# WES Development Guidance – Lessons Learnt from Real Sea Deployments

# Approach and Supply Chain

## WES_KH03_ER_01

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# Project Participants










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# 1 Introduction

The wave resource potential in the UK alone is theoretically estimated to be up to 27 gigawatts (GW)[1], with immense opportunities for R&D, in addition to job creation and internationalisation. However, challenges associated proving device survivability, reliability and performance in an open water environment have to date undermined the successful development of the wave energy sector.

In order to address a number of these challenges, the European Marine Energy Centre (EMEC) has been commissioned by Wave Energy Scotland (WES) to create a set of Wave Energy Converter (WEC) development guidance documents which draw upon the lessons learnt from real sea deployments of marine renewables at the Orkney-based test site.

The guidance documents produced here will provide an insight into what technology developers should be considering at early stages of development, notably in areas of offshore operations, HSE, logistics, installation support, and regulatory compliance. These will aid WEC developers in their technology development across a range of maturity levels and technology types so that informed design decisions can be made at earlier stages of the design process.

## Why capture lessons learnt from the Orkney Supply Chain?

With the formation of WES in 2014, the aim has been to bring a measured and phased approach to technology development to address the challenges of developing and proving technology within the sector. The phased approach is now established using the stage-gated programme and the WES Development Pathway. Novel Wave Energy Converters (NWEC), PTO developers, material specialists, subsystem and component innovations passing through the WES programme will be thoroughly analysed and tested, and assisted to prepare for large scale prototype deployments in the sea.

EMEC is the world's first laboratory accredited, open-sea test facility for developers of marine energy converters. To date, EMEC has hosted the majority of the world's wave and tidal sector prototype testing – 27 different versions of devices from 17 different technology developers from 9 different countries. This has generated a wealth of experience, and a great deal of learning that should inform future wave technology development, to ensure challenges presented by the real sea environment are considered as early as possible in project plans.

The guidance documents are underpinned by the deployment experience built up around the EMEC test sites over the last 12 years within the Orkney Supply Chain (OSC). There have been over 100 deployments with over 500,000 hours of marine operations in Orkney waters. The input to development of these guidance documents is unprejudiced in drawing together both the positive and negative lessons learnt and cover a depth of expertise captured within each of the participating supply chain companies.

A range of companies with experience of working on EMEC's sites in Orkney were invited to participate[2], and the final group comprised a range of expertise encompassing environmental, electrical, marine operations management, diving and vessel hire companies: Aquatera, Bryan J Rendall Electrical, EMEC, Green Marine, Leask Marine, Offshore Subsea Consultancy Services, Orcades Marine, Scotmarine, Sula Marine and the Xodus Group.

[1] Delivering UK Energy Investment: Low Carbon Energy, DECC, March 2015

[2] Whilst Orkney-based companies were prioritised for inclusion in the project, companies based outside Orkney, with experience of working on EMEC's sites were also invited to express interest in participation.

## How were the lessons learnt captured?

Within Section 2 of this introductory report, it is described how the project was brought together, how feedback was discussed, and how the priority lessons learnt were captured. It is also explained how the data collected was integrated with the topics of Compliance, Handling, Installation, and Operations and Maintenance (O&M) to provide guidance. These guidance documents are supplied as distinct, standalone guidance documents. A short overview of each document is also included here in Section 0.

Each guidance document also includes relevant checklists related back to stages of the WES programme, developed during three intensive workshops with the OSC. These checklists and accompanying proformas will provide a reference point for developers as they plan activities moving from the pre-WES stage of concept feasibility through the Stages 1-3, and eventually post-WES to full scale deployment in sea.

Lastly, Section 4 provides profiles of the aforementioned supply chain companies who gave their time and effort to inform this industry guidance. The profiles demonstrate the breadth of skills and experience which have contributed to the development of this project. It is hoped the value of these guidance documents will be utilised interactively and provide a framework for continued learning amongst WES, the wave energy developers, EMEC and the Orkney supply chain [3].

## The typical WES Stages

An indication of the typical activities that would be completed during WES Stages 1-3 have been provided below. In addition, a high level overview of the pre-WES requirements is also included.

It is understood that each of the WES programmes will have a variation of these typical activities, dependent on the system development programme and the most appropriate stage gated progression.

| **Pre-WES**<br><br>**Initial Concept Creation & Feasibility Work** | **WES Stage 1**<br><br>**Concept Characterisation & Refinement** | **WES Stage 2**<br><br>**Concept Optimisation & Engineering Demonstration** | **WES Stage 3**<br><br>**Detailed Design and Large-Scale Prototype Demonstration** |
|---|---|---|---|
| • Basic technology research<br>• Technology concept formulated<br>• Small scale tests | • Concept development<br>• Simulation modelling<br>• Power performance estimates<br>• Scale model / component testing | • Concept refinement<br>• Technology optimisation<br>• Scale model / component testing<br>• Numerical model validation | • Refined system<br>• Design and fabrication understood<br>• Large scale system testing<br>• Open water testing of scaled WEC |

[3] It is acknowledged that the participants, and indeed final guidance documents and checklist are not an exhaustive list, but provide a comprehensive range of lessons learnt, reflective of the current stage of the industry.

# 2 Knowledge Capture Approach

WES identified four core areas of real-sea testing experience around which lessons learnt could be captured, and fed back into other WES projects: Compliance, Handling, Installation, and O&M activities. There are many physical and logistical challenges within each of these themes and the EMEC test sites have witnessed the majority of these. As an example of the financial impact of these challenges, it has been noted throughout the industry that the current installation costs for wave (and tidal) energy prototype projects are prohibitively high (18% of lifetime costs for wave)[4]. Efficiencies within overall operations will improve wave technology cost competitiveness.

Engagement with the Orkney Supply Chain (OSC) was imperative to identify those issues that can make the biggest impact on cost reductions in each of the four themes. This dialogue began with a series of three full day workshops in Orkney. In order to generate the lessons learnt, EMEC created a facilitation team comprising of personnel from EMEC, Aquatera and Xodus Group; industry leaders within their respective fields. The goal of the facilitation team was to identify, gather and analyse the real issues behind any operational failures that had occurred, along with disseminating best practice demonstrated within these companies. The objective of the first workshop was framed around the activities with which the supply chain is familiar and could contribute lessons from their past experiences of working with marine technology developers and prototype deployment. These activities covered key stages of the technology development process; technology programme management, device design and testing, device supply, onshore operations, deployment design and management, data capture, marine operations, and decommissioning (see figure 1 below). Each of the above stages were further discussed in breakout sessions, where participants were encouraged to write down events, both positive and negative including what a developer should have known to prevent the negative event or reinforce best practice.

**WES Knowledge Capture Workshop**

This generated an extensive list of lessons (214 individual lessons learnt). The analysis of the lessons learnt generated common threads that were used as a basis for the second workshop. These 23 threads were prioritised based on recommendations from the workshop participants.

[4] Wave and Tidal energy Market Deployment Strategy for Europe, SI Ocean, June 2014

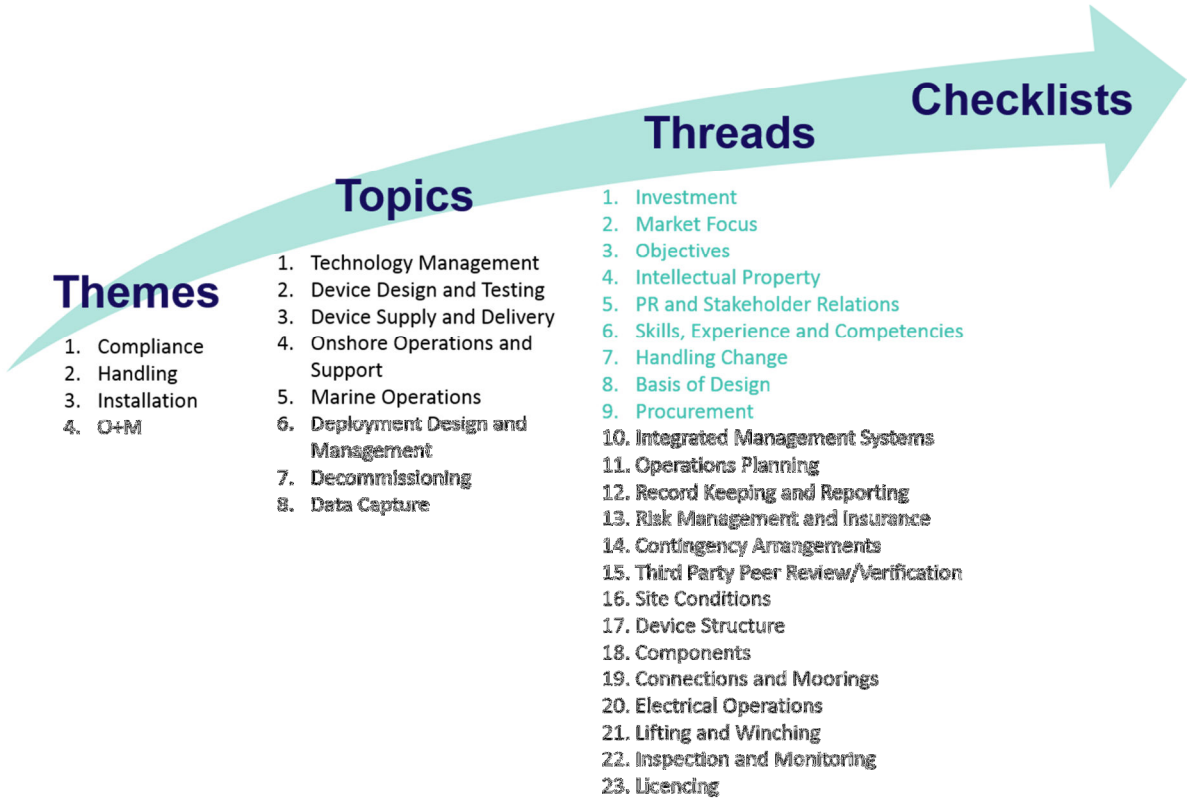



**Figure 1. Lessons Learnt workflow**

To make best use of the workshop time, 14 threads were reviewed as a group (items 10-23, figure 1) and the other 9 were developed outside the workshops by the facilitation team (items 1-9 highlighted in blue, Figure 1).

Through compiling the initial report, it became apparent that many of the threads overlap one another, and are therefore relevant to each of the WES themes of Compliance, Handling, Installation and O&M at different stages of development. In order to address this, WES-stage-specific proformas were developed for each thread. The proformas provide a snapshot of the lessons learnt and how they relate to each WES stage, with related checklists. These proformas are included in the guidance document appendices.

The applicability of Compliance, Handling, Installation and O&M themes cover many supply chain and developer activities, both onshore and offshore. These activities have been identified, and checklists have been constructed, with reference to different stages, in terms of what developers need to be aware of, plan for, engage with and implement, depending on their stage of technology development.

The lessons learnt for each thread relative to each of the topics were developed through group discussion during the workshops. An example of this can be show if you were to take #18 Components, which in this instance is as follows:

- Technology Management – Developers should plan for a component strategy appropriate to the deployment conditions and market objectives.
- Device Design and Testing – Developers should optimise design and procurement for wet tested, quality and if possible standardised components that are saltwater safe.

- Device Supply & Delivery – Developers should have in place an asset management system from fabrication through to assembly.
- Onshore Operations and Support Activities- Developers should ensure onshore equipment is suited to local conditions; including carrying suitable spares for key at risk components.
- Marine Operations – Developers should prepare and implement a suitable inspection and preventative maintenance regime; carrying suitable spares for key at risk components with long delivery times and or critical functions.
- Deployment Design & Management – Developers should ensure vulnerable components are fully protected during installation.
- Decommissioning – If suitable, device and subcomponent designs should use reusable/recyclable parts or materials.
- Data Capture – Developers should ensure suitable records are maintained for components (manufacturer, specifications, operating conditions, standards if applicable) including capturing failed components for analysis (FMEA).

The above topics had synergy across the compliance, handling, installation and O&M topics. However, to eliminate duplication, the participants agreed to place components under the O&M topic. Creation of the checklist items within the appropriate Stages was agreed for the most critical items. For example;

- Pre WES – Awareness of industry best practice or existing guidelines/standards on components, including integrity design codes.
- Stage 1 – Plan to utilise standardised components where possible.
- Stage 2 – Create an engineering Bill of Materials (BOM) register to include components.
- Stage 3 – Inspect vulnerable components, such as cables, are fully protected during commissioning and installation.

The outputs from the workshops formed the checklists and checklist items, which are supported by a narrative within the guidance documents, which addresses the key performance issues for each theme, tying all of the threads and stages together. There are key questions (highlighted in a blue box at the end of each respective section) which emphasise particular issues/topics and provide guidance to check they have been considered. These can be referenced back as appropriate to the checklist proformas.

It is noteworthy that in the second workshop each thread was reviewed by one or more industry representative at each stage of the analysis – validating the integrity of the threads and creating high level checklist items, in total 440 checklist items. These were reviewed in workshop 3 and edited down to 150 checklist items.

# 3 Guidance Documents

A summary of each of the 4 guidance documents resulting from the project is provided. The detailed documents provide much more detailed reference points to aid developers in their planning. At each WES stage identification and prioritisation of each checklist item (located in the guidance document appendices) should provide guidance to developers moving from one stage of development to the other, ultimately ensuring lessons learnt to date from at-sea operations can be addressed ready for successful full scale commercial deployment.

## 3.1 Compliance (WES_KH03_ER_02)

The issues surrounding compliance pertain to adherence of regulatory and statutory requirements, standards and industry best practices. The Compliance theme has a number of synergies with the other themes of Handling, Installation and O&M; there are overlaps which reinforce licensing requirements at pre-consented and non-consented sites, third party verification requirements, including safe onshore and offshore regulations, and best practice. The main compliance issues affect all aspects of a programme lifecycle. The holistic understanding of where specific compliance issues have arisen (from the perspective of the OSC) covers all phases of a programme lifecycle. These range from unclear programme testing and deployment objectives, through to failure to plan for decommissioning.

Often compliance is treated as an afterthought and therefore not budgeted for. A key threat to development programmes is a lack of budget covering these processes. By looking ahead, to create an understanding of the compliance requirements at the next project lifecycle stage, budgetary arrangements can be planned for. It is therefore important to develop a compliance plan. The integration of a compliance plan within an integrated management system de-risks any delays through the programme lifecycle, to decommissioning of the WEC device.

The introduction of compliance in a programme lifecycle allows preparations to be made around issues encountered during site screening, understand the licensing and permitting requirements, the H&S requirements, and the impacts the design compliance issues have at different stages, and the overlap with handling, installation and O&M activities. Beginning a high level compliance plan within the programme lifecycle will ensure confidence that the trajectory from earlier Technology Readiness Levels (TRLs) through to prototype in-sea deployments, is realistic and shortened.

## 3.2 Handling (WES_KH03_ER_03)

Handling generally means any physical interaction with a marine energy device/subsystem or component. The OSC defined handling in terms of mobilisation, demobilisation, onshore delivery and offshore delivery activities. The OSC identified aspects of handling that cross over with compliance (licensing and risk management), installation, recovery, operations, and maintenance of a marine energy converter and subsystems. Procedures are not discussed in terms of ‘how to’ but more so an overview of requirements involved in the safe handling of a device and the associated recommended work practices.

It is also recognised that onshore, quay to sea, and offshore handling involves a range of operators including vessel owners, logistical experts, marine contractors, haulage companies and crane operators. As mentioned in the compliance guidance document the Construction Design and Management regulations (CDM) require the device designer to adopt early consideration of handling activities to ensure the safe planning, management, risk identification and execution of these activities.

The key issues highlighted during the OSC workshops were those involving the device configuration, device loads, centre of gravity (CoG) and lift, or lack of appropriate lifting points on the device. It is important that the needs of all lifting and winching operators have

been identified, including contingency lifts; for example, unscheduled maintenance lifts, and that all suitable and available lifting equipment has been identified and held in place.

It is recommended that at the conceptual stage the designer should describe how the device will be handled including both the onshore and offshore movement of the device. By Stage 2, engagement with a competent onshore/offshore marine contractor should take place to support development of lifting plans, especially for complex lifts. At Stage 3 if possible, lift tests should be implemented for bespoke equipment prior to deployment.

## 3.3 Installation (WES_KH03_ER_04)

Installation is a very specific part of the device development program where the equipment supporting the open water testing of the device is deployed and commissioned. The action of installation is specific to Stage 3, as prior to this all testing is done in controlled test tank conditions. However, preparation and risk mitigation will be covered within Stage 2 activities.

Depending on the type of device, installation can include the deployment of permanent moorings, the installation of shore based power conditioning equipment or even the permanent deployment of the device or subsystem onto a fixed seabed foundation. The tasks undertaken here are often considerably outside the skillset and experience of a developer, and require involvement of the supporting supply chain. The temptation to assign these tasks to internal resources with little or no experience of operating in open water environments should be resisted, as this has time and again proven to be a false economy with significant cost increases later due to inappropriate and inefficient approaches being used.

The base concepts of the installation should be highlighted in concept development during Stages 1 and 2, and as the design becomes more certain, and the site for Stage 3 deployment becomes apparent, review of concepts and development of procedures should take place using a HIRA with all participants providing feedback.

## 3.4 Operations and Maintenance (O&M) (WES_KH03_ER_05)

Operations and Maintenance (O&M) entails all the onshore and offshore activities that are part of the planned and unplanned test schedule, after the initial installation of device and moorings/foundation are complete. This is specific to Stage 3 testing, as previous stages are focused on test tanks where requirements are much lower, and far more defined.

This section of the technology lifecycle can become an iterative testing phase, where lessons are learnt and applied in a continuous process. Marine operations become more refined, and areas for improvement are often identified. Crew members become more practiced at their tasks, and thus the operation can be attempted in wider and wider weather windows, potentially moving away from daylight only operations. As marine operations (and onshore operations to a lesser extent) are such a significant part of the Levelised Cost of Energy (LCoE) for a wave energy converter, it is important to take advantage of the opportunity to refine and reduce forecasting uncertainties not only for the device, but for the support operations associated with it.

The key to making progress and getting benefit from this iterative cycle is in the pre-planning and post-analysis of each operation. Planning should be done with experienced contractors/internal resources wherever possible, and should cover all risks, contingencies and potential opportunities. Post operational analysis provides the chance to capture what went well, what needs improved and any unforeseen risks that became apparent.

# 4 Company Profiles

Complementing the WES development programme is the experience and know-how that has been developed within the OSC through EMEC's test sites. There have been over 100 deployments with over 500,000 hours of marine operations which include the following wave energy companies;

- Pelamis Wave Power,
- E.ON,
- ScottishPower,
- Aquamarine Power,
- Wello Oy,
- AW Energy and
- Seatricity.

It is estimated 300,000 person days or 2,400,000 hours of land based support has been provided to the wave sector over the last 12 years at EMEC. The value of the practical experience from successful and not so successful marine operations is considerable. In supporting these developers, the OSC has adopted, implemented and characterised best practices in many areas, including project management, QHSE, licensing, consenting, third party inspections/verifications, handling and lifting, installations, recovery and operations which have the potential to ensure safe and cost effective methods are employed going forward.

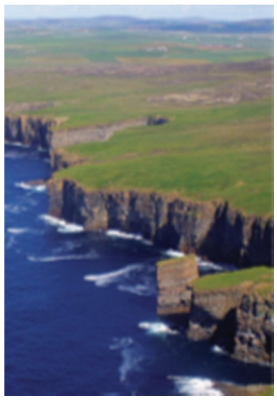
Orkney has committed considerable resources to ensuring the ongoing development of both the wave and tidal sectors towards commercial deployments, with ~£76M invested in equipment and 350 staff employed. Encouraging collaborations, and assembling the last 12 years of wave and tidal energy deployments in Orkney will ensure further, needed innovations across the sector become a reality. It is through the work undertaken with WES that EMEC and the OSC have been able to demonstrate the value industry collaboration has for the future wave energy sector.

Following are the profiles for the company participants involved in providing the invaluable lessons learnt that informed the content of the four guidance documents. These profiles explain their experience in the sector, and demonstrate why these companies in the Orkney Supply Chain were included in this project.

# Aquatera

**Old Academy Business Centre, Stromness, Orkney, KW16 3JW**
**www.aquatera.co.uk | office@aquatera.co.uk | +44 (0)1856 850088**

Aquatera has worked on over 250 marine energy studies/activities for over 70 clients across over 20 counties. Headquartered in Orkney the team have worked for 30 years to develop the wave and tidal sectors, focusing on cost effectiveness and enabling clients to meet the necessary standards of ecological, social and safety stewardship.



The team has experience in the planning, development, consenting, management and delivery of demonstration and commercial scale projects. These services are delivered by teams comprising: in-house staff, regular associates, and collaborating delivery team partners in Orkney and internationally. Aquatera acts as an integrator of a range of services as well as delivering a broad spectrum of services directly.

## Key services & projects:

| List of Services | |
|---|---|
| • Strategic planning including: market intelligence and assessment; regional development plans; infrastructure needs<br>• Environmental survey and permitting including: site screening, scoping, option assessment, consultation, EIA & HRA, navigational risk assessments, environmental surveys and research<br>• Technology and array development support including: programme development and management, risk management, peer review/assist, due diligence, TPV, basis of design, conceptual design, design review, site surveys, site layouts, route finding | • Resource and site assessment including: site identification and feasibility studies<br>• Financial assistance including: project costing, LCOE analysis, funding applications<br>• Operational planning and execution including: CDM and health and safety management, cabling studies and operations, onshore facilities support<br>• Enabling technologies including: vessel/platform design and selection, cable laying techniques<br>• Communication and outreach including: stakeholder engagement, information materials, public meetings, exhibitions |

| Wave Energy Clients/Projects | |
|---|---|
| • 17 Wave technology and project developers including: Pelamis Wave Power, Finima, Seatricity, OPT, Wavegen, ITRI, AWS, ETYMOL, OceanLinx, Wello, AlbaTern, Perpetuwave, Ausind, Maestranser Diesel, Wave Power Technology, M2 (USA), ENDESSA | • 22 tidal technology & project developers<br>• 17 government and public bodies<br>• 10 industry clusters and organisations<br>• 8 research institutions |

## Projects undertaken in:

UK, Barbados, Canada, Canary Islands, Chile, Columbia, Faroe Islands, France, Germany, Hong Kong, Indonesia, Ireland, Japan, Latvia, Norway, Philippines, Portugal, Peru, Singapore, Spain, Taiwan, Turkey, USA.

## Bryan J Rendall (Electrical) Ltd

### Crowness Place, Hatston Industrial Estate, Kirkwall, Orkney, KW15 1RG
### www.bjre.co.uk/marine | info@bjre.co.uk | Tel. +44 (0)1856 879086

BJRE is an electrical contractor to the marine energy industry with experience dating back to 2001, from conducting the first electrical feasibility studies for EMEC. That association continues today, as the company remains EMEC's electrical engineering consultant and contractor. Staff expertise in offshore and onshore oil and gas can be traced back to 1985.

The company has worked with all developers of grid connected devices at EMEC, from design reviews through deployment, operations, maintenance and recovery - assisting developers right through the process.

With electrical and telecommunications expertise in assisting marine energy developers BJRE are often involved at the design stage when early issues can be readily resolved.

### Key services & projects:

| List of Services | |
|---|---|
| • Design, design review and verification<br>• High voltage engineering on/offshore<br>• Subsea cable connections and splicing | • Fibre optic installation, splicing and testing<br>• Electrical testing to 60 kV<br>• Microwave telecommunications |

| Clients/Projects | |
|---|---|
| • Wave technology developers: Pelamis Wave Power, Aquamarine, Wello | • Tidal technology developers: Sustainable Marine Energy, Atlantis, Nautricity, Voith, Alstom, Meygen, Andritz Hydro Hammerfest, OpenHydro, Scotrenewables |

### Projects undertaken in:

Australia, Canada, France, Greece, Italy, North America, New Zealand, UK and Ireland.

# European Marine Energy Centre (EMEC)

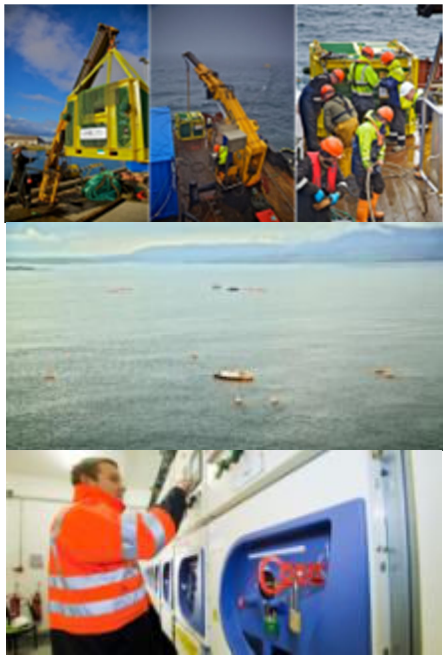
## Old Academy Business Centre, Stromness, Orkney, KW16 3AW
## www.emec.org.uk | info@emec.org.uk | +44 (0)1856 852060

EMEC provides developers of both wave and tidal energy converters with purpose-built, accredited open-sea testing facilities.

With 14 grid-connected test berths in close proximity to sheltered waters and harbours, there have been more marine energy converters deployed at EMEC than any other single site in the world.

EMEC also operates two scale test sites where smaller scale technologies, supply chain companies, and equipment manufacturers, can gain real sea experience in less challenging conditions.

EMEC operates to relevant test laboratory standards enabling the Centre to provide independently verified performance reports to help innovative technologies reach the market.



## Key services & projects:

| List of Services | |
|---|---|
| • Grid-connected wave test site (Billia Croo) and scale wave test site (Scapa Flow)<br>• Environmental monitoring, consenting and operational support with baseline and real-time data<br>• UKAS accredited (ISO 17025) performance assessment and (ISO 17020) technical verification | • Integrated Quality, Health, Safety, and Environmental Management System<br>• Technology assessment process<br>• Funding identification, proposal writing and assistance with business planning, marketing and project coordination |

| Clients/Projects | |
|---|---|
| • Wave technology developers: Aquamarine Power, AW Energy, CorPower Ocean (HiDrive project), E.ON, Laminaria (LAMWEC project), Pelamis Wave Power, Scottish Power Renewables, Seatricity, Wello Oy<br>• In total 26 devices from 17 companies from 9 countries have tested at EMEC to date totalling more than 2000 marine operations | • Research projects: Wildlife Data Analysis (Scottish Government), component analysis project (ORE Catapult), and Reliability in a Sea of Risk (RiaSOR) project (OCEAN-ERANET)<br>• Standards development |

## Projects undertaken in:

Australia, Barbados, Canada, Chile, China, Denmark, France, Ireland, Japan, Netherlands, New Zealand, Philippines, Portugal, Singapore, South Korea, Spain, Taiwan, UK, and USA.

## Green Marine (UK) Ltd

**Euston House, Back Road, Stromness, Orkney, KW16 3AJ**
**www.greenmarineuk.com | info@greenmarineuk.com | +44 (0)1856 851966**

The founders of Green Marine have a long history working in the marine sector having owned and operated a fleet of fishing vessels, operating as far afield as the Pacific Ocean. In 2012 Green Marine (UK) Ltd was established, with over 150 years of real sea time experience in its core team, to provide cost effective solutions for the safe installation, removal and maintenance of a wide range of tidal and wave energy devices and gravity bases.

Based in Orkney, Green Marine operates throughout Europe, hosting a range of versatile vessels and a skilled team. Green Marine recognised that many marine renewable companies were using higher cost oil and gas assets to carry out their offshore operations; specifically operations that required heavy lifting of their devices. With this in mind the GM700 Catamaran Gantry Barge was identified as a versatile vessel which has been used as a lower cost, capable vessel working in the marine renewables sector.

### Key services & projects:

| List of Services | |
|---|---|
| • Operational planning, consultancy, Method Statements & Risk Assessments<br>• Marine operations, vessel hire, specialised heavy lifting, towage, offshore cable installation, subsea installations | • Mooring deployment and removal<br>• Construction, naval architectural services and engineering<br>• Decommissioning and salvage |

| Clients/Projects | |
|---|---|
| • Wave technology developers: Corpower Ocean, Wello Oy, Seatricity, Albatern<br>• Tidal technology developers: Andritz Hydro Hammerfest, MeyGen, Atlantis | • Other organisations: Wave Energy Scotland, Balfour Beatty, EMEC, Aquatera, Orkney Islands Council Marine Services, Gardline, ProSafe, Land & Marine, EDPR |

### Projects undertaken in:

UK, France, Sweden, Norway, Denmark, Belgium, Indonesia.

# Leask Marine Ltd

**6 Crowness Road, Hatston Industrial Estate, Kirkwall, Orkney, KW15 1RG**
**www.leaskmarine.com | info@leaskmarine.com | +44 (0)1856 874725**

Leask Marine supports wave & tidal energy projects from consultancy, survey and installation, to on-going maintenance and decommissioning. With a broad knowledge and experience of installing devices the company has been sought to participate in marine energy projects around the world.

A key supply partner to developers, Leask Marine are committed to ensuring commercially viable devices, and have developed technologies and procedures encompassing a range of specifically designed vessels to support marine energy operations.

These vessels and equipment, together with the skilled technical team of marine consultants in naval engineering, naval architecture, mariners, and commercial divers, positions the business to deliver all phases of a project's lifecycle, from conception, design, engineering, reliability and survivability studies, testing, economic modelling, installation, operations & maintenance, and environmental decommissioning.

## Key services & projects:

| List of Services | |
|---|---|
| • Project management and engineering services<br>• Marine consultancy, workboats, divers/dive teams<br>• HDD cable installation, operational maintenance of cable and site infrastructure equipment | • Subsea rock anchor drilling and cable deployment<br>• Installation of temporary moorings, subsea gravity base, device installation, routine maintenance, and environmental decommissioning |
| **Clients/Projects** | |
| • Wave technology developers: Wello (installation of 1600t Penguin WEC), Aquamarine Power and Pelamis Wave Power | • Tidal technology developers: Sustainable Marine Energy (PLAT-O installation), OpenHydro (decommissioning 300 tone sub-sea gravity base), MeyGen (HDD exit & subsea preparations for turbine frames), Nova Innovation (deployment of subsea cable and 2 turbines), plus 9 others |

## Projects undertaken in:

UK, Ireland, Norway, Germany, France, Poland.

# Orcades Marine Management Consultants Ltd

**Innovation Centre – Orkney, Hatston, Kirkwall, Orkney, KW15 1ZL**
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Orcades Marine provides specialist marine risk management and practical consultancy advice, third party verification, independent auditing and assessment, and project management to the marine energy sector, and to the offshore, shipping and port industry.

Employing specialist personnel with extensive practical experience and appropriate professional qualifications, all work carried out is in accordance with their Safety and Environmental Policy and Safety Management System – accredited to ISO 9001 and OHSAS 18001 quality and safety standards.

Based in Orkney but working worldwide has given Orcades Marine experience working in challenging environments both political and geographic, focused on ensuring safe offshore operations, and the production of economic and innovative solutions.

## Key services & projects:

| List of Services | |
|---|---|
| • Provision of Marine Superintendency and oversight<br>• Third party review of marine operations and procedures, project planning and consultancy for device operations and maintenance<br>• Marine operations management and risk management including Navigational Risk Assessment and safe systems of work | • Retro design and shipyard supervision of new build and modifications, ship survey and inspection<br>• Vessel chartering and contract preparation, supervision of trial project marine works, tow preparation passage planning<br>• Land and marine logistics and supply chain capability |

| Clients/Projects | |
|---|---|
| • Wave technology developers: Aquamarine Power, Pelamis Wave Power, Magallanes Renovables, Seatricity, AWS Ocean Energy, Wello Oy<br>• Other organisations: Oregon Wave Energy Trust, EMEC, Systems Engineering and Assessment Ltd, ITRI, Taiwan, SSE | • Tidal technology developers: Andritz Hydro Hammerfest, Atlantis, Nova, Flumill, Sustainable Marine Energy, Voith |

## Projects undertaken in:

UK, USA, Norway, Taiwan, Indonesia, Singapore.

# Offshore Subsea Consultancy Services Ltd

**10 The Woodlands, Ballina, County Mayo, Ireland, F26 K4P9**
**www.offshoresubseaconsultancyservices.com | eamonhowlin@eircom.net | +353 (0)8680 71394**

OSCS Ltd[5] is an international energy and marine industry service provider working in project and operations management; consultancy & supervision of offshore/onshore operations.

Managed by a Chartered Engineer with over 25 years' experience in the marine industry including oil & gas, wave energy, offshore wind and professional diving, OSCS can provide clients with practical advice on all aspects of their marine renewable energy projects.

## Key services & projects:

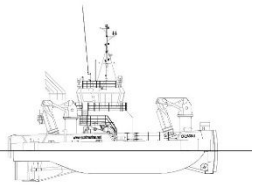
| List of Services | |
|---|---|
| • Health & Safety driven operating to IMCA, ISO1400 & 9001, Norsok & UKOOA operating standards<br>• Technical skills in EPCI contracts, business change management, asset integrity, strategic planning, strategy implementation, quantitative analysis and auditing<br>• Operations management, subsea inspection programmes, marine operations management<br>• Documentation audits, feasibility studies and design appraisals | • Design of bespoke tooling working on offshore & subsea installations / IRM (Inspection, Repair, Maintenance) and decommissioning projects internationally<br>• Project management of onshore & offshore engineering and surveying projects<br>• Client representation liaising at Consultant/Contractor/Sub-Contractor level and interfacing with government departments and statutory authorities |

| Clients/Projects | |
|---|---|
| • Wave technology developers: Aquamarine Power (offshore operations management) and Seapower Ltd (installation documentation and technical documentation)<br>• OEDU – (Offshore Energy Development Unit), advising the Irish semi state department on wave energy device feasibility studies | • Other offshore clients: Technip, Norway (installation and decommissioning projects), Subsea 7 (installation, repair & maintenance projects for Shell's North Sea assets) and contracting to 'Offshore Marine Management Ltd' (producing matrices for offshore windfarm foundations) |

## Projects undertaken in:

UK, Ireland, Norway, Middle East, USA.

[5] OSCS provided review services and did not actively participate in workshops.



# Scotmarine Ltd

**Innovation Centre-Orkney, Hatston Pier Road, Kirkwall, Orkney, KW15 1ZL**
**www.scotmarine.net | office@scotmarine.net | + 44 (0)1856 874983**

Scotmarine owns and operates a Damen 2613 MultiCat® work vessel. The M.V. ORCADIA II is highly versatile with capabilities including a 100 tonne anchor handling winch, 60 tonne towing winch and twin 290 HS Marine knuckle boom hydraulic cranes each capable of lifting over 42 tonne.

The crew and management team have over 26 years direct experience in marine renewables. The M.V. ORCADIA II provides a range of support services, from anchor handling, towing and mooring deployment, to hydrographic survey, diving support and the installation and recovery of wave and tidal energy systems and the associated infrastructure.

## Key services & projects:

| List of Services | |
|---|---|
| • Device installation and removal | • Survey - ADCP |
| • Mooring installation and repair | • Diving support |
| • Cable works, towing and offshore support services | • Barge towing |

| Clients/Projects | |
|---|---|
| • Wave technology developers: Wello, Pelamis Wave Power | • Leask Marine |
| • Tidal technology developers: Scotrenewables Tidal Power, Open Hydro, Tidal Generation Ltd, Andritz Hydro Hammerfest, Voith | • Green Marine |
| | • EMEC |

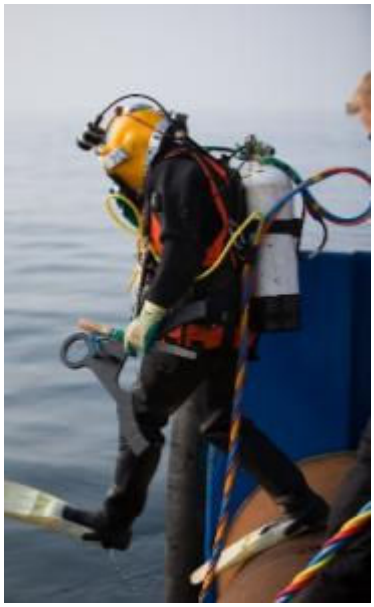
## Projects undertaken in:

UK, Germany.

## SULA Diving

### Block 1, Old Academy Business Centre, Stromness, Orkney, KW16 3AW
### www.suladiving.com | info@suladiving.com | +44 (0)1856 850285

SULA Diving provides commercial diving, remote survey and small vessel charter services. SCUBA and surface supply diving techniques are used to carry out underwater survey, inspection and engineering works for a variety of clients including oil companies, marine renewable developers, environmental consultants and academic organisations.



Remote survey capabilities include side scan sonar, magnetometer and remote video survey, which are effective in a variety of situations including site investigation, object location and seabed characterisation.

SULA Diving also provides advice on marine archaeology, particularly on historical unexploded ordnance and shipwrecks and provides regular input to seabed cable and pipeline projects.

### Key services & projects:

| List of Services | |
|---|---|
| • Commercial diving services, providing installation, inspection and maintenance of subsea assets.<br>• Scientific and archaeological diving services.<br>• Marine archaeological consultancy | • Hyperbaric support (recompression systems)<br>• Remote sensing services, including side scan sonar, magnetometer and drop video survey.<br>• Vessel charter in support of diving, marine survey or personnel transfer. |

| Clients/Projects | |
|---|---|
| • Wave technology developers: Seatricity, Aquamarine Power, Pelamis Wave Power, Wello Oy, AW Energy. AWS Ocean Energy, NEMOS GmbH | • Other organisations: Aquatera, Orkney Research Centre for Archaeology (ORCA), EMEC, Heriot Watt University, Orkney Islands Council, Scotrenewables Tidal Power Ltd, Green Marine UK Ltd |

### Projects undertaken in:

UK.

# Xodus Group Limited

**8 Garson Place, Stromness, Orkney, KW16 3EE**
**www.xodusgroup.com | liz.foubister@xodusgroup.com | +44 (0)1856 851451**

Xodus offers analytical tools and methodologies to scope and model a marine energy project, together with the expertise to support projects throughout their lifecycle.

As an offshore energy consultancy, Xodus provides integrated engineering, environmental and safety expertise across project lifecycles for marine energy technology and project development. Involved in site selection (including resource assessment and cable routing studies), project feasibility, planning and management, EIA and consenting, safety, option selection, engineering (concept; FEED, detailed design), execution and operation & maintenance, through to decommissioning.

Xodus places particular focus on integration - at each stage in the process drawing on multidisciplinary input from in-house professionals who have built up years of experience in the renewables and wider offshore energy industries.

## Key services & projects:

| List of Services | |
|---|---|
| • Strategic planning, market, feasibility, technology and resource assessment, technology assessments; geophysical and geotechnical, structural, materials, electrical, instrumentation and controls; GIS constraints mapping<br>• Peer review; due diligence & risk management; construction and installation strategy and planning<br>• Subsea engineering; cable routing and design, including cable protection; advanced engineering (CFD, FEA, dynamic analysis, fatigue analysis); and reliability engineering | • Project and Package Management; management plans and contingency planning; O&M strategy development; Asset integrity support (including operational monitoring); Decommissioning programmes<br>• Environmental impact assessment and consent applications, environmental survey and monitoring; stakeholder engagement<br>• HSE (construction design management (CDM), management systems); Chair and facilitate risk assessments (HIRA, HAZOP)<br>• Training; research and development |

| Clients/Projects | |
|---|---|
| • Wave technology developers: Aquamarine Power, Pelamis Wave Power, AWS Ocean Energy<br>• Government organisations: Marine Scotland, Scottish Enterprise, Highlights and Islands Enterprise, ORE Catapult | • Also 6 tidal technology developers, and 17 tidal / wave project developers including: Costa Head Wave Energy; Brough Head Wave Farm; and Voith Hydro Wavegen; |

## Projects undertaken in:

UK, Ireland, Indonesia, Japan, Australia

European Marine Energy Centre (EMEC) Ltd
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