Simulation of pivot location impact on passive hydrofoil in regular wave

    Junxian Wang (Cranfield University)

12. Enhancing energy system security using tidal stream energy

    Daniel Coles (University of Plymouth)

13. Underwater sound measurements of the Nova Innovation tidal turbine array at Bluemull Sound, Shetland Islands

    Chris Pierpoint (Seiche Limited)

14. Impact of wave conditions on siting of tidal stream energy arrays

    Jon Hardwick (University of Exeter)

15. Numerical Modelling on Scour Around a Circular Pile Due to Wave Induced Current in the swash zone

    K.Thiruvenkatasamy (Bangor University)

16. Towards the modelling, control and optimization of wave energy converter arrays

    Xuxin Pooley (University of Exeter)

17. Dynamic performance of a land-based OWC device under the action of solitary wave

    Rongquan Wang (Dalian University of Technology)

18. Experimental Measurement on Water Focusing with Underwater Structure

    Yi Huang (University of Strathclyde)

19. Natural phasing of tidal stream and tidal range

    Deri Lamb (ORE Catapult – Wales)

20. The MEECE buoy - a versatile marine test platform

    Jonathan Payman (ORE Catapult – Wales)

Keynote speakers for the 10th PRIMaRE Conference

Name: Commodore (Rtd) Steven Jermy RN - Celtic Sea Power

Bio: An offshore renewable energy leader, Steve is: CEO at Celtic Sea Power; Non-Executive Director on the Cornwall & Isles of Scilly LEP; represents the Celtic Sea Cluster on the UK's Offshore Wind Industry Cluster Group. His offshore experience includes ships' diving, fishery protection, offshore aviation, sea training and sea command. He has worked for Mojo Maritime Ltd and James Fisher Group plc, on the installation and operation of offshore wind, tidal and wave energy devices and led six major offshore renewables R&D projects. Between 2019 and 2021, he oversaw the conversion of a Cornish offshore test & demonstration zone to floating offshore wind, and its sale in 2021 to Hexicon for the installation of the first floating offshore wind project in the Celtic Sea. He now leads Celtic Sea Power, an arm's length Cornwall Council owned company, with the mission of making floating offshore wind an economic development success for Cornwall and the Celtic Sea Region. Steve has a BSc in Applied Maths and Physical Oceanography from Bangor University, a MPhil in International Relations with International Economics from Cambridge University, is the author of *Strategy for Action: Using Force Wisely in the 21st Century*, and is a Fellow of the Nautical Institute and the Institute of Marine Engineers, Scientists and Technologists.

Title: *An overview of the Cornwall FLOW Accelerator and PDZ project outputs, and the implications for FLOW in the Celtic Sea*

Name: Simon Cheeseman – ORE Catapult

Bio: Simon Cheeseman is an experienced programme manager, having worked in both the private and public sectors. Working within the Offshore Renewable Energy Catapult's Strategy & Emerging Technology Directorate, Simon manages the Catapult's activities in the Southwest focusing on accelerating the deployment of floating wind into the Celtic Sea. Simon sits on the Celtic Sea Cluster Board. Prior to working with ORE Catapult, Simon was the Marine Programme Manager for the Energy Technologies Institute based in Loughborough, England. During his career Simon has held various senior manager roles with responsibility for high value technology development projects.

Title: *Tidal Stream Energy: Converting the Opportunity - The TIGER Project a Review of the Achievements*

Name: Stephen Thompson - META

Bio: Stephen has worked in the marine industry throughout his career, from education to commercial marine aquaculture, fisheries and conservation. Immediately prior to coming to Pembrokeshire, Stephen spent some years observing the development of the offshore wind industry in the southern North Sea, and was involved in assessing and commenting on marine licence applications and EIAs for those project. As META Project Delivery Manager he is responsible for building on the success of META as Wales' flagship test centre.

Title: *Why test? What should govern the choice of a test site and testing regime?*

Name: Paul Taylor - Intertek

Bio: Paul is Intertek's modelling team leader, with 25+ years' experience in marine, coastal and estuarine environmental consultancy. After gaining his MSc in Physical Oceanography at Bangor University, he initially worked on offshore geophysical surveys, and then as a marine environmental modelling consultant for BMT and then Metoc (now Intertek Energy and Water), undertaking a varied range of hydrodynamic and water quality modelling assessments for numerous clients and projects in the water and energy sectors, including offshore wind and marine renewables. Paul worked for Geoscience Australia for about a year in 2010 as a Project Leader, looking how climate change might affect the risk and impact of natural hazards such as tsunamis and storm surge.

Title: *Multi Purpose Interconnectors and Energy Islands: The next stage in offshore wind*

Name: Alfred Cotton – Mocean Energy

Bio: Since completing his PhD in wave energy in 2019 at the University of Edinburgh, Alfred has continued to specialise in the design and development of wave energy technology, using his experience in numerical modelling and optimisation to improve the performance of Mocean's wave energy converters. Recent research strands include time-domain modelling and optimisation development, reinforcement learning for control, and array modelling.

Title: *Research and development of wave energy technology at Mocean Energy*

Name: Deborah Greaves, FREng, OBE – University of Plymouth

Bio: Professor Deborah Greaves is Director of the Interdisciplinary Research Centre for Decarbonisation and ORE, Director of the COAST Laboratory and was Head of the School of Engineering, Computing and Mathematics (2017-2022) at the University of Plymouth with previous appointments at the University of Oxford, UCL and the University of Bath. Her research interests include marine and offshore renewable energy, and physical and numerical modelling of wave-structure interaction. She is Director of the Supergen ORE Hub, has led many national and international research projects in ORE in collaboration with industrial and academic partners and has secured over £27 million research income. In the Queen's Birthday Honours List, 2018, she was awarded an OBE for services to Marine Renewable Energy, Equalities, and Higher Education and in 2020, she was elected to be a Fellow of the Royal Academy of Engineering. She was appointed as a Member of EPSRC Council in 2022.

Title: *Offshore Renewable Energy Research: Supergen ORE Hub*

Keynote speakers for the CCP-WSI Focus Group Workshop 4

Name: Alex Argyros – BP Offshore Wind

Bio: Alex is floating systems lead within the BP Offshore Wind organisation and is responsible for floating wind substructure technology. Prior to joining bp in 2021 he spent 10 years at DNV as lead naval architect and technical authority for moorings, working across O&G, floating wind, wave, tidal and solar energy sectors, where he specialised in hydrodynamics, mooring design, integrity management, and marine operations. Before that he obtained his PhD from Cambridge University on ultra-deepwater mooring dynamics and still maintains an active interest in research & development.

Title: *Floating wind turbines – opportunities, challenges and numerical analysis*

Name: Francesc Fàbregas Flavià – DNV GL

Bio: Francesc Fàbregas Flavià is a control and loads engineer at DNV GL Bristol. Before joining DNV GL, Francesc worked as a Lecturer in the Fluid Mechanics section in the department of Civil and Environmental Engineering of Imperial College London. His research focuses on advanced hydrodynamics and on the dynamics of floating structures. Francesc holds an MEng degree in Mechanical Engineering from Universitat Politècnica de Catalunya (UPC, ETSEIB) and an MSc in Renewable Energy Engineering from Cranfield University. After completing his MSc, he worked as a research engineer in the Ocean Systems Test Laboratory of Cranfield University where he participated in the design and testing of small-scale wind and wave energy converter prototypes. He then moved to the LHEEA laboratory of Ecole Centrale de Nantes where he undertook his PhD on the hydrodynamic interactions in large clusters of wave energy converters.

Title: *Numerical Modelling for floating Offshore Wind Turbines*

Name: Matt Lewis - Intertek Water & Energy

Bio: Dr. Matt Lewis is a senior consultant with Intertek, water and energy team. Matt uses hydrodynamic models to map the marine renewable resource, and improve water quality of our rivers and coasts. He has over a decade of academic experience, including previously having held a EPSRC fellowship in marine renewable energy, and has published over 50 peer-reviewed scientific papers with a H-index of 30.

Title: *Better ocean characterisation needed for marine renewables and offshore aquaculture: coupled wave-current mean flows*

Name: Jonathan Hodges - Wave Energy Scotland

Bio: Following an early career in the aerospace industry, developing and testing Rolls-Royce turbofan engines, Jonathan moved to ocean energy sector where he gathered innovation, resource assessment and tecno-economic analysis experience. In his role as Innovation and Strategy Manager at Wave Energy Scotland (WES), he aims to identify innovation opportunities, influence research agendas and develop funding strategy to help the sector deliver cost competitive wave energy technologies. Jonathan is involved in global collaboration activities to develop technology assessment tools and processes, deliver consensus on performance metrics, and seek technology transfer opportunities to advance the sector towards commercialisation.

Title: *WES driving innovation and cross-sector collaboration*

Abstracts by sessions

Oral presentations

Session 1 Offshore Wind

Floating Wind Turbine Maintenance by Rapid Swap and Tow

Marcin Kapitaniak[1], Alicia Terrero Gonzalez[1], Richard Neilson[1], Jim Papadopoulos[2]

[1] National Decommissioning Centre, University of Aberdeen

[2] T-OmegaWind Ltd.

This work focuses on modelling of a novel floating wind turbine concept designed by T-Omega Wind, that has a light structure (20% of the conventional floating turbine in terms of its weight), thereby allowing it to glide over the worst North Atlantic waves. A set of detailed modelling studies are performed it the state-of-the-art, Marine Simulator at the National Decommissioning Centre (NDC) to study the feasibility of deploying this design, with particular focus on towing dynamics and modelling of the rapid swap maintenance concept. Based on the completed wave tank tests of a 1:60 scale prototype, the full-scale numerical model of the floating wind turbine, has been calibrated to replicate the fluid-structure interactions and wave loading under wide range of environmental conditions. This in turn allowed to study the feasibility of deploying T-Omega Wind turbine concept, identifying risks and rectifying them ahead of planned future offshore operations. Moreover, detailed numerical simulations allow to predict and verify the response of the floating wind turbine to extreme weather conditions, as predicted by limited small scale experiments.

Conceptual design and optimisation of a novel hybrid device for capturing offshore wind and wave energy

Emilio Faraggiana, M. Sirigu, A. Ghigo, E. Petracca, G. Mattiazzo, G. Bracco

Politecnico di Torino

Polytechnic University of Turin

The access to the offshore wind resource in the deep sea requires the development of innovative solutions which reduce the cost of energy. This work proposes a novel hybrid wind and wave energy system integrating a floating offshore wind turbine with three-point absorbers wave energy converters (WECs). The WECs are an integral part of the floating structure and contribute significantly to the hydrostatic and dynamic stability of the system. Their geometry is optimized considering a cylindrical, semi-cylindrical and spherical shape for the Pantelleria case study. The cylindrical shape with the largest radius and the lowest height is the optimal solution in terms of reducing structural costs and maximising the performance of the WECs. The in-house hydrostatic stability tool and the time-domain model MOST are used to optimize the WECs using a meta-heuristic genetic algorithm combined with the Kriging surrogate model and the Nelder-Mead algorithm. The power of the WECs is estimated with both linear and variable motor flow hydraulic PTOs to obtain a more realistic electrical power generation. Generally, the hybrid device proved to be more competitive than the floating wind turbine alone, with a LCOE reduction up to 12%.

New Investigations on Wave Loading on Offshore Wind Turbine Foundations

Haoyu Ding[1], Jun Zang[1], Tianning Tang[2], Saishuai Dai[3], Paul H. Taylor[4], Thomas Adcock[2]

[1] University of Bath

[2] University of Oxford

[3] University of Strathclyde

[4] University of Western Australia

This presentation aims to present a novel efficient approach for accurately predicting nonlinear wave loadings on offshore structures, focusing specifically on a vertical cylinder in the regime relevant to offshore wind turbine foundations. We conducted a new series of physical experiments using focused wave groups interacting with a vertical cylinder in the Kelvin Tank at the University of Strathclyde to add to the dataset that we have collected in our previous experiments conducted at DHI, Denmark. Advanced Computational Fluid Dynamics (CFD) models, including the open-source OpenFOAM and our in-house Particle-In-Cell (PIC) model, were applied to provide further in-depth analysis and improved understanding of the physics involved in the wave interactions with offshore wind turbine foundations.

Our results, analysed through spectral decomposition, enabled us to identify that longer wavelengths and larger amplitudes can lead to a significant increase in the proportion of high-order wave loadings. We used the Stokes-type expansion to establish relations between high-order wave loading harmonics and linear wave loading, and predicted the high-order components based on incoming wave conditions. This new approach has been verified by the new experimental studies.

Review of Analysis Methods for Floating Offshore Wind Turbines under Extreme Environmental Conditions

Lige Zhao, Alistair G.L. Borthwick, Edward J. Ransley, Deborah M. Greaves

University of Plymouth

This work summarises the present state-of-the-art of methodologies used to simulate the motion response and structural behaviour of floating offshore wind turbines (FOWTs) subject to extreme environmental conditions. Consideration is given to the prospects of these methodologies as future design tools for the floating offshore wind industry. The review discusses physical experiments at laboratory and field scale, mid-fidelity engineering-level analysis tools, and high-fidelity computational fluid dynamics (CFD) methods for estimating extreme wind and wave loading on FOWTs. Particular attention is given to floating offshore wind projects that have already been installed in the ocean, which leads to the discussion of the design load cases (DLCs) for identifying the survivability of FOWTs in extreme storm conditions. Existing approaches to developing fully coupled models under extreme environmental conditions are reviewed and analysed, and the benefits and drawbacks of different methods discussed. The present work will inform future research investigating the load-response behaviour of fully coupled numerical and physical models of FOWTs under extreme conditions such as breaking wave excitation.

An experimental investigation of nonlinear wave loading on a vertical cylinder - Stokes type expansion and secondary load cycle

Tianning Tang[1], Haoyu Ding[2], Saishuai Dai[3], Xi Chen[2], Paul H. Taylor[4], Jun Zang[2], Thomas Adcock[1]

[1] University of Oxford

[2] University of Bath

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Environmental loading is one of the key design drivers for offshore structures such as wind turbine foundations, marine renewable energy device support structures, bridge piers, and floating vessels. The physics behind wave-structure interaction is complex and still not fully understood especially for non-linear loads as experienced in the most severe conditions. This presentation analyses the nonlinear loads on a bottom-mounted vertical cylinder in the regime relevant to fixed offshore wind turbines. We compare high-quality wave tank measurements, and fully nonlinear viscous model simulations, and present a novel Gaussian Process based prediction model to fit the force coefficients and predict the force time history in new tests. We further consider the secondary load cycle and confirmed an additional load component associated with a violent splash behind the cylinder. We further examine this loading component with a novel three-phase decomposition and wavelet analysis. The detailed wave fields around the cylinder and the associated run-up will be reported with numerical simulation results and synchronised videos.

Session 2 Tidal energy

Development of a passive blade-pitch mechanism to reduce the loads on a tidal turbine in high-flow conditions

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This study seeks to develop a novel and reliable passive blade-pitch mechanism which reduces the loads on a tidal turbine in high-flow conditions, enabling larger rotors to be installed on Tocardo's current generation of fixed-pitch turbines.

An initial design for a passive-pitch mechanism has been created. The pitch mechanism is actuated by the hydrodynamic forces developed by the rotor such that the blades pitch-to-feather in high-flow conditions. The design is compatible with Tocardo's proven passive reversible rotor blade technology.

A fluid-structure interaction tool has also been developed. This couples the mechanical response of the passive-pitch mechanism with NREL's AeroDyn blade element momentum code. Turbine performance has then been modelled for a range of operating conditions, allowing the influence of parameters such as blade geometry, rotor diameter and passive-pitch characteristics to be analysed in terms of rotor loading and turbine performance.

Initial analysis suggests that installing blades with a passive-pitch mechanism could reduce the loads on the rotor in high-flow conditions down to just 25% of the loads that would act on an equivalent rotor with fixed-pitch blades. This would allow larger diameter rotors to be installed, which could improve annual energy yield by over 40% at a typical site.

Cross-comparison of the prediction of resource and turbine fatigue loading at a tidal site from models and multi-point measurements

Hannah Mullings[1], Samuel Draycott[1], Tim Stallard[1], Ed Mackay[2], Jon Hardwick[2], Phillip Thies[2], Slyvain Guillou[3], Jerome Thiebot[3], Philippe Mercier[3]

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Planning for tidal stream turbine deployments relies upon an understanding of the resource. For energy yield predictions the occurrence of disc averaged velocity is typically employed whereas knowledge of flow shear, turbulence, and occurrence of waves are important for assessment of design loads. A range of models can be used to predict the resource across different spatial resolutions, with deployments of measurement devices, typically from current profilers, used for validation and to complement predictions. The unsteady conditions which contribute to fatigue loading can only be captured using models and measurements with a high level of spatial resolution. This work aims to establish the variation in resource characteristics between measurement locations within a tidal stream site and between modelling techniques. The study site is Raz Blanchard, one of six sites considered in the Interreg TIGER project. Simultaneous measurements have been obtained from three locations within the site to establish spatial variation over 140 m. The current profiler measurements of shear and turbulence are compared to predictions from models which have been validated against previous measurement campaigns; TELEMAC-RANS, TELEMAC-LES, LBM-LES and DELFT3D. Differences in shear profile prediction and turbulence magnitude are observed and discussed. A previously validated BEM fatigue load model is employed to assess the impact of such flow- differences - between locations and models - on the damage equivalent loads experienced by a representative turbine.

Deep Learning for optimal usage of battery storage coupled with tidal farms

Alex Cox, Stefano Bruno, Anna Young

University of Bath

Tidal energy represents a significant opportunity to help achieve the UKs Net Zero energy ambitions. The UK has some of the most promising locations for tidal energy generation, and tidal energy has the potential to be a significant contributor to the UK's energy mix.

In contrast to other renewable sources of energy such as wind and solar power, tidal energy has the advantage that its generation patterns are extremely predictable. Unfortunately while tidal generation is highly predictable, the supply is also highly variable, with peak energy generation coinciding with peak tidal flow, so energy generation will vary strongly during the course of a day and also over longer tidal periods. As a consequence, peaks of energy generation may not coincide with peaks of demand for electricity.

In this work, we examine how the predictability of tidal power can be leveraged, through the use of battery storage, to contribute to meeting energy demand. At the heart of our approach is a novel Deep Learning method, which allows us to model optimal usage of battery storage in the presence of market information about external supply and demand, incorporated in our models through the use of electricity prices to determine optimal battery usage.

Are Vortex Generators of interest for tidal turbine blades? A proof-of-concept study

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If tidal energy is to play a significant role in the transition to a Net Zero economy, the associated levelized cost of energy needs to be reduced. One way of achieving this is by increasing the efficiency of the tidal turbine blade rotors. Vortex generators (VGs) are a flow control device used to reduce or suppress flow separation on airfoils and blades and is close to becoming an industry standard for Wind Turbines. Their operating principle is that they generate streamwise vortices close to the solid surface, which energize the boundary layer and enable it to better withstand adverse pressure gradient. The present proof-of-concept study investigates the effect of passive VGs on a 85kW tidal turbine blade. An integrated approach was followed including wind tunnel tests to design the VGs and Reynolds Averaged Navier Stokes simulations to better understand the flow around the blade. The presentation will discuss the challenges in the design and physical and computational modelling of VGs as well as the differences between VG application on Wind and Tidal turbine blades.

Investigating the impact of multi-rotor structure shadowing on tidal stream turbine performance

Bryn Townley[1,2], Weichao Shi[3], Athanasios Angeloudis[4], Ian Ashton[5], Bevan Wray[2]

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As the tidal stream energy sector develops, reducing the Levelised Cost of Energy (LCOE) is essential to sustain commercialisation. Modular multi-rotor foundations, with bi-directional turbines, reduce offshore operational complexity due to lower turbine diameters and lift weights, therefore reducing Operational Expenditure (OpEx). As modular, multi-rotor foundations are introduced, the impact of their wake-induced impacts on turbine performance must be investigated to better estimate energy yield, loading, and fatigue life. This research seeks to address the magnitude of this impact and investigates the interaction between the turbulent wake generated by a modular foundation and 2-bladed Horizontal Axis Tidal Turbines (HATT) motivated by the HydroWing multi-rotor device. Initially, a transient Computational Fluid Dynamics (CFD) simulation environment with a sliding mesh is configured and validated against experimental data. A turbine in free-stream isolation is simulated as a benchmark case with the modular foundation sequentially introduced to analyse its impact. Results quantify the magnitude of loads exerted on the blades and the frequency of the cyclic loading. Spatial configuration sensitivity is investigated to explore optimal spacing between the structure and the turbines with the intention of negating severe Vortex Induced Vibrations (VIV) and turbulent flow into the turbines.

Session 3 Design tools and methods in marine renewable energy

A new robotic investigative tool to aid geotechnical design of offshore renewables: the ROBOCONE

James Creasey[1], Ahmad El Hajjar[1], Andrea Diambra[1], Dave White[2], David Igoe[3]

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Considerable acceleration of marine renewable energy deployment is required in the forthcoming years to meet the net zero target by 2050. Among several aspects, the use of specifically designed in-situ geotechnical testing can generate data much earlier in the project cycle, making the whole design process quicker and more efficient. However, while recent developments in both robotic and sensing technologies have been embraced by the offshore industry, geotechnical site investigation tools have not seen such big impact.

This work will present the initial design, preliminary testing, and specification requirements of a new robotic investigation tool – ROBOCONE. This new device will feature different modules and will be designed to be included behind the standard penetrometer frequently used in offshore investigation The device, once inserted into the ground can be used to mimic stress and strain histories experienced by soil elements around many offshore renewable foundations. Through innovative probing of the soil, this tool can enable the efficient extraction of both simple and advanced soil constitutive properties and support the efficient and modern design of many offshore renewable infrastructures.

Numerical Study of Wave Interaction with Multiple Floating Buoys by qaleFOAM

Yi Zhang, Qian Li, Ningbo Zhang, Shiqiang Yan, Qingwei Ma

City, University of London

In this paper, an in-house hybrid CFD model qaleFOAM is developed and extended to investigate the wave interaction with arrays of wave energy converters (WECs). This hybrid model adopts the domain decomposition approach, which combines a two-phase Navier–Stokes (NS) model and the fully nonlinear potential theory (FNPT). In a confined region around the structure (NS domain), the problem is solved by the open-source solver OpenFOAM/interDyMFoam. In the rest of the computational domain (FNPT domain), the quasi arbitrary Lagrangian–Eulerian finite element method (QALE-FEM) is adopted. The proposed model is firstly verified against the experimental data for the motion responses of the CorPower Ocean buoy in regular waves. Then the wave interaction with multiple CorPower buoys arranged in a line array and other configurations (e.g., 2x2 array, 4x4 array) is investigated, and the interference between multiple buoys is discussed. The surface elevation field near the buoy and motion responses of each buoy are further analyzed.

High-fidelity multi-region overset mesh Computational Fluid Dynamics model for offshore renewable energy

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In response to the global energy crisis and climate change, the UK government raised the target offshore wind energy capacity from 12.7GW in 2022 to an ambitious 50GW by 2030, in which an extra 5GW of floating wind is added. In addition to the national policy to facilitate offshore wind energy's rapid growth, the Engineering and Physical Sciences Research Council, the UK, also released the steps targeting to reduce the Levelised Cost of Energy (LCoE) to £90/MWh by 2035 and install 22GW capacity by 2050. Sound knowledge and a good understanding of the dynamic behaviour of Offshore Renewable Energy (ORE) devices in a complex marine environment are critical for assessing their stability, survivability, and power generation. Although the dynamic behaviour and performance of the ORE devices can be tested and obtained at model scale in the laboratory, the scaling effects can not be neglected. To fully reveal the dynamics and performance of ORE devices in a complex marine environment, a high-fidelity multi-region overset mesh computational fluid dynamics model is proposed and developed in this study. This proposed model will be applied to investigate a floating offshore wind turbine and floating wave energy converter farm after successful validations against the available experimental measurements.

Identifying risk of conflict between fisheries and potential marine renewable energy sites

Matt Lewis, Morwenna Pearson, Jenny Shepperson, Jon Demmer

Intertek & Bangor Uni

Conflict between stakeholders is expected as Marine Renewable Energy (MRE) developments increase. Here, we demonstrate the value in digital environment data and the application to predicting future markets and conflict. A reduction in fishing within an Offshore Wind Farm (OWF) is expected alongside potential travel distances to fishing grounds, however the industry may also benefit (e.g. artificial reefs and OWF acting as marine protected area). Furthermore, it is hypothesised any impact of OWF development will not scale linearly with size (i.e. cumulative installed capacity) or time as technology will change the environment developed (from shallow sandbanks to deeper exposed sites). We develop a method to monitor the impact to fisheries from MRE developments. The location and status of OWF is available from The Crown Estate and fishing effort (i.e. catch weight and value, fishing hours) was estimated using the satellite Vessel Monitoring

Systems (VMS) and International Council for the Exploration of the Sea (ICES) data. Over 10 years of data were interpolated to a regular 0.05° (~15km) grid, and discretised with wind farm development (i.e. planning–consenting–construction–operational). The average value of fishing reduced by 78% once Offshore Wind Farm (OWF) becomes operational but with much variability.

Numerical Simulation of a floating solar farm in waves

Yujia Wei, Junxian Wang, Liang Yang, Luofeng Huang

Cranfield university

The growing awareness of the energy and climate crisis has spurred the development of renewable energy sources. Photovoltaic (PV) solar power plants offer a promising alternative to traditional power sources in the transition to a low-carbon society, as they harness clean solar energy and convert it into electricity. However, traditional PV systems are limited by their low power density and require significant amounts of land or inland rivers. To address this limitation, industries are turning to offshore Floating PhotoVoltaics (FPV) as a solution. FPV systems have minimal impact on the marine environment and do not consume valuable land resources or interfere with human activities.

This study conducts a hydrodynamics-based structural response analysis on a novel FPV system using OpenFOAM. The Solar2Wave project designed a wave-proof FPV platform that integrates breakwater technologies to ensure survivability in harsh ocean-wave environments. The study first examines appropriate mooring types for FPVs installed near islands considering the effects of the seabed. Next, extensive parametric studies are conducted to identify an effective design strategy for mitigating wave impact. Finally, this study evaluates the potential effects of the proposed platforms on the hydrodynamics and net primary production in a coastal sea for the first time.

Session 5 Wave Energy

Motion behavior and wave power absorption of multi-degree-of-freedom floating oscillating water column (OWC) devices

Peiwen Cong, Dezhi Ning, Lifen Chen

Dalian University of Technology

A numerical model has been developed for the hydrodynamic analysis of arbitrarily shaped three-dimensional oscillating water column (OWC) devices. When the device is free to move or moored in

waves, the airflow in the chamber is coupled with the movement of internal fluid and the hydrodynamic response of the device. By taking the coupling effects into account, boundary-integral equations are formulated with supplemental theoretical relations. The coupled motions and hydrodynamic efficiency are then evaluated by integration. To achieve the maximum wave power absorption, an optimal turbine parameter is derived for devices undergoing multiple modes of body motions. Numerical studies are then conducted for three cylindrical OWC scenarios that are floating in waves, attached by a reflector and connected to a submerged caisson, respectively. In the latter two scenarios, the wave power absorption is characterised by a series of obvious peaks which are associated with the resonant internal fluid motion and around the resonance frequencies of different body motions, i.e., surge, heave and pitch. Numerical results indicate the benefits of floating OWCs from the coupled rigid-body motion modes and the OWC's resonance, expanding the frequency range of efficient conversion and improving the device's adaptability to variable oceanic environments.

Improving WEC Power Performance through Wave Channel Optimisation Approaches

Nian Liu[1,2], Gabriel Scarlett[1], David Forehand[2], Helen Smith[3], Laibing Jia[4]

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In recent years, research progress in the wave energy sector has been accelerated due to global commitments to net-zero targets. However, the design process of Wave Energy Converters (WECs) still faces various challenges. Mocean Energy is a company designing and developing innovative WECs. The Mocean WEC devices are hinged-rafts with wave channels attached at both ends. The addition of these channels provides a substantial performance uplift compared to a simple hinge raft geometry.

This research focuses on wave channel optimisation and considers it separately from the full device initially. A new wave channel generation code is produced which provides higher flexibility in device geometry definition. A parametric analysis is then performed using the Boundary Element Method (BEM) code WAMIT, to identify critical factors that have a significant influence on hydrodynamic performance. Single and Multi-objective optimisations are carried out using Particle Swarm and Genetic Algorithms to maximise power and minimise cost. Simulations considering the full geometry with hulls and wave channels are finally carried out to compare with wave channel geometry results.

This numerical investigation will assist further developments in exploring designs for a range of different wave climates and conditions.

Optimising the Oscillating Water Column (OWC) to enhance wave energy extraction

Bashir Ahmed, Jun Zang, Haoyu Ding

University of Bath

Wave energy is an untapped energy source with the potential to generate large amounts of renewable energy in the coming years. This research briefly explores the current methods of energy extraction from waves in the industry, before focusing on the optimisation of the Oscillating Water Column (OWC). The OWC device, due to its exciting potential to generate sustainable energy, has been widely investigated by other researchers. Our own research, conducted in conjunction with a broad overview of the latest research, including conventional and multi-chamber OWCs, proposes a unique design idea that involves multiple OWCs arranged in a tandem arrangement. This innovative design has the potential to serve as a floating breakwater and reduce the impact of coastal erosion, aside from its primary function of extracting wave energy. The functional performance of OWCs in our study is evaluated using a Computational Fluid Dynamics (CFD) model called OpenFOAM, which underwent a series of numerical model validations before being employed for the study.

Mooring design for field demonstration of a large-scale wave energy converter

Faryal Khalid, Philipp R Thies, Lars Johanning, Tony Lewis

University of Exeter

Harnessing wave energy can make a significant contribution to achieving the European Union Green Deal target. The Ocean Energy buoy (OE Buoy) is one such wave energy device that has designed as a floating oscillating water column with a large, submerged, chamber open to the sea and filled with water. While the working principle of the device has been proven previously through numerical modelling, tank testing and field-testing, long-term field operation is needed to demonstrate the commercial viability of the device. To this end, the 'Wave Energy Demonstration at Utility Scale to Enable Arrays' (WEDUSEA) project aims to conduct a 2-year demonstration of a 1 MW utility scale device in a more energetic operational environment.

This presentation provides an overview of Phase 1 of the WEDUSEA project that focuses on the system design and demonstration planning at the European Marine Energy Centre's (EMEC) Billia Croo test site in Orkney, Scotland. This includes integration of sub-components such as moorings in numerical models to improve the efficiency, reliability, scalability, sustainability and circularity of the technology and reduce the LCOE by over 30%.

Wave power extraction from a floating elastic disk-shaped wave energy converter

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We propose a concept of a floating elastic wave energy converter consisting of a disk-shaped elastic plate. The floating plate is moored to the seabed through a series of power take-off (PTO) units. A theoretical model based on the linear potential flow theory and eigenfunction matching method is developed to study the hydroelastic characteristics and evaluate wave power absorption of the device. The PTO system is simulated as a discrete PTO, and moreover, it is also modelled as a continuum PTO to represent the case when the PTO system is composed of a large number of PTO units. The continuum PTO approximation is tested against the discrete PTO simulation for accuracy. Two methods are proposed to predict the wave power absorption of the device. After running convergence analysis and model validation, the present model is employed to do a multiparameter impact analysis. The device adopting a continuum PTO system is found to capture wave power efficiently in an extensive range of wave frequencies. For the continuum PTO system, it is theoretically possible to adopt optimised PTO damper and stiffness/mass to guarantee the absorption of 100% of the energy flux available in one circular component of the plane incident wave.

Session 6 Resources and environments

The expansion of offshore windfarms: implications for ecosystem services

Claire Szostek, Nicola Beaumont, Stephen Watson, Andrew Edwards-Jones

Plymouth Marine Laboratory

Globally, the deployment of offshore wind is expanding rapidly, with offshore wind capacity in UK waters expected to grow five-fold by 2030 (and potentially ten-fold by 2050). An improved understanding of the social and environmental impacts of this sector, and how they compare with those of other energy systems, is necessary to support energy policy and planning decisions. It may be assumed that offshore infrastructures have a largely negative impact on the environment; less often acknowledged and publicised are positive environmental or socio-economic outcomes.

The UKERC energy, environment & landscapes project (2020-2024) is applying ecosystem service and natural capital approaches to understand environmental and social implications of offshore wind development. We have collated evidence through a qualitative process of mapping ecological and cultural parameters and linking this to ecosystem services outcomes, from peer-reviewed and grey literature, from the UK and globally. We highlight key considerations for policy makers when considering the type and breadth of evidence to inform decision making, in order to balance and maximise ecosystem services benefits in offshore wind farm development. Our approach will help facilitate communication with decision makers and will aid in the evaluation of trade-offs such as environmental net gain and the potential for co-location with other economic activities.

Deriving Spatial Wave Data from a Network of Buoys and Ships

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Real-time availability of accurate spatial wave data, at appropriate spatial resolution, is essential for the sustainable operations of marine renewable energy devices. Surrogate modelling for ocean wave, driven by machine learning techniques, has the potential to bypass the large computational requirements but offers a high level of accuracy. The work presented here is an extension of a previously developed surrogate wave modelling framework which learnt the spatial correlations between a network of buoys and the entire computational domain in a high-fidelity physics-based nearshore wave model. This model is capable of estimating high-quality spatial wave data purely using the wave buoy network as input. In the present work, the previous framework is extended to use a hybrid of vessel motion-based wave parameters and buoy observation as input. Different configurations are benchmarked with buoy observations and the Met Office UK Shelf Seas Wave

Model to assess the impact that utilising these imperfect measurement devices has on the surrogate model results. This system has significant potentials to using a fleet of offshore vessels to get measurement from where wave buoy cannot be deployed, map to larger domain, and support offshore operations decision-making.

Investigating the contribution of contaminants by offshore wind farms to the marine environment and implications for aquaculture co-location

Georgina Banfield, Gordon Watson

University of Portsmouth

With a global international commitment to lower carbon emissions, the focus on sourcing energy from clean, renewable resources is growing rapidly. Wind power is gaining particular attention, especially offshore wind farms (OWF's) as they are viewed as a low-environmental impact solution with the potential to co-locate aquaculture species. But are these OWFs as "green" as we assume? Without surface protection, steel turbine foundations exposed to the marine environment will corrode rapidly. As such, a number of strategies are employed to enhance protection, but these methods may also be a significant source of contaminants. Using mean release rates of a variety of protection methods e.g. anti-fouling paints, sacrificial anodes and other coatings we assess the contribution of contaminants by OWF's to the environment. We then compare these release rates to seawater and sediment concentrations in close proximity to OWFs and with toxicity thresholds for species that might be co-located for culture. Finally, we use the predicted increase in OWF capacity in Europe to generate future inputs based on different investment scenarios. Understanding the full impacts of OWFs is critical to ensure that adequate risk assessments are performed in future decision-making and policy development.

An end-to-end approach to estimate Significant Wave height from marine X-band radar backscatter by using deep convolution neural networks

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Knowledge of marine conditions is important for transport and port operations, coastal protection, and for site characterisation in the rapidly evolving marine renewable energy industry. The most useful measure of sea state is Significant Wave height (Hs). Established methods of Hs measurement

involve deploying a surface-following wave buoy, or a bottom-mounted acoustic sensor, to obtain data at a point location. Marine X-band radars - installed on every large vessel and relatively easy to mount on land are cheaper to install, maintain and recover and less prone to damage than "wet" sensors. They could also, in principle offer a detailed and accurate picture of the waves' spatial variation in complex coastal locations, particularly in regions of strong wave refraction and wave-current interaction. However, turning 2D radar backscatter images into accurate Hs measurements remains a significant research challenge, with only limited field-data validation in the literature of existing experimental methods such as signal-noise ratio fitting which also relies on calibration with in situ data from an installed buoy). Inspired by the potential of Convolution Neural Network (CNN) techniques in addressing image identification problems, a novel concept is to use the end-to-end approach and deep learning, where the mapping of the input to the desired output is obtained from the corresponding data pairs in a learning process. In this research, a dataset of pairs of back-scatter images recorded by radar and their corresponding in situ Hs values has been used. Regarding the desired output (Hs), CNN automatically extracts effective features from the X-band radars images in the training process through multiple layers of the model, without the need to rely on feature extraction in a separate pre-processing step. The performance of the proposed model over the test data to predict accurate Hs in terms of mean square error (MSE) is studied.

Satellite wave data for a surrogate wave model for the marine operations of offshore wind farms

Sophie Whistler[1], Ian Ashton[1], Ajit Pillai[1], Graham Quartly[2]

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Marine operations are a significant expense for offshore wind farms, representing up to one third of total project costs. A better understanding of the variation of met-ocean conditions across a wind farm site offers potential to reduce the amount of weather downtime and associated costs. This project utilises a machine learning approach that creates a surrogate wave model by learning the relationship between wave conditions at measurement locations to locations over the model domain. This surrogate model can then be run with real-time data inputs to provide a spatial data set for waves, without the high computational power needed to run the numerical wave model itself.

This approach has already proven successful with fixed measurement buoys, and this work tests the method using satellite-derived wave data as input to the framework. Several Earth Observation satellite missions host radar altimeters that record along-track measurements of wave height. With freely available global coverage, satellite data acts as a useful complementary measurement to wave buoy data to enhance the surrogate wave model. The resulting wave model will improve the accessibility of met-ocean data to allow more informed decision making for the installation, operation, and maintenance of offshore wind farms.

Posters

Session 1

Impact of lateral turbine spacing on the performance of a multi-rotor tidal energy device

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In this work, the impact of local blockage on the power production of a tidal array due to multiple turbines positioned in close proximity is studied. A numerical model of the HydroWing tidal energy device, which features multiple turbines on a retrievable wing, is being developed using geometry-resolved computational fluid dynamics (CFD), and the influence of two turbines at several spacings is considered.

The CFD model is used to perform both quasi-static steady-state and transient simulations of two turbines in a twin rotor configuration. The lateral spacing between the rotors is varied and the resulting impact on the power performance of the two turbines and the surrounding flow field is studied, with the aim of identifying the optimal turbine spacing for the HydroWing device. The results will be used in future design optimisation work to minimize the levelized cost of energy of a large scale array using HydroWing technology at the proposed site for the Morlais tidal energy project.

Key trends in the evolution of floating offshore wind platform designs

Emma Edwards, Anna Holcombe, Scott Brown, Edward Ransley, Martyn Hann, Deborah Greaves

University of Plymouth

Using floating platforms to support offshore wind turbines will be necessary for many countries to reach their Net-Zero targets, since much of the wind resource is located at water depths at which fixed offshore wind turbines are unfeasible. Floating platforms for wind turbines are still at a relatively early stage of development, and there has been a recent rapid development of technology.

A recent review has been completed of floating offshore wind platform designs. In this presentation, key trends identified during this review are discussed. Four phases have been identified, which show the chronological shifts in design thinking. There has been a number of alternative cost reduction strategies recently, including (i) specializing the platform to a particular location or environment, (ii) increasing manufacturability, and (iii) designing an innovative platform which diverges further from conventional designs. For the latter strategy, there has been an emergence of multi-turbine platforms, hybrid platforms, platforms which use a combination of stability mechanisms, and hydrodynamically specialized platforms. Finally, potential future trends are discussed, and it is shown that competing priorities for platform designers in the future will likely mean that the design space must compromise between increasing standardization and increasing specialization.

Floating elastic circular plate in ocean waves

Simone Michele, Siming Zheng, Federica Buriani, Alistair G.L. Borthwick, Deborah M. Greaves

University of Plymouth

An understanding of the hydroelastic response of a flexible circular plate to water waves is relevant to many problems in ocean engineering ranging from offshore wave energy converters and solar wind devices to very large floating structures such as floating airports and ice sheets. This work describes results from physical model tests undertaken in the COAST laboratory at the University of Plymouth. Response amplitude operators (RAOs) of a floating flexible circular disk are determined for incident monochromatic and irregular wave trains, the latter defined by JONSWAP spectra. Free-surface displacements are measured using wave gauges, and the plate motion recorded using a QUALISYS® motion tracking system. Different basin depths and plate thicknesses are considered in order to quantify the effects of water depth and flexural plate rigidity on the overall dynamic behaviour of the circular disk. We present synchronous and subharmonic nonlinear responses for monochromatic waves, and displacement spectra for irregular waves. The measured wave hydrodynamics and disk hydroelastic responses match theoretical predictions based on linear potential flow theory.

Computational damage modelling of flexible wave energy convertors

Deepak George, Ieuan Collins, Mokarram Hossain, Ian Masters

Swansea University

In recent years, there has been a growing interest in flexible body wave energy converters (FlexWECs). This is due to their significant benefits over conventional rigid-type wave energy

converters. FlexWECs use a flexible primary mover, typically manufactured of low-cost rubber-like elastomers, to convert wave energy to mechanical energy. These materials require high stretchability, low viscoelasticity, and resistance to marine corrosion. The aim of the study is to evaluate the effect of damages of different grades on the behaviour of FlexWECS. A gradient-enhanced damage model is used here to regularise the damage. A parametric study on three different FlexWECs' geometries namely stadium, cylindrical tube, and spherical balloon are considered in the study. A decoupled approach is used whereby the nonlinear effects of the fluid-structure interaction are neglected. Instead, the membrane is placed under reduced order analytical boundary conditions allowing for a quasi-static assumption. These simulations are performed in the commercial finite element software Abaqus through the user-routine interface. The effects of damage are characterized in terms of change in membrane shape, stress softening and increase of the enclosed volume. The simulations suggests that the onset of damage adversely affects the pressure-volume relation leading to an early formation of aneurysms and instabilities.

Recent experimental wave load study on bottom fixed vertical cylinder study at the Kelvin Hydrodynamics laboratory

Guangwei Zhao[1], Saishuai Dai[1], Jun Zang[2], Thomas Adcock[3], Paul Taylor[4], Haoyu Ding[2], Tianning Tang[3]

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Monopile wind turbines are typically anchored to the seabed using a large steel tube, when subjected to extreme wave loading, the monopile foundation can experience high stresses and strains that can lead to fatigue and failure, particularly when the higher-order components of the wave loading match the structural natural frequency. A better understanding of extreme wave loading on a monopile structure, therefore, is critical for engineers. The Kelvin Hydrodynamics Laboratory of the University of Strathclyde has been involved in several extreme wave loading on bottom fixed cylinders since 2018, including utilising the four-phase decomposition method to extract higher-order components, 1000K waves loading, compliant cylinder response and more recently: breaking extreme wave loading through the EPSRC funded Seaswallow project. This work will briefly introduce the experiments performed in the past, including methodology and data available. Showcase some latest development of the breaking wave study.

A CFD framework for simulating site-specific tidal and wind turbine arrays

Ioannis Polydoros, Xiaorong Li, Alison J. Williams, Ian Masters

Swansea University

The United Kingdom has a significant tidal and wind energy density due to its island status and location, the exploitation of which requires the deployment of wind and tidal turbine arrays in several sites. This research aims to provide a site-specific computational fluid dynamics framework for studying horizontal axis tidal turbine arrays and to assess the optimal configuration and deployment location. The rotors are modelled with the Generalised Actuator Disk (GAD) method which considers the losses along the blade by computing the downwash, and thus provides an efficient and accurate rotor representation. As a case study, the West Anglesey Demonstration Zone is chosen, and site-specific data of the seabed geometry and ADCP measurements of the current velocities are employed. Several cases are simulated and compared, and the results acquired indicate the optimal deployment technology, formation, and placement location for the array. The study demonstrates the ability of the GAD-CFD model to predict array behaviour and the importance of utilising site data to design optimum tidal turbine arrays. An extension of this framework to model arrays of horizontal axis wind turbines will also be demonstrated.

Using low resolution multibeam imaging sonar data to investigate animal underwater behaviour

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With increasing interest in renewable sources of energy, investigation into potential interaction of Marine Renewable Energy (MRE) devices with the biotic and abiotic environment is required to make informed decisions on future development. Multibeam imaging sonar allows continuous observation of animal behaviour irrespective of visibility. Due to the nature of most stationary multibeam echosounder surveys, thousands of terabytes of data are being collected, in various marine environments, but the detection of fish, seals, seals and seabirds is not certain and can be highly variable with potential long stretches of data without targets. Such data in its current form usually still have to be manually reviewed/processed to verify target detections.

In this study, data collected from two 14-day surveys at a wave energy site with a low resolution multibeam were analysed. The aim of the methodology is extraction of animal behaviour throughout the water column to inform stakeholders about potential interactions of MRE devices with marine animals. Candidate animal targets were extracted and changes in behaviour were observed between the two surveys, across ebb/flood and diel cycles.

Low-frequency energy capture and water wave attenuation of a hybrid WEC-breakwater with nonlinear stiffness

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Wave energy is attractive for its generous, sustainable and clean, the combination of floating breakwater (FB) and wave energy converter (WEC) is an economical approach to capture wave energy and attenuate waves. The conventional hybrid WEC-FB system is ineffective for low-frequency waves. To overcome this shortcoming, this paper proposed a novel WEC-FB with nonlinear stiffness mechanism to improve its wave attenuation and power capture performance. A hybrid semi-analytical nonlinear frequency-domain approach including the eigenfunction expansion matching method (EEMM) and multi-harmonic balance method (MHBM) is proposed to solve the nonlinear waves-structures interaction problem. The performance of the nonlinear WEC-FB is demonstrated by comparing with conventional linear counterpart, and the underlying reason for the effect of nonlinear mechanism is explored. The phase control mechanism for improving low frequency performance of wave elimination and energy capture is revealed by using the analytical method. This study shows that the introduction of the nonlinear mechanism can both improve the wave attenuation and energy absorption performance, especially in the low-frequency wave region.

Review on determination of thermal soil properties to optimize submarine cable design

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Submarine cables are widely used for renewable energy power system in marine environments, such as offshore wind, wave, and trans-continental shelf power transmission applications. The heat flow pattern and potential implications on near surface sediments surrounding heat sources in

submarine cable design are little known. To boost an understanding for thermal properties of the marine substrate, it is important to distinguish the differences between existing methods for estimation under onshore and offshore circumstances and identify potential improvements towards cable design optimization.

This presentation is a review of the state-of-the-art methodologies for soil laboratory and in-situ thermal properties characterization. An overview is presented introducing the procedure of cable design and the role that heat will play in it. Various detecting methods are critically discussed and evaluated, including their applicability in practical design projects. Fundamental influential factors on thermal properties from internal and external conditions will be considered. The influence of diversified dissipation processes around the heat source driven by convection and conduction mechanisms on cable design and lifetime performance will be discussed.

All the results would be expected to improve submarine cable design procedures and reduction of uncertainties for thermal properties determination.

Session 3

Hydro-elastic response of flexible membrane exposed to regular waves

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The use of flexible responsive systems for energy extraction from ocean waves is likely to lead to significant cost reduction. A novel example is a system designed according to origami principles that consists of rigid and flexible membrane panels arranged in specific configurations. This paper presents results from preliminary experiments on the wave-structure interaction of flexible, initially horizontal membranes of length 998 mm, width 594 mm, and thickness 1 mm, fixed along their four edges using a sandwich arrangement of aluminium plates and supported by four vertical rods. Each membrane was immersed in water at a depth of 108 mm below still water level and tested

separately in a wave flume of mean water depth of 700 mm. The response of each flexible membrane was investigated at various positions along its length and width. Results are presented for membrane interactions with regular waves at three frequencies, 1.75 Hz, 1.25 Hz, and 1.02 Hz, and a range of wave amplitudes. Fast Fourier transforms are used to determine dominant response frequencies and amplitudes, and hence interpret the behaviour of each membrane. The findings should be useful in the calibration and validation of numerical models used to assess non-linear hydro-elastic interactions.

Simulation of pivot location impact on passive hydrofoil in regular wave

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The society is making effort to cope with the urgent 'Global warming' issue, for instance, by reducing fossil fuel consumption step by step. Wave in the ocean contains large amount of green energy which could be collected and utilized as a replacement of the traditional resources. One popular solution is to employ wave energy converters (WECs) to extract wave energy and convert to electricity via in-built PTO device (Power take-off).

Research has shown a flapping foil with a combined motion of heave and pitch could generate thrust. And thus, a further study demonstrates that subject to wave excitation, a submerged foil can have heave and pitch response, and meantime generate propulsive force, indicating a prospective application on power generation for marine vessels. The present study performs simulations about a submerged passive foil interacted with regular wave. The foil can move along wave direction freely, and the heave tension spring, pitch torsion spring are attached to provide restoring force. The emphasis is about the impact of the pivot location (i.e., torsion spring position), and the centre of gravity. The corresponding result will help to determine the optimal passive foil for the best propulsion performance.

Enhancing energy system security using tidal stream energy

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University of Plymouth

This research investigates the role of tidal stream energy in enhancing energy system security during periods of 'wind-drought'. Energy security is defined as 'the uninterrupted process of securing the

amount of energy that is needed to sustain people's lives and daily activities while ensuring its affordability'. For this reason energy security enhancement requires multi-objective optimisation to find Pareto Front solutions to often conflicting system performance metrics. The Energy System Model for Remote Communities (EnerSyM-RC) is used to simulate power flows between system components, based on the Isle of Wight energy system. Wind, solar and tidal stream power are the primary sources of supply. Initial analysis of a 20 year wind resource time series identifies an array of periods with wind resource that is significantly below its expected availability. Results based on simulations over these wind-drought periods demonstrate that diversifying the renewable power mix with the inclusion of tidal stream alongside solar and wind results in significant uplifts in supply-demand balancing, and reduced reliance on energy storage/grid upgrades.

Underwater sound measurements of the Nova Innovation tidal turbine array at Bluemull Sound, Shetland Islands

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Understanding of the underwater acoustic emissions produced by tidal current energy converters is required to assess their environmental impact on marine species that utilise tidal race habitats. In February 2023 Seiche Ltd. carried out measurements as part of an ORE Catapult study, at the Nova Innovation tidal turbine array in Shetland. Field methods followed British standard IEC TS62600-40:2019, a framework for the measurement and analysis of associated underwater sounds. A novel data collection method was used for which a calibrated hydrophone was suspended from a buoy that was tethered to a drifting support boat. Hydrophone depth was limited to a safe working depth of 10m, and the hydrophone cable was relayed 30m to a PAM-Go data-acquisition system onboard the boat. Global Navigation Satellite System data were recorded at the buoy, directly above the hydrophone position. System advantages over an independently drifting sound recorder included: a) real-time monitoring of the hydrophone signal to optimize signal-to-noise ratio and avoid digital clipping; b) drift path assessment from the boat enabling rapid hydrophone recovery and redeployment, should the strong currents and eddies carry it off-course. We present the methodology and measurements that describe the acoustic characteristics of the turbine array.

Impact of wave conditions on siting of tidal stream energy arrays

Jon Hardwick, Ed Mackay

University of Exeter

Exact positioning of tidal energy converters within a high-flow site should be carefully considered to ensure that the resource can be fully exploited. Identifying the best locations for turbines involves more than simply selecting the areas with the fastest flow speeds. The presence of waves can reduce the range of operational conditions as well as having an impact on reliability and survivability. Results from a one-way coupled flow-wave of the model of the Alderney Race are presented and discussed. The data from three ADCP deployments are compared with the model output for validation of both the flow and waves. An examination of the spatial data created by the model across the site shows that the locations of maximum flow speeds also correspond to areas with the largest wave conditions, due to wave-current interactions. Analysis shows that the largest horizontal wave-induced velocities in this area are of the order of 20% of the maximum tidal speeds in these areas. Positioning turbines at areas with slightly lower peak flow speeds but significantly reduced wave action may increase the time that generation is possible and hence improve the output from a tidal energy site.

Numerical Modelling on Scour Around a Circular Pile Due to Wave Induced Current in the swash zone

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Ocean renewable energy has strong potential for substituting power plants that rely on the combustion of fossil fuels. Due to maturity, offshore wind farms are one of the most promising forms of ocean renewable energy. There are several windfarms around the world located in nearshore/beach regions (e.g., Bangui Wind Farm, Philippines). Scour around the foundation of nearshore windfarm structures is one of the important technical aspects to be addressed.

In this study, the scour around a circular pier subjected to a steady current were studied numerically using two dimensional MIKE21 Flow Model (FM) and Sand Transport (ST) Module. To predict scour around circular pier and to compare flume experimental results with numerical results, an unstructured flexible mesh generated with rectangular flume dimension of 10 m wide, 1 m deep, and 30 m long with a water depth of 1.0 m was maintained in the numerical model. Following are

the parameters used: The grain size of the sand d50=0.16 mm; sediment gradation=1.16; pile diameter D=30 mm and D=90 mm. Depth averaged current velocity; U = 0.449 m/s is considered in the model as described in the flume experimental study. Figure 1 shows the variation of scour depth with changing a) Manning's Resistance and b) Smogrinsky coefficient in Eddy terms for pile diameter, D of 0.03 m. Figure 2 shows the variation of relative scour depth for constant pier diameter, D of 0.03 m after 1.5 hours and after 4 hours of simulation, for, a) change in depth average current speed, and b) change in Froude number.

The Engelund-Hansen model was chosen for this study. The numerical results have been compared with flume experimental results. The numerical results indicate that the relative scour depth S/D is order of 1.73 and show that the scour depth estimates using Engelund-Hansen model is in good agreement with experimental results. Further, the study shows that Engelund-Hansen method can be adopted to estimate the scour depth in the steady current region, to provide suitable scour protection around the circular pile. This paper will give a detailed analysis on this important analysis.

Towards the modelling, control and optimization of wave energy converter arrays

Xuxin Pooley, Marcus Mueller, Mohammad Abusara
University of Exeter

Computational models and simulation outputs for single point absorber WECs are considered. Control is realised through damping of the motion of a point absorber via actuators using a reinforcement learning algorithm (the approach is also applicable to other WEC designs). The aim is to maximise the power generated from the wave within the constraints associated with supplying power into the grid. Current work has focussed on different RL implementations of single unit devices and their simulated performance in sea states with different characteristics. Further work will be orientated to extending these models into multi-model representations of WEC arrays.

Dynamic performance of a land-based OWC device under the action of solitary wave

Rongquan WANG, Dezhi NING, Di MU, Chongwei ZHANG
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The survivability is an important factor for the design of a wave energy converter (WEC). Thus, it's necessary to get a better understand of the dynamic performance of a land-based oscillating water column (OWC) WEC under the extreme wave conditions. The dynamic performance of OWC WEC under the solitary waves are experimentally and numerically investigated in the present study. It is found that the nondimensional horizontal wave force decreases with the increase of wave height. A large horizontal wave force is induced due to the occurring of overflow of the orifice when the surface elevation inside the chamber exceeds the orifice's bottom edge. The overflow induced wave force is larger than that solely by the solitary wave crest. The the pneumatic pressure inside the OWC air chamber has a significant influence on the horizontal forces. The pressure crest increases with the wave height and the pressure trough increases with the wave height first to its maximum and then decreases due to the overtopping. The pressure trough is larger than the crest when there is no overtopping (i.e, the incident wave height smaller than a certain value) due to the fact that there is no continuous incident wave power to push the OWC.

Experimental Measurement on Water Wave Focusing with Underwater Structure

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This research highlights a wave measurement encompassing an entire area of interest on the water surface with wave focusing achieved by an underwater structure. It utilizes stereo camera technology to capture precise data on water wave motion. Our study demonstrates the influence of underwater structures on wave propagation through the measurement technique. We provide an explanation of the foundational principles behind stereo camera wave measurement, focusing on its potential to augment our understanding of water wave dynamics.

We introduce our experimental apparatus—a high-resolution stereo camera setup—tailored for capturing intricate patterns illustrating water wave movement. The precision of our approach is rigorously tested using a still water surface as a baseline, allowing for the accurate calibration of our stereo camera setup. Subsequently, we conduct measurements on unobstructed water waves, followed by waves with an object introduced into the environment, examining the changes in wave behaviour. Our results demonstrate the focusing phenomenon of a submerged spherical cap. The research contributes to various potential applications such as exploration of wave energy sources, coastal and harbour protection.

Natural phasing of tidal stream and tidal range

Deri Lamb, Arne Vogler, Magnus Harrold

ORE Catapult

Tidal energy, being driven by gravitational forces, is amongst the most predictable forms of renewable energy. Despite the UK being in possession of up to 50% of the available tidal resources in Europe, this energy source has not been widely adopted. This could be due to the recognised periods within each tidal cycle whereby there is zero power yield.

Previous investigations have considered both tidal range and stream separately, considering tidal phasing over a large geographical area. These encompass numerous grid networks, which do not provide the continuity required for local grid systems.

Tidal stream produces power directly from the currents, at periods of peak tidal flow. Tidal range produces power by inducing a head difference between one side of a barrage and another, thereby naturally producing a phase lag on the tidal cycle.

This study combines natural phasing, which occurs across larger geographical areas, and the distinguishable processes that induce phasing from both technologies, facilitating the levelling of power output over a smaller geographic area, improving continuity within one local grid network system.

The benefits of tidal stream and range phasing are demonstrated in this study based on the combination of Ramsey Sound and Swansea Bay in South-west Wales.

The MEECE buoy - a versatile marine test platform

Arne Vogler, Diego Miguez, Jonathan Payman, Deri Lamb

ORE Catapult

This poster provides an overview of the MEECE Buoy of the ORE Catapult, a versatile test platform previously used as a power buoy for wave energy converter testing. Following acquisition and relocation of the buoy to Pembrokeshire in 2020, a refurbishment programme was implemented the following year. This included structural upgrades to the buoy top platform, a new power management system consisting of a wind generator and solar panels, and a Raspberry Pi based data acquisition system (DAQ) with 4G shore communication. A suite of additional sensors was also fitted, integrating an NMEA2000 protocol for: GPS, weather station, Gyro compass and echosounder; together with analogue load shackles to capture mooring forces, an active pressure management system to support a novel mooring damper solution, xyz accelerometers, and an HF receiver to relay time-series data from a wave measurement buoy at the deployment site. The refurbished MEECE test buoy was initially launched at the Dale Roads META test site in the Milford Haven waterway in April 2022, and was subsequently recovered and redeployed twice to allow equipment upgrades and fitting of additional test pieces. Examples of recent tests are presented, together with some buoy performance data.