Cross border laboratory and field test procedures

Deliverable 3.4.2 from the MERiFIC Project

A report prepared as part of the MERiFIC Project "Marine Energy in Far Peripheral and Island Communities"

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Executive Summary

This report is a deliverable of MERiFIC Work Package 3.4: *'Test Facilities'* and has been produced by the University of Exeter.

In contrast to the early days of the Marine Renewable Energy (MRE) industry a larger range of resources are available to device developers, comprising scientific knowledge, test facilities and a handful of offshore deployment examples. Whilst not all of the knowledge gained is in the public domain due to the confidential nature of commercial designs, EU funded projects have actively disseminated guidelines for the design and testing of devices (i.e. EquiMar protocols and CORES: Components for Ocean Renewable Energy Systems, report as well as the forthcoming IEC TC114 guidelines). It is the purpose of this document to provide state-of-the-art guidance of cross border laboratory and field test procedures, starting with a list of guidelines and standards relevant to MRE devices. The dual-purpose of physical testing to validate numerical design tools and to incrementally achieve proof of concept is then summarised. This section is not intended as a guide to physical modelling per se, because there are several well-established references. A list of current funding schemes which have been set up to enable facilities and equipment access is provided as well as insight into country-specific funding schemes in France and the UK. MERiFIC work package 3.5 is then presented as an example of transnational collaboration between MERiFIC partners, IFREMER (L'Institut Français de Recherche pour l'Exploitation de la Mer) and the University of Exeter. To facilitate the planning process of physical testing a generic procedure is then proposed.

Contents

Introduction

The MERiFIC Project

MERiFIC is an EU project linking Cornwall and Finistère through the ERDF INTERREG IVa France (Manche) England programme. The project seeks to advance the adoption of marine energy in Cornwall and Finistère, with particular focus on the island communities of the Parc naturel marin d'Iroise and the Isles of Scilly. Project partners include Cornwall Council, University of Exeter, University of Plymouth and Cornwall Marine Network from the UK, and Conseil général du Finistère, Pôle Mer Bretagne, Technôpole Brest Iroise, IFREMER and Bretagne Développement Innovation from France.

MERiFIC was launched on 13th September at the National Maritime Museum Cornwall and runs until June 2014. During this time, the partners aim to

- Develop and share a common understanding of existing marine energy resource assessment techniques and terminology;
- Identify significant marine energy resource 'hot spots' across the common area, focussing on the island communities of the Isles of Scilly and Parc Naturel Marin d'Iroise;
- Define infrastructure issues and requirements for the deployment of marine energy technologies between island and mainland communities;
- Identify, share and implement best practice policies to encourage and support the deployment of marine renewables;
- Identify best practice case studies and opportunities for businesses across the two regions to participate in supply chains for the marine energy sector;
- Share best practices and trial new methods of stakeholder engagement, in order to secure wider understanding and acceptance of the marine renewables agenda;
- Develop and deliver a range of case studies, tool kits and resources that will assist other regions.

To facilitate this, the project is broken down into a series of work packages:

WP1: Project Preparation
WP2: Project Management
WP3: Technology Support
WP4: Policy Issues
WP5: Sustainable Economic Development
WP6: Stakeholder Engagement
WP7: Communication and Dissemination

1 Existing Marine Renewable Energy device guidelines and testing procedures

A standardised approach of testing marine energy devices and associated components has yet to be formalised internationally and this is partly due to the variety of marine renewable energy (MRE) device designs proposed (including the variety of standard and non-standard components used) and lack of device deployments conducted to-date. At the time of writing (July 2013), three of the planned eight International Electrotechnical Commission TC114 guidelines covering *Marine energy - Wave, tidal and other water current converters* have been published. It is expected that the series will be completed by the end of 2015 and include a comprehensive range of relevant topics for MRE design, testing and resource assessment. In the meantime, several generalised performance assessment guidelines exist which are relevant for MRE devices, including those produced by the EquiMar project and the European Marine Energy Centre (EMEC) [1, 2]. Procedures for the use of field test facilities are likely to comprise elements which are specific to the host country of the test facility including local geographical information, consenting processes and legislative requirements (e.g. Site d'Experimentation en Mer; SEM-REV and the National Wave Energy Test Site, Galway Bay [3, 4]).

Guidelines for scale model testing have been produced by the Supergen Marine project and EMEC [5, 6]. In general, model testing of scaled-down MRE systems is usually conducted based on well-established tank testing procedures (i.e. as produced by the International Towing Tank Conference committee [7]) or utilising previous experience of small-scale testing in other areas of offshore engineering [e.g. 8, 9].

Perhaps the most comprehensive example of MRE device development which is available in the public domain is the CORES (Components for Ocean Renewable Energy Systems) sea trials [10]. As the project title implies, the emphasis of this study was on the performance of components in the mooring, riser, data acquisition, instrumentation and power take-off sub-systems, with an Oscillating Water Column system selected as a test platform. The final report from the study also includes a key insight into the background activities required to install, operate, maintain and decommission the project.

In the absence of specific standards for component testing it is necessary to use existing offshore equipment standards[1], for example those produced by Bureau Veritas, Det Norske Veritas (DNV), and the American Bureau of Standards (Table 1).

Category	Document	Publication year	Author(s)
Power performance	Marine energy - Wave, tidal and other water current converters - Part 102: Wave energy converter power performance assessment at a second location using measured assessment data	2014	International Electrotechnical Commission
	The PerAWaT project: Performance, Assessment of Wave and Tidal Array Systems	2010	Rawlinson-Smith, R. et al.
	Assessment of Performance of Wave Energy Conversion Systems, Assessment of Performance of Tidal Energy Conversion Systems	2009	European Marine Energy Centre
Mooring	Marine energy – Wave, tidal and other water current converters - Part 10: The assessment of mooring system for marine energy converters (MECs)	2013	International Electrotechnical Commission
	DNV-OS-E301: Offshore standard - position mooring	2010	Det Norske Veritas

[1] The MERiFIC deliverable report *D3.5.1: Testing of Synthetic Ropes* outlines the main sources of guidance used by offshore equipment developers and rope manufacturers for device station keeping.

Mooring	Guidance Notes on the Application of Fiber Rope for Offshore Mooring	2011	American Bureau of Standards
	ISO 18692: Fibre ropes for offshore station keeping – Polyester	2007	International Standards Organisation
Design/Structures	Marine energy - Wave, tidal and other water current converters - Part 2: Design requirements for marine energy systems	2013	International Electrotechnical Commission
	Marine energy - Wave, tidal, and other water current converters - Part 20: Guideline for design assessment of Ocean Thermal Energy Conversion (OTEC) system	2013	International Electrotechnical Commission
	DNV-OS-C401: Fabrication and Testing of Offshore Structures	2013	Det Norske Veritas
	Guidelines for Manufacturing, Assembly and Testing of Marine Energy Conversion Systems	2009	European Marine Energy Centre
	IEC 61400-3-2 Design requirements for floating offshore wind turbines	2013 (TBD)	International Electrotechnical Commission
Power	Ship Systems and Equipment - Hydraulic System Design Criteria for Marine Vehicles	2013	SAE
	IEC 60308 EN-Hydraulic turbines - Testing of control systems-Second Edition	2005	International Electro Technical Commission
	IEC 60193 EN-Hydraulic Turbines Storage Pumps and Pump-Turbines - Model Acceptance Tests-Second Edition	1999	International Electro Technical Commission
	IEC 60034 Rotating electrical machines	Various	International Electro Technical Commission
	Marine Energy - Wave, tidal and other water current converters - Part 30: Electrical power quality requirements for wave, tidal and other water current energy converters	2015	International Electro Technical Commission
Certification	DNV-OSS-312: Certification of Tidal and Wave Energy Converters	2012	Det Norske Veritas
	NI 572 DT R00 E: Classification and Certification of Floating Offshore Wind Turbines	2010	Bureau Veritas
Pre-prototype testing	Marine energy - Wave, tidal and other water current converters - Part 103: Guidelines for the early stage development of wave energy converters: Best practices & recommended procedures for the testing of pre-prototype scale devices	2014	International Electro Technical Commission
	Protocols for the Equitable Assessment of Marine Energy Converters	2011	EquiMar
	ITTC Recommended Procedures	2006	International Towing Tank Conference
	Guidance for Experimental Tank Testing	2008	Supergen Marine
	Tank Testing of Wave Energy Conversion Systems	2009	European Marine Energy Centre
	Guidelines for wave modelling in flumes and basins: Hydraulic model testing in waves	2009	HYDRALAB III
Sea trials	Protocols for the Equitable Assessment of Marine Energy Converters	2011	EquiMar
	T02-2.1: Guidelines for the Development and Testing of Wave Energy Systems	2010	B. Holmes and K. Nielsen
Installation and decommissioning	Offshore Renewable Energy Installations (OREIs) - Guidance on UK Navigational Practice, Safety and Emergency Response Issues.	N/K	Maritime and Coastguard Agency
	Decommissioning of offshore renewable energy installations under the Energy Act 2004	2011	Department of Energy and Climate Change
	Guidelines for Grid Connection of Marine Energy Conversion Systems	2009	European Marine Energy Centre
Resource assessment	Marine energy - Wave, tidal and other water current converters - Part 101: Wave energy resource assessment and characterization	2013	International Electrotechnical Commission
	Marine energy - Wave, tidal and other water current converters - Part 201: Tidal energy resource assessment and characterization	2012	International Electrotechnical Commission

Resource assessment	Assessment of Wave Energy Resource, Assessment of Tidal Energy Resource	2009	European Marine Energy Centre
	UK Wave and Tidal Key Resource Areas Project	2012	The Crown Estate
Environmental Impact Assessment	A Strategic Environmental Assessment (SEA) to examine the environmental effects of developing wave and tidal power	2007	Scottish Government
	Environmental Impacts of Tidal Power Schemes	2009	Wolf, J. et al.
Health and safety	Guidelines for Health and Safety in the Marine Energy Industry	2008	British Wind Energy Association and European Marine Energy Centre
	Health and Safety, Galway Bay Ocean Energy Test Site	N/K	Marine Institute
	Offshore Wind and Marine Energy Health and Safety Guidelines	2013	RenewableUK

Table 1: A non-exhaustive list of guidance and procedures relevant to the testing of marine renewable energy devices and associated components

Research institutes can also achieve higher level accreditation of testing procedures from certification agencies such as the International Standards Organisation. As an example, MERiFIC consortium member IFREMER has ISO9001 accreditation (see certificate in at the end of this document).

2 The current development state of Marine Renewable Energy devices

To date, no one design of MRE device exists which is considered to be superior in terms of power capture capabilities, reliability and maintainability. Whilst progress in tidal energy industry is slightly more advanced than wave energy device industry, in both cases a consensus (such as the now widely adopted three-blade horizontal axis design of wind turbines) has yet to be reached. Ultimately it is likely that a range of MRE designs will exist with variants suited to particular resource characteristics and locations[2]. Considering the diversity of approaches proposed over the past four decades, developers are under considerable commercial pressure to reach the 'proof of concept' stage which can perilously lead to the temptation to launch directly from an unrefined design to full-scale prototype deployment. Due to uncertainty regarding device performance and reliability in this early stage, a more cautious approach is required in order to reduce the financial risks of the project through concept verification. At present, the priority of physical testing is to obtain a greater understanding of the engineering, scientific and operational processes involved and to calibrate numerical tools. These tools are necessary to predict the performance of the device and in the long-term be used for design optimisation. Once the MRE industry has matured, the reliance on numerical modelling will have increased to a point where standardised tools exist and physical testing will only be used to investigate special applications or novel designs. This inverse relationship is illustrated in Figure 1.

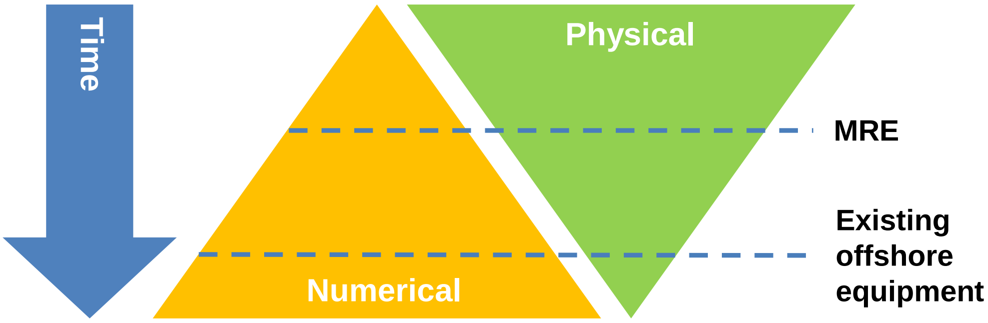


Figure 1: Mutual relationship between numerical model and physical testing utilisation

MRE device concepts are typically tested using reduced scale models in wave and/or current flumes, providing low-cost insight into design suitability and performance. The selected model scale is governed by scaling criterion[3] and the physical dimensions of available facilities. In general, the largest scale that is representative of the full-scale prototype in its intended location is selected. When the physical dimensions of the flume would otherwise limit the scale of the model (i.e. the water depth of the flume with deep water models), established modelling techniques can be used to circumvent such issues (e.g. the truncation of mooring lines). Subsequent testing stages may include the following steps:

- **Different model scales**, *to determine the scalability of the concept and observed physical processes.*
- **Test repetition at different facilities**, *to make sure that the observed behaviour of a model is not due to spurious effects which are unique to a facility (i.e. flume effects such as seiche waves). This step can also be used to harmonise test procedures and methods used at each facility.*

[2] For example, the design of a wave energy converter (WEC) is in general governed by the intended operating environment (i.e. shore-based, near-shore and deeper water sites)
[3] Froude scaling is usually adopted for wave energy converter (WEC) modelling

Component testing equipment and techniques can also be harmonised when it is possible to apply similar conditions. For example, as part of the MERiFIC work package 3.5 *Dynamic behaviours of marine energy devices,* comparative tests have been conducted using tension testing equipment at IFREMER and the University of Exeter. Although the capability ranges of the two machines differ[4] identical tests were carried out using overlapping parameters on both machines to compare machine performance and determine test repeatability. Because of the costs involved with accessing different facilities this step may only be justifiable for collaborative projects which have mutually beneficial outcomes to all parties involved, or as a secondary outcome of a project.

Once a MRE concept has reached the prototype stage, due diligence is mandatory for obtaining necessary consents as well as device classification and certification (i.e. in the UK from The Crown Estate and Lloyd's Register). Proof of compliance is also necessary when applying to progressive funding calls, such as the Marine Renewables Proving Fund from the Carbon Trust (http://www.carbontrust.com/client-services/technology/innovation/marine-renewables-proving-fund). As the MRE industry continues to grow, specific procedures for classification and certification of devices will be established based on relevant standards [e.g. 11].

[4] Further details can be found in MERiFIC deliverable D3.5.1 *Testing of synthetic fibre ropes*

3 Relevant facilities and international research funding schemes

On the US Department of Energy website there is an interactive map of marine and hydrokinetic projects located around the world: http://www1.eere.energy.gov/water/hydrokinetic/GlobalProjectMap.aspx. A useful summary of each project, its capacity and status[5] is included as part of this tool. On the same website a list of hydrodynamic facilities located in the US has been compiled: http://www1.eere.energy.gov/water/hydrodynamic/facilityList.aspx.

Additionally an interactive map of test facilities located in the UK and France was created in 2013 for the MERiFIC consortium: http://www.merific.eu/documents/work-package-3-technology-support/3-4-test-facilities. France Energies Marines, a cluster comprising private and public organisations involved in MRE, has further information regarding test sites located in France: http://en.france-energies-marines.org/Test-sites.

An up-to-date summary focused on the South West UK was published by REGENSW at the end of 2012 [12]. The document is a review of research capabilities and available test sites in the South West which also has a directory listing of companies involved in the development, installation, operation and maintenance of MRE.

3.1 Non-country specific funding schemes

Testing at a range of scales clearly requires access to facilities and expertise which may require significant funds and therefore be prohibitively expensive for small start-up companies or research groups. In view of this, international schemes such as the MARINET (marine renewables infrastructure network for emerging energy technologies) Transnational Access fund have been set up to provide facilities access and travel funds for research groups and device developers. The aims of the fund are the standardisation of testing procedures and instrumentation, the harmonisation of data, the scalability of models with prototypes and the development of data analysis techniques. Given the significance of this fund and its emphasis on cross border collaboration, a summary of available facilities (sorted by category) is listed in Table 2. Further details, including the current 5th call for applications can be found on the MARINET website (http://www.fp7-marinet.eu).

With similar aims to MARINET, the HYDRALAB network was started in 1997 to provide transnational access to facilities and stimulate joint research in topics covering hydraulics, ship dynamics, ice engineering and fluid dynamics research. Now in its fourth incarnation (HYDRALAB IV), expressions of interest for accessing the facilities listed in Table 3 until 2014 can now be made (further details are on the HYDRALAB III website: http://www.hydralab.eu/hydralabIII/calls.asp).

[5] As it is not clear how often this tool is updated, this may serve as a historical record of projects rather than a state-of-the-art database

Scale	Focus area			
	Wave Energy	**Tidal Energy**	**Offshore Wind Energy and Environmental Data**	**Cross-cutting Areas e.g. Electrical, PTO, Materials etc.**
Small Scale Lab	AAU – Wave Basin QUB - Wave Basin UCC-Beaufort– Wave Basin UEDIN – Curved Wave Tank UNI-STRATH - Kelvin Hydrodynamics Lab UNIFI - Wave-Current Flume	DTU – Current flume With Carriage UNI-STRATH – Kelvin Hydrodynamics Lab USTUTT - Laminar Wind Tunnel UNIFI-CRIACIV - Boundary Layer Wind Tunnel UNIFI - Wave-Current Flume	UNIFI-CRIACIV - Boundary Layer Wind Tunnel UNI-STRATH - Kelvin Hydrodynamic Lab USTUTT - Laminar Wind Tunnel	SINTEF – Renewable Energy Lab - SmartGrids TECNALIA – Electrical PTO Lab UCC-Beaufort – Rotary Test Rig USTUTT – Turbine Test Rigs UNEXE - Dynamic Marine Component Test Facility
Large Scale Lab	CNR-INSEAN - Wave Tank ECN - Hydrodynamic and Ocean Engineering Tank IFREMER – Deep Seawater Wave Tank IFREMER - Wave-Current Circulation Tank NAREC – Wave Flume PU - Ocean Wave Basin UEDIN - FloWave Test Tank	CNR-INSEAN – Circulating Water Channel IFREMER – Wave-Current Circulation Tank PU - Ocean Wave Basin UEDIN - FloWave Test Tank	ECN - Hydrodynamic and Ocean Engineering Tank	DTU - Mechanical Test Facilities DTU – PowerLabDK IFREMER – Materials in Marine Environment Laboratory NAREC - CPTC Energy Link Labs NAREC – Nautilus Rotary Test Rig
Medium Scale Site	AAU - Nissum Bredning EMEC – Nursery Test Site (Wave) SEAI-OEDU - Galway Bay	EMEC - Nursery Test Site (Tidal) QUB – Portaferry Tidal Centre TTC - Den Oever Tidal Site	AAU - Nissum Bredning QUB - Portaferry Tidal Test Centre SEAI_OEDU - Wave Site Data Galway	UNEXE – South West Mooring Test Facility
Large Scale Site	EVE – Biscay Marine Energy Platform SEAI-OEDU - Belmullet Test Site	No Infrastructure Currently Available	DTU - Database of Wind Characteristics DTU - Mobile Offshore Wind Measuring DTU - National Wind Test Site ECNETH - Database of Measurements on OWEZ NTNU - Full Scale Wind Measurement Station PU - HF Radar for offshore wave/current SEAI-OEDU - Belmullet Test Site Data USTUTT - Offshore Nacelle LiDAR	EVE - Mutriku OWC Plant FH-IWES – Offshore Field Test Facilities WaVEC – OWC Pico

Table 2: Accessible MARINET facilities listed on the funding scheme website

The INORE (International Network on Offshore Renewable Energy) International Collaboration Scheme was set up to assist cross border research. The sums available are relatively small (up to €500 per applicant in 2013) and therefore the scheme is not geared towards funding equipment purchases or facilities access costs. Instead successful applicants can utilise funds to pay for international travel expenses and other expenditure arising from collaborative journal paper creation. This scheme is therefore suited to research dissemination after laboratory experiments have been conducted. Further details can be found on the INORE website (http://www.inore.org/grants/)

Provider	Facility
Deltares Delft, the Netherlands	Delta Flume, Vinje Bassin, Schelde Flume, Rotating Anular Flume, Water & Soil Flume, and GeoCentrifuge
CNRS, France	Coriolis platform (Grenoble) Stratified Flume (Toulouse)
DHI Horsholm, Denmark	Shallow Water Basin and Offshore Wave Basin
HSVA Hamburg, Germany	Large Ice Model Basin (LIMB) and Arctic Environmental Test Basin (AETB)
LUH Hannover, Germany	Large Wave Channel
Marintek Trondheim, Norway	Ocean Basin
NTNU Trondheim, Norway	Bay of Hopavågen with the Sletvik field station
Teknillinen Korkeakoulu Espoo, Finland	Ship Laboratory / Ice Tank
University of Hull, UK	Total Environment Simulator
CIEM Barcelona, Spain	CIEM Barcelona, Spain

Table 3: Accessible HYDRALAB IV facilities listed on the funding scheme website

3.2 Country specific funding schemes

With the focus of the MERiFIC project on the adoption of marine renewable energy in France and the United Kingdom, relevant funding schemes for these two countries are summarised in this section.

3.2.1 United Kingdom

In the past Regional Development Agencies (RDAs) enabled University facilities access to organisations and members of the public with promising inventions, including MRE devices. RDAs were abolished in 2012 and this form of public funding no longer exists. The remit of most UK engineering research institutions (i.e. the Engineering and Physical Research Council, Royal Society, Royal Academy of Engineering, Institution of Engineering and Technology, Institution of Mechanical Engineering and Institution of Civil Engineering) includes MRE. Hence there are potentially a wide range of applicable funding schemes which can be used for equipment loan, facilities access and international travel for applicants based in the UK. Whilst these projects can involve the collaboration of industrial partners, the eligibility of research funding tends to be limited to projects based at Universities and other Higher Education establishments (e.g. EPSRC Responsive Mode funding). Recent examples of stand-alone funding competitions which are more suitable for device developers include:

- *Marine energy: Supporting array technologies* (2012, £10.5m invested by the Technology Strategy Board, Scottish Enterprise and the Natural Environment Research Council)
- *The Marine Energy Array Demonstrator (MEAD) scheme* (2012, £20m invested by Department of Energy and Climate Change)
- *NER300 - EU Funding Mechanism for Renewables Demonstration Projects* (2013, EU)
- *WATERS2 Wave and Tidal Energy: RD&D Support* (2012, £6m invested by the Scottish Government)

- *The Marine Renewables Commercialisation Fund* (2012, £18m invested by the Scottish Government and administered by The Carbon Trust)
- *Convergence European Regional Development Funding: ERDF* (2013, Cornwall recently obtained £2m funding)

Another noteworthy competition is the on-going *Saltire Prize* worth £10m (Scottish Government). This will be awarded to any of the five shortlisted projects able to generate over 100GWh during a continuous two year period at tests sites located in Scotland.

3.2.2 France

Clearly a lot of the funding schemes in the UK originate from the Scottish Government and/or EU funding. There are currently less specific schemes running in France, and the few that are available are administered on a national and regional level. The national body ADEME (Agence de l'Environnement et de la Maitrise de l'Energie or Environment and energy efficiency agency) launched in 2009 a call entitled *Appel à Manifestations d'Intérêt (AMI) Energies Marines* utilising EU NER 300 funding for 5 R&D projects including two tidal turbines (SABLLA D10 and ORCA), two floating wind turbine projects (VERTIWIND and WINFLO) and one wave energy project (S3). In order to continue to support MRE development, ADEMA have recently announced another call for expressions of interest as part of the €1,275m Programme des Investissements d'Avenir (*Future Investment Programme*) which since 2010 has supported the development of renewable technologies [13]. Particular emphasis has been placed on the mitigation of technological blocks which are preventing the widespread deployment of MRE and may be common to several types of MRE device (e.g. installation challenges). Expressions of interest for wave energy device demonstrator projects are also encouraged. Whilst another state-run agency l'Agence nationale de la recherché (French national research agency) do not currently have any MRE related funding calls, based on previous renewable energy and decarbonisation schemes it is likely that MRE technologies will be supported in the future.

Through regional technology clusters[6] the Fond Unique Interministeriel (FUI) supports collaborative research and development projects which may lead to commercialised products or services in the short or medium term. Particular companies from the clusters are also grouped by specialism under umbrella groups. Typical recipients range from large companies through to small and medium sized enterprises (SMEs) as well as research institutes, for example a recent wet mate connector project [14]. Other funding sources include Fonds Ministériel Spécifique (Ministerial funding for special projects), Agence De l'Environnement and similarly to the UK, ERDF funds. Interest-free loans (which are repaid if a project is successful) are available from OSEO Anvar for small companies (less than 2000 employees) and SMEs.

On a more localised level, a significant amount of funding for projects carried out by companies located in the Pole Mer Bretagne cluster originates from Région Bretagne, Départements and Communautés d'agglomération de Bretagne (Brittany administrative districts and urban communities).

[6] For example, MERiFIC partners, Pole Mer Bretagne.

4 Transnational research case study: MERiFIC Work Package 3.5

The purpose of MERiFIC is to foster collaboration between project partners located in Cornwall and Finisterre with the unified aim of facilitating the development of marine renewable energy (MRE) for remote communities. Work packages within the project are focused on diverse topics ranging from resource assessment and community adoption of MRE. Work package 3.5 is an investigation of MRE device dynamics, in particular the use of synthetic mooring lines for device station-keeping. As well as focusing on the operational performance of ropes constructed from Nylon fibres, the long-term conditioning of this material in the marine environment is also being studied. The investigation involves the collaboration of the Renewable Energy group based at the University of Exeter, Penryn (UK) and the Materials & Structures Group based at IFREMER, Plouzané (France). Utilising the equipment and expertise at both facilities, the following collaborative activities have been conducted to-date:

		Facility	
		IFREMER	**University of Exeter**
1.	**Analysis of full-scale mooring data**	-	Mooring loads measured during the first SWMTF deployment in Falmouth Bay (June 2009 and September 2011)
2.	**Material testing and analysis**		
2.1	**Rope scale**	High magnitude, low frequency loads using 100 Tonne tension machine	Low magnitude, high frequency loads using DMaC facility
2.2	**Yarn scale**	Froude and N/Tex scaled loading regimes	-
2.3	**Fibre scale**	Scanning electron microscope imaging of new and aged yarns	-
3.	**Scale model testing of the SWMTF**	1:5 scale model tested in the salt water basin at IFREMER	-
4.	**Numerical modelling**	Hydrodynamic parameter calculation and dynamic numerical simulations (*HYDROSTAR* and *Deeplines*)	Dynamic numerical simulations (*Orcaflex*)

Table 4: MERiFIC WP3.5 activity summary (April 2012-May 2013)

This integrated scheme of work draws upon measurements recorded by the South West Mooring Test Facility (SWMTF). Mooring loads measured by this facility may be representative of loads experienced by buoy-like wave energy converters (WECs) or other small offshore equipment. Representative loading regimes have been applied to rope samples (and rope yarns) using tension testing equipment in the Materials & Structures laboratory at IFREMER and the University of Exeter's Dynamic Marine Component (DMaC) facility. Comparisons between the performance of new rope samples and 'aged' samples (taken from one more mooring rope deployed on the SWMTF for 18 months) are currently in progress. Particular tests have been replicated at both locations to harmonise test procedures at both facilities and to check measurement repeatability. Scanning electron microscope (SEM) equipment has also been used to produce highly magnified images of new and aged rope fibres. To determine the scalability of buoy and mooring line dynamics, a 1:5 scale model of the SWMTF was subjected to scaled wave conditions in the salt water wave basin at IFREMER. Several mooring line variants were tested to determine the influence of mooring line condition on buoy response, for example small-scale mooring lines were constructed to represent the Nylon rope used on the SWMTF in both new and 'aged' states. The numerical simulation of the dynamic responses measured in the IFREMER wave flume is another collaborative element of work package 3.5. The purpose of this exercise was to conduct a baseline study in order to compare the performance of two commercially available mooring line simulation packages *Deeplines* (Principia) and *Orcaflex* (Orcina) using the geometry of the 1:5 SWMTF scale model and hydrodynamic parameters calculated by *HYDROSTAR* (VeriSTAR). Utilising experimental data, both of the numerical models were incrementally verified. Results from quasi-static and dynamic analysis will appear in several forthcoming publications [15-17].

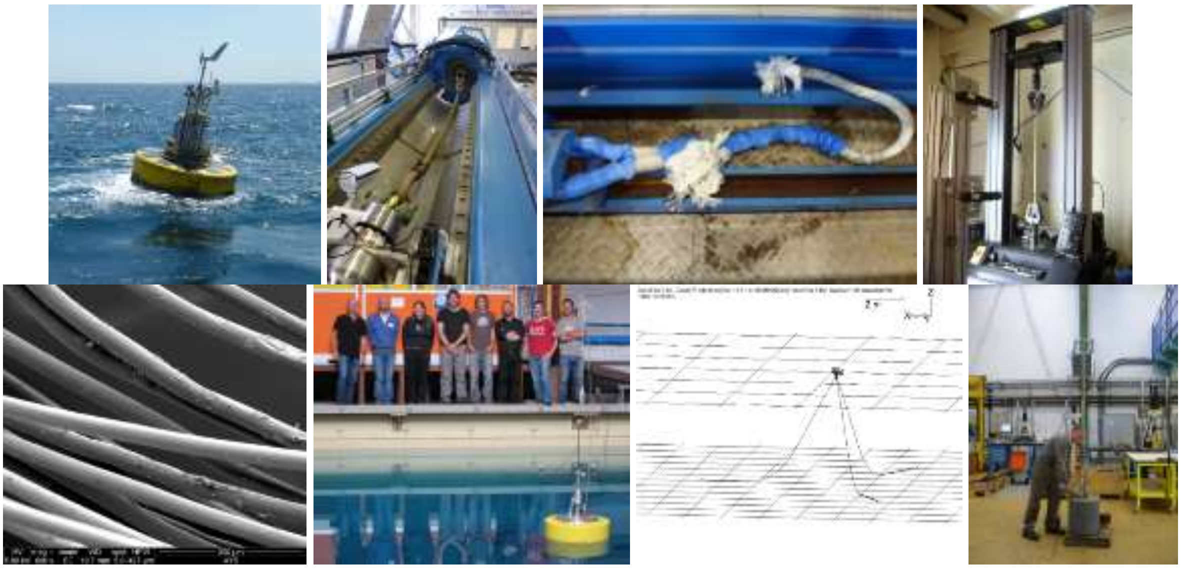
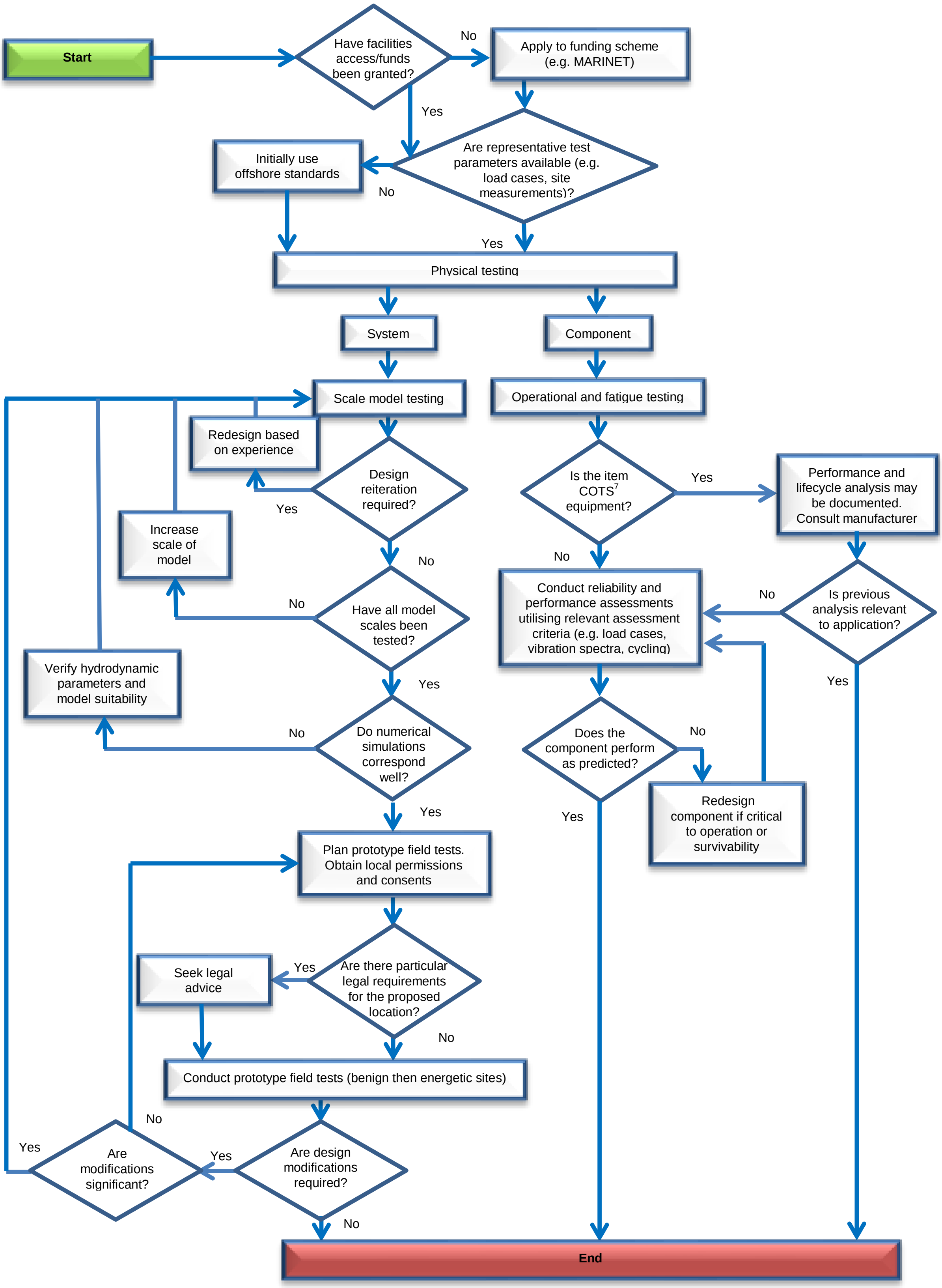


Figure 2: Photo montage of MERiIFC WP3.5 activities (*clockwise from top left*) SWMTF in Falmouth Bay, DMaC test facility, load-to-failure test at IFREMER, yarn tensile testing at IFREMER, SEM image of an aged rope yarn showing fibre wear, 1:5 scale model of the SWMTF, *Orcaflex* simulation screenshot, natural period rope tests at IFREMER

5 Proposed generic physical test procedure

Figure 3: A suggested procedure for transnational physical testing



[7]Commercial Off The Shelf

The flow chart in Figure 3 outlines a simplified procedure that could be adopted for physical testing on a transnational basis. The chart is intended to be a tool to assist the planning process rather than exhaustive list of stages to obtain transitional facilities access. To stimulate further thought, Table 5 lists considerations which may be relevant for transnational testing stages. For greater detail regarding particular elements of the chart it is recommended that relevant guidelines are consulted including those listed in this report.

Topic	Considerations
Funding	*Eligibility of project for local, national and transnational funding. Costing of project to include allowances for unforeseen events (e.g. delays, equipment failure etc.)*
Organisation of project partners	*Delegation of roles and responsibilities of collaborating partners. Assignment of project milestones and regular status reporting. Accountability in case of non-compliance*
Intellectual Property	*Contractual non-disclosure agreements with involved parties*
Legal requirements	*Consent for scheme of work with local and/or national authorities. Compliance with relevant legislation of host country. Insurance policies (e.g. public liability) and certification*
Environmental impacts	*Environmental impact assessments. Seasonal site access restrictions*
Transportation logistics	*Hire of transportation and vessels. Clearance of equipment and goods through country borders (e.g. customs)*
Installation and recovery	*Weather windows. Equipment availability and cost. Spare equipment provision in case of failure at site*
Safety and risk mitigation	*Compliance with health and safety practices. Detailed risk assessment of proposed work*

Table 5: Possible topics of consideration during project planning

6 References

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[17] Harnois, V., Weller, S., Le Boulluec, M., Davies, P., Le Roux, D., Soule, V., and Johanning, L. (TBD) Experimental and Numerical Investigation of a Small-scale Mooring Test Facility model. *In preparation*

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AFNOR CERTIFICATION

Certificat
Certificate

N° 2009/33967.1

AFNOR Certification certifie que le système de management mis en place par :
AFNOR Certification certifies that the management system implemented by:

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for the following activities:

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155, rue Jean Jacques Rousseau FR 92138 ISSY-LES-MOULINEAUX CEDEX

(Liste des sites certifiés en annexe n° 1)
(List of certified locations on appendix n° 1)

Ce certificat est valable à compter du (année/mois/jour) *This certificate is valid from (year/month/day)*	**2012-11-14**	Jusqu'au *until*	**2015-11-13**

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Annexe
Appendix

Annexe / *Appendix* n° 1

N° de certificat / *certificate n°*

2009/33967.1

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Liste complémentaire des sites entrant dans le périmètre de la certification :
Complementary list of locations within the certification scope:

Centre de Bretagne Technopole Brest Iroise ZI la Pointe du Diable BP 70 FR-29280 PLOUZANE
Centre Atlantique Rue de l'Ile d'Yeu BP 21105 FR-44311 NANTES CEDEX 3
Centre de Méditerranée Zone Portuaire de Brégaillon CS 20330 FR-83507 LA SEYNE-SUR-MER CEDEX
Centre Manche Mer du Nord 150, Quai Gambetta BP 699 FR-62321 BOULOGNE-SUR-MER CEDEX
Centre du Pacifique Taravao BP 7004 PF-98179 TARAVAO

Station de Port-en-Bessin Avenue du Général de Gaulle BP 32 FR-14520 PORT-EN-BESSIN
Station de Concarneau Station de Biologie Marine Place de la Croix BP 40537 FR-29185 CONCARNEAU CEDEX
Station de la Trinité-sur-Mer 12, rue des Résistants FR-56470 LA TRINITE-SUR-MER
Station de Lorient 8, rue Francois Toullec FR-56100 LORIENT
Station Ifremer CRESCO Dinard 38, rue du Port Blanc BP 70134 FR-35801 DINARD CEDEX
Station d'Argenton Presqu'Ile du Vivier FR-29840 ARGENTION-EN-LANDUNVEZ
Station de Bouin Polder des Champs FR-85230 BOUIN
Station d'Arcachon Quai du Commandant Silhouette FR-33120 ARCACHON
Station de la Rochelle Place du Séminaire BP 7 FR-17137 L'HOUMEAU
Station de Bidart 1, allée du Parc Montaury FR-64600 ANGLET
Station de Palavas-Les-Flots Chemin de Maguelone FR-34250 PALAVAS-LES-FLOTS
Station de Corse Immeuble Agostini SCI Endajola-Pastoreccia ZI de Bastia-Furiani FR-20600 BASTIA
Station de la Tremblade Avenue du Mus de Loup Ronce Les Bains FR-17390 LA TREMBLADE
Station de Sète Avenue Jean Monnet BP 171 FR-34203 SETE CEDEX

Délégation des Antilles 79, route de Pointe-Fort MQ-97231 LE ROBERT
Délégation de la Réunion Rue Jean Bertho BP 60 RE-97822 LE PORT CEDEX
Délégation de Guyane Domaine de Suzini BP 477 GF-97331 CAYENNE
Délégation de Nouvelle-Calédonie Quai des Scientifiques BP 2059 NC-98846 NOUMEA CEDEX