

Annual Report

20

21



FRANCE
ENERGIES
MARINES

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EDITORIALS



It can be said that the ability to write a summary, a difficult exercise if ever there was one, is proportional to the number of events to be considered; 2021 therefore sets a challenge in terms of its overview and the future prospects it entails.

The position I have been generously entrusted with at France Energies Marines nevertheless gives me the advantage of a dual viewpoint: that of actor and observer. I will therefore not dwell on the events that curbed our capacity to take action, but rather I shall take advantage of them to put things into perspective.

2021 was a patchwork year, pieced together with, if not contradictory, at least contrasting events; calm and violence in the world, essential reflection on our activities and the need for action revealed by the urgency of social, climate and strategic issues... Against this backdrop of water and fire, France Energies Marines continued to steer its course and adapt to a world that must be remodelled to face all kinds of pressures.

“Those who support us—the French State, public and private entities—made no mistake in doing so and have renewed their commitment.”

Now is the time to safeguard and cultivate our unity and our enthusiasm: public and private, social and technological, environmental and strategic, our actions must reflect our ambitions. Our wealth lies above all in our people, who form committed, efficient teams. Those who support us—the French State, public and private entities—made no mistake in doing so and have renewed their commitment.

This review demonstrates the quality and validity of the projects conducted at France Energies Marines.

Many challenges remain, and to echo those who express their interest, I would like to highlight the importance of promoting our R&D projects, disseminating knowledge and uniting territories in the acceptance of these new low-carbon production methods.

Jean-Philippe Pagot,

Chairman of France Energies Marines SAS



In 2021, to support a growing number of stakeholders across the offshore renewable energy sector, France Energies Marines ventured more often and further offshore to acquire data and to test technical solutions and procedures. To do so, the Institute pursued its growth, with a 50% increase in its workforce and budget. Its scientific rigour was demonstrated before Hcéres, the French public service agency responsible for the periodic evaluation of all State-contracted higher education and research institutions in France. Finally, like all companies, the simplified joint-stock company, or SAS, produced a financial result that was deemed satisfactory, with equilibrium restored. These successes were pivotal when asking our members and the French State to renew their commitments.

While this annual report widely covers our collaborative projects conducted within national and European contexts, it cannot possibly convey all the details of the work achieved, which also saw strong growth this year, for the benefit of our public and private partners. The construction of bottom-fixed wind farms, the imminent installation of new pilot floating wind farms and the global progress of ocean energies have helped to drive this momentum.

“We strive to continue to methodically demonstrate that collaborative research ensures that well-founded, useful solutions will progress further and faster.”

However, on a graver note, 2021 will be remembered as a prosperous year of economic recovery, marked with a sudden heightened awareness of the climate emergency, at a time when the economy was being reinvented in response to a still-evolving health crisis. At the time of writing of this editorial, in 2022, this brief lull marked with certainties may be seen as a valuable respite. The international context has fanned new flames, those of energy independence, which calls for an even faster roll-out of marine energies, which are clearly identified as meeting the criteria of decarbonisation and resilience. Our research institute was created to reduce time-to-market for these solutions.

Rather than revelling in self-satisfaction at this rising trend which may appear favourable to us, we strive to continue to me-

thodically demonstrate that collaborative research ensures that well-founded, useful solutions will progress further and faster. To illustrate this point, this report develops a wide range of themes related to our activities, with emphasis on the applicable results whenever investments are possible. Our team channels all its efforts into achieving this ambition.

Yann-Hervé De Roeck,

Executive Director of France Energies Marines

01

IDENTITY



is the Institute
for the Energy Transition
for offshore renewable
energies.

A 60-strong
multidisciplinary team



80+ partners

WORLDWIDE

A public-private partnership

supported by the Investments for the Future Programme



Headquarters in **BREST**
Offices in **NANTES**
and **MARSEILLE**



Involvement in over
65 R&D projects
since 2012



30% of activities
devoted to R&D services



€6 million
annual budget

Mission

To define, set up and apply the scientific and technical environment required to overcome the obstacles related to the development of ORE technologies while ensuring optimal environmental integration.

Position

France Energies Marines sets itself apart with its cross-cutting approach through which it is able to provide the entire sector with tested tools to:

- › Bring down levelised energy production costs through global optimisation by taking into account site conditions and adapting the technologies,
- › Cut back farm project financing costs by developing standards tailored to OREs,
- › Reduce farm construction duration by providing consultation methods and recommendations in particular relating to environmental integration;

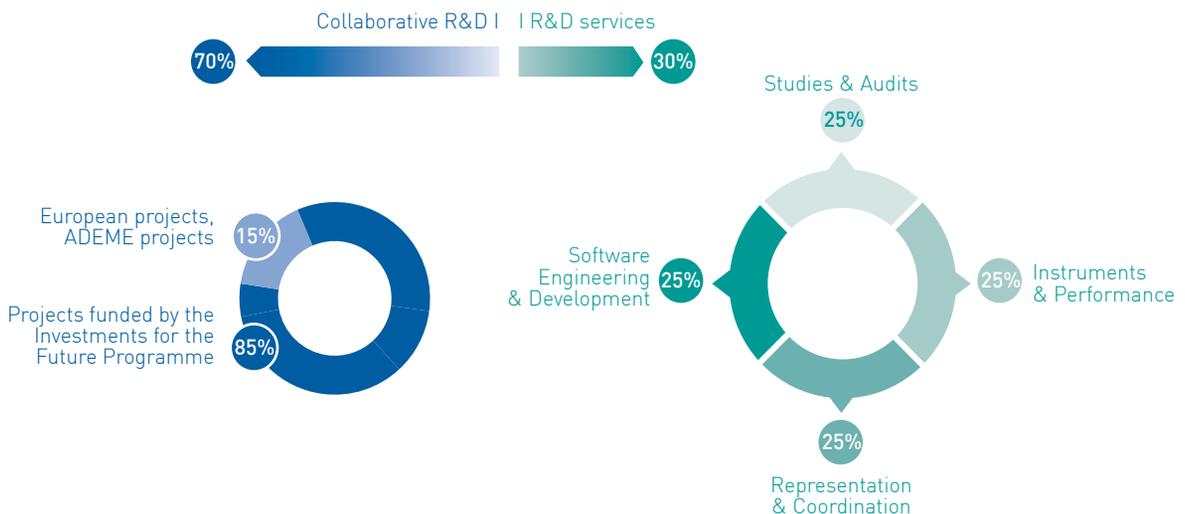
- › Boost the sector's visibility through resource pooling.

The Institute provides services across the full range of ORE technologies: bottom-fixed and floating off-shore wind energy, tidal and wave turbines, ocean thermal energy conversion, tidal energy, and osmotic energy.

Activities

The Institute's activities are largely concentrated around collaborative R&D, encompassing research as well as project setup, coordination and scientific guidance. To ensure the success of its development model, France Energies Marines also provides R&D service offerings based on detailed market analysis and tailored to the needs of sector stakeholders.

Breakdown of France Energies Marines' activities





3 QUESTIONS for... Jean-François Filipot

*Scientific Director
France Energies Marines*

What is the France Energies Marines scientific and technological roadmap?

It is a document that has laid out the Institute's R&D activities ever since its creation. Each of the four programmes is broken down into different axes and sub-axes. For each of the sub-axes, the context, the industrial roadblocks and the R&D strategy for the next five years are described. The roadmap is jointly drafted by our team and our members. It is reviewed by our Scientific and Technological Committee, composed of eight independent, international experts, and is validated by the General Assembly.

Why was it revised in 2021?

The first roadmap was prepared in 2011 at the time of the call for proposals for institutes of excellence in the field of low-carbon energy. It has been revised twice since then. In 2021, we completely overhauled the roadmap, in synergy with the preparation of our assessment by the High Council for the Evaluation of Research and Higher Education, Hcéres. This document is regularly updated, because the priorities of the ORE sector evolve, industrial issues change according to the maturity of the sector and roadblocks are regularly eliminated thanks to the R&D projects carried out.

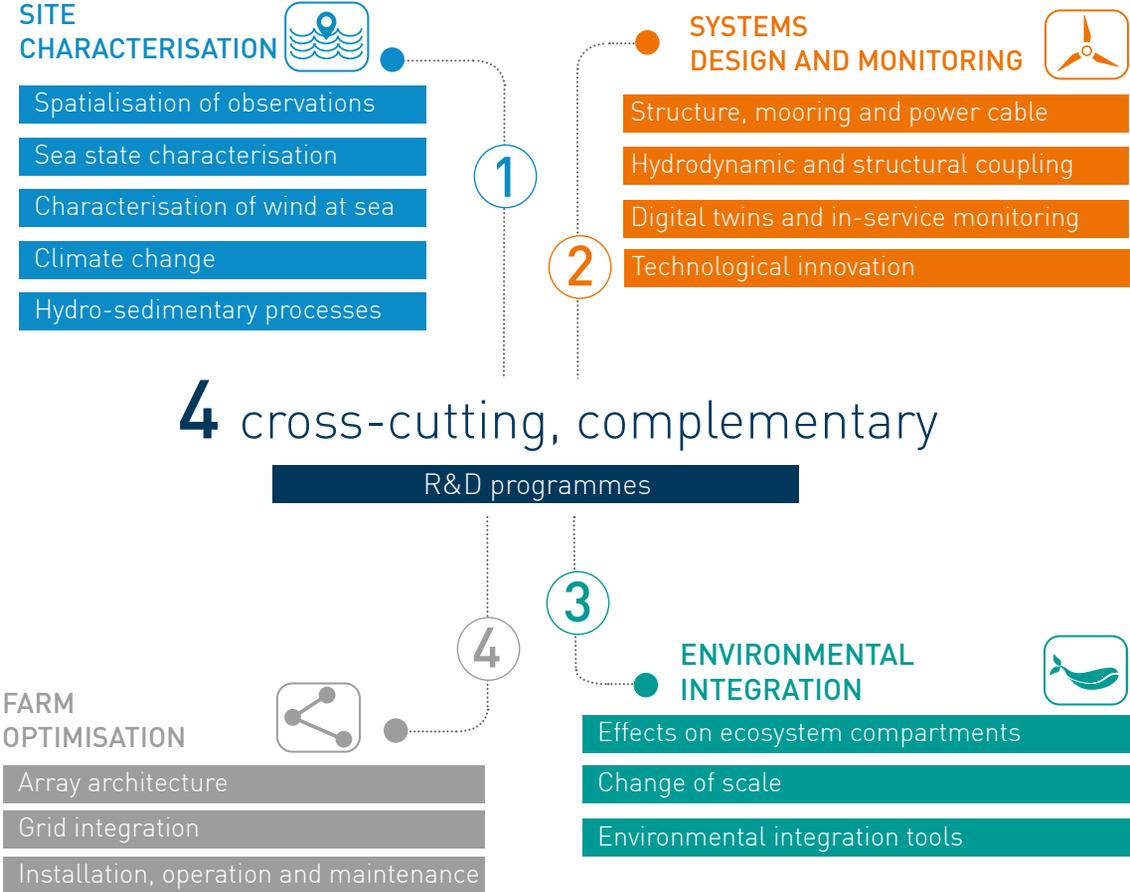
What are the main changes in the new version of the roadmap?

In view of the evolution of the French ORE sector over the last five years, the 2021 roadmap has a strong focus on topics related to the development of offshore wind. We will be channelling our efforts into the characterisation of offshore winds and atmospheric turbulence, and continuing our work on the observation and modelling of extreme winds and waves. The latter will be addressed through the prism of climate change. In terms of systems design and monitoring, the subject of digital twins of floating wind turbines is set to gain momentum, without neglecting studies on dynamic cables and moorings. At farm scale, the optimisation of offshore operations appears crucial to reduce the cost of floating wind power. Energy storage and power conversion solutions for energy produced at sea and converted into hydrogen are also a key focus. In terms of environmental integration, the interactions between ORE farms and megafauna, from the scale of a single turbine to that of one or more farms, are at the heart of the industry's concerns. Modelling the cumulative effects of ORE together with other human activities on ecosystems, against a backdrop of climate change, is an innovative approach advocated by the sector's stakeholders.

Themes

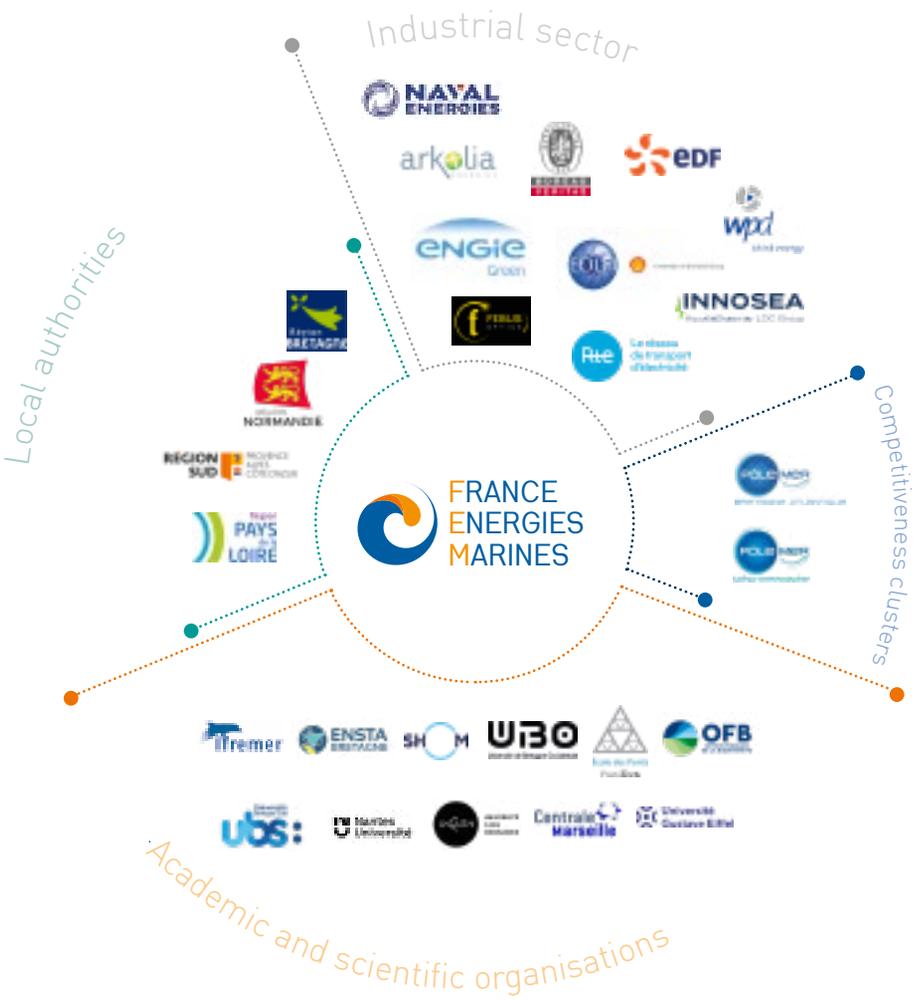
In order to take into account the main ORE development challenges and the objectives of national players, France Energies Marines' scientific and technological roadmap defines 4 research programmes.

Designed to be cross-cutting and complementary, they focus on site characterisation, design and monitoring, environmental integration, and farm optimisation. The collaborative R&D activities and services are all set within this framework.



Governance

The Institute's activities are managed by a joint-stock company (SAS) built around a public-private partnership that brings together 18 shareholder members and 9 contributor members—all key French ORE sector players—from industry, academic and scientific organisations, local authorities and maritime competitiveness clusters.



Selection of the Institute's collaborative projects

As part of its collaborative R&D activity supported by the Investments for the Future Programme, France Energies Marines has set up a selection process for new projects promoting excellence. Every two years, projects are set up through a very open approach

shared by all members of the Institute. It is also possible to propose more restricted projects.

The selection process for both types of projects is composed of three main phases.

1 Identification of priority industrial focal issues

- For **“open” projects**, the industrial members of France Energies Marines present the bottlenecks to be overcome and propose topics related to the Institute's roadmap. All of France Energies Marines' members and staff then work together in groups to identify high-priority issues.
- For **“restricted” projects**, the themes are directly defined with industrial members of France Energies Marines involving a restricted group of partners.

Pre-proposals

2 On the basis of the selected topics, pre-proposals are drafted. At this stage, the scope of action of each member of the consortium is defined and an initial provisional budget is prepared.

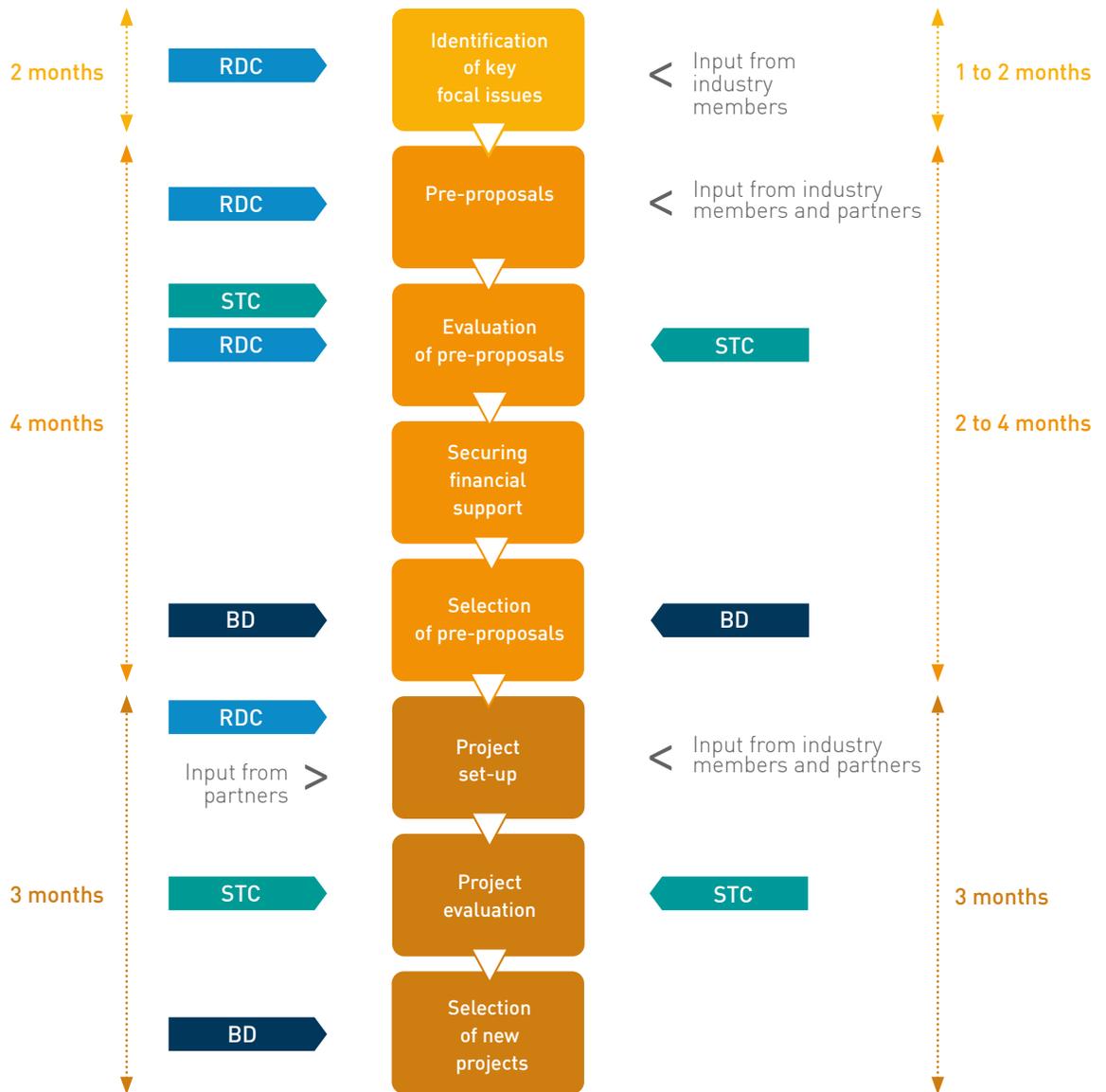
- For **“open” projects**, these pre-proposals are reviewed by the members of France Energies Marines, the Scientific and Technological Committee composed of independent international experts, and the Institute's management team. Then, financial pledges from stakeholders are gathered. Building on these different elements, the Board selects the most promising pre-proposals.
- For **“restricted” projects**, the pre-proposals are evaluated by the Scientific and Technological Committee and the Institute's management team. The funding plan is drawn up by the project partners and France Energies Marines. The Board then selects the most relevant pre-proposals.

3 Project set-up

Based on the evaluations received and funding obtained, each project is prepared in terms of its scientific, organisational, human resources and budgetary aspects. This phase results in a detailed document, around 40 pages long, which is then evaluated by the Institute's management team and the Scientific and Technological Committee. Taking into account the different appraisals, the Board validates the new projects to be launched.

“Open” projects

“Restricted” projects



RDC
The **Research & Development Committee** which brings together all the Institute's members

BD
The **Board of Directors** made up of 10 members elected from the Institute's shareholders

STC
The **Scientific and Technological Committee** composed of 8 independent international experts



3 QUESTIONS for... Senu Sirnivas

*Member of France Energies Marines' Scientific and Technological Committee
Mechanical engineering researcher, National Renewable Energy Laboratory, USA*

How did you get involved in our Scientific and Technological Committee?

One of my colleagues from the National Renewable Energy Laboratory regularly attended FOWT, an event dedicated to floating offshore wind turbines. I imagine that's where she met people from the France Energies Marines team and they asked her to join the Institute's Scientific and Technological Committee. As she was very busy, she asked if I would be willing to sit on the Committee. At the time, I didn't know France Energies Marines at all. That's how ties are formed: you go to conferences, you meet people and you start working together.

Can you explain the role of this Committee?

The main role of the Committee is really to guide France Energies Marines in its research to meet the sector's needs. We examine the proposals that come in, give advice, and ask questions. This improves the quality of the projects put forward to the Institute's Board of Directors, which makes the final decision on the projects selected. The other strength of this Committee is that it is composed of researchers from different backgrounds, laboratories and countries. This leads to very rich and stimulating discussions.

What do you appreciate most about being involved in this Committee?

What I appreciate the most is the international nature of Committee's membership. There are people from Norway, Denmark, the UK and the USA. There is a lot of communication about the type of research each person is doing and the experience shared. We are therefore able to offer advice on what work needs to be done and what is not a priority or not relevant. I think that discussions like these are very valuable.

Being a member of this Committee is very useful, not only for France Energies Marines, but also on a personal level and, to a greater extent, for the National Renewable Energy Laboratory. For example, if the Institute carries out research in a given field, there is no point in us repeating the same thing, rather we should collaborate or do something different. The aim is to carry out work with high added value.



3 QUESTIONS for...

Lisa Garnier

R&D Manager for Biodiversity

Damien Saffroy

Marine environment and consultation officer

Réseau de Transport d'Electricité (RTE)

Why did you decide to take part in the SPECIES project? What was your role?

The SPECIES project aimed to monitor the impact of underwater power cables on marine flora and fauna. For RTE, it was quite natural to become a partner in such a project. In addition to providing financial support through our R&D department, our role was mainly to provide feedback from our own environmental impact studies on underwater power cables, to provide data and to contribute to discussions on project objectives and protocol adaptation. In a nutshell, we played the role of an industrial stakeholder.

What interested you particularly about this project?

The results! They were essential both to improve knowledge on this subject and to optimise our future impact studies and provide answers for public consultation phases prior to new projects. But if that had been all, we could have contented ourselves with contributing only financially. In reality, it was very important for us to be truly involved in the project to give substance to the partnership dimension in which we strongly believe. As an industrial firm, we could, for instance, help the research teams to appropriately design their protocols. We were very involved in discussions on the study of magnetic fields and heat emissions, which are complex subjects that call for a particular area of expertise.

What will you take away from this project?

SPECIES was a real success, despite a few unforeseen difficulties. We obtained very relevant results that can be exploited today. With the future development of wind farms and their grid connections, further research will become essential. In this context, SPECIES paves the way with real advances in terms of methodology, both in the laboratory and in situ. We are also very satisfied with the links established with the various research teams: the project results came to fruition thanks to true collaboration and mutual trust between industry stakeholders and scientists.

02

HIGHLIGHTS OF 2021

Cross-cutting activities |

January

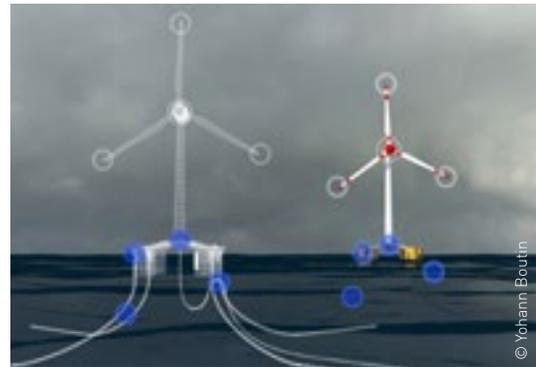
Yann-Hervé De Roeck elected for 2 years as Chair of IEA-OES, the Ocean Energy Systems Technology Collaboration Programme



Systems design & monitoring |

January

Publication of an instructional video explaining the development of a digital twin of a floating wind turbine mooring (SUBSEE 4D project)



Environmental integration |

March

Webinar and recommendations report on the potential effects of underwater power cables on benthic communities (SPECIES project)



Site characterisation I

March

Study of waves and marine flooding combining stereoscopy and *in-situ* measurements on the coastline (within the framework of the MARLIT project)



Systems design and monitoring - Environmental integration I

May

Buoy deployment off Groix & Belle-Île to study biofouling (APPEAL and ABIOP+ projects)



Environmental integration I

May

Overflights off Courseulles-sur-mer with a view to standardising tools and methods for monitoring marine megafauna at the scale of offshore wind farms (OWFSOMM project)



Cross-cutting activities |

May

Publication of the 2nd annual report on the evolution of the ocean energy sector in Europe (OCEANSET project)



Site characterisation |

June

Multichannel seismic reflection data acquisition campaign off Groix & Belle-Île (GEOSISMEM project)



Institute |

July

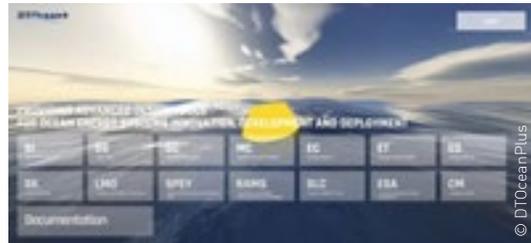


wpd offshore France, a pioneer in offshore wind energy, became a contributing member of France Energies Marines

Farm optimisation |

August

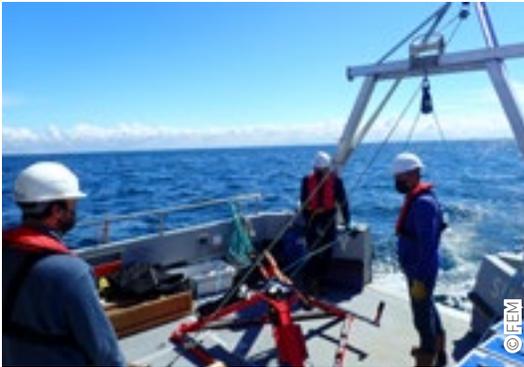
Delivery of a software suite for the design and optimisation of tidal and wave farms (DTCOCEANPLUS project)



Site characterisation I

September

End of bathymetric and current measurement campaigns off Dunkirk (DUNES project)



Site characterisation I

October

Webinar on the characterisation of extreme sea states with breaking waves (DIME project)



Institute I

November



FEBUS Optics, an SME that develops fibre optic sensor systems to monitor infrastructure integrity, became a contributing member of France Energies Marines

Environmental integration I

December

Kick-off webinar for a project focusing on developing an acoustic telemetry network to monitor fish populations in the Channel (FISH INTEL project)



SITE CHARACTERISATION

The goal of this programme is to ensure better selection of farm installation areas, while continuing to streamline turbine design and marine operations. Site characterisation now focuses on drawing up an intra-site study of wave, current, wind and temperature fields. This is accompanied by a description of the high frequency variability in resources, a key piece of information, yet which is poorly known, that is required to calculate the energy yield and predict the fatigue of ORE systems.

The characterisation of the temporal and spatial variability of resources explores new *in-situ* and satellite observation methods. Over and above these qualification needs, knowledge of extreme conditions is an indispensable prerequisite to guarantee the offshore survival of ORE systems. Wave and current couplings have a strong influence on each of the resources and must be taken into account during the design phase. In order to be quantified, research is required to understand the underlying physical processes and to be able to configure them in numerical models. Meanwhile, the development of short term metocean forecasting tools will enable the optimisation of offshore operations related to farm installation, maintenance and dismantling.

The seabed on which the devices are installed is often complex in terms of its morphodynamics and geology. It is therefore essential to have reliable data and characterisation methodologies before deciding to install systems. Against a background of climate change, the nearshore zone must also be precisely characterised due to its sensitivity to cable shore landing operations. These operations often give rise to questions during consultation phases prior to farm deployment.

2021 key figures:



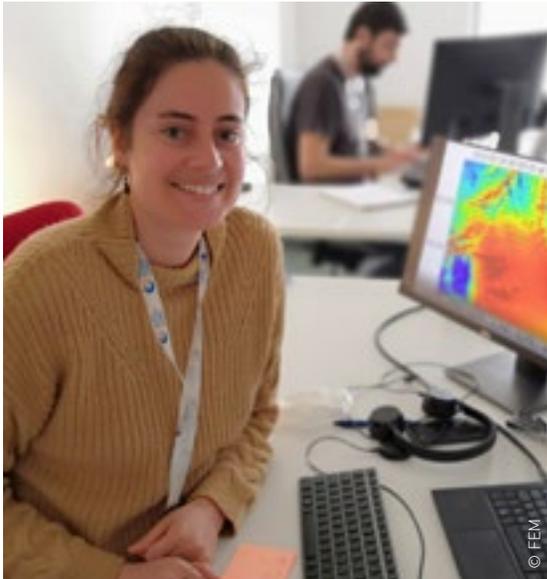
10 collaborative projects



€17,200K cumulative budget



82 different partners



3 QUESTIONS for... Marie Cathelain

*Expert in atmospheric flow modelling
France Energies Marines*

Which R&D project are you involved in?

I work on the CASSIOWPE collaborative project, which aims to better characterise metocean conditions in the Gulf of Lion, with a view to supporting the deployment of floating wind farms in the Mediterranean. This area has specific environmental conditions: strong onshore winds generating particular sea states and winter storms inducing considerable turbulence. However, these configurations are not properly taken into account in the operational numerical models currently used. We are therefore developing a coupled modelling chain to assess the impact of air-sea interaction on the wind resource. A database comprising one year of wind, wave and current data will then be generated using this coupled simulation. We will thus be able to determine the precise conditions in which it should be used.

What is your role in the CASSIOWPE project?

I am the project leader, along with Jean-Luc Redelsperger, CNRS emeritus researcher at the Laboratoire d'Océanographie Physique et Spatiale (LOPS). In this capacity, I liaise between the project's various technical partners, while ensuring continuity in communications with the project's industry partners who fund the project. Whenever a new partner becomes involved in the project, I organise introductory meetings, and I regularly send out a newsletter to keep everyone informed of the progress of all the different tasks. Liaising with the project partners is really important to me. Thus, we organised the latest progress meeting at Toulon University, one of the academic partner in the CASSIOWPE project. In addition to my coordination role, I also work on technical tasks related to atmospheric modelling for coupled simulation.

What for you are the challenges and strengths of this project?

When I first started, the whole team was working from home and the CASSIOWPE project had started six months previously. So I had to quickly get onboard with little opportunity to physically meet the rest of the team.

I'm enjoying working on large-scale weather aspects, as I didn't have the opportunity to do so during my studies or previous positions. Working together with experts at Ifremer who have 30 to 40 years' experience in this field is incredibly enriching. At France Energies Marines, I work with three other experts in the modelling of sea states, ocean circulation and exchanges at the air-sea interface. The "wind" theme is relatively recent at the Institute. It's really motivating to contribute to the development of a new expertise based on which we can offer advanced R&D and a specific range of services.

ARCWIND

Adaptation and implementation of floating wind energy conversion technology for the Atlantic region



Technology I



Stages in the value chain I

Duration: 48 months | **Launched:** 2018

Objective:

› To assess the feasibility of floating wind farms in deep waters in the Eastern Atlantic.

Scientific and technical content:

- › Assessment of wind resources.
- › Assessment of sea state conditions for wind turbine design.
- › Adaptation and assessment of different types of floaters.
- › Experimental studies on the selected concepts.
- › Development of an array architecture comprising the components relating to installation logistics and maintenance planning.
- › Estimation of costs and economic feasibility.

2021 achievements:

› Review of the work on selecting the most appropriate sites for floating offshore wind turbines, and the design of the two technologies at the project's sites of interest with an estimation of the associated energy cost.

Partners:

This project is coordinated by *Instituto Superior Técnico*.



Total project budget: €3,920K

This project receives funding from the European Interreg Atlantic Area programme.







Wind characterisation for offshore renewable energy applications

Duration: 46 months | **Launched:** 2017 | **Completed:** 2021

Objective:

- › To improve the characterisation of extreme winds by combining atmospheric models with satellite and in-situ observations.

Scientific and technical content:

- › Extrapolation of surface winds from satellite data, at nacelle height.
- › Determination of the spatial variability of wind fields from high-resolution observations performed using synthetic aperture radar (SAR), and coupling with wind forecast models.
- › Trials in a wave tank fitted with a wind generator to study air-sea interactions during extreme events.
- › Improvement of the accuracy of atmospheric models by combining them with SAR observations, using machine learning methods.

2021 achievements:

- › Development of a methodology to determine the optimal position of floating lidar devices in order to measure the spatial variability of marine winds.
- › Experimentation in the University of Miami's wind-wave tank to further understand the effect of breaking waves on the radar signal for satellite wind measurements.
- › Development of an algorithm to determine fine-scale wind properties by combining satellite images and numerical model outputs.

2021 dissemination:

- › Publications:
 - Platzer P., *et al.* [2021] Probability Distributions for Analog-To-Target Distances. *Journal of the Atmospheric Sciences*, Vol. 78, pp. 3317-3335
 - Stringari C., *et al.* [2021] A New Probabilistic Wave Breaking Model for Dominant Wind-Sea Waves Based on the Gaussian Field Theory. *JGR Oceans*, Vol. 126, e2020JC016943
- › Event:
 - Organisation of a results presentation webinar in November

Partners:

This project is led by Ifremer and France Energies Marines.



Total project budget: €1,753K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Brittany, Normandy and Réunion.

This project is approved by the maritime cluster Pôle Mer Bretagne-Atlantique.



Experimentation in the University of Miami's wind-wave tank to gain a better understanding of the effect of breaking waves on the radar signal for satellite wind measurements.

CASSIOWPE



Characterisation of atmosphere-sea surface interactions for offshore wind energy in the Gulf of Lion

Technology I



Stages in the value chain I

Duration: 30 months | **Launched:** 2020

Objective:

- › To provide a database of high resolution observations of wind, wave and current fields, as well as a new numerical tool to model metocean conditions in the Gulf of Lion area.

Scientific and technical content:

- › Collection of available observation data to describe the complexity of metocean conditions in the Gulf of Lion.
- › Development of a new level 2 processing chain for synthetic aperture radar (SAR) images.
- › Development of a coupled numerical system and incorporation of new physical parameterisations.
- › Validation of the coupled model for the specific conditions.

2021 achievements:

- › Implementation of the coupled chain which is now to be rolled out for several weather events typical of the Gulf of Lion for a calibration and validation exercise, using different atmosphere, ocean and wave datasets.

Partners:

This project is led by the LOPS laboratory (Laboratoire d’Océanographie Physique et Spatiale) and France Energies Marines.



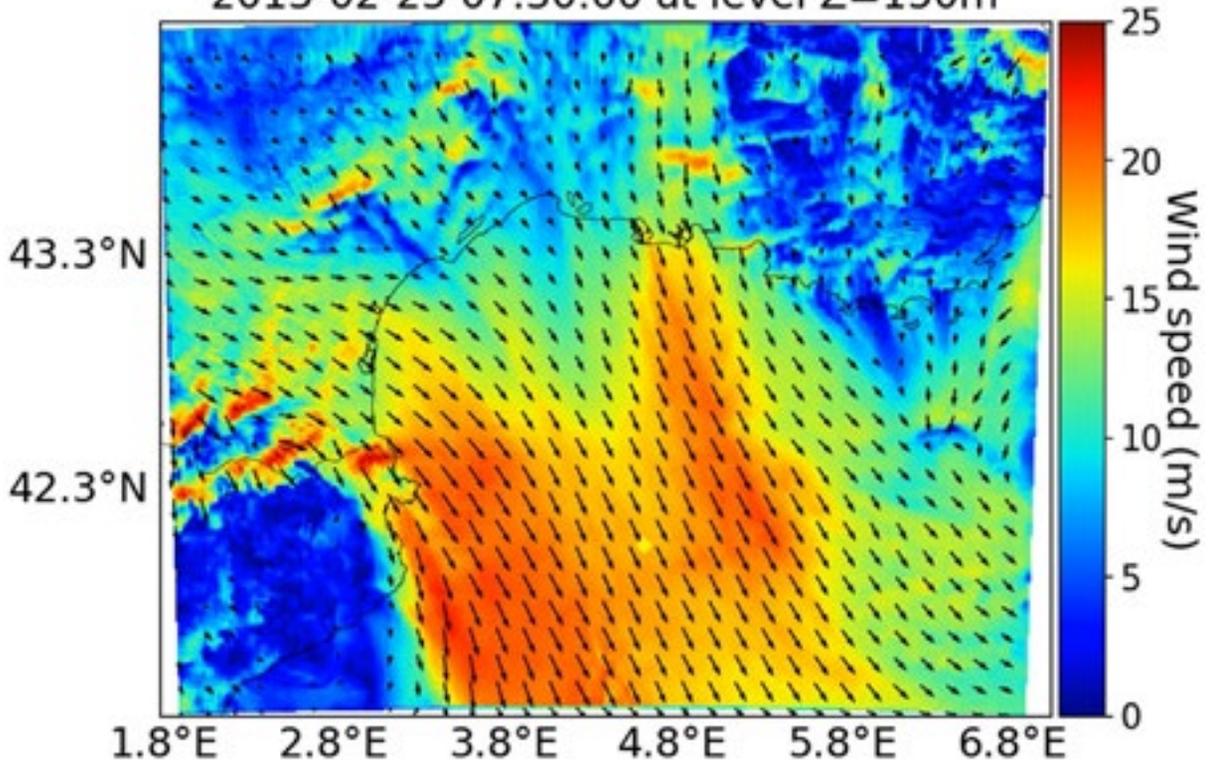
Total project budget: €1,290K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Provence-Alpes-Côte d’Azur Region and from the maritime cluster Pôle Mer Méditerranée.



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© CASSIOWPE

Simulation of a Mistral wind event by an atmospheric model (Meso-NH), an ocean model (CROCO) and a wave model (WAVEWATCH III) each forced by AROME WMED



Modelling and observations of extreme sea states with breaking waves for offshore renewable energies

Duration: 52 months | **Launched:** 2017 | **Completed:** 2021

Objective:

- › To improve the characterisation of extreme sea states with breaking waves by combining observations and modelling.

Scientific and technical content:

- › Use of deterministic simulations to determine the non-linear nature and precise kinetics of extreme sea states in the surf zone.
- › Implementation of a coupled ocean-atmosphere model to explore the role of interactions between wind and waves in storm and cyclone conditions.
- › In-situ measurements using an offshore lighthouse heavily exposed to storm waves and located on a bathymetric slope, allowing the structure to be used as a full-scale experimental device.

2021 achievements:

- › Continued documentation of occurrence statistics and properties of breakers under storm conditions through winter measurement campaigns at La Jument lighthouse, which is located in an area that is representative of the bathymetry of the future floating wind farm areas in Southern Brittany.
- › Finalisation of the development of a sea state model specific to storm conditions, which will constitute a reference tool for defining design standards relating to extreme sea states for ORE systems.
- › Finalisation of the development of a new phase-resolving sea state model to more accurately derive the kinematic and geometric properties of shallow breaking waves.
- › Preparation of a recommendation report for the industry, summarising all the results and outlining their applications in relation to offshore renewable energy systems.

2021 dissemination:

- › Publications:
 - Varying A., *et al.* (2021) A new definition of the kinematic breaking onset criterion validated with solitary and quasi-regular waves in shallow water. *Coastal Engineering*, Vol. 164, p. 103755
 - Stringari C., *et al.* (2021) Deep neural networks for active wave breaking classification. *Scientific Reports*, Vol. 11, pp. 1-12
 - Stringari C., *et al.* (2021) A New Probabilistic Wave Breaking Model for Dominant Wind-sea Waves Based on the Gaussian Field Theory. *Journal of Geophysical Research: Oceans*, Vol. 126, e2020JC016943
 - Stringari C., *et al.* (2021) Remote Sensing Observations of Dominant Breaking Waves in Intermediate to Deep Water from a Lighthouse During Storm Conditions. *Remote Sensing*
- › Presentations:
 - Filipot J.-F. (2021) Caractérisation de déferlantes géantes par stéréo-vidéo pour le design des systèmes EMR. Thematic days organised by the Association Francophone de Vélocimétrie Laser (AFVL), Virtual event, 25/03/2021
- › Event:
 - Organisation of a results presentation webinar in October

Partners:

This project is led by France Energies Marines.



Total project budget: €1,664K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Brittany, Normandy and Réunion.

The testing carried out at La Jument lighthouse receives funding from Crédit Agricole's 'Filière Mer'.

This project is approved by the maritime cluster Pôle Mer Méditerranée.



Re-commissioning the radar on La Jument lighthouse for larger-scale wave field mapping

DIMPACT

Designing floating wind turbines taking into account the impacts of energetic steep and breaking waves



Technologies I



Stages in the value chain I

Duration: 42 months | **Launched:** 2020

Objective:

- › To provide less conservative certification guidelines and an appropriate engineering tool taking into account the impact of energetic steep and breaking waves in terms of slamming, run-up, green water and vibration-induced effects.

Scientific and technical content:

- › Numerical simulations of energetic steep and breaking waves interacting with a floating offshore wind turbine.
- › Wave tank experiments in sea states of growing steepness up to the occurrence of large breaking waves.
- › Field experiment from the full-scale floating offshore wind turbine *Unitech Zephyros* off Norway.

2021 achievements:

- › Study of impact scenarios between a wind turbine, exposed to wind and wave action, and a breaking wave, which showed that in general the movements of the floating turbine tend to reduce the slamming forces compared to a bottom-fixed turbine exposed to the same conditions.
- › Development of a new methodology to define the sea state and the design wave to be applied by taking into account both the occurrence of breakers and their severity in a sea state.
- › Launch of the first tests in the wave tank in order to validate the models' capacity to derive the properties of the breaking waves that will hit the floating wind turbine model during future tests.
- › Continuation of winter measurement campaigns at La Jument lighthouse, initiated under the DIME project, to document occurrence statistics and the properties of breaking waves in storm conditions.

2021 dissemination:

- › Presentation:
 - Hulin F. (2021) Validation d'un modèle de statistiques de déferlement en mer. Journée scientifique du GDR-EMR & Doctoriales ANCRE, Paris, 25/11/2021-26/11/2021

Partners:

This project is led by France Energies Marines.



Total project budget: €2,144K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Brittany and Réunion.

This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.



DUNES

Dynamics of underwater dunes and impact on ORE projects



Technologies I



Stages in the value chain I

Duration: 40 months | **Launched:** 2019

Objectives:

- › To understand the sediment and ecosystem dynamics of underwater dunes off the coast of Dunkirk.
- › To offer ORE-sector technology developers and industrial firms knowledge and complementary approaches for working in environments with hydraulic dunes.

Scientific and technical content:

- › Mapping of the dunes of French mainland coasts.
- › Acquisition of high-resolution spatio-temporal data on Dunkirk dune dynamics.
- › Understanding the short-term evolution of these underwater dunes.
- › *In-situ* characterisation of the structure of dune ecosystems.
- › Characterisation of ecosystem function by studying food webs through isotopic analyses.

2021 achievements:

- › Analysis and drafting of the reports on the collection of biological samples in 2019 and 2020.
- › End of bathymetric data acquisition with two campaigns carried out in January and March. Processing and analysis of the eight bathymetric surveys conducted since 2019 in three areas of the farm.
- › 1.5-month data acquisition campaign to qualify and quantify current and sediment flows in the area with the use of three current meters (ADCP), a velocimeter (ADV) and a hydrophone.

2021 dissemination:

- › Publication:
 - Bary M. (2021) Morphodynamique des dunes sous-marines et flux sédimentaires associés, application au site éolien offshore de Dunkerque. Master 2 internship report, University of Rouen Normandy, Rouen
- › Poster:
 - Nexer M., *et al.* (2021) Evolution of underwater dunes on the future Dunkirk offshore windfarm. Seanergy, Nantes, 21/09/2021 - 24/09/2021

Partners:

This project is led by SHOM and France Energies Marines.



Total project budget: €1,284K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Brittany and Normandy, and from the maritime cluster Pôle Mer Bretagne Atlantique.



Deploying three current meters, a velocimeter and a hydrophone off Dunkirk

FOWRCE SEA



Offshore wind energy research platform

Technology |



Stages in the value chain |

Duration: 12 months | **Launched:** 2020 | **Completed:** 2021

Objectives:

- › To study the technical and economic feasibility of establishing an offshore research platform to meet the needs of the offshore wind sector.

Scientific and technical content:

- › Qualification of needs in terms of environment, sensors, technological components and research activities.
- › Inventory of existing platforms, gap analysis and functional description of the best candidate solutions.
- › Financial engineering study to evaluate the CAPEX and OPEX of this infrastructure as well as the different sources of financing and available revenues.
- › Analysis of the data policy to be implemented according to the activities carried out and the stakeholders investing in the platform.
- › Study of the spatial representativeness of the observations collected by the platform for the most relevant sites.

2021 achievements:

- › Identification of the sector's needs in terms of observation of the physical environment and marine ecosystems.
- › Review of existing infrastructure solutions (weather masts, instrumented buoys) as well as the instrumentation available to record the relevant parameters.
- › Definition of the roadmap for a permanent observatory of interactions between offshore wind farms and the environment, which could draw on identified technological solutions deployed along the various coastlines and implemented in addition to the marine environment observation programmes already in place.

Partners:

This project is led by France Energies Marines.



Total project budget: €202K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Region of Normandy.







Geophysical surveys for the seabed characterisation of offshore renewable energy sites

Duration: 52 months | **Launched:** 2018

Objective:

- › To develop a new seabed characterisation methodology based on a combination of geophysical and geotechnical data in order to make recommendations for use in the offshore wind sector.

Scientific and technical content:

- › Development of new methodologies for processing existing geophysical data.
- › Implementation of geophysical multitrace seismic and electromagnetic measurements.
- › Development of an effective methodology for optimising geophysical and geotechnical surveys.
- › Drafting of recommendations relating to the integration of geophysical data into site characterisation for project engineering purposes.

2021 achievements:

- › Marine resistivity measurement campaign conducted off Groix island.
- › Continued use of data from offshore campaigns to study the inference of geotechnical information from geophysical measurements.

2021 dissemination:

- › Publication:
 - Flamme J. (2021) Nouvelle approche de l'étude du sous-sol marin : application conjointe de l'électromagnétisme, de la sismique multitrace et de la géotechnique (Thèse de doctorat) Ecole doctorale des sciences de la mer, Brest

Partners:

This project is led by the Université de Bretagne Occidentale and France Energies Marines.



Total project budget: €775K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Region of Brittany.

This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.





MODULLES

Modelling of underwater dunes: local and large-scale evolutions in an offshore wind context



Technologies |



Stages in the value chain |

Duration: 36 months | **Launched:** 2021

Objective:

- > To predict the impact of dune movement on offshore wind farm components.
- > To gain a better understanding of the resiliency of underwater dunes after the construction phase.

Scientific and technical content:

- > Numerical modelling of scouring and sediment transport close to offshore wind farm components.
- > Numerical modelling of several underwater dune fields in an offshore wind farm context.
- > Thermal studies of a cable buried in a underwater dune field.
- > Physical modelling of underwater dunes subjected to complex hydrodynamic forcings.
- > Pre-study of dune ecological resiliency.

2021 achievements:

- > Project launch in November and initiation of various scheduled initiatives.

Partners:

This project is led by SHOM, MARUM and France Energies Marines.

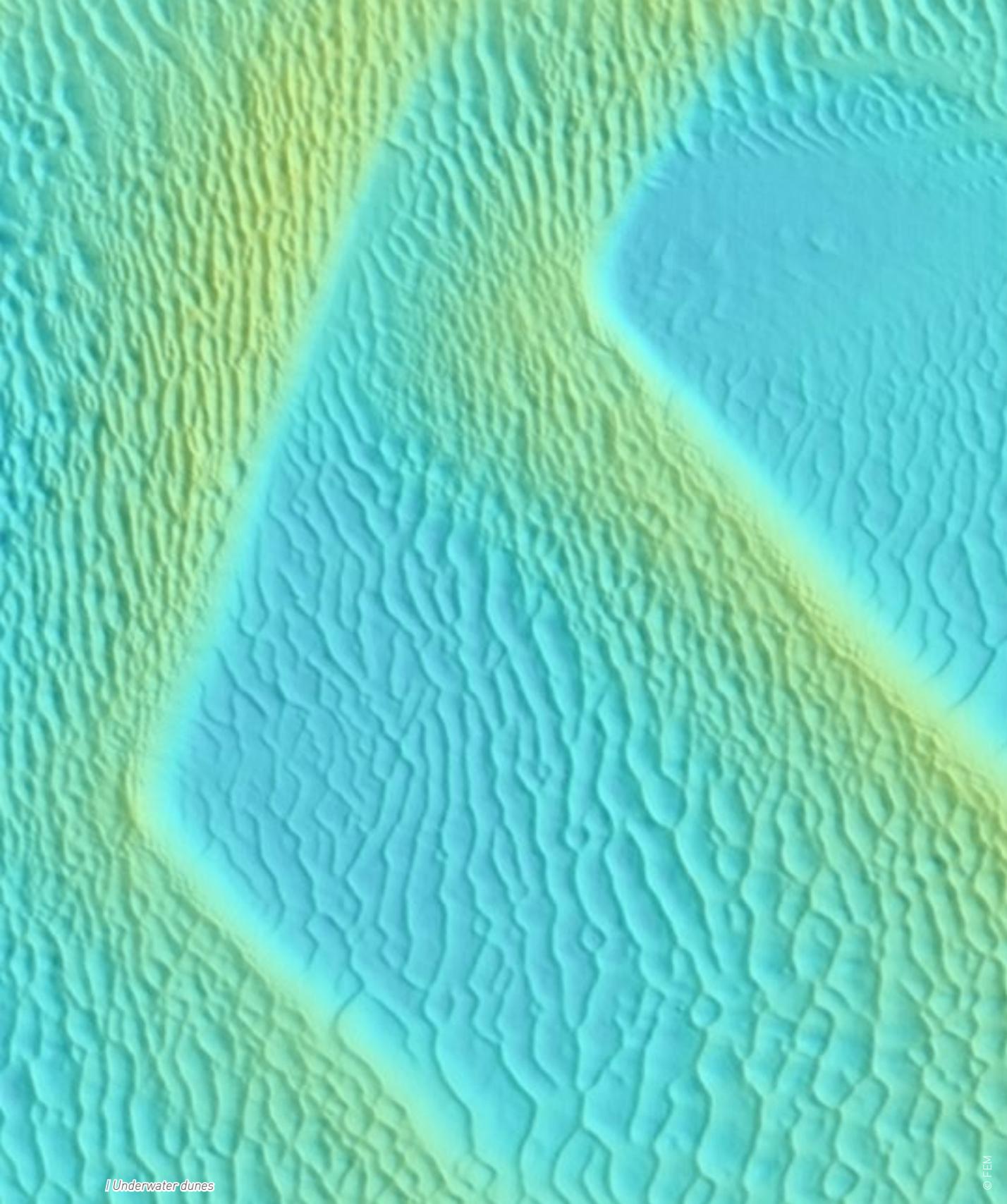


Total project budget: €3,339K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Region of Normandy.





POWSEIDOM



Technology I



Stages in the value chain I

Deployment of wind and turbulence observations in the Mediterranean

Duration: 30 months | **Launched:** 2021

Objective:

- › To overcome the lack of wind and turbulence data from in-situ measurements in the Gulf of Lion.
- › To propose specific recommendations for the design of offshore wind turbines in this region.

Scientific and technical content:

- › Deployment of a WindCube v2 lidar operating at 4 Hz (acquisition frequency 4 times higher than a commercial lidar of the same type).
- › Preliminary study of the lidar’s capacity to measure turbulence by comparison with a measuring mast equipped with anemometers.
- › Characterisation of turbulence in the Gulf of Lion by measuring the lidar deployed on Planier Island.
- › Testing of the lidar on board a mobile platform reproducing the movements of a buoy deployed in the Gulf of Lion.
- › Development of a motion compensation algorithm.

2021 achievements:

- › Project launch in October and initiation of various scheduled activities.

Partners:

This project is led by France Energies Marines.



Total project budget: €834K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Region of Normandy.

This project is approved by the maritime cluster Pôle Mer Méditerranée.





Extreme wind conditions

Clients targeted

- Technology developers.
- Farm owners and operators.
- State services.

Type of services provided

- Characterisation of wind, wave and tidal energy resources.
- Optimisation of the design of offshore systems and operations by accurately characterising extreme sea states, slamming, hazardous areas and/or coastal hydrodynamics.
- Support for offshore instrumentation deployment: specifications (site, instruments, etc.), floating platform design, component selection, procurement, installation, operation.
- Statistical processing and joint analysis of metocean and inertial data from measurement buoys deployed in the Mediterranean and the Atlantic.

Team

Oceanographers with complementary skills in modelling and observation: wind and atmospheric turbulence, extreme sea states, marine current turbulence, hydrosedimentary dynamics.

Instrumentation

- Lidar operating at 4 Hz.
- Stereo video system for 3D wave field reconstruction
- Directional wave buoy.
- 4 x 5-beam ADCP to study current, current turbulence and wave parameters.



Measuring buoy at the Gulf of Fos test site in the Mediterranean

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Numerical tools

- Site characterisation module from DTOcean+ software suite.
- Wind: weather forecasting model (AROME), advanced weather research model (Meso-NH).
- Waves: spectral models (WAVEWATCH III®, SWASH), phase-resolved breaking wave model, laws for breaking wave statistics.
- Python tools developed for data processing, model output analysis, machine learning, etc.

Databases

- North Sea: bathymetry of the underwater dunes off Dunkirk.
- Channel: currents and hydrosedimentary resources, advanced hydrokinetics-meteorology (Meso-NH).
- Atlantic Ocean: rogue wave measurement campaigns.
- Mediterranean: numerical wind forecasts.



Flagship achievements

• Coastal risk assessment

As part of the European MARLIT project, the SUEZ group's Rivages Pro Tech research centre, a member of the project consortium, called on France Energies Marines to conduct measurement campaigns geared towards studying waves and marine flooding on the the central beach ("Grande Plage") in Biarritz. The stereoscopic video system and associated know-how developed during the DIME project were used to produce 3D reconstructions of the wave field near the coastline. The results obtained show very good agreement between stereoscopy and measurements obtained by pressure sensors installed on the coast. The agreement between these two types of instrumentation opens up interesting prospects for wave observation in coastal areas.

• Wave energy potential in Breton ports

Cerema and France Energies Marines are finalising a study for the region of Brittany on the classification of Breton ports with regard to their wave energy potential. The Institute was responsible for estimating the sea states at the selected sites. It also drafted a review and recommendations for possible further work such as *in-situ* measurements and bathymetric surveys.

04

SYSTEMS DESIGN AND MONITORING

The main challenges of this programme relate to the maximisation of overall system performance, but also to improving their reliability, competitiveness, as well as the adaptation of design standards. The primary objective is to provide industry stakeholders with the means of optimising ORE technologies to gain a better market position.

Interaction between the environment and components or structures must be addressed in order to optimise the design and functioning of ORE systems. The first challenge is therefore to develop methodologies and tools -both numerical and experimental- that can simulate the behaviour of these systems in wind, waves and currents. The second challenge is to integrate these methods and innovations into marine environments and offshore practices in order to achieve realistic and robust solutions.

Two evolutionary phenomena should be considered: biofouling, in particular of cables and mooring lines, and material ageing, in order to predict their lifespan thanks to in-service monitoring. A relevant strategy is required to supervise

the farm and optimise the maintenance process, two actions with a high potential to reduce costs, in particular for components subject to considerable constraints, which is the case of dynamic cables and moorings.

The majority of the projects in this programme are therefore designed to provide information that can advance current standards and be used to draft recommendations. The aim is to define a clear design framework in order to optimise the solutions developed and ensure their integrity while mitigating risks.

2021 key figures:



7 collaborative projects



€14,500K cumulative budget



36 different partners



3 QUESTIONS for... Adrien Hirvoas

Research in applied mathematics in the field of offshore renewable energy, France Energies Marines

What topics do you work on at France Energies Marines?

I'm currently involved in two collaborative R&D projects focusing on the development of a digital twin of a floating wind turbine: SUBSEE 4D and DIONYSOS. When I first joined France Energies Marines about a year ago, I worked mainly on the graphic interface to display the results from the floater and mooring line fatigue monitoring system. After that, I got started on building a digital model using multiphysics tools capable of taking into account parameters relating to the turbine's structure, aerodynamics, control system and hydrodynamics. This was followed by the model validation phase then mathematical work to correlate the simulated and field data.

What do you enjoy most about your work?

As part of DIONYSOS, a full-scale floating wind turbine operating off the coast of Norway is to be instrumented with various sensors, thanks to which we will be able to collect field data. This groundbreaking study is really stimulating. The France Energies Marines team is growing steadily, boosting the digital twins focus. We nevertheless have quite a small number of staff, meaning that we need to be curious and multidisciplinary, while regularly communicating with our various partners. For example, I'm currently working with a post-doctoral researcher from IMT Atlantique, specialised in neural networks, to help her apply her scientific approach to the context of floating offshore wind. Another strength lies in the fact that we have considerable internal computing resources and access to a GENCI (Grand Équipement National de Calcul Intensif) supercomputer, which is noteworthy for an organisation of our size. This means that several simulations can be run simultaneously.

Do you work on other tasks on top of these two projects?

Yes, I help to represent France Energies Marines within the broader scientific community by taking part in two mathematical research groups: UQSay which focuses on uncertainty quantification and the design and analysis of computer experiments, and GdR MASCOT-NUM on stochastic methods for the analysis of numerical codes.



Accounting for biofouling through established protocols of quantification for engineering

Duration: 40 months | **Launched:** 2019

Objectives:

- › To provide characterisation protocols for biofouling on cable and mooring line materials which are very vulnerable to this biological process, in order to collect quantitative data *in situ*.
- › To inventory existing biofouling management methods and test the solutions best suited to floating wind turbines.

Scientific and technical content:

- › Multi-scale characterisation at different ORE sites with biofouling.
- › Improvement of biofouling characterisation protocols in terms of standardisation, operability and cost.
- › Development of a quantitative image analysis method.
- › Assessment of existing biofouling management solutions.

2021 achievements:

- › Installation of biofouling monitoring panels off Groix & Belle-Île, at two different monitoring points.
- › Training of the crew of the buoy tender Atlantique in a biofouling photography and thickness measurement protocol used during maintenance operations in the Bay of Biscay. To date, over 300 photos and thickness measurements have been taken and will be subsequently analysed.
- › Taking of photos and videos as well as surveys of colonised panels in the Mediterranean (Cap Couronne, Leucate) and in the Atlantic (Ria d'Étel).
- › Design of a buoy to provide dynamic data in addition to the results that will be obtained following the retrieval of the static frame immersed in the Ria d'Étel.
- › Conducting of two series of tests to determine the heat transfer coefficient of macrofouling on 2 x 3 tubes deployed in contrasting marine environments.
- › Launch of work to adapt artificial intelligence algorithms for image analysis to work towards the automatic detection of certain biofouling species developing on ORE structures.
- › Monitoring of the effectiveness of different antifouling solutions showing that a single coating is effective in both static and dynamic conditions, in both the Mediterranean and the Atlantic.

Partners:

This project is led by the University of Nantes and France Energies Marines.



Total project budget: €1,990K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Brittany, Normandy, Pays de la Loire, Provence-Alpes-Côte d'Azur and Réunion and from the maritime cluster Pôle Mer Méditerranée. This project is approved by the maritime cluster Pôle Mer Méditerranée.



Training of the crew of the buoy tender Atlantique in a photography protocol and installation of biofouling monitoring panels on the Basse des Chats buoy

DIONYSOS

Digital intelligent operational network using hybrid sensors/simulations approach



Technology I



Stages in the value chain I

Duration: 36 months | **Launched:** 2021

Objectives:

- › To develop and test a fatigue monitoring system for floaters and mooring lines of a floating wind turbine.

Scientific and technical content:

- › Review of the structural health methodology useful for the fatigue life of floater parts.
- › At-sea testing of functionalities thanks to the deployment of sensors on a real offshore wind turbine.
- › Assimilation of data from field observations on the floating wind turbine digital twin with a machine learning methodology to improve integration between sensors (wave, wind, motions, structural health monitoring) and numerical models of the floating wind turbine.
- › Web platform development.
- › Construction of the digital twin: sensor calibration and deployment, numerical tool development, default detection, analysis of outputs, meta-model learning assessment, multi-level analysis.

2021 achievements:

- › Project launch in December and initiation of various scheduled activities.

2021 2021 dissemination:

- › Poster:
 - Ribault R., *et al.* (2021) Overall floating offshore wind turbine digital twin: modelling of subsea and aerodynamic components. Seanergy, Nantes, 21/09/2021 - 24/09/2021

Partners:

This project is led by France Energies Marines.



Total project budget: €1,302K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme. It also receives funding from the maritime cluster Pôle Mer Bretagne Atlantique.



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1 Simplified diagram showing how the learning database is designed

In-service monitoring of dynamic cables



Technologies |



Stages in the value chain |

Duration: 26 months | **Launched:** 2020

Objectives:

- > To develop recommendations for the optimisation of in-service monitoring solutions for subsea cables at farm level.
- > To propose a roadmap for the development of the identified promising technologies.

Scientific and technical content:

- > Compilation of feedback and experimental data on local failure modes (electrical, mechanical, thermal) of dynamic cables.
- > Identification of parameters reflecting the emergence of failure modes.
- > Identification of sensor technologies available or under development capable of detecting several of the failure modes.
- > Study of the best technological and economic strategies for the deployment of sensors to monitor the electrical cable network of a farm.

2021 achievements:

- > State-of-the-art review of public data on major submarine power cable failures and gathering of feedback from project partners on observed and expected failure modes.
- > Selection of the main failure modes, among all those identified, in order to pick out those expected to be the most critical for in-service monitoring.
- > Identification and comparison of in-service monitoring technologies and offshore sensors using a pre-defined analysis grid.
- > Definition of offshore wind farm case studies which will act as reference cases and will be used to address the complexities related to the subsea cable network at the scale of a whole farm.

Partners:

This project is led by EDF and France Energies Marines.



Total project budget: €1,304K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme. It also receives funding from the Region of Brittany.





Close-up of a dynamic export cable for a floating wind turbine



Effective lifetime extension in the marine environment for tidal energy

Duration: 48 months | **Launched:** 2019

Objective:

- › To use artificial intelligence to improve tidal turbines' performance and accelerate their commercialisation.

Scientific and technical content:

- › Testing of a system prototype through experiments on the test bench and then towing and deployment at two tidal sites.
- › Testing on underwater and floating systems, with gearbox and direct drive turbines.
- › Socio-economic assessment of tidal turbine energy at regional, national and European levels.
- › Independent verification of project findings.
- › Environmental characterisation of deployment sites, and assessment and modelling of the potential environmental impacts of tidal turbines.

2021 achievements:

- › Deployment and retrieval of acoustic profilers (ADCP) to characterise turbulence processes and current dynamics in a new part of the Ria d'Étel.
- › Installation of PVC panels to study biofouling and probes to measure temperature and light intensity at three stations in the Ria d'Étel.
- › Analysis of data from the physical and environmental characterisation of the Ria d'Étel to determine whether there is a correlation between biofouling and turbulence.
- › Finalisation of the socio-economic impact assessment of the installation of a tidal turbine in the Ria d'Étel.

2021 dissemination:

- › Publications:
 - Innosea (2021) French Estuary site assessment. ELEMENT Deliverable D12.3, 40 p.
 - IDETA (2021) Regional Impact Analysis Report. ELEMENT Deliverable D12.2, 38 p.
- › Event:
 - Organisation in February of a webinar on the socio-economic, environmental and commercial prospects for wind energy in Europe.

Partners:

This project is coordinated by Nova Innovation.

NOVA
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wood.

NORTEK

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Strathclyde
Glasgow

DNV-GL

FRANCE
ENERGIES
MARINES

ABB

CATAPULT

Total project budget: €4,985K

This project receives funding from the Horizon 2020 European research and innovation programme.



Biofouled PVC panel after deployment in the Ria d'Etel



Monitoring of polyamide mooring lines

Duration: 42 months | **Launched:** 2020

Objective:

- › To develop modelling tools for the mechanical behaviour of nylon fiber rope and the appropriate long-term monitoring instruments based on a deep understanding of material degradation mechanisms.

Scientific and technical content:

- › Dedicated model based on the rheological hypothesis of a visco-elasto-plastic material.
- › Development of sensors that provide information on both the interactions between global constraints and sub-constraints.
- › Development of an approach comprising long-term sensors and a technique for high cycle fatigue prediction.
- › Validation of sensors and models through at-sea testing.

2021 achievements:

- › Finalisation of the design study for a buoy with a semi-taut hybrid mooring for moderate depths, corresponding to a reduced-scale floating wind turbine float, ensuring maximum representation of moderate tension with its dynamic variations.
- › Numerous discussions about the development of sensors to equip the buoy, resulting in the definition of the necessary power supply, computer equipment, connections and transmission means.
- › Proposal of original experimental devices to qualify the internal inter-strand friction parameter and an original empirical law to improve the state-of-the-art by covering all the situations corresponding to the various current models, based on physical considerations.
- › Continuation of work on the use of synthetic fibre as an internal stress sensor by light wave interrogation and identification of a promising solution with polymethyl methacrylate.
- › Integration and at-sea testing under representative conditions to validate an internal elongation sensor.

2021 dissemination:

- › Publications:
 - Robinry S. (2021) Simulations numériques et essais sur cordages en nylon. 2nd year engineering course internship report, ENSTA Bretagne, Brest
 - Ralec A. (2021) Architecture, development, and test of web softwares for DTOcean+, SUBSEE 4D and MONAMOOR projects. Engineering dissertation, ISEN Yncréa Ouest, Brest
- › Poster:
 - Civier L., et al. (2021) Study of the long-term creep behaviour of polyamide mooring lines for floating wind turbines. Seanergy, Nantes, 21/09/2021 - 24/09/2021

Partners:

This project is led by Ifremer and France Energies Marines.



Total project budget: €2,000K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Brittany, Pays de la Loire and Provence-Alpes-Côte d'Azur.

This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.



|| Polyamid mooring lines stored on reels



Dynamic umbilicals for floating offshore renewable energy systems

Duration: 48 months | **Launched:** 2018 | **Completed:** 2021

Objective:

- › To experimentally characterise then model the constraints on dynamic cables and put forward an in-service fatigue monitoring methodology.

Scientific and technical content:

- › Implementation of a test bench to characterise the behavioural laws of a dynamic cable and to validate the lifespan modelling of its components.
- › Conducting of large-scale tank tests to confirm the hydrodynamic forces to be considered in global simulation models.
- › Use of these models to obtain the sensitivity of lifespan to the cable's hydromechanical parameters.
- › Testing of marine observation and measurement systems to periodically calibrate numerical models.

2021 achievements:

- › Conducting of mechanical fatigue tests that resulted in premature ruptures, preventing electrical fatigue tests and coupled tests from being carried out for safety reasons.
- › Sampling of material from the various cable components for further testing to gain a better understanding of the impact of mechanical fatigue on the behaviour of the materials and the cable as a whole.
- › Finalisation of a one-dimensional analytical model representing the state of the art of engineering models with a particular focus on inter-component friction identified as a key and sensitive parameter to be determined and modelled.
- › Finalisation of a complex three-dimensional finite element model to identify the sensitivity of the response to certain physical parameters, including friction, and to guide the specifications and understanding of internal mechanisms. Creation of an interface to automatically generate the mesh and boundary conditions of a cable section model.

2021 dissemination:

- › Publications:
 - Maksassi Z., *et al.* (2021) Thermal characterization of biofouling around a dynamic submarine electrical cable. Proceedings of the Congrès Français de Thermique 2021, 8 p.
 - Marty A., *et al.* (2021) Experimental study of hard marine growth effect on the hydrodynamical behaviour of a submarine cable. *Applied Ocean Research*, Vol. 114, 102810
 - Marty A., *et al.* (2021) Effect of roughness of mussels on cylinder forces from a realistic shape modelling. *Journal of Marine Science and Engineering*, Vol. 9, 598
 - Seved T. (2021) Modélisation numérique du comportement mécanique local d'un câble de puissance dynamique pour l'éolien flottant. Master's course internship report, ENSTA Bretagne, Brest
- › Presentations:
 - Maksassi Z., *et al.* (2021) Thermal characterization of biofouling around a dynamic submarine electrical cable. Congrès Français de Thermique, virtual event, 01/06/2021 - 03/06/2021
 - Schoefs F. & Gourd C. (2021) Modeling of loading on dynamic power cables colonized by marine growth.

Partners:

This project is led by the Ecole Centrale de Nantes and France Energies Marines.

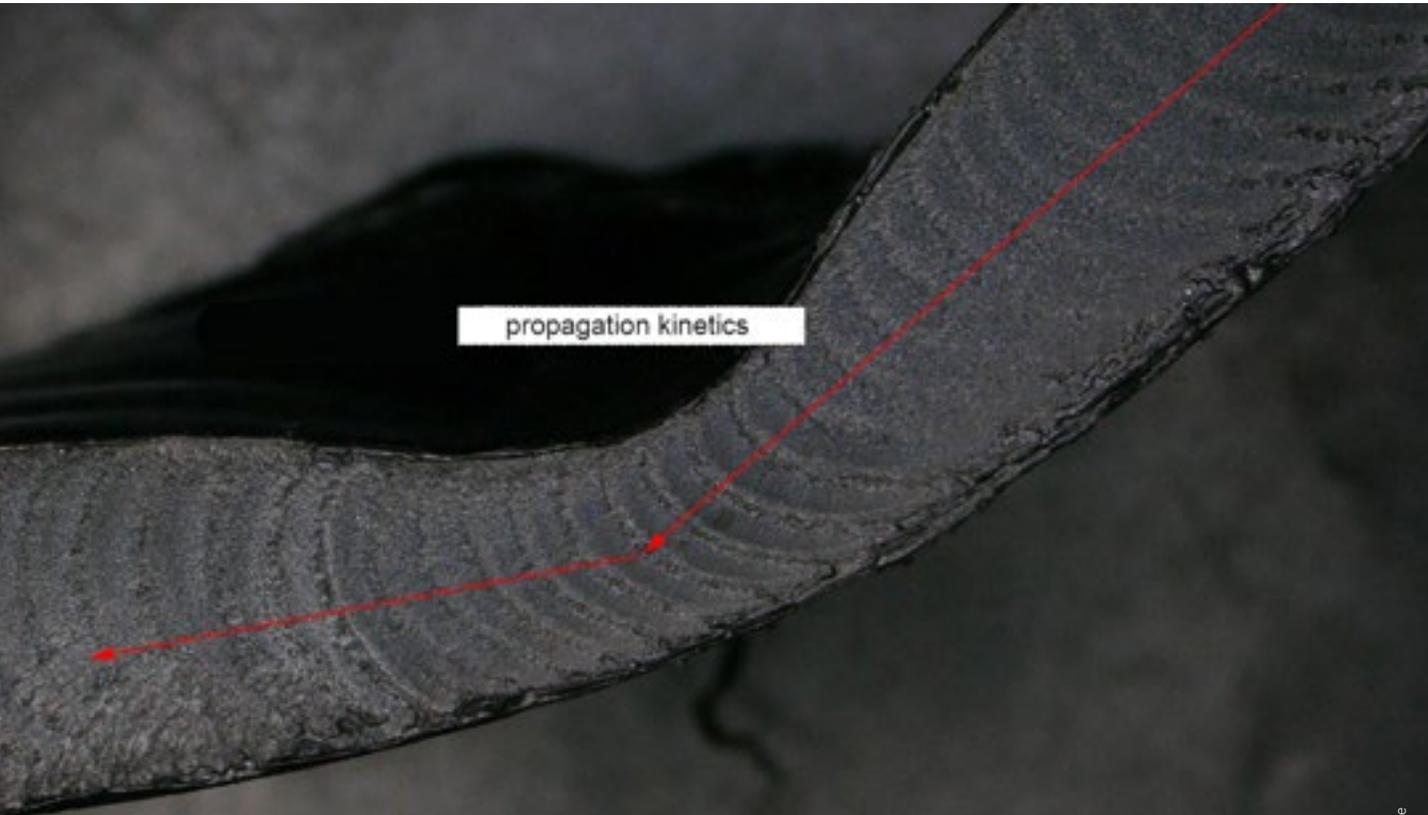


Total project budget: €2,143K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Normandy, Pays de la Loire and Réunion.

This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.





Development of a digital twin to facilitate the operation of floating wind farms

Duration: 24 months | **Launched:** 2020

Objective:

- › To optimise and plan maintenance operations, but also to improve the reliability of submerged systems, by developing a digital twin solution comprising two sub-modules: one for in-service monitoring of mooring lines and one for automated processing for the recognition and improvement of underwater vision.

Scientific and technical content:

- › Detection of anomalies on mooring systems and calculation of remaining fatigue lifetime for mooring components using time domain simulations coupled with state-of-the-art numerical techniques.
- › Development of a methodology for identifying the critical parameters of a mooring system and definition of a sensor deployment strategy.
- › Development of an algorithm for image analysis based on texture recognition in degraded visual conditions.
- › Laboratory image testing in controlled visual conditions.
- › At-sea image analysis testing on a static device in real conditions, including biofouling aspects.

2021 achievements:

- › Development, as a complement to the DIONYSOS project, of a convolutional neural network model in order to create a substitution model with a high dimension output, while providing access to the prediction accuracy.
- › Gradual increase in the complexity of input and output data prior to testing on real data from motion sensors deployed in 2022 on the Zephyros floating wind turbine.

2021 dissemination:

- › Publication:
 - Ralec A. (2021) Architecture, development, and test of web softwares for DTOcean+, SUBSEE 4D and MONAMOOR projects. Engineering dissertation, ISEN Yncréa Ouest, Brest
- › Poster:
 - Ribault R., et al. (2021) Overall floating offshore wind turbine digital twin: modelling of subsea and aerodynamic components. Seanergy, Nantes, 21/09/2021 - 24/09/2021

Partners:

This project is led by Cerwal.



Total project budget: €730K

This project receives funding from the Region of Brittany, the European Regional Development Fund, and Brest Métropole.

This project is approved by the maritime cluster Pôle Mer Bretagne-Atlantique and competitiveness cluster Images & Réseaux.

It also receives support from Corimer.



Digital twin of a floating wind turbine mooring

Clients targeted

- Consultancy firms.
- Technology developers.
- Farm owners and operators.

Types of services

- On-site deployment of instrumented buoys: dynamic design of buoy + mooring systems, post-deployment offshore installation monitoring.
- Design and in-service monitoring of power cables and moorings: stability study on an export cable in an open tidal energy environment, specification of characterisation and fatigue testing on dynamic cables under combined electro-thermo-mechanical loadings, specification, monitoring and analysis of hydrodynamic tests.
- Design and in-service monitoring of moorings: pre-design and adaptation to a given site of a float/mooring/foundation system, qualification of a nylon mooring line, methodology and development of digital twins for in-service monitoring of mooring lines, custom development of numerical tools and physical models for designing foundations and mooring lines for tidal and wave energy systems.

Team

Engineers and scientists with multidisciplinary expertise in: structural design, hydrodynamics, machine learning, offshore in-service monitoring.

Instrumentation

- Floating wind turbine instrumentation consisting of a nacelle-mounted lidar and a motion recording unit.
- 27 m³ buoy with a real time data acquisition system and the possibility of integrating new sensors.
- Experimental device designed to determine the thermal resistance of biofouling.

Numerical tools

- Advanced user: OpenFAST suite, NEMOH for floater behaviour at sea, DeepLines™ license and nylon mooring line behaviour module that can interface with DeepLines™.
- Tools developed in-house: DTOcean+ suite mooring and foundation modules, mooring line in-service monitoring software, local dynamic cable fatigue model, real time data acquisition from sensors.

Databases

- Floating wind: wind, waves, currents and real-time data from an inertial measurement unit.
- Mooring lines: tension, elongation and internal pressure parameters
- Dynamic cables: electrical, mechanical and thermal failure modes.

py C:\Users\earaigno\Document... 1
py C:\Users\earaigno\Documen... 2
ns.py Q:\DTOcean+\Code\dtoc... 2
lex.py C:\Users\earaigno\Docum... 6

OPENED

It yet opened a folder.

Open Folder

```
33 data = {}
34 data['QuiSuisJe'] = {}
35 data['QuiSuisJe']['Prenom'] = firstname
36 data['QuiSuisJe']['Nom'] = name
37
38 return jsonify(data)
39
40 @bp.route('/EIA/Global', methods=['GET'])
41 def return_Global():
42     """
43     @oas [get] /ESA/EIA/Global
44     description: Returns result of business logic function foo()
45     """
46     Global = {}
47     Global['ScorePositive'] = 9
48     Global['RangePositive'] = '[3:9]'
49     Global['Score']
50     return jsonify(Global)
51
52 @bp.route('/EIA/Phase', methods=['GET'])
53 def return_Phase():
54     """
55     @oas [get] /ESA/EIA/Phase
56     description: Returns result of business logic function foo()
57     """
```

Development of numerical tools using Python language

05

ENVIRONMENTAL INTEGRATION

The goal of this programme is to identify the real ecological and socio-economic challenges raised by ORE projects throughout their life cycle. It aims to promote their environmental integration by pooling R&D efforts and providing answers during public consultations and debates. By promoting a holistic approach that reintroduces human beings into the ecosystem, the programme focuses on developing tools and methods to conciliate ecosystem preservation with the economic activities conducted in the areas where offshore energy farms are to be installed.

To reach an understanding of environmental integration, studies must take a twin-track approach, cross-referencing the types of pressure and effects created by ORE systems with the affected organisms or receptors. Alongside such studies, operational approaches should also be developed.

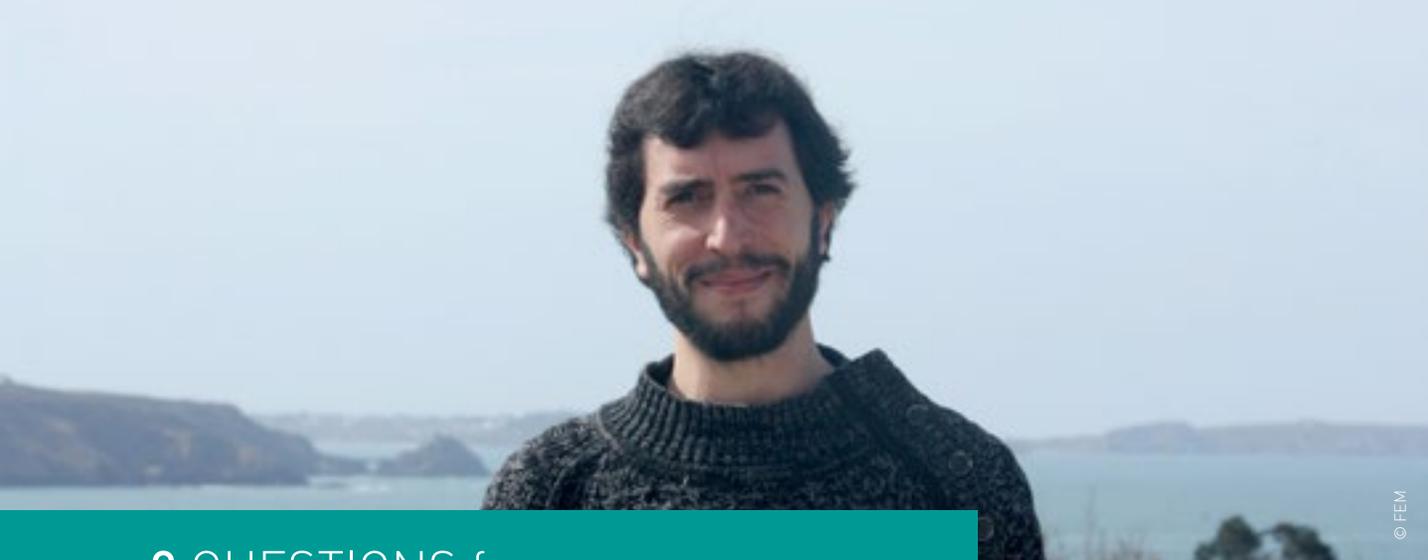
Effects created by ORE systems can fall into several categories such as noise, electromagnetic fields, risk of collision or the creation of new substrates or protected areas. Receptors are often ecosystem compartments such as birds, marine mammals, fish or benthos. To optimise the installation of ORE projects, it is also necessary to consider social and economic aspects, which vary depending on project phases and the ecosystems in question. Studied through several of the Institute's projects, the biofouling process is a special case in which pressure is exerted by the environment, and the receptors are ORE system components.

For all these studies, operational approaches are gradually being established. It appears particularly critical to consider impacts at ecosystem level, to put them into context and rank them. Meanwhile, a socio-ecosystem approach should be developed, integrating both natural and human dimensions. This should result in a more global appraisal of impacts. Innovative characterisation and modelling tools are being developed, particularly through collaborative projects led by France Energies Marines.

Over and above its R&D aspects, this programme is part of an equally essential approach targeting knowledge production and transfer to the sector and citizens through summaries, recommendation reports and popular science bulletins, as well as public debates.

2021 key figures:

-  11 collaborative projects
-  €17,055K cumulative budget
-  68 different partners



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3 QUESTIONS for... **Georges Safi**

*Scientific Officer in Ecosystemic Approach,
France Energies Marines*

What was your role in the APPEAL project?

As project coordinator, I worked in close collaboration with the scientific lead François Le Loch at the Université de Bretagne Occidentale. My main missions were to ensure the smooth implementation of the work, oversee the completion of deliverables and liaise with all the partners. I also contributed to the work of Marie Le Marchand for her PhD thesis by providing expertise on the use of environmental health indicators.

What would you say was the main difficulty in the project?

There were several, APPEAL was a project with a lot of ups and downs! Just after the project kicked off, we had to deal with delays in receiving funding, a partner leaving the project and, later on, the Covid pandemic. The tense social context surrounding the development of the Groix & Belle-Île pilot site was also a setback for us in April 2018, at the time of the first offshore data collection campaign. From day one, fishermen, who had not been informed of the scientific campaign, arrived on site to find out what the boat was doing there. This experience served as a lesson for us and from then on we communicated

a lot to announce and explain the subsequent campaigns which went ahead smoothly. In terms of its scientific content, APPEAL was a very ambitious project with a consortium made up of a wide variety of partners from different backgrounds: legal specialists, geographers, biologists, economists, sociologists, etc. Initially, its coordination was something of a challenge, however this diversity was a true strength for the project.

On a personal level, what will you take away from this project?

For me, APPEAL was a journey of discovery in the different research fields that had been brought together. During the project, our collaboration led to pioneering work resulting in the creation of innovative bridges. It is one of the first projects to have developed tools capable of assessing the environmental and socio-economic impacts of floating wind farms in a balanced manner. APPEAL developed a cross-cutting approach providing insight into the complexity of interactions at play and laying the groundwork for an ecosystem-based vision integrating humans as a component of a complex ecosystem.



Socio-ecosystem approach to the impact of floating wind farms

Duration: 48 months | **Launched:** 2018

Objective:

- › To develop an integrated approach to measure the effects of floating wind farms on the functioning of coastal ecosystems.

Scientific and technical content:

- › Acquisition of environmental data from the Groix & Belle-Île and Leucate sites.
- › Description of the structure and functioning of the benthic compartment of these sites.
- › Characterisation of benthic food webs down to fish living near the seabed, although they may not permanently dwell there.
- › Establishment of a spatial knowledge base on human activities at sea.
- › Construction of a methodological approach to measuring infrastructures' social acceptability.
- › Modelling and scenario-building for 2030 and 2050.
- › Study on the legal impacts and professional fishing activities and analysis of the stakeholder network.
- › Modelling of the socio-ecological system.

2021 achievements:

- › Completion of an online survey on the perceptions of the Groix & Belle-Île offshore floating wind farm project by the nautical sector.
- › Construction of a model combining the analysis of the network of stakeholders affected by the Groix & Belle-Île pilot farm and ecosystem modelling. Testing of several scenarios.
- › Deployment of a buoy on the Groix & Belle-Île site to study the biofouling process in an offshore environment.
- › Continuation of work on the geographical approach to interactions between uses of the sea and floating wind projects.
- › Continuation of work on the definition of sensitivity indices for human activities and benthic habitats to pressures from floating wind farm activities.

2021 dissemination:

- › Publications:
 - Jac C., *et al.* (2021) Assessing the impact of trawling on benthic megafauna: comparative study of video surveys vs. scientific trawling. *ICES Journal of Marine Science*, Vol. 78, pp.1636-1649
 - Niquil N., *et al.* (2021) The Merits of Loop Analysis for the Qualitative Modeling of Social-Ecological Systems in Presence of Offshore Wind Farms. *Frontiers in Ecology and Evolution*, Vol. 9, 635798
 - Nogues Q., *et al.* (2021) Cumulative effects of marine renewable energy and climate change on ecosystem properties: Sensitivity of ecological network analysis. *Ecological Indicators*, Vol. 121, 107128
- › Event:
 - Preparation of a public meeting in Lorient to present the project results scheduled for 2022.

Partners:

This project is led by the Université de Bretagne Occidentale and France Energies Marines.



Total project budget: €2,036K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives public funding from the Regions of Brittany and Normandy.

This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.



| Groix & Belle-Île pilot farm project

ECOAP



Technologies |



Stages in the value chain |

Ecotoxicology analysis of cathodic protections to assess the chemical risk of elements released from galvanic anode and impressed current on the marine environment and its food webs

Duration: 36 months | **Launched:** 2021

Objective:

- › To produce a knowledge base of the potential environmental impacts of anticorrosion protections commonly used in the offshore renewable energy industry, including galvanic anode cathodic protection (GACP), impressed current cathodic protection (ICCP) and anticorrosion coatings.

Scientific and technical content:

- › A literature review and an audit of current practices in terms of cathodic protections and anticorrosion coatings.
- › Laboratory study to assess the impact of the cocktails of elements released by cathodic protection systems on marine organisms.
- › Laboratory characterisation of all elements, including (chloro)brominated compounds, released by impressed current cathodic protection, and study of their stability in seawater.
- › Upgrading and development of models to simulate the elements' dispersion and investigate the trophic transfer of elements from cathodic protection systems.
- › Publication of a recommendation report for ORE stakeholders.

2021 achievements:

- › Project launch in October and initiation of scheduled initiatives.

Partners:

This project is led by the University of Caen Normandy and France Energies Marines.



Total project budget: €2,189K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Provence-Alpes-Côte d'Azur Region, Brittany and Normandy.





Galvanic anodes on a jacket foundation

ECOSYSM-EOF

Prefiguration of an observatory of marine ecosystems in interaction with floating offshore wind farms in the Gulf of Lion



Technology |



Stages in the value chain |

Duration: 24 months | **Launched:** 2020

Objective:

- › To put forward a high-frequency observatory architecture relying on the underwater cable network of the Gulf of Lion to determine the state and evolution of marine ecosystems in interaction with high-power floating wind farms.

Scientific and technical content:

- › State of the art of knowledge and available means of observation concerning the functioning of Mediterranean marine ecosystems (fish, cetaceans...).
- › Evaluation of the instrumentation currently used and/or developed by academic research and the private sector.
- › Summary of the measurement needs for the observation of marine ecosystems and the associated technical and environmental constraints.
- › Drafting of specifications for potential architectures of observation networks.

2021 achievements:

- › Installation of sensors on the MEMOFLOW observatory's instrumented buoy in the Gulf of Fos to measure and monitor the concentrations of various substances (such as polycyclic aromatic hydrocarbons, heavy metals and plastic additives) in the water.

Partners:

This project is led by the maritime cluster Pôle Mer Méditerranée.



Total project budget: €470K

This project receives funding from French Agency for Ecological Transition (ADEME) under the call for sustainable energy research projects (2018-2019).

This project is approved by the maritime cluster Pôle Mer Méditerranée.





View of the Gulf of Lion

FISH INTEL



Technologies |



Stages in the value chain |

Monitoring the movements and favoured habitats of several important marine species through a cross-Channel acoustic telemetry network

Duration: 24 months | **Launched:** 2021

Objective:

- › To deploy an acoustic telemetry network and monitor the movements and favoured habitats of important marine species at seven pilot sites in the Channel, including two ORE areas.
- › To share the data obtained with key project stakeholders, managers and policy makers to facilitate the implementation of ecosystem-based fisheries management programmes in the Channel.

Scientific and technical content:

- › Roll-out of an acoustic telemetry network, tagging of different target species and habitat characterisation of seven pilot sites.
- › Analysis of individual movement data and identification of critical fish habitats.
- › Use of project data to operationalise the ecosystem approach to fisheries at local and regional scales.

2021 achievements:

- › Planning and beginning of roll-out of an acoustic telemetry network at different pilot sites including two ORE sites.
- › Installation of acoustic transmitters on target species (bluefin tuna, spiny lobster and sea bass) to study their movements and preferred habitats.
- › Awareness-raising among the different local stakeholders.

2021 dissemination:

- › Event:
 - Organisation of a public webinar in November to present the project.

Partners:

This project is led by the University of Plymouth.



Total project budget: €4,100K

This project receives funding from the European Regional Development Fund through the Interreg France (Channel) England programme.





| Shoal of European sea bass

FISHOWF

Effective monitoring strategies to identify and evaluate effects of offshore wind farms and their export cables on fish communities



Technologies |



Stages in the value chain |

Duration: 36 months | **Launched:** 2021

Objective:

- › To develop a long-term monitoring approach capable of detecting effects of both bottom-fixed and floating offshore wind farms and their export cables on fish communities.

Scientific and technical content:

- › Monitoring of occupancy patterns, habitat use and individual movements of fish using acoustic telemetry to identify effects of offshore wind farms at different spatial scales.
- › Proposal of methodological guidelines using acoustic telemetry to update regulatory environmental impact assessment methods.
- › Development of an effective combined approach using complementary innovative methodologies to investigate the effects of offshore wind farms and export cables on fish communities.

2021 achievements:

- › Project launch in October and initiation of various scheduled initiatives.

Partners:

This project is led by France Energies Marines.



Total project budget: €2,363K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Université de Bretagne Occidentale and the Regions of Provence-Alpes-Côte d'Azur Region and Brittany.

This project is approved by the maritime cluster Pôle Mer Méditerranée.





| Shoal of fish near an underwater structure

GEOBIRD

Development of an innovative geolocation tag for seabirds



Technology |



Stage in the value chain |

Duration: 50 months | **Launched:** 2017 | **Completed:** 2021

Objective:

› To develop a miniature geolocation tag for medium-sized seabirds and test it on birds in real conditions.

Scientific and technical content:

- › Technological development of a tag prototype.
- › Testing of the prototype on shearwaters in the Atlantic and Mediterranean.

2021 achievements:

› Drafting and publication of a bulletin summarising the work carried out.

2021 dissemination:

› Publication:

Heerah K., *et al.* (2021) Développement d'une balise de géolocalisation pour les oiseaux marins, Bilan et perspectives du projet GEOBIRD (2017-2021). Plouzané: France Energies Marines Editions, 12 p.

Partners:

This project is led by France Energies Marines.



Total project budget: €858K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Brittany and Provence-Alpes-Côte d'Azur.

This project is approved by the maritime cluster Pôle Mer Méditerranée.





Attaching a tag prototype to a Scopoli's shearwater



Tackling environmental, socio-economic and technological challenges for life cycle assessments of offshore wind farms

Duration: 36 months | **Launched:** 2020

Objectives:

- › To develop a comprehensive methodological framework for environmental and social life cycle assessment, then validate it by applying it to a selection of offshore wind farms (pilot and commercial, floating and bottom-fixed).
- › To identify ways to improve the environmental and societal sustainability of offshore wind farms using the results of their life cycle assessments.

Scientific and technical content:

- › Development of detailed guidelines and reference materials for environmental and social analysis of the life cycle of offshore wind energy projects.
- › Identification of specific indicators (not existing or identified today) for biodiversity and socio-economic aspects for integration in the life cycle assessment.
- › Case studies based on data from several offshore wind farms: life cycle analysis of the environmental and then societal aspects and preliminary identification of the crucial points for the eco-design of offshore wind projects.
- › Transfer of the methodology and best practices to the sector via an online platform and workshops.

2021 achievements:

- › Development of a parameterised model describing the environmental performance of offshore, onshore and floating wind farms.
- › Consolidation of methodological and theoretical choices for the integration of biodiversity indicators in current life cycle assessments.
- › Review of international knowledge on social life cycle assessment.
- › Collection of technical and socio-economic data from offshore wind developers and case studies.

2021 dissemination:

- › Presentations:
 - Baulaz Y., *et al.* (2021) An integrated conceptual model to characterize the effects of offshore wind farms on ecosystem services. Estuaries and coastal seas in the Anthropocene, ECSA 58 & EMECS 13: Estuaries and coastal seas in the Anthropocene, Hull, United Kingdom, 06/09/2021 - 11/09/2021
 - Lehmann J., *et al.* (2021) Towards social life cycle assessment of energy systems, Case study on offshore wind farms from companies' perspective. International Conference on Life Cycle Management, virtual event, 05/09/2021 - 08/09/2021
- › Poster:
 - Sansa M., *et al.* (2021) Life cycle assessment of offshore wind projects: Beyond potential impact on climate change. Seanergy, Nantes, 21/09/2021 - 24/09/2021

Partners:

This project is led by MINES Paris - PSL and France Energies Marines.



PSL



FRANCE
ENERGIES
MARINES



Le réseau
de transport
d'électricité



EDF

INNOSEA
Accélérateur LDC Group



NTNU
Norwegian University of
Science and Technology

Total project budget: €1,466K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Region of Normandy.





Prefiguration of an observatory of birdlife in the Gulf of Lion interacting with offshore floating wind farms

Duration: 24 months | **Launched:** 2019

Objective:

- › To propose a high-frequency observatory architecture in the Gulf of Lion to study the condition and evolution of birdlife interacting with high-power floating wind farms.

Scientific and technical content:

- › Review of available knowledge and data, as well as of data currently being gathered, on Mediterranean birdlife.
- › Study and specifications of birdlife observation systems.
- › Detailed 3D mapping of Scopoli's shearwater activity in the Gulf of Lion.
- › Birdlife migration monitoring by land-based radar.
- › Specification of the observation network architecture.
- › Test of the repercussions of a series of future Gulf of Lion wind farm installation scenarios on the energy landscape of Scopoli's shearwaters, as a model species.

2021 achievements:

- › Acquisition and exploitation of radar data.
- › Acquisition of data on the flight behaviour of Scopoli's shearwaters.

Partners:

This project is led by the maritime cluster Pôle Mer Méditerranée.



Total project budget: €450K

This project receives funding from French Agency for Ecological Transition (ADEME) under the call for sustainable energy research projects (2018-2019).

This project is approved by the maritime cluster Pôle Mer Méditerranée.





OWFSOMM

Offshore wind farm surveys of marine megafauna: standardisation of tools and methods for monitoring at farm scales



Technologies |



Stages in the value chain |

Duration: 36 months | **Launched:** 2020

Objectives:

- › To provide an operational roadmap for conducting a robust inter-calibration of marine megafauna aerial surveys at ORE farm scale using different technologies.
- › To improve the efficiency of multiple sensors in detecting, identifying and characterising marine megafauna by using an AI tool.

Scientific and technical content:

- › Development of an inter-calibration methodology between digital and human-based aerial surveys.
- › Development of AI solutions coupling multimodal data (radar, acoustic) to enhance the identification and estimation of targets (birds, marine mammals).
- › Drafting of technical recommendations for marine megafauna monitoring in relation to ORE projects to ensure inter-operability of datasets.
- › Implementation of a cost-effectiveness analysis of sampling strategies using different acquisition methods.

2021 achievements:

- › Marine megafauna aerial monitoring campaigns with visual and digital data acquisition at different altitudes at the offshore wind farm sites of Fécamp, Courseulles-sur-Mer and in the Gulf of Lion.
- › Development of an algorithm for the passive acoustic detection and identification of marine mammals.

Partners:

This project is led by Université de Bretagne Sud's laboratory IRISA, CEFE and France Energies Marines.



Total project budget: €1,447K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Region of Normandy, the French Biodiversity Agency (OFB) and the French Directorate General for Energy and Climate (DGEC).





Overflight heading towards the site of the future offshore wind farm in Calvados

© Avion-Jaune WIPSEA



Monitoring and study of marine megafauna in wind farms by automatic characterisation

Duration: 36 months | **Launched:** 2019

Objective:

- › To demonstrate the ability of aerial photography processing and analysis software to automatically inventory marine megafauna.

Scientific and technical content:

- › Implementation of an aerial megafauna observation campaign (standard visual method and VHR digital photography system), integrating the seasonal variability of species and environmental conditions.
- › Development and qualification of two types of automatic aerial photography processing algorithms for animal identification and classification.
 - Detection using a deep neural (end-to-end) network, moving directly from the global image to bounding boxes.
 - Anomaly detection by unsupervised deep learning.
- › Assessment of the performance of each detection method tested based on indicators classed by species or group of species, as well as according to environmental conditions.

2021 achievements:

- › Continuation of work on the development of automated aerial photography processing algorithms.
- › Aerial overflights to survey marine megafauna in the Gulf of Lion, in the Mediterranean.

Partners:

This project is coordinated by IRISA (Université de Bretagne Sud).



Total project budget: €600K

This project receives funding from French Agency for Ecological Transition (ADEME) under the call for sustainable energy research projects (2018-2019).

This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.





WINDSERV



Technology I



Stage in the value chain I

Towards a multi-model approach to indicators of ecosystem services

Duration: 24 months | **Launched:** 2020

Objectives:

- › To develop a multi-model approach to predict offshore wind farm impacts on ecosystems and the resulting services.
- › To guide a win-win strategy between offshore wind farm developments and biodiversity conservation strategies.

Scientific and technical content:

- › Development of an end-to-end model consisting of a trophic and spatial model forced by ecological niche models outputs and a biogeochemical model for the areas of future wind farms in the Eastern English Channel and the Gulf of Lion and their related ecosystem indicators.
- › Development of novel ecosystem service indicators specific to offshore wind energy, building on ecosystem model outputs.

2021 achievements:

- › Review of the effects of wind farms on ecosystem services.
- › Organisation of workshops on the link between ecosystem services and ecological indicators taken from trophic models.

Partners:

This project is led by the Université du Littoral Côte d'Opale and France Energies Marines.



Total project budget: €1,076K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Normandy and Provence-Alpes-Côte d'Azur.

This project is approved by the maritime clusters Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée.





Offshore wind farm

R&D SERVICES

Clients targeted

- Consultancy firms.
- Farm owners and operators.
- State services.

Type of services provided

- Building 0 to 2-dimensional models of an ecosystem's trophic functioning and scenario testing.
- Development and implementation of protocols for monitoring biofouling on ORE system components.
- Development and implementation of protocols to study interactions between marine ecosystems and their compartments and ORE farms.

Team

Biologists and sociologists with complementary skills in: benthic ecology, ornithology, marine mammals, ichthyofauna, ecosystem modelling, socio-ecosystems.

Instrumentation

- Two multi-instrumented measurement buoys deployed in Southern Brittany and the Mediterranean.
- Cross-Channel acoustic telemetry network to monitor fish movements.
- Video camera system for monitoring marine mammals and birds.

Numerical tools

- 0 to 2-dimensional models of an ecosystem's trophic functioning (Ecopath, Ecosim, Ecospace) or static models (linear inverse modelling).
- Environmental and social acceptability module from DTOcean+ software suite.
- Data processing and analysis algorithms.

Databases

- Biofouling along the French coasts: protocols and measured data.
- Biofouling along the French coasts: protocols and measured data.
- Marine megafauna monitoring: aerial imagery databases.

Flagship achievements

Monitoring of birds and bats in the Gulf of Lion

Against the backdrop of the development of offshore wind farms in the Mediterranean, the MIGRALION programme, launched at the end of May 2021, sets out to tackle a challenge: to gain a better understanding of the migration flows at sea of birds and bats on the scale of the Gulf of Lion, as well as the use of marine areas by birds that depend on them. Through the use of a wide range of technologies, this €4.2 million programme led by the French Biodiversity Agency (OFB) brings together 14 partners with a view to acquiring key knowledge to ensure the preservation of these populations. OFB tasked France Energies Marines with the overall coordination of this large-scale project, as well as placing the Institute in charge of various work packages. In addition to day-to-day project management, the Institute was responsible for producing a literature review on birds and bats in the Gulf of Lion, producing various communication materials for the general public and participates in the development of a combined modelling method for the data collected.



Pied avocets, a species monitored under the MIGRALION project, in flight

FARM OPTIMISATION

This programme—which covers all ORE applications via a cross-cutting approach—focuses on a number of key challenges: overall improvement of farm performance, developing design standards and grid integration. It is closely linked to the Institute's three other R&D programmes. The aim is to develop tools and methodologies for players in the sector to optimise the overall costs of a commercial farm, in compliance with the most relevant technical and economic criteria.

An ORE farm should be considered to be a system, and not simply an aggregation of turbines. Its design requires a multi-disciplinary scientific approach geared towards building a global architecture that will offer the best cost and availability compromise while complying with predefined constraints. Thanks to the implementation of new software or modules interfaced with pre-existing numerical tools, it is possible to put forward a proposal suited to all technologies.

Electricity grid design is another challenge for ORE integration in the energy mix. This more specifically concerns innovations relating to substations, inter-array grid topology optimisation and subsea cable reliability. Transmission alternatives for the power produced also enter into the equation. The objective

here still remains the same: to put forward optimisation solutions at farm scale in order to achieve a technical and economic optimum.

Issues related to offshore operations are another important aspect to be taken into consideration in optimisation. Whether it be for array installation, maintenance or decommissioning, the associated costs are high and must be rationalised as far as possible. To do so, three aspects are particularly crucial: optimised operation planning, heavy maintenance solutions and monitoring during the operation phase.

2021 key figures:

-  5 collaborative projects
-  €12,100K cumulative budget
-  39 different partners



3 QUESTIONS for... Marie Robert

*ORE research project manager
France Energies Marines*

You joined France Energies Marines just over a year ago. What was your first task?

I was initially recruited to set up two projects: OPHARM on renewable hydrogen and DIONYSOS on the fatigue monitoring of floaters and mooring lines for floating wind turbines. I really enjoyed the very stimulating discussions held during this phase, both internally and with our members and partners. Contemplating the best way to contribute to a theme and really exploring the subject in depth are also aspects I appreciate. The tight turnaround times we have at France Energies Marines to set up projects means that we have to advance at a very fast pace, but on the plus side this avoids getting sidetracked.

Once the project set-up was complete, were you asked to coordinate them?

I'm in charge of coordinating OPHARM, which involves leading the consortium of partners, overseeing the progress of the work and the submission of deliverables, as well as managing human resources and the budget. Although this role requires a lot of time and energy, this is counterbalanced by the very rich discussions I regularly have with the different people involved in the project. DIONYSOS on the other hand is led by a colleague who works on the Systems design and monitoring programme. This was agreed from the outset, giving me time to offer scientific and technical input to several projects.

Can you tell us a little more about these scientific and technical contributions?

In the case of OPHARM, my main contribution focuses on the state of the art of existing hydrogen production, storage and export technologies, as well as the market potential analysis. In this regard, I prepared and ran seven workshops to discuss the different offshore supply chain options with the relevant stakeholders.

For DIONYSOS, I'm going to be contributing to the state-of-the-art review for offshore sensors. In the context of MODULLES, on the modelling of underwater dunes, I'm involved in the work of Alban Gilletta. Alban is a PhD student at LEGI (Laboratoire des écoulements géophysiques et industriels) in Grenoble where he works on the numerical simulation of scouring around the foundations of offshore wind turbines. I also build synergy between the different modelling scales studied in the project. Having studied hydrodynamics, I'm no stranger to this field: I really appreciate getting back in touch with familiar reasoning methods and tools.



Advanced design tools for ocean energy systems

Duration: 40 months | **Launched:** 2018 | **Completed:** 2021

Objective:

- › To develop the second generation of an open source software suite for the design and optimisation of wave and tidal farms.

Scientific and technical content:

- › Identification of end user needs.
- › Development of numerical tools for structured innovation, stage-gating, deployment and evaluation of wave and tidal farms, from the subsystem to the whole farm.
- › Integration of different tools and tests with real deployment scenarios in order to obtain software with Technology Readiness Level (TRL) 6.
- › Ocean energy sector market analysis.

2021 achievements:

- › Integration of previously developed modules into a main module to facilitate use and data flow interpretation from one module to another.
- › Drafting of software documentation (user manual, methodology description, etc.).
- › Final testing of the suite with the industrial project partners, compilation of their feedback and comments, and improvement of certain features.

2021 dissemination:

- › Publications:
 - Apolonia M., *et al.* (2021) Legal and political barriers and enablers to the deployment of marine renewable energy. *Energies*. Vol. 14, 4896
 - Correia da Fonseca F.X., *et al.* (2021) A Decision Support Tool for Long-Term Planning of Marine Operations in Ocean Energy Projects. *Journal of Marine Science and Engineering*. Vol. 9, 810
 - Kerr P., *et al.* (2021) Implementing Radical Innovation in Renewable Energy Experience Curves. *Energies*. Vol. 14, 2364
 - Roberts O., *et al.* (2021) Bringing Structure to the Wave Energy Innovation Process with the Development of a Techno-Economic Tool. *Energies*. Vol. 14, 8201
 - Tunga I., *et al.* (2021) Addressing European Ocean Energy Challenge: The DTOceanPlus Structured Innovation Tool for Concept Creation and Selection. *Energies*. Vol. 14, 5988
 - Yang Y. & Sønderkær Nielsen J. (2021) Availability-Based Selection of Electricity Delivery Network in Marine Conversion Systems Using Bayesian Network. *Energies*. Vol. 14, 3574
 - Energia de Portugal, *et al.* (2021) Demonstration results of integrated design tools for wave Energy - DTOceanPlus Deliverable D7.7, 85 p.
 - Open Cascade, *et al.* (2021) Database visualisation and maintenance tool - DTOceanPlus Deliverable D7.5, 31 p.
 - Open Cascade, *et al.* (2021) Final suite of design tools for devices and arrays - DTOceanPlus Deliverable D7.6, 23 p.

- Energia de Portugal, *et al.* (2021) Demonstration results of integrated design tools for wave Energy - DTOceanPlus Deliverable D7.7, 85 p.
 - Orbital Marine Power, *et al.* (2021) Demonstration results of integrated design tools for tidal energy - DTOceanPlus Deliverable D7.8, 76 p.
 - Energia de Portugal, *et al.* (2021) Overall technical and sector recommendations - DTOceanPlus Deliverable D7.9, 46 p.
 - The University of Edinburgh, *et al.* (2021) Feasibility and cost-benefit analysis recommendations - DTOceanPlus Deliverable D8.3, 151 p.
 - Energy Systems Catapult, *et al.* (2021) Developing Ocean Energy standards for Business management models in Ocean Energy - DTOceanPlus Deliverable D8.4, 155 p.
 - WavEC Offshore Renewables, *et al.* (2021) Relevant legal, institutional, and political frameworks - DTOceanPlus Deliverable D8.5, 58 p.
 - Ralec A. (2021) Architecture, development, and test of web softwares for DTOcean+, SUBSEE 4D and MONAMOOR projects. Engineering dissertation, ISEN Yncréa Ouest, Brest
- › Presentations:
- Ruiz-Minguela P. (2021) New software suite will strengthen future wave and tidal energy projects. Ocean Energy ENEA Workshop, virtual event, 12/01/2021
 - Nicolas E. (2021) H2020 - Projet DTOceanPlus pour développer des outils de conception numérique pour les systèmes de marées et de vague. Atelier Energies, virtual event, 05/02/2021
 - Tunga I. & Bradley S. (2021) Tools for selecting the most promising technology concepts for ocean energies: the experience in H2020 DTOceanPlus project. International Conference on Ocean Energy, virtual event, 28/04/2021 - 30/04/2021
 - Nava V., *et al.* (2021) The novel paradigm of Digital Representation of Ocean Energy Systems for enhancing the interoperability of data in DTOceanPlus. International Conference on Ocean Energy, virtual event, 28/04/2021 - 30/04/2021
 - Araignous E., *et al.* (2021) Assessing the Environmental and Social Acceptance of Ocean Energy Array Using DTOceanPlus Design Tools. International Conference on Ocean Energy, virtual event, 28/04/2021 - 30/04/2021
 - Noble D. & Kerr P. (2021) Integrating radical innovation into ocean energy cost modelling. Institute for Energy Systems seminar, Edinburgh, United Kingdom, 09/07/2021
 - Ruiz-Minguela P. (2021) On the relevant, realistic and effective criteria for wave energy technology assessment. European wave and tidal energy conference, Plymouth, United Kingdom, 07/09/2021 - 09/09/2021
- › Events:
- Live online training session on the stage-gate design tool on 6 July.
 - Live online training session on the roll-out and assessment tools on 1st July.
 - Final webinar to present the main results, with several presentations posted online over the summer, followed by a live question and answer session on 31 August.

Partners:

This project is coordinated by Tecnalia.



Total project budget: €8,000K

This project receives funding from the Horizon 2020 European research and innovation programme.





DTOcean+, a software suite for designing wave and tidal farms



Floating offshore wind turbines operation and maintenance

Duration: 36 months | **Launched:** 2021

Objective:

- › To contribute to the development of heavy lift solutions for the offshore maintenance of floating wind turbines.
- › To provide high resolution short term metocean forecasts for the Gulf of Lion for maintenance operations.

Scientific and technical content:

- › Offshore heavy lift maintenance methods:
 - Investigation of methods and technologies for offshore heavy lift operations at floating wind farms through stakeholder workshops.
 - Assessment of a selected heavy lift solution through numerical simulations using different turbine and floater designs.
 - Validation of the method statement through tank tests.
- › High resolution probabilistic forecasts:
 - Construction of the dataset, including implementation of *in-situ* surveys.
 - Development of wind and wave learning-based model: end-to-end architecture, tuning and testing at test site, transfer learning.
 - Implementation of an online forecasting system with scoring: iterative design with end-user feedback.

2021 achievements:

- › Start of the state-of-the-art review and data collection work on the offshore heavy maintenance component.
- › Preparation of an industry survey, first bilateral interviews with offshore heavy lift companies.
- › Definition and sharing of case studies in preparation for brainstorming workshops.
- › Beginning of literature study and dataset collection work.
- › Launch of the development of a visualisation interface for the operational forecasting system.

Partners:

This project is led by France Energies Marines.



Total project budget: €1,600K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Region of Brittany.





Assessment of a heavy lift solution for offshore maintenance



Monitoring strategies for innovative substations

Duration: 24 months | **Launched:** 2020

Objective:

- › To develop and demonstrate a comprehensive methodology for in-service electrical and structural health monitoring (including mooring) of floating offshore substations with currently available solutions and identify challenges for future technologies.

Scientific and technical content:

- › Review of feedback from past experience and definition of specific needs related to floating offshore substations.
- › Development of a maintenance optimisation approach: identification of the risks for offshore substations, identification of degradation processes and development of simplified models, determination of system reliability taking into account in-service electrical and structural health monitoring.
- › Specification of in-service electrical and structural health monitoring: performance, redundancy.

2021 achievements:

- › Preparation of a review of feedback from past experience and definition of specific needs related to floating offshore substations.
- › Organisation of the first workshops on coordinating the drafting of system reliability specifications.
- › Initiation of work on the mathematical formalisation of floating substation reliability and the impact of repairs, inspection and continuous monitoring by sensors.

2021 dissemination:

- › Poster:
 - Ahmadivala M., *et al.* (2021) Time-dependent system reliability of Innovative concepts for floating offshore substation: first results. Seanergy, Nantes, 21/09/2021 - 24/09/2021

Partners:

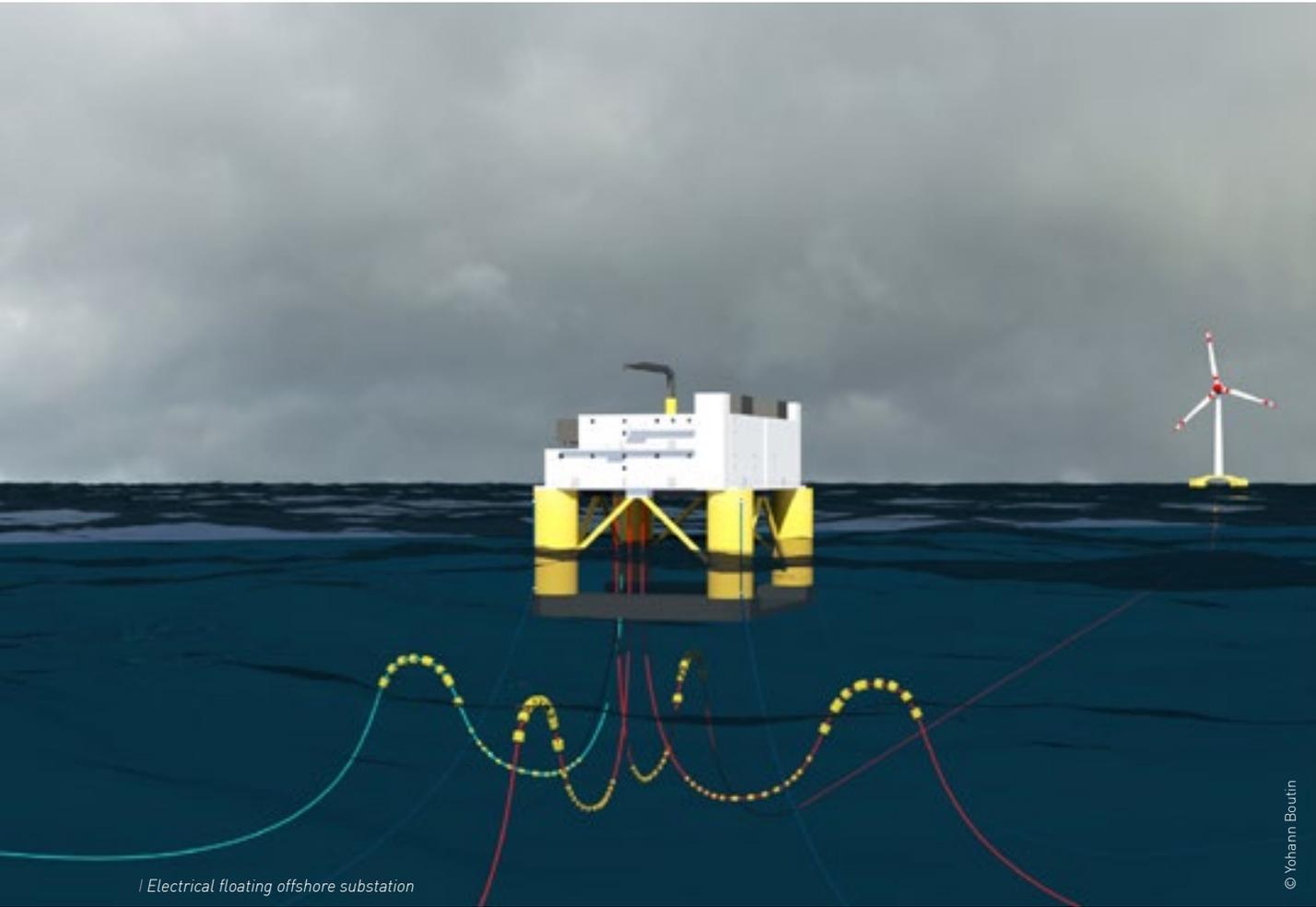
This project is led by the University of Nantes and France Energies Marines.



Total project budget: €892K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.





Electrical floating offshore substation



Mutualised anchors for offshore wind farms

Duration: 36 months | **Launched:** 2021

Objective:

- › To study the potential of mutualised anchors to reduce the levelised cost of energy of floating offshore wind farms.

Scientific and technical content:

- › Mooring system design and shared anchor load analysis.
- › Geotechnical modelling with 3D finite element numerical method.
- › Centrifuge tests on small-scale models to study multidirectional loadings and cyclic loadings.
- › Cost estimation of mooring systems through expert consultation and existing cost models.

2021 achievements:

- › Running of four workshops with the project partners to establish the framework for the anchor design study.
- › Initiation of modelling of the overall system to prepare the anchoring analyses for the design phase.
- › Launch of the study to improve the centrifuge for testing.

2021 dissemination:

- › Poster:
 - Ahmadivala M., *et al.* (2021) Time-dependent system reliability of Innovative concepts for floating offshore substation: first results. Seanergy, Nantes, 21/09/2021 - 24/09/2021

Partners:

This project is led by France Energies Marines.



Total project budget: €1,343K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Region of Pays de la Loire and from the maritime cluster Pôle Mer Bretagne Atlantique.





Centrifuge tests on small-scale models to study multidirectional loadings and cyclic loadings



Offshore production of hydrogen analysis and roadmap

Duration: 18 months | **Launched:** 2021

Objective:

- › To produce a roadmap and decision-making tools for the future players of the offshore renewable hydrogen market, with a focus on wind farms.

Scientific and technical content:

- › Sector analysis.
- › Identification of solutions and risks for offshore hydrogen production.
- › Development of tools for offshore hydrogen production analysis.
- › Preparation of a hydrogen roadmap for the offshore wind industry.

2021 achievements:

- › State-of-the-art on production (electrolysis) and processing (compression, liquefaction) technologies of hydrogen and its derivatives (ammonia, methanol).
- › Documentation on the qualification of hydrogen production, storage and transport technologies.
- › Mapping of the offshore renewable hydrogen potential, covering resources, infrastructure and users across Europe, production of a prospective description of the renewable hydrogen market in Europe by 2050.

2021 dissemination:

- › Presentation:
 - Robert M. (2021) Présentation du projet OPHARM. École Industrie 2021 - L'hydrogène Vert : une opportunité pour la filière éolienne, Le Havre, 09/11/2021 - 10/11/2021

Partners:

This project is led by France Energies Marines.



Total project budget: €338K

This project receives funding from France Energies Marines and its members and partners, as well as French State funding managed by the French National Research Agency under the Investments for the Future Programme.

It also receives funding from the Regions of Normandy, Pays de la Loire and Provence-Alpes-Côte d'Azur.

This project is approved by the maritime cluster Pôle Mer Méditerranée.





Offshore wind farm

Clients targeted

- Consultancy firms.
- Technology developers.
- Farm owners and operators.

Type of services provided

- Software solutions and related support: assistance and support for the definition of technical specifications for farm optimisation tools, integrated custom development of DTOcean+ suite modules, technical support and training in the use of DTOcean+ tools.
- Design and analysis using DTOcean+ tools: foundation design (including mooring lines and many types of anchors) for ocean energy recovery systems at farm scale, analysis of the environmental impacts and social acceptability of tidal and wave farms.

Team

Engineers and scientists with multidisciplinary expertise in: structural design, mooring engineering, offshore in-service monitoring, electrical architecture, operation and maintenance.

Instrumentation

- Floating wind turbine instrumentation consisting of a nacelle-mounted lidar and a motion recording unit.

Numerical tools

- Design: DTOcean+ software suite for farm evaluation and optimisation based on different criteria.
- Substations: methodology for in-service electrical and mechanical monitoring of floating offshore substations.
- Hydrogen: rapid assessment tool for hydrogen production scenarios based on offshore wind energy.

Databases

- Grid reference components: cables, connectors and hubs.
- Mooring and foundation reference components: properties of mooring lines, drag anchors.
- Maritime logistics and operations: operations and maintenance activities, equipment, port terminals, etc.

07

CROSS-CUTTING ACTIVITIES

In addition to its R&D projects and services, France Energies Marines is greatly involved in various cross-cutting initiatives with a common goal of supporting ORE development through research.

The Institute provides national support to the sector by offering guidance to regional authorities, contributing to public debates, participating in numerous expert panels and leading and coordinating research, development and innovation initiatives with other key industry stakeholders. France Energies Marines also coordinates an initiative to rank environmental challenges for ORE. The Institute is an active participant in numerous international R&D networks that bring together various types of stakeholders. These networks aim to generate data and

tools to provide structured assistance to the sector at every stage of the value chain, as well as to share expertise and knowledge acquired through R&D.

As a member of such networks, France Energies Marines organises frequent events to communicate with other players in the sector, holds training sessions, and participates in scientific outreach activities.

2021 key figures:

-  19 organisations represented on the COME3T steering committee
-  121 participants in the OCEANSET results presentation webinar
-  More than 5,500 subscribers to the France Energies Marines LinkedIn page



3 QUESTIONS for... Nathalie Tertre and Camille Senn

*Environment project managers
EDF Renouvelables*

Why are you involved in the COME3T initiative?

Today, regulations require environmental impacts to be taken into account in offshore wind farm projects. However, it is also necessary to answer the questions raised by the general public. The COME3T project is important to us as it fits with this approach: addressing environmental challenges while working to educate the public. The strength of this project lies in the fact that it brings together neutral, independent experts to address a given subject and rapidly provide concrete answers based on existing scientific knowledge.

What role do you play?

We are members of the COME3T steering committee. Based on the feedback from local stakeholders, we identify the questions that appear to be addressed as a priority and we may suggest experts who could contribute to providing answers. We proofread the bulletins that are produced and contribute to discussions to guide the project.

What do you think should be the project's guiding principle?

The ORE sector does not have the same questions as the general public. It's therefore important to avoid the pitfall of producing documents that are far removed from the project's primary objective: addressing the population at large. To ensure that COME3T remains an effective tool for leading consultation on environmental issues, it is important that we strive to root out preconceived ideas and falsehoods that are spread on an everyday basis in order to enlighten the general public with reliable information from experts to directly address their questions.

7.1. National support for the sector's development

Guidance for regional authorities

> Brittany:

Technical consultant for the Conférence Régionale Mer Littoral (CRML); participation in the annual scientific committee for the selection of scholarships co-financed by the Region; management of ORE-related activity under the redesigned Regional Strategy for Research and Innovation, including identification of core projects, operational objectives and initiatives that will contribute to the sector's European growth.

> Occitania:

Support for AD'OCC, the regional economic development agency.

> Pays de la Loire:

Technical consultant for Assemblée Régionale Mer Littoral (ARML).

> Provence-Alpes-Côte d'Azur Region:

Technical consultant for Assemblée Maritime pour la Croissance Régionale et l'Environnement (AMCRE).

Participation in public debates

> Offshore wind power in the Mediterranean:

Contributions in relation to prevailing issues and the state of knowledge on the effects of wind farms on the ecosystem, in particular on birdlife, production of video clips in the form of interviews with researchers, drafting of stakeholder statements conveying a message of support for the development of the offshore wind sector.



Screenshots from the video clips produced on birdlife (top) and life cycle assessment (bottom)

Participation in national panels of experts

> Mirror groups created by certification organisations:

EC/TC114 to establish future international standards, with particular involvement in the resource characterisation working group, **IEC/TC209** to examine the foundations and anchor systems of floating wind turbines, **IECRE** to establish certification procedures.

> Environmental expert panels:

ORE and biodiversity working group of the French committee of the **International Union for the Conservation of Nature (IUCN)**; biodiversity working group of the French Renewable Energy Trade Association (SER); consultation and monitoring body (ICS) for the **Groix and Belle-Île** floating wind farm project; Scientific Interest Group steering committee for the **Dieppe - Le Tréport** offshore wind farm project, Scientific Interest Group steering committee for the **Yeu and Noirmoutier islands** offshore wind farm project.



| Birdlife and offshore wind

Leadership and coordination of research, development and innovation

- Contribution to the strategy and implementation of collective initiatives of the **Campus Mondial de la Mer** and its community of stakeholders in marine science and technology and maritime economy in western Brittany.
- Initiatives in close collaboration with **Pôle Mer Bretagne Atlantique** and **Pôle Mer Méditerranée**, including approval of most R&D projects.
- Participation in the specialised wind energy commission of the **Conseil maritime de façade de Méditerranée**.
- Participation in the ORE and hydraulics programme group of the **French National Alliance for Energy Research Coordination (ANCRE)** by contributing to the revision of a national public research road map for the French Ministry for Higher Education and Research.
- Regular contributor to the CNRS-certified Marine Renewable Energies Research Group (**GDR EOL-EMR**) through co-leadership of the potential impact theme and active participation in its steering committee.
- Working with industry through **Comités Stratégiques de Filières (CSF)**: assisting CSF Nouveaux Systèmes Energétiques by defining the number of necessary test sites for offshore wind turbines; co-leadership of the smart offshore industries sector's research, development and innovation programme, for CSF Industriels de la Mer, including revision of the roadmap and evaluation of CORIMER projects.
- Strong involvement of the **8 IRTs and 7 ITEs** in the French Institutes of Technology (FIT) Association, with participation in the Operational Committee, involvement in the working group on training, and contribution to shared communication initiatives such as the website redesign and preparation of the press conference.

7.2. Coordination of expert panels

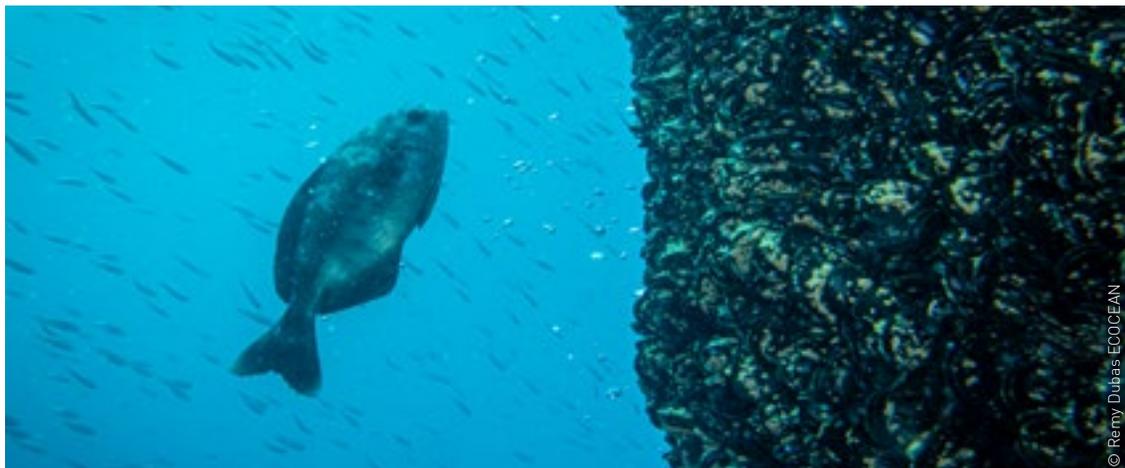
Ranking environmental challenges - COME3T

France Energies Marines has been coordinating the COME3T initiative since 2018. This project, which brings together national ORE stakeholders, aims to put environmental questions to a panel of neutral and independent experts. The questions addressed are based on challenges identified by the sector as well as public queries relating to the development of offshore renewable energies in France. France Energies Marines acts as the interface between the steering committee, which ranks the issues to be tackled, and the panel of experts, who provide scientific insight.

The steering committee comprises a wide range of public and private stakeholders organised into different colleges: clusters and consultancy firms, network developers, NGOs, State and government institutions, regions and local authorities, universities, farm developers. It jointly selects the scientific topics to be addressed and ensures that the experts are independent and neutral. Each expert panel aims to examine the question raised in depth and to classify the topic according to the associated environmental issue. Information bulletins are prepared for each topic addressed. They are richly illustrated and present the scientific information

justifying the issue's classification. These documents are then used as a basis for the development of short videos.

Launched in late 2020, the second phase of COME3T continued throughout 2021. It is organised into several sessions tackling different themes: reef effect, marine mammal monitoring, coastline dynamics, effect of noise emissions, etc. In 2021, the bulletins on the reef effect and marine mammals were prepared for publication in spring 2022. Previously published bulletins were made available at the public debate organised on the development of floating wind power in the Mediterranean and were used as input for the production of video clips based on interviews with experts involved in the COME3T project.



! Biofouling process at work on an underwater structure

7.3. Participation in European networks

Support for implementation of the ocean energy component of the European Strategic Energy Technology Plan - OCEANSET

The European Strategic Energy Technology Plan (SET Plan) aims to improve new technologies and reduce their cost by coordinating national research initiatives and contributing to project financing. Its operational roll-out in the ocean energy sector is set for 2025 for tidal energy and 2030 for wave energy.

The European H2020 OCEANSET project was launched in March 2019 to support this implementation. With a 3-year lifespan and a budget of 1 million, it is coordinated by the Sustainable Energy Authority of Ireland and is comprised of 9 partners, including France Energies Marines. The project has three key objectives: to facilitate and support technology development; to promote knowledge sharing among stakeholders in the ocean energy sector; and to investigate mechanisms for pooled funding between member States and Regions. OCEANSET's annual operational process of data collection and analysis, monitoring and recommendations is summarised in a public report.

Three of the project's flagship actions were implemented in 2021:

- Dissemination of a third survey to member States and technology developers based on pre-defined indicators selected by project partners;
- Publication on 24 May of the second annual report, presenting an overview and analysis of ocean energy-sector progress;
- A webinar held on 26 May to present the results of the second annual report;
- Production of a video promoting the results of the project and the support it provides to the Ocean Energy Implementation Working Group. This video was presented at the 15th SET Plan Conference held on 25-26 November in Bled, Slovenia;
- A workshop held on 8 December during the international OEE conference to share the preliminary results of the survey conducted during the second year of monitoring.

Common Environmental Assessment Framework - CEAF

France Energies Marines pursued its action as the French representative for the Common Environmental Assessment Framework (CEAF), a stakeholder network that meets several times a year to work on marine environments and wind energy in the Channel and North Sea alongside participants from the Netherlands, Germany, Denmark, Belgium, Scotland, England and France. Their objective is to support the EU energy policy declaration by making recommendations on implementing a common environmental assessment framework.



Second annual public report of the OCEANSET project

7.4. International reach

The International Energy Agency's Ocean Energy Systems (IEA-OES) Technological Collaboration Program

At an international level, the most visible France Energies Marines initiative takes place within IEA-OES. This action, for which the Institute was mandated by the French Directorate General for Energy and Climate, receives financial support from ADEME. The Institute plays a significant role in the operational management of the Programme, and has been chairing it since 1st January for a period of 2 years. In addition to overseeing the Executive Committee, this involves acting as editor of the programme publications as well as representing programme at many events. IEA-OES is one of the organisers of the International Conference on Ocean Energies (ICOE), which was held virtually in 2021. The Programme Chair was in great demand at this event for various presentations. The year was also marked by the extension of IEA-OES for the 2022-2027 period, on the basis of a solid case that had to be presented before a high-level international commission.

Although international travel was not possible this year, there were many opportunities to participate remotely in international meetings and conferences. France Energies Marines also leads a French mirror group which improves the dissemination of initiatives and makes it easier to share information of international interest, thereby raising the profile of the French sector and its successes.

OES Environmental

The Institute continued its participation in OES-Environmental, an international collaborative programme involved in examining the environmental effects of ORE development. This programme brings together 15 nations from all five continents. France Energies Marines staff members participate in the organisation's quarterly analyst meetings, most often held by videoconference. The Institute was commissioned to conduct a paid study by the US Department of Energy, which leads OES Environmental.

This study consisted of a state-of-the-art review of ecosystem models for the world's oceans, based on the expertise demonstrated through the collaborative R&D projects TROPHIK, APPEAL and WINDSERV.



© IEA-OES

| 2020 IEA-OES Annual Report

Working Together to Resolve Environmental Effects of Wind Energy - WREN

France Energies Marines ranks among the Ambassadors of WREN, an international collaborative programme that focuses on the environmental effects of onshore and offshore wind energy. Launched by the international organisation IEA Wind in October 2012, WREN represents 12 European and North American nations. The Institute acts as the French representative among the other WREN Ambassadors, communicating on national progress in wind energy and biodiversity. In its role as an Ambassador, France Energies Marines participates in drafting reports and takes part in plenary sessions aimed at establishing an inventory of scientific knowledge and techniques in the field.

7.5. Dissemination and communication

Scientific & Technological Tribune

Since 2017, France Energies Marines has been holding a Scientific & Technological Tribune to discuss R&D challenges and the results of collaborative projects led by the Institute, its members and its partners. Thanks to its biennial occurrence, there is always a wide choice of topics, given the quantity and breadth of the work carried out between each edition. The 2022 event will be set within a wider operation to mark France Energies Marines' 10 year anniversary. In 2021, the groundwork began in order to define the objectives, format and main themes to be addressed. The aim is to promote the Institute's role in and action towards supporting the ORE sector over the past 10 years off the different French coasts. The format will be slightly different with two half-days of panel sessions, one held in Brest and the other in Marseille. For the Channel and Atlantic coasts, the topics addressed will be related to site characterisation and systems design and monitoring; for the Mediterranean coast discussions will focus more on environmental integration and farm optimisation.

Themed presentation workshops

In addition to the Scientific & Technological Tribune, France Energies Marines set itself the objective of organising a presentation workshop to wrap up each of its R&D projects. These workshops may be open to a wide audience subject to agreement by the consortium. These workshops are particularly important in cases where new methodologies have been developed during a project and the sector would benefit from them being disseminated as widely as possible. Due to the Covid pandemic, the 2021 workshops were run as webinars. To boost their visibility, they were recorded and posted on the France Energies Marines website.

Webinar held on 15/03/2021

Power cables and benthos

/ SPECIES project /



170 participants



476 views (reruns)

Webinar held on 15/10/2021

Modelling and observation of extreme sea states

/ DIME project /



54 participants



159 views (reruns)

Webinar held on 26/10/2021

Characterisation of extreme winds

/ CARAVELE project /



30 participants



142 views (reruns)

/ Presentation workshops for completed R&D projects

Resource centre

The development of RESCORE, the national resource centre for the French ORE sector, was completed on 31 December, with a view to opening it to the public in early 2022. Several communication actions have been scheduled to support the launch. RESCORE will offer shared access to relevant information for the development of the sector. While it currently focuses on the results obtained from R&D projects conducted by France Energies Marines, it will gradually be expanded to include data from various players in the sector so as to be a one-stop shop devoted to ORE development in France. By complying with European and international data formatting standards, it has the advantage of being interoperable and hence compatible with the main French and foreign resource centres.

RESCORE takes the form of a web portal via which data searches can be performed applying many different criteria, such as the type of technology involved or the specific coast, and results are displayed via an ergonomic mapping tool. The basic function consists in displaying metadata relating to the data. The existence of these data and the identity of their owner are thus made public. Their availability depends on the confidence level or usage rights defined by their holder. RESCORE thus offers all the sector's data producers the possibility to disseminate underutilised data. Several tutorials have been produced to help new users. More than 150 metadata sheets are already available: site characterisation, environmental parameters, component and system characteristics, reports, literature reviews, etc.

RESCORE is targeted towards all ORE sector players: developers, operators and owners of pilot and commercial farms, technology developers, consultancy firms, decision-makers at national and regional levels, and academic researchers.

It is possible to interact with RESCORE in two ways:

- Consulting: Given its vocation to centralise data, RESCORE is the primary gateway to data specific to offshore renewable energy in France. It ensures that its users can efficiently consult the currently available data related to the chosen search criteria.
- Contributing: By depositing data or inputting meta-data to RESCORE, the information is given high visibility and may generate financial revenue for the owner. Contributors earn financial compensation, making for a win-win relationship.

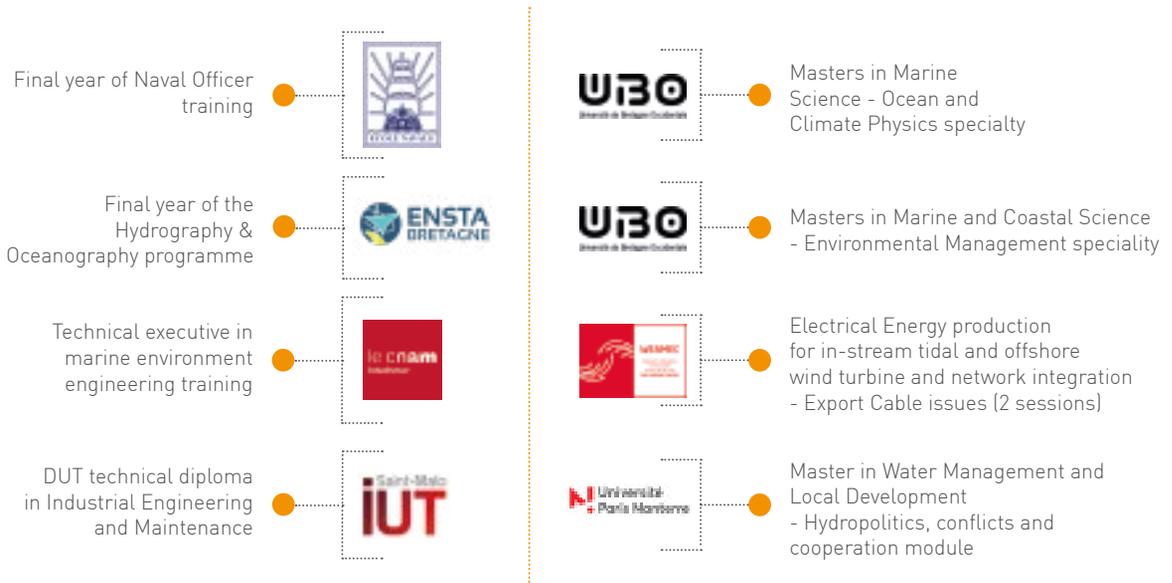


| Web interface of the RESCORE platform

Training programmes

The Institute is involved in various training programmes on offshore renewable energy. A wide range of topics are covered: metocean, environmental integration, marine environment design, in-service monitoring and array architecture. In 2021, most of the training courses delivered by France Energies Marines took place at higher education establishments.

Lecturers were selected from our multidisciplinary team according to their expertise and experience in the topics covered. The course materials provided for these training sessions are richly illustrated with diagrams and videos, and are based on the results of R&D projects carried out over the past 10 years.



General public

The France Energies Marines team is very involved in communication with the general public. It is vital to communicate about ORE-related environmental, technological and economic issues as well as the research work that is conducted in order to provide citizens with factual information on these new energy sources. The many media communication initiatives carried out in 2021 are summarised in the following table.

After redesigning its website in 2020, France Energies Marines continues to update it on weekly basis with news items, project information sheets, pages on our services as well as team member profiles. The Institute has continued to be very active on social media, where the promotion of its staff, members, partners and initiatives leads to interactive discussion and a strong relationship with its subscribers. The following statistics illustrate the popularity of France Energies Marines' 2020 posts and publications:

- **Twitter:** a 37% increase in the number of subscribers (more than 830 by year end), a monthly average of 27 posts clocking up 12,850 views.
- **LinkedIn:** a 66% increase in the number of subscribers (more than 5,500 by year end), a monthly average of 25 posts and 28,800 views.
- **YouTube channel:** 67 videos were posted during the year, generating a total nearly 10,900 views, representing an increase of over 140% compared to 2020.

On 24 September 2021, despite complications due to the Covid pandemic, France Energies Marines took part in European Researchers' Night, an event aimed at raising public awareness about science. The event in Brest was hosted and organised by Océanopolis and attracted several thousand visitors. This year's theme was travel. Several scientists from the Institute prepared a game entitled: "From the ocean floor to offshore winds: on course for offshore renewable energy". Visitors were taken on a world tour of ORE. They could choose the character they wanted to play before tackling a series of brain-teasers through which they would discover the different technologies to harness the ocean's energy. Research conducted in this field was in the spotlight, covering a broad range of topics including marine current measurements, biofouling of submerged systems, mooring design for floating wind turbines and birdlife studies.



! Resounding success for the France Energies Marines stand at European Researchers' Night

Date	Subject	Press coverage
February	DIME 4 th measurement campaign at La Jument lighthouse.	9 articles + 3 reports
March	DTOCEANPLUS Beta version ready for demonstration phase.	4 articles
March	FISH INTEL Fish population monitoring through a cross-Channel acoustic telemetry network.	4 articles
May	ABIOP+ and APPEAL Deployment of the buoy off Groix & Belle-Île.	3 articles
May	OWFSOMM Overflights off Courseulles-sur-mer to standardise tools and methods for monitoring marine megafauna.	1 article
May	OCEANSET Publication of the first OceanSET project annual report: an overview and analysis of progress.	3 articles
June	SPECIES Report on potential interactions of power cable with coastal benthic ecosystems.	6 articles
July	INSTITUTE Changes and current news at France Energies Marines.	3 articles
July	INSTITUTE wpd offshore joins France Energies Marines	2 articles
August	DTOCEANPLUS Announcement of the official launch of the DTOcean+ software suite.	11 articles
Sept.	DUNES End of measurement campaigns off Dunkirk and initial results.	4 articles
Sept.	INSTITUTE Christophe Chabert, new President of the France Energies Marines Association.	5 articles
October	LISORE and MOISS Main results on the technological bottlenecks and potential solutions to reduce the cost of offshore substations.	2 articles
Nov.	INSTITUTE FEBUS Optics joins France Energies Marines	

08

FINANCIAL SUMMARY

Two organisations still co-exist in the 2021 financial report: the Association created at the inception of France Energies Marines, and the joint-stock company (SAS) responsible for the Institute's activities since 1st January 2019. Following the granting of Institute for the Energy Transition status to the Institute in the form of a joint-stock company, the Association no longer initiates projects and all personnel are gradually being transferred to the joint-stock company.

France Energies Marines Association

The Association's activity dropped considerably in 2021 as the majority of the projects managed have come to an end. Five projects were completed in 2021, while four are still in progress and will be completed in 2022. This activity represents approximately €1M.

In line with its provisional budget, the Association experienced major losses, but has maintained sufficient cash flow to comfortably complete the projects in progress in 2022. The goal is to close down the Association in 2023.

	FY 2021
Operating expenses	
Operating expenditure	€1,393,873
Research, development and innovation subcontracting	€387,767
Depreciation and provisions	€133,785
Total	€1,915,425
Operating income	
Income from provided services	€32,150
Funding by private sector members of France Energies Marines	€45,033
French public funding excluding State funding	€67,399
Community funding (Europe)	€400,433
French state funding excluding Investments for the Future funding	€10,800
Investments for the Future funding	€569,211
Total operating income	€1,125,025
Operating result	€-790,400

	Year-end cumulative total
Balance sheet • Assets	
Fixed assets	
Intangible assets	€4,954
Tangible assets	€128,005
Long-term investments	€50
Total	€133,009
Current assets	
Advances and deposits paid on orders	€605
Receivables	€3,119,523
Liquid assets	€1,081,879
Prepaid expenses	€583
Total	€4,202,590
Grand total	€4,335,599
Balance sheet • Liabilities	
Equity	€620,377
Loans and debts	€3,715,221
Grand total	€4,335,598

/ Operating result for the Association

/ Association balance sheet

France Energies Marines joint-stock company

The eight projects approved in the summer by the Board of Directors officially started in the fourth quarter. Many recruitments were made in 2021. The employees transferred to the joint-stock company (SAS) continued to work on the Association's projects, in the form of secondment. The joint-stock company is growing and saw a strong rise in its activity. The structural deficit of the first two financial years, although entirely accounted for, is being cancelled out, with the financial balance restored and a financial result slightly higher than anticipated in the provisional budget.

The renewed commitment of members for another three-year period (2022-2024) was an opportunity for regions and private entities to substantially increase their individual contributions. This echoes the research tax credit (CIR) accreditation obtained by the joint-stock company. The introduction of several new members reinforces these strong dynamics.

	FY 2021
Operating expenses	
Operating expenditure	€3,546,517
Research, development and innovation subcontracting	€322,751
Depreciation and provisions	€5,8051
Total	€3,927,319
Operating income	
Income from provided services	€105,553
Public R&D contributions	€10,000
Private R&D contributions	€95,000
Community funding (Europe)	€63,187
Operating subsidy	€2,217,657
Other products	€1,516,296
Total	€4,007,693
Operating result	€80,374

| Operating result for the joint-stock company

	Year-end cumulative total
Balance sheet • Assets	
Fixed assets	
Intangible assets	€9,263
Tangible assets	€198,207
Long-term investments	€202,800
Total	€410,270
Current assets	
Advances and deposits paid on orders	€918,607
Receivables	€9,805,874
Liquid assets	€1,302,048
Prepaid expenses	€20,472
Total	€12,047,001
Grand total	€12,424,090
Balance sheet • Liabilities	
Equity	€377,089
Loans and debts	€12,047,001
Grand total	€12,424,090

| Joint-stock company balance sheet

OUTLOOK

The Institute is set to pursue its development with an expected 15% growth of its R&D budget each year for the 2021-2024 period. This is due to more ambitious projects supported by the French State, local authorities, members of France Energies Marines, as well as to the participation in European and ADEME-funded projects. This growth goes hand-in-hand with an increase in staff numbers, comprising both the Institute's employees and staff seconded to France Energies Marines by its members for R&D activities. Numerous recruitments, both completed and planned, will bring the Institute's team to a total of 85 employees within 12 months, including around ten based at our Mediterranean office and five at the Atlantic office. To expand our presence along the French coasts, a Channel & North Sea office is set to be created in the near future.

Several key research topics have been identified by France Energies Marines' members. The beginning of 2022 will see the preparation of new collaboration projects focusing on:

- Obtaining better joint information on wind, currents and climate change to design wind turbines for hurricane-prone sites,
- Characterising biofouling along mainland France's three coasts concerned by the development of wind farms based on a standardised protocol for spatio-temporal monitoring and the study of the impacts on structures, particularly floating structures,
- Nested models to assess the cumulative impacts of ORE installations, taking into account local and regional environmental and socio-economic challenges,
- Architecture and design of a floating offshore substation for direct current applications,
- Multi-criteria optimisation for off-grid power generation from offshore renewable energy installations.

Alongside these R&D projects supported by Plan France 2030, the Institute will also be leading and contributing to SEMAPHOR. This ADEME-funded project focuses on the observation and prediction of bird migration based on weather radars. France Energies Marines will also be a member of the consortium for SEETIP Ocean, a project funded by the Horizon Europe programme and that aims to strengthen cooperation and collaboration between the various stakeholders in the ocean energy sector.

France Energies Marines will also continue to develop a range of services, in particular to support the sector prior to the preparation of commercial tenders for future offshore wind farms. This is possible thanks to the Institute's recognised expertise, as well as its presence in several regions and the establishment of partnerships with consultancy firms. Several proposals are currently being drawn up to bolster the growth of this new activity.

The beginning of new year will be marked by the renewal of all the R&D agreements for the 2022-2024 period

with its associate and contributor members. Several entities are poised to join the Institute, including TotalEnergies, RWE and the Region of Occitania.

After having built an impressive skillbase resting on the country's largest R&D team in the ORE sector, France Energies Marines must now consolidate its physical assets to secure its position. The roadmap drawn up in 2021 for the creation of a permanent observatory of interactions between offshore wind farms and the marine environment is thus set to come to fruition in 2022, with the first investments in this research infrastructure.





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